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Digital networks – Optical transport networks

Architecture of optical transport networks

ITU-T Recommendation G.872

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ITU-T Recommendation G.872

Architecture of optical transport networks

Summary

This Recommendation describes the functional architecture of optical transport networks using the modelling methodology described in ITU-T Rec. G.805. The optical transport network functionality is described from a network level viewpoint, taking into account an optical network layered structure, client characteristic information, client/server layer associations, networking topology, and layer network functionality providing optical signal transmission, multiplexing, routing, supervision, performance assessment, and network survivability.

Source

ITU-T Recommendation G.872 was revised by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 29 November 2001.

FOREWORD

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

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

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

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

NOTE

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

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ITU-T Recommendation G.872

Architecture of optical transport networks

1 Scope

This Recommendation describes the functional architecture of optical transport networks using the modelling methodology described in ITU-T Rec. G.805. The optical transport network functionality is described from a network level viewpoint, taking into account an optical network layered structure, client characteristic information, client/server layer associations, networking topology, and layer network functionality providing optical signal transmission, multiplexing, routing, supervision, performance assessment, and network survivability.

This Recommendation is restricted to the functional description of optical transport networks that support digital signals. The support of analogue or mixed digital/analogue signals is outside of the current scope.

It is recognized that the design of optical networks is subject to limitations imposed by the accumulation of degradations introduced by the number of network elements and their network topology. However, many of these degradations and the magnitude of their effects are associated with particular technological implementations of the architecture described in this Recommendation and are therefore subject to change as technology progresses. As such the description of these effects is outside the scope of this Recommendation.

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.

- ITU-T Recommendation G.652 (2000), *Characteristics of a single-mode optical fibre cable*.
- ITU-T Recommendation G.653 (2000), *Characteristics of a dispersion-shifted single-mode optical fibre cable*.
- ITU-T Recommendation G.655 (2000), *Characteristics of a non-zero dispersion shifted single-mode optical fibre cable*.
- ITU-T Recommendation G.707/Y.1322 (2000), *Network node interface for the synchronous digital hierarchy (SDH)*, plus Corrigendum 1 (2001).
- ITU-T Recommendation G.709/Y.1331 (2001), *Interfaces for the optical transport network (OTN)*.
- ITU-T Recommendation G.798 (2002), *Characteristics of optical transport network hierarchy equipment functional blocks*.
- ITU-T Recommendation G.803 (2000), *Architecture of transport networks based on the synchronous digital hierarchy (SDH)*.
- ITU-T Recommendation G.805 (2000), *Generic functional architecture of transport networks*.

- ITU-T Recommendation G.957 (1999), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.
- ITU-T Recommendation I.326 (1995), *Functional architecture of transport networks based on ATM*.
- ITU-T Recommendation M.495 (1988), *Transmission restoration and transmission route diversity: Terminology and general principles*.
- ITU-T Recommendation M.496 (1988), *Functional organization for automatic transmission restoration*.

3 Terms and definitions

This Recommendation defines the following terms:

- 3.1 adaptation management:** The set of processes for managing client layer network adaptation to/from the server layer network.
- 3.2 administrative domain:** (see ITU-T Rec. G.805)
- 3.3 connection supervision:** The set of processes for monitoring the integrity of a connection which is part of a trail. This set consists of the processes associated with connectivity and continuity supervision.
- 3.4 connectivity supervision:** The set of processes for monitoring the integrity of the routing of the connection between source and sink trail terminations.
- 3.5 continuity supervision:** The set of processes for monitoring the integrity of the continuity of a trail.
- 3.6 inter-domain interface (IrDI):** A physical interface that represents the boundary between two administrative domains.
- 3.7 intra-domain interface (IaDI):** A physical interface within an administrative domain.
- 3.8 maintenance indication:** The set of processes for indicating defects in a connection which is part of a trail in downstream and upstream directions.
- 3.9 management communications:** The set of processes providing communications for management purposes.
- 3.10 OTN compliant interface:** An interface for the optical transport network based on the architecture defined in this Recommendation (G.872).
- 3.11 OTN non-compliant interface:** An interface that does not comply to the interface recommendations that will be defined for the optical transport network based on the architecture defined in this Recommendation (G.872).
- 3.12 overhead information:** Six types of overhead information are defined:
- 1) Trail Termination Overhead Information is the information generated by the trail termination source and extracted by the trail termination sink to monitor the trail. This overhead information is specific to a layer network and is independent of any client/server relationship between network layers.
 - 2) Client-Specific Overhead Information is associated with a particular client/server relationship and is therefore processed by a particular adaptation function.
 - 3) Auxiliary Channel Overhead Information is information that may be transferred by an optical network layer but which does not by necessity have to be associated with a particular connection. An example of such an auxiliary channel is a data communications channel for the purposes of transferring management data between management entities.

NOTE – These management entities are not trail termination and adaptation functions.

- 4) Reserved Overhead Information.
- 5) Unassigned Overhead Information. This overhead may be of types 1, 2, 3 or 4 as defined above.
- 6) Network Operator-Specific Overhead Information that may be used by an operator to support its unique optical networking needs and/or for service differentiation. The information content is not standardized.

3.13 optical transport network: A transport network bounded by optical channel access points.

3.14 optical supervisory channel (OSC): The optical supervisory channel is an optical carrier that transfers overhead information between optical transmission section transport entities. The optical supervisory channel supports more than one type of overhead information and some of this overhead information may be used by one or more transport network layers.

3.15 protection control: The information and set of processes for providing control of protection switching for a trail or subnetwork connection.

3.16 signal quality supervision: The set of processes for monitoring the performance of a connection that is supporting a trail.

3.17 subnetwork connection supervision: The set of processes providing connectivity supervision and/or continuity supervision and/or signal quality supervision for a subnetwork connection that is supporting a trail.

4 Abbreviations

This Recommendation uses the following abbreviations:

AP	Access point (see ITU-T Rec. G.805)
APS	Automatic protection switching
ATM	Asynchronous transfer mode (see ITU-T Rec. I.326)
BDI	Backward defect indication
CP	Connection point (see ITU-T Rec. G.805)
FDI	Forward defect indication
IaDI	Intra-Domain Interface
IrDI	Inter-Domain Interface
LOC	Loss of continuity
MPCP	Multipoint connection point
NE	Network element
NRZ	Non return to zero
OCh	Optical channel
OCh/Client_A	Optical channel/Client adaptation
OCh_LC	Optical channel link connection
OCh_NC	Optical channel network connection
OCh_SN	Optical channel subnetwork
OCh_SNC	Optical channel subnetwork connection

OCh_TT	Optical channel trail termination
ODU	Optical channel data unit
OMS	Optical multiplex section
OMSn	Optical multiplex section of order n
OMS/OCh_A	Optical multiplex section/Optical channel adaptation
OMS_LC	Optical multiplex section link connection
OMS_NC	Optical multiplex section network connection
OMS_TT	Optical multiplex section trail termination
OSC	Optical supervisory channel
OTM	Optical transport module
OTMn	Optical transport module of order n
OTN	Optical transport network
OTS	Optical transmission section
OTSn	Optical transmission section of order n
OTS/OMS_A	Optical transmission section/Optical multiplex section adaptation
OTS_LC	Optical transmission section link connection
OTS_NC	Optical transmission section network connection
OTS_SN	Optical transmission section subnetwork
OTS_SNC	Optical transmission section subnetwork connection
OTS_TT	Optical transmission section trail termination
OTU	Optical transport unit
OTUGn	Optical transport unit group of order n
PDH	Plesiochronous digital hierarchy
PTI	Payload type identifier
RS	Regenerator section (see ITU-T Rec. G.803)
SDH	Synchronous digital hierarchy (see ITU-T Rec. G.707)
SNC	Subnetwork connection (see ITU-T Rec. G.805)
SNC/I	Subnetwork connection protection with inherent monitoring
SNC/N	Subnetwork connection protection with non-intrusive monitoring
STM-N	Synchronous transport module level N (see ITU-T Rec. G.707)
TCP	Termination connection point (see ITU-T Rec. G.805)
TDM	Time division multiplexing
WDM	Wavelength division multiplexing

5 Transport functional architecture of optical networks

5.1 General principles

Optical networks are comprised of functionality providing transport, multiplexing, routing, supervision and survivability of client signals that are processed predominantly in the photonic domain. The current optical technology has limitations on supervision and performance assessment capabilities. Therefore digital processing is needed in order to overcome these limitations. This functionality for optical networks is described from a network level viewpoint using the generic principles defined in ITU-T Rec. G.805. The specific aspects concerning the optical transport network layered structure, characteristic information, client/server layer associations, network topology, and layer network functionality are provided in this Recommendation. It uses the terminology, functional architecture and diagrammatic conventions defined in ITU-T Rec. G.805.

In accordance with ITU-T Rec. G.805, the optical transport network is decomposed into independent transport layer networks where each layer network can be separately partitioned in a way which reflects the internal structure of that layer network.

In the following functional description, optical signals are characterized by wavelength (or central frequency) and may be processed per wavelength or as a wavelength division multiplexed group of wavelengths. The functional description of other optical multiplexing techniques (e.g. time division multiplexing (TDM), optical time division multiplexing (OTDM), or optical code division multiplexing (OCDM)) in optical networks is for future study.

5.2 Optical transport network layered structure

The optical transport network layered structure is comprised of the optical channel, optical multiplex section and optical transmission section layer networks, as illustrated in Figure 1. Motivation for this three-layer structure is as follows:

Optical channel layer network: This layer network provides end-to-end networking of optical channels for transparently conveying client information of varying format (e.g. SDH STM-N, PDH 565 Mbit/s, cell-based ATM, etc.). The description of supported client layer networks is outside the scope of this Recommendation. To provide end-to-end networking, the following capabilities are included in the layer network:

- optical channel connection rearrangement for flexible network routing;
- optical channel overhead processes for ensuring integrity of the optical channel adapted information;
- optical channel operations, administrations, and maintenance functions for enabling network level operations and management functions, such as connection provisioning, quality of service parameter exchange and network survivability.

Optical multiplex section layer network: This layer network provides functionality for networking of a multi-wavelength optical signal. Note that a "multi-wavelength" signal includes the case of just one optical channel. The capabilities of this layer network include:

- optical multiplex section overhead processes for ensuring integrity of the multi-wavelength optical multiplex section adapted information;
- optical multiplex section operations, administrations, and maintenance functions for enabling section level operations and management functions, such as multiplex section survivability.

These networking capabilities performed for multi-wavelength optical signals provide support for operation and management of optical networks.

Optical transmission section layer network: This layer network provides functionality for transmission of optical signals on optical media of various types (e.g. G.652, G.653 and G.655 fibre).

The capabilities of this layer network include:

- optical transmission section overhead processing for ensuring integrity of the optical transmission section adapted information;
- optical transmission section operations, administrations, and maintenance functions for enabling section level operations and management functions, such as transmission section survivability.

Physical media layer network: The physical media layer network for an optical network is a defined optical fibre type. This physical media layer network is the server of the optical transmission section.

The detailed description of this layer is outside the scope of this Recommendation.

The detailed functional description of the optical layer networks is given in the following clause.

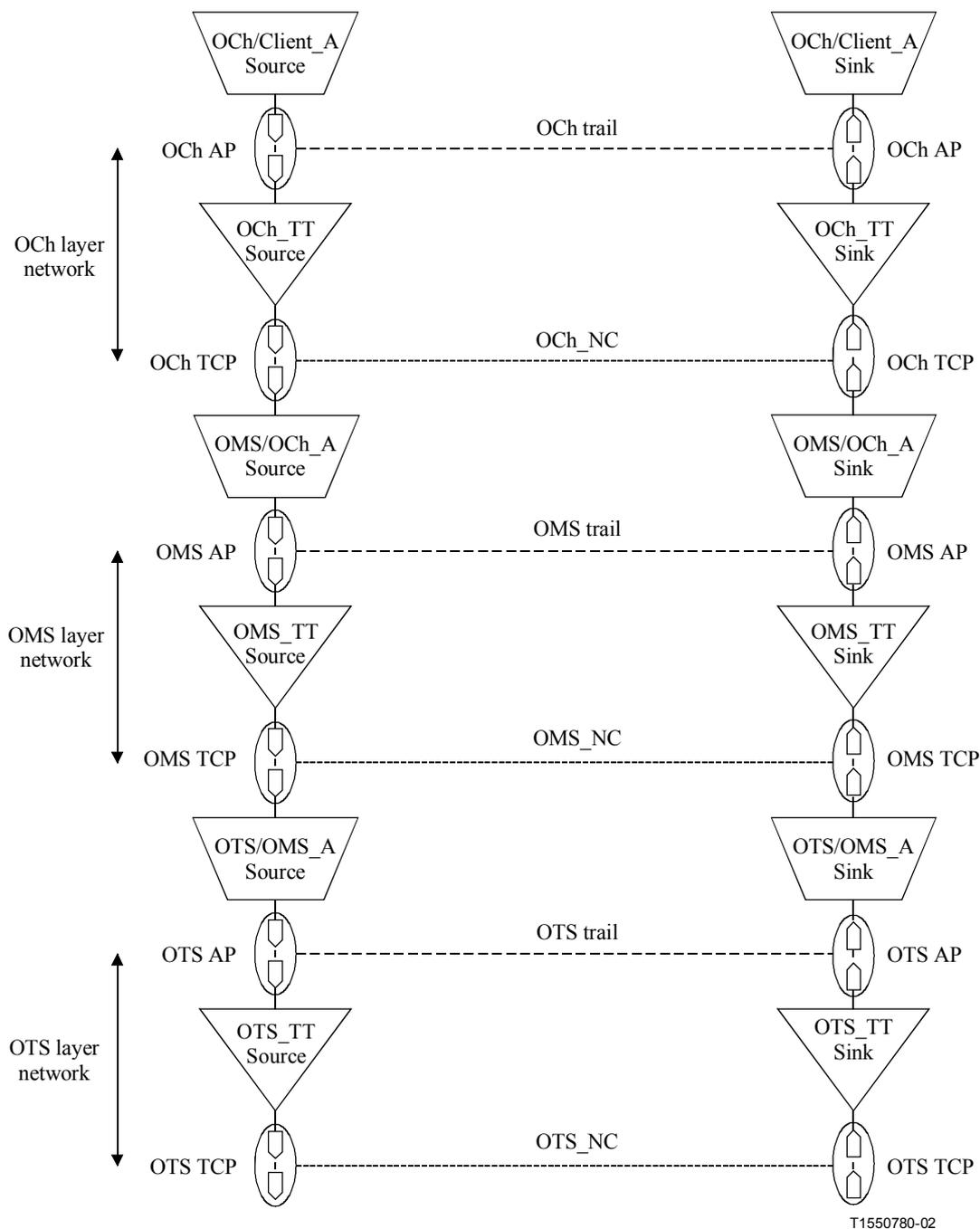


Figure 1/G.872 – Client server associations in an optical transport network

5.3 Optical channel layer network

The optical channel layer network provides for the transport of digital client signals through an optical channel trail between access points. The characteristic information of an optical channel layer network is composed of two separate and distinct logical signals:

- an optical signal of defined maximum bandwidth and signal-to-noise ratio, associated with the optical channel network connection.
- a data stream that constitutes out-of-channel overhead.

NOTE – The definition of the characteristic information reflects the form of the information that needs to be presented to the server layer and is transported across the network connection. This hides the digital informational content from the underlying server (see clause 10 for implementation aspects of the optical channel).

The optical channel layer network contains the following transport functions and transport entities (see Figure 2):

- Optical channel trail;
- Optical channel trail termination source (OCh_TT_Source);
- Optical channel trail termination sink (OCh_TT_Sink);
- Optical channel network connection (OCh_NC);
- Optical channel link connection (OCh_LC);
- Optical channel subnetwork (OCh_SN);
- Optical channel subnetwork connection (OCh_SNC).

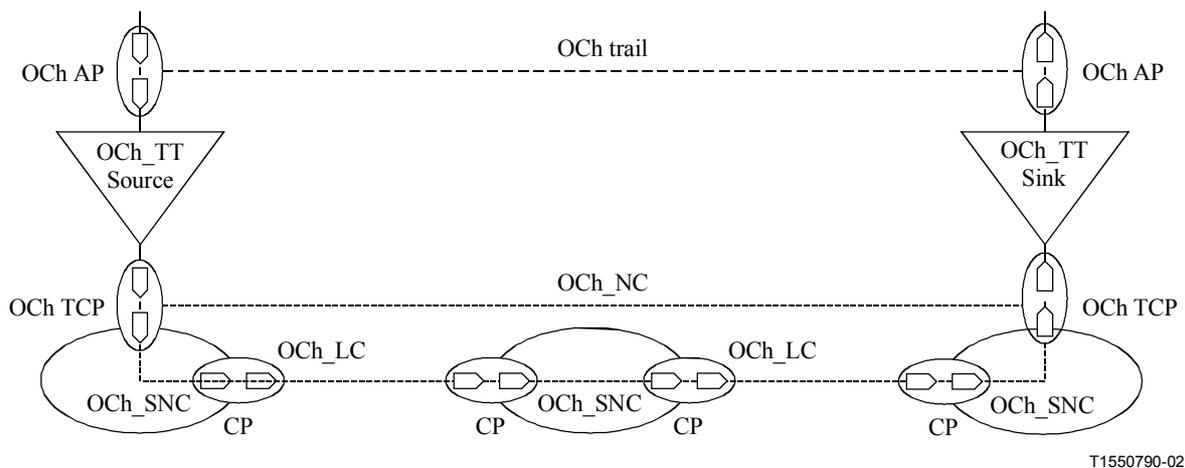


Figure 2/G.872 – OCh layer network example

5.3.1 Optical channel trail termination

The following generic processes may be assigned to the optical channel trail termination:

- validation of connectivity integrity;
- assessment of transmission quality;
- transmission defect detection and indication.

The requirement for these processes is outlined in detail in 6.2.

There are three types of optical channel trail termination:

- Optical channel bidirectional trail termination: consists of a pair of collocated optical channel trail termination source and sink functions.
- Optical channel trail termination source: accepts adapted information from a client layer network at its input, inserts the optical channel trail termination overhead as a separate and distinct logical data stream and presents the characteristic information of the optical channel layer network at its output.
- Optical channel trail termination sink: accepts the characteristic information of the optical channel layer network at its input, extracts the separate and distinct logical data stream containing the optical channel trail termination overhead and presents the adapted information at its output.

5.3.2 OCh transport entities

Network connections, link connections and trails are as described in ITU-T Rec. G.805.

The OCh subnetwork, OCh_SN, provides flexibility within the optical channel layer. Characteristic information is routed between input (termination) connection points [(T)CPs] and output (T)CPs. The connection function may be used by the network operator to provide routing, grooming, protection and restoration.

5.4 Optical multiplex section layer network

The optical multiplex section layer network provides the transport of optical channels through an optical multiplex section trail between access points. The characteristic information of an optical multiplex section layer network is composed of two separate and distinct logical signals:

- a data stream that constitutes the adapted information of the optical channel layer. The data stream contains a set of n optical channels which taken as a set have a defined aggregate optical bandwidth;
- a data stream that constitutes the optical multiplex section trail termination overhead.

Each channel has a defined carrier wavelength (frequency) and optical bandwidth (the supported optical channel bandwidth plus source stability). Individual optical channels within an optical multiplex may be either in-service or out-of-service. Out-of-service channels are either lit or unlit.

The characteristic information of the optical multiplex section is an Optical Multiplex Unit of order n (OMU-n).

The optical multiplex section layer network contains the following transport functions and transport entities (see Figure 3):

- OMS trail;
- OMS trail termination source (OMS_TT_Source);
- OMS trail termination sink (OMS_TT_Sink);
- OMS network connection (OMS_NC);
- OMS link connection (OMS_LC).

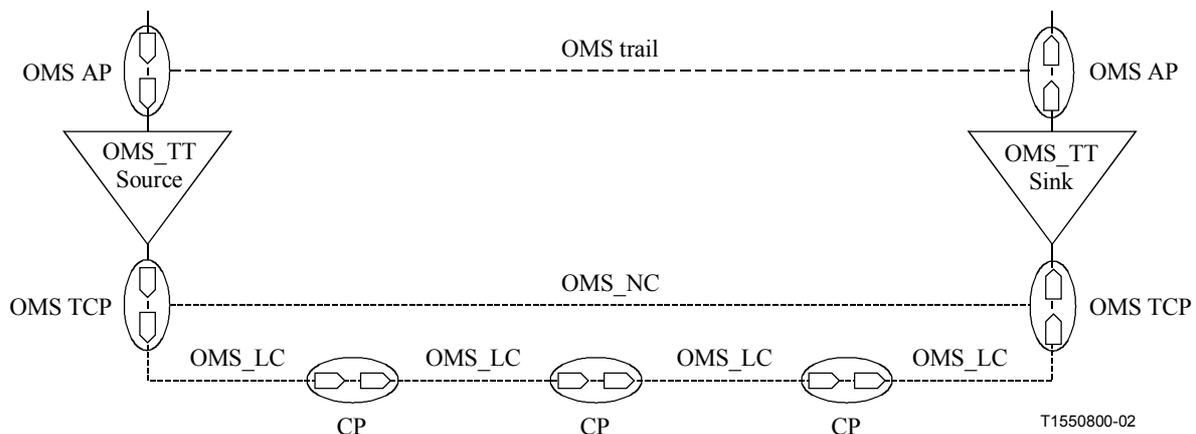


Figure 3/G.872 – OMS layer network example

5.4.1 Optical multiplex section trail termination

The following generic termination processes may be assigned to the optical multiplex section trail termination:

- assessment of transmission quality;
- transmission defect detection and indication.

The requirement for these processes is outlined in detail in 6.2.

There are three types of optical multiplex section trail termination:

- OMS bidirectional trail termination: consists of a pair of collocated optical multiplex section termination source and sink functions.
- Optical multiplex section trail termination source: accepts adapted information from the optical channel layer network at its input, inserts the OMS trail termination overhead and presents the characteristic information of the OMS layer network at its output.
- Optical multiplex section trail termination sink: accepts the characteristic information of the OMS layer network at its input, extracts the OMS overhead and presents the adapted information at its output.

5.4.2 OMS transport entities

Network connections, link connections and trails are as described in ITU-T Rec. G.805. There is no OMS subnetwork defined, as there is no flexibility in this layer network.

5.5 Optical transmission section layer network

The optical transmission section layer network provides for the transport of an optical multiplex section through an optical transmission section trail between access points. An optical transmission section of order n supports a single instance of an optical multiplex section of the same order. There is a one-to-one mapping between the two layers. The OTS defines a physical interface, with optical parameters such as frequency, power level and signal-to-noise ratio. The characteristic information of the OTS is composed of two separate and distinct logical signals:

- the adapted information of the OMS layer;
- the OTS trail termination-specific management/maintenance overhead.

Physically it consists of the following.

- an optical multiplex of order n ;
- an optical supervisory channel.

This characteristic information is an Optical Transport Module of order n (OTM n).

NOTE – In the case of an OTS-1 in a system without back-to-back OTS terminations, or in the case of an OTS-1 used as an OTN_IrDI (see clause 8), alternatives to an OSC for carrying overhead information are for further study.

The OTS layer network contains the following transport functions and transport entities (see Figure 4):

- OTS trail;
- OTS trail termination source (OTS_TT_Source);
- OTS trail termination sink (OTS_TT_Sink);
- OTS network connection (OTS_NC);
- OTS link connection (OTS_LC);
- OTS subnetwork (OTS_SN);
- OTS subnetwork connection (OTS_SNC).

NOTE – OTS_SN and OTS_SNC exist only in the case of OTS 1+1 NC protection.

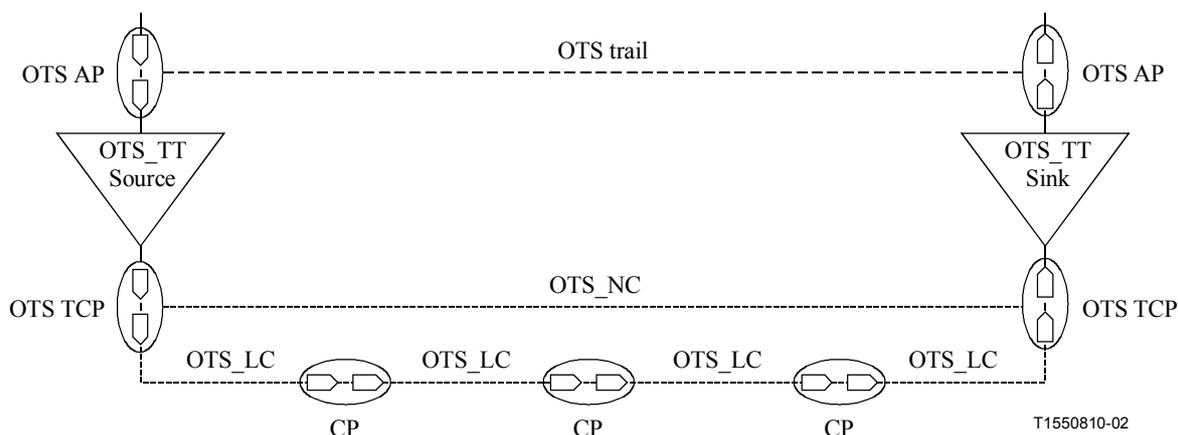


Figure 4/G.872 – OTS layer network example

5.5.1 Optical transmission section trail termination

The following generic processes may be assigned to the optical transmission trail termination:

- validation of connectivity;
- assessment of transmission quality;
- transmission defect detection and indication.

The means of providing these processes is described in 6.2.

There are three types of optical transmission section trail termination:

- OTS bidirectional trail termination: consists of a pair of collocated optical transmission section trail termination source and sink functions.
- OTS trail termination source: accepts adapted information from a client layer network at its input, adds the OTS trail termination overhead and generates the optical supervisory channel, and adds the optical supervisory channel to the main signal. The trail termination function conditions the information for transmission over the physical medium and ensures that the optical signal meets the physical interface requirements. The output of the OTS trail termination source is the characteristic information of the optical transmission section layer network. This characteristic information is referred to as an optical transport module (OTM).
- OTS trail termination sink: accepts the characteristic information of the transmission section layer network at its input, reconditions the information to compensate for signal degradation resulting from transmission over the physical medium, extracts the optical supervisory channel from the main optical signal, processes the OTS trail termination overhead contained within the optical supervisory channel and presents the adapted information at its output.

5.5.2 OTS transport entities

Network connections, link connections and trails are as described in ITU-T Rec. G.805.

The OTS subnetwork, OTS_SN, provides NC protection, within the optical transmission section layer. Characteristic information is routed between input (termination) connection points [(T)CPs] and output (T)CPs.

5.6 Client/server associations

A principal feature of optical transport networks is the possibility of supporting a wide variety of client layer networks. Examples of these client layer networks include an SDH STM-N, and a contiguous ATM cell stream. Restrictions or rules that limit the capability of an optical channel to transfer a particular client layer network are for further study.

The structure of the optical layer networks and the adaptation functions are shown in Figure 1. For the purposes of description of the optical transport network, the interlayer adaptation is named using the server/client relationship.

5.6.1 OCh/Client adaptation

The OCh/Client adaptation (OCh/Client_A) is considered to consist of two types of processes: client-specific processes and server-specific processes. The description of the client-specific processes is outside the scope of this Recommendation.

The bidirectional OCh/Client adaptation (OCh/Client_A) function is performed by a collocated pair of source and sink OCh/Client adaptation functions.

The OCh/Client adaptation source (OCh/Client_A_So) performs the following processes between its input and its output:

- all the processing required to generate a continuous data stream that can be modulated onto an optical frequency carrier. The processes required are dependent upon the particular client/server relationship and may be null. For a digital client the adaptation may include processing such as scrambling and channel coding (e.g. NRZ). For a digital mapping the adapted information is a continuous data stream of defined bit rate and coding scheme;
- generation and termination of management/maintenance signals as described in 6.2.

The OCh/Client adaptation sink (OCh/Client_A_Sk) performs the following processes between its input and its output:

- recovery of the client signal from the continuous data stream. The processes are dependent upon the particular client/server relationship and can be null. For a digital client the adaptation may include processes such as timing recovery, decoding and descrambling;
- generation and termination of management/maintenance signals as described in 6.2.

5.6.2 OMS/OCh adaptation

The bidirectional OMS/OCh adaptation (OMS/OCh_A) function is performed by a collocated pair of source and sink OMS/OCh adaptation functions.

The OMS/OCh adaptation source (OMS/OCh_A_So) performs the following processes between its input and its output:

- modulation of an optical carrier by the optical channel payload signal by means of a defined modulation scheme;
- wavelength (or frequency) and power allocation to the optical carrier;
- optical channel multiplexing to form an optical multiplex;
- generation and termination of management/maintenance signals as described in 6.2.

NOTE – The adaptation function is considered as having two data streams associated with it, one regarding the main optical payload and a second associated with that part of the overhead that is not processed by the OMS_TT. This is also true for the sink adaptation function.

The OMS/OCh adaptation sink (OMS/OCh_A_Sk) performs the following processes between its input and its output:

- optical channel demultiplexing according to carrier wavelength (or frequency);
- termination of the optical carrier and recovery of the optical channel payload;
- generation and termination of management/maintenance signals as described in 6.2.

5.6.3 OTS/OMS adaptation

The bidirectional OTS/OMS adaptation (OTS/OMS_A) function is performed by a collocated pair of source and sink OTS/OMS adaptation functions.

The OTS/OMS adaptation source (OTS/OMS_A_So) performs the following process between its input and its output:

- generation and termination of management/maintenance signals as described in 6.2.

NOTE – The adaptation function is considered as having two data streams associated with it, one regarding the main optical payload and a second associated with that part of the supervisory channel information that is not processed by the OTS_TT. This is also the case for the sink adaptation function.

The OTS/OMS adaptation sink (OTS/OMS_A_Sk) performs the following process between its input and its output:

- generation and termination of management/maintenance signals as described in 6.2.

5.7 Optical network topology

Optical network layers can support unidirectional and bidirectional point-to-point connections, and unidirectional point-to-multipoint connections.

5.7.1 Unidirectional and bidirectional connections and trails

A bidirectional connection in a server layer network may support either bidirectional or unidirectional client layer network connections, but a unidirectional server layer network may only support unidirectional clients.

A bidirectional optical transmission section layer network connection may be supported by one optical fibre for both directions (single fibre working), or each direction of the connection may be supported by different fibres.

Operation, administration and maintenance and overhead transfer in single fibre working is currently not considered in this Recommendation.

5.7.2 Point-to-multipoint connections and trails

A unidirectional point-to-multipoint connection broadcasts the traffic from the source to a number of sinks. This is illustrated in Figure 5 where a point-to-multipoint connection is provided in the optical channel layer by means of a multipoint connection point (MPCP). The MPCP is a reference point that binds a port to a set of connections. It represents the root of a multipoint connection. The broadcast function provided by the MPCP binding is limited to the subnetwork in which it exists. It may form part of a multicast (selective broadcast) function within a larger (containing) subnetwork. The multipoint connection is restricted to a unidirectional broadcast multipoint connection in optical transport networks. This type of connection can be applied in the optical channel layer network.

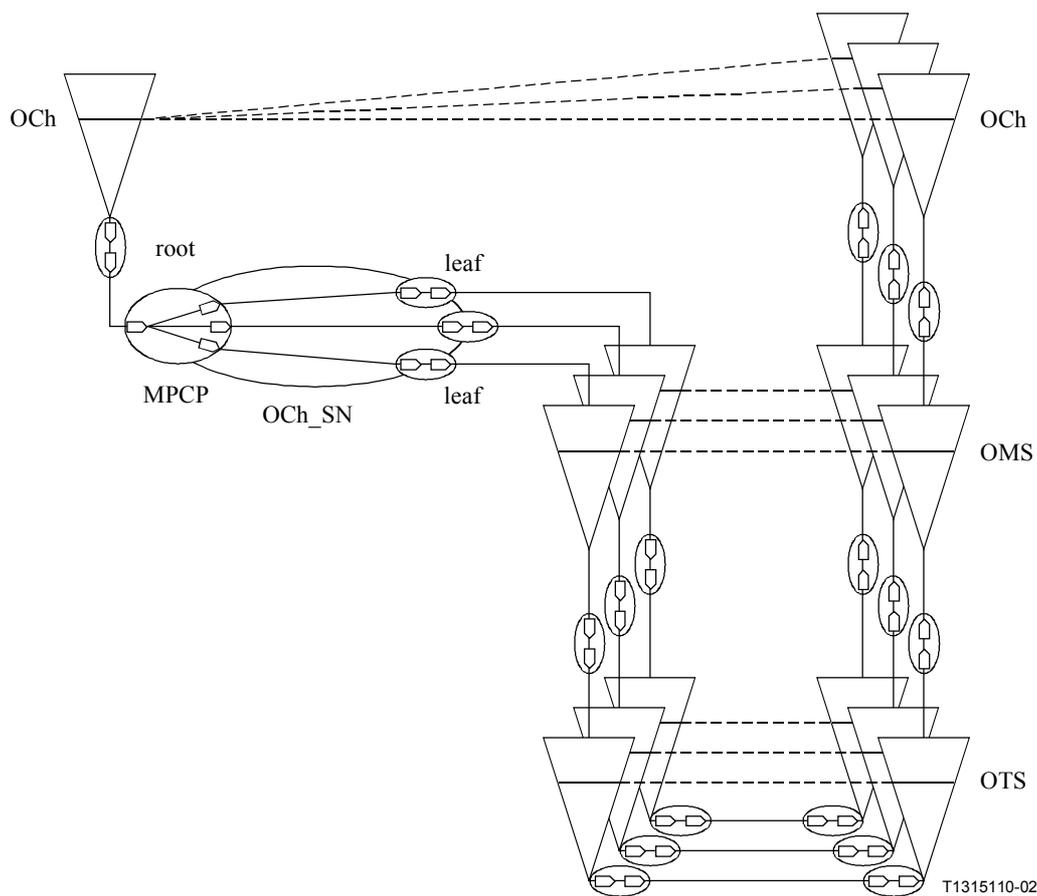


Figure 5/G.872 – Point-to-multipoint optical channel connection

6 Optical network management

This clause describes network management for the optical transport network. In particular, it describes the generic requirements for fault, performance and configuration management. The management processes required in each of the layer networks are outlined in 6.2 and summarized in Table 1. This clause also describes techniques for connection supervision.

6.1 Generic requirements

6.1.1 Generic fault, configuration and performance management

The optical transport network shall provide support for fault, configuration and performance management end-to-end and also within and between administrative boundaries.

It shall provide a means of detection and notification in the event of a misconnection.

The optical transport network shall provide facilities to:

- ensure interconnection of transport network entities that have compatible adapted or characteristic information;
- detect faults, isolate faults and initiate recovery actions where applicable. The optical transport network shall provide facilities for single-ended maintenance.

In the event of a signal within the server layer being interrupted, upstream and downstream network entities in the server layer shall be notified.

The optical transport network shall be able to detect performance degradations to avoid failures and verify quality of service.

6.1.2 Generic management communications

The optical transport network shall support communications between:

- personnel at remote sites;
- OSs and remote NEs;
- craft terminals and local or remote NEs.

These forms of communication may also be supported externally to the optical transport network.

6.1.3 Generic client/server interaction management

The optical transport network shall detect and indicate when a signal is not present at a client layer, within the OTN, also in the case where the server layer is operating normally.

In order to avoid unnecessary, inefficient or conflicting survivability actions, escalation strategies (e.g. introduction of hold-off times and alarm suppression methods) are required:

- within a layer;
- between the server and client layer.

6.2 Optical layer network management requirements

Requirements for management capabilities with respect to the Optical Channel, Optical Multiplex Section and Optical Transmission Section layer networks are identified in this clause. A summary of the optical layer network management requirements is given in Table 1 and discussed in detail below.

Table 1/G.872 – Optical transport network – Network level management requirements

Management capability	Process	Function	Layer network			Comments
			OCh	OMS	OTS	
Continuity supervision	<ul style="list-style-type: none"> • Loss of continuity detection 	TT	R	R	R	See 6.2.1.
Connectivity supervision	<ul style="list-style-type: none"> • Trail trace identification 	TT	R ^{a)}	–	R	See 6.2.1.
Maintenance information	<ul style="list-style-type: none"> • Forward defect indication 	TT	R	R	R	See 6.2.1.
	<ul style="list-style-type: none"> • Backward defect indication 	TT	R	R	R	
	<ul style="list-style-type: none"> • Backward quality indication 	TT	R	FFS	FFS	
Signal quality supervision	<ul style="list-style-type: none"> • Performance monitoring (parameters are for further study) 	TT	R	FFS	R	See 6.2.2.
Adaptation management	<ul style="list-style-type: none"> • Payload type indication 	A	R	FFS	–	See 6.2.3.
Protection control	<ul style="list-style-type: none"> • Automatic protection switching protocol 	A/T	R*	R*	–	See 6.2.4.

Table 1/G.872 – Optical transport network – Network level management requirements

Management capability	Process	Function	Layer network			Comments
			OCh	OMS	OTS	
Connection supervision	<ul style="list-style-type: none"> • Inherent monitoring • Non-intrusive mon. • Intrusive mon. • Sublayer mon. 	TT	R*	R*	R*	See 6.3.
			R*	–	–	
			R*	R*	R*	
			R*	–	–	
Management communications	<ul style="list-style-type: none"> • Message-based channel • Auxiliary channel • Operator-specific • National use 	A	–	FFS	R	See 6.2.5
		A	–	–	R*	
		A	–	–	R	
		A	–	–	FFS	
–	Not applicable	R	Required			
A	Adaptation function	R*	Required (if management capability has to be supported)			
FFS	For further study	TT	Trail termination function			
a) The only exception to this requirement is described in 6.2.1.						

6.2.1 Connection supervision

It is a management requirement to provide supervision of the integrity of network connections that are supporting the trails in any layer network. A link connection supported by a server layer network is supervised by means of continuity supervision. The subnetwork connections that result from the flexible association of connection points across the subnetwork are supervised by means of connectivity supervision. For the particular case that there is no possibility to rearrange network connections between a group of OCh source and a group of OCh sink trail terminations, connectivity supervision is not required.

Continuity supervision

Continuity supervision refers to the set of processes for monitoring the integrity of the continuity of a trail.

The following process is identified for continuity supervision:

- Detection of Loss of Continuity (LOC).

In general, the failure of a link connection in a server layer will be indicated to a client layer through some form of server signal fail indication. The OTS layer, the lowest layer of the OTN, is a special case since its network connections are supported directly by the optical physical media layer. Since the latter does not contain active components, the OTS trail termination sink will not receive server fail indications – as is the case for trail terminations in higher layers – and has to detect failures in the optical physical media layer by itself.

Optical network failures include fibre disruptions and equipment failures. Equipment failures as such will be detected and reported by equipment monitoring capabilities.

The fibre disruption case is the most important failure scenario to consider from a network level view. Following a fibre disruption, loss of the aggregate signal may be observed at the first downstream OTS trail termination sink. The aggregate signal consists of the multiplexed wavelengths carrying the optical channels and the wavelength carrying the optical supervisory channel. Loss of the aggregate signal therefore results in loss of continuity of the multiplexed wavelengths and loss of continuity of the optical supervisory channel. Subsequently, the detection of the loss of the aggregate signal will be indicated towards the client layer. Note that loss of continuity of the optical supervisory channel by itself shall not initiate consequent actions on the client signal. In general, the same philosophy should be adopted in any layer network where payload and overhead have independent failure mechanisms.

At the OTS layer an optical component failure may lead to the loss of optical channels but may not lead to the loss of the optical supervisory channel. This will generate a server signal fail indication to the OMS layer and a forward deflection indication within the OTS layer, the same consequent actions as in the fibre disruption case.

A server signal fail detected by the OMS trail termination sink will lead in turn to a server signal fail towards the OCh layer. In the OMS adaptation source the server signal fail will lead to a forward defect indication of the affected optical channels. It is conceivable that the OMS trail termination sink will detect a loss of continuity of the OMS trail without a loss of continuity being detected in the OTS trail. Consequent actions are the same as for the server signal fail case.

A server signal fail detected by the OCh trail termination sink will lead in turn to a server signal fail towards the client layer. The processing in the OCh adaptation source of the server signal fail is client specific. It is conceivable that the OCh trail termination sink will detect a loss of continuity of the OCh trail without a loss of continuity being detected in the OTS or OMS trail. Consequent actions are the same as for the server signal fail case.

Note that failure conditions within the OTN and/or unused (unlit) optical channel layer connections can result in missing optical payload for downstream server layer trails (e.g. the fibre disruption at the input of an optical amplifier results in missing channels at the output of the optical line amplifier). This shall not result in loss of continuity for that trail (e.g. loss of channels at following OTS trail terminations in the example above). Appropriate maintenance signalling shall be used to prevent this.

Connectivity supervision

Connectivity supervision refers to the set of processes for monitoring the integrity of the routing of the connection between source and sink trail terminations.

Connectivity supervision is necessary to confirm proper routing of a connection between trail termination source and sink during the connection set-up process. Furthermore, connectivity supervision is needed to ensure that connectivity is maintained while the connection is active.

The following process is identified for connectivity supervision:

- Trail Trace Identification (TTI)

Trail Trace Identification is necessary to ensure that the signal received by a trail termination sink originates from the intended trail termination source. The following requirements are identified:

 - Trail Trace Identification is necessary at the OTS layer to ensure proper cable connection.
 - Trail Trace Identification is not needed at the OMS layer because there is a one-to-one relationship between the OTS and OMS layers, i.e. connectivity at the OMS layer is fixed; therefore, the OMS connection is already covered by the OTS trail trace identification. Flexible connectivity at the OMS layer is not envisaged.

- Trail Trace Identification at the OCh layer is only needed where there is a possibility of channel rearrangement between OCh source/sink trail terminations.

Detection of connectivity defects will lead to the same consequent actions as described above for the detection of loss of continuity for the characteristic information.

Maintenance information

Maintenance information refers to the set of processes for indicating defects in a connection, which is part of a trail. The defect indications are given in downstream and upstream directions of a bidirectional trail.

Three maintenance information processes are identified:

- Forward Defect Indication (FDI);
- Backward Defect Indication (BDI);
- Backward Quality Indication (BQI).

These processes enable defect localization and single-ended maintenance.

FDI is used to indicate downstream that a defect condition has been detected upstream. This allows the suppression of superfluous failure reports due to the defect.

BDI and BQI signal the state of the trail at the trail termination sink back to the remote trail termination sink. This assists in the maintenance of Inter-Domain Interfaces (see clause 9). In addition, BDI and BQI support the real-time requirements of bidirectional performance monitoring.

In general, FDI and BDI are associated with the activation of server signal fail. Detailed requirements for individual layers are for further study.

FDI and BDI are applicable at the OCh, OMS and OTS layers.

BQI is applicable at the OCh layer, applicability for OMS and OTS layers is for further study.

NOTE – FDI, BDI and BQI terminology is used instead of the traditional AIS, RDI and REI terminology in order not to prejudice the fault maintenance indications and functionality required by the OTN.

6.2.2 Signal quality supervision

Signal quality supervision refers to the set of processes for monitoring the performance of a connection, which is supporting a trail.

Signal quality supervision is necessary for determining the performance of connections. Generic processes include parameter measurement, collection, filtering and processing. In terms of network level management, signal quality supervision is needed to manage channels and multiplexed channels. Thus, performance parameter monitoring at the OCh and OTS layers is required. Identification of specific parameters required to be monitored for determining the quality of OCh and OTS connections is for further study.

The requirement to monitor parameters in OMS layer is for further study.

6.2.3 Adaptation management

Adaptation management refers to the set of processes for managing client layer network adaptation to/from the server layer network.

The following process is identified for adaptation management in the OTN:

- Payload Type Identification (PTI);

This process is necessary to ensure the client layer is assigned at connection set-up to the appropriate source and sink OCh/Client adaptations. A payload type identifier mismatch detected at source or sink adaptations would indicate an incorrectly provisioned or altered client-OCh server layer adaptation. The OCh/Client adaptation may contain client-specific supervision processes. Definition of these processes is outside the scope of this Recommendation.

Application of the PTI process at the OMS layer is for further study.

The PTI process is not applicable at the OTS layer. A client of the OTN is transparent at this layer.

6.2.4 Protection control

Protection control refers to the information and set of processes for providing control of protection switching for a trail or subnetwork connection. Protection switching is controlled on the basis of local criteria generated by the trail or subnetwork connection supervision and by the TMN/OS. Additionally, control from the remote network element using an automatic protection switching protocol (APS) is possible depending on the protection switching architecture.

Clause 7.1 describes two protection architectures:

- those that are controlled by local information of the NE (e.g. 1+1 unidirectional trail or SNC protection architectures); an automatic protection switching (APS) protocol is not required for these protection architectures;
- those that are controlled in addition by information from the NE being the remote end of the protected entity (e.g. 1:N trail protection or shared protection rings). These architectures require an APS protocol.

6.2.5 Subnetwork/tandem/unused connection supervision

Supervision for subnetwork, tandem and unused connections is required for the OCh layer and is for further study for the OMS and OTS layer. Connection supervision techniques and applications are listed in 6.3 and 6.4.

6.2.6 Management communications

General management communications that are not associated to a particular OTN layer (e.g. ASON signalling, voice/voiceband communications, software download, and operator-specific communications) are transported via a logical overlay management network. Depending on an operator's implementation of their logical overlay management network, a link connection of this logical management overlay network may share the facility supporting the ONNI (e.g. certain general management communications may be carried over the OSC).

6.3 Connection supervision techniques

Connection supervision is the process of monitoring the integrity of a given connection in the optical transmission section, optical multiplex section or optical channel layer networks. The integrity may be verified by means of detecting and reporting connectivity and transmission performance defects for a given connection. ITU-T Rec. G.805 defines four types of monitoring techniques for connections.

The connection supervision process can be applied to network connections and connection segments, where the latter is defined as an arbitrary series of subnetwork connections and link connections.

6.3.1 Inherent monitoring

Connections may be indirectly monitored by using the inherently available data from the server layers and computing the approximate state of the client connection from the available data.

Optical channel layer connections may be indirectly monitored by using the inherently available data from the optical multiplex section and computing the approximate state of the optical channel connection from the available data.

Optical multiplex section layer connections may be indirectly monitored by using the inherently available data from the optical transmission section and computing the approximate state of the optical multiplex section connection from the available data.

Inherent monitoring is not applicable in the optical transmission section as the server layer is the physical media and provides no data.

6.3.2 Non-intrusive monitoring

The connection is directly monitored by use of listen-only (non-intrusive) monitoring of the original data and overhead. The approximate state of the connection can be determined by the information provided at each of the monitoring points.

Non-intrusive monitoring of the characteristic information transported by a connection is an application that can be used to provide fault localization. If a trail termination sink function detects a disturbance, it may not be immediately obvious where this disturbance first originated. The trail termination sink function therefore indicates that there is a disturbance of a certain kind but not where it is. In order to locate such a disturbance, the trail is viewed as a series of link connections. At the end of every link connection, a non-intrusive monitoring termination sink function (TTm) may be used to monitor the characteristic information at that point. The TTm does not provide any adapted information at its output. An example of the application of non-intrusive monitoring is illustrated in Figure 6. Traversing from the trail termination sink function and going towards the trail termination source, the fault is located between those two termination sink functions of which the upstream function reports disturbance free performance while the other reports the disturbance condition.

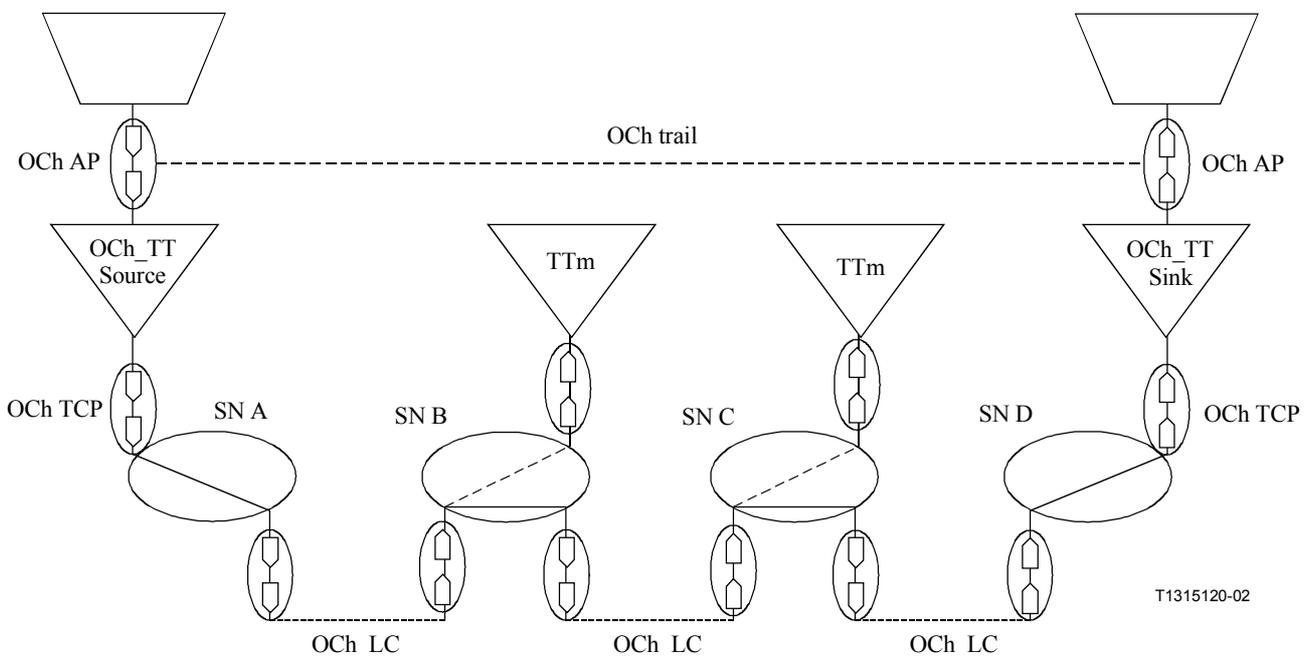


Figure 6/G.872 – Example of subnetwork connection supervision using non-intrusive monitoring

Connections may be directly monitored by means of the relevant overhead information in the optical multiplex section and optical channel layers and then computing the approximate state of the

connection from the difference between the monitored states at each end of the connection. Non-intrusive monitoring is not required in the OTS, unless OTS-level network connection is employed in systems without line amplifiers.

6.3.3 Intrusive monitoring

A connection is directly monitored by breaking the original trail and introducing a test trail that extends over the connection for the duration of the test. This allows all parameters to be monitored directly; however, the user trail is not complete and this technique is therefore restricted to the beginning of trail set-up, or intermittent testing.

Intrusive monitoring may be used for testing fibre continuity and for fault localization.

6.3.4 Sublayer monitoring

Some portion of the original trail's overhead capacity is overwritten such that the part of the connection that is of interest can be directly monitored by a trail created in a sublayer. With this technique all parameters can be tested directly. This scheme can provide for nested sublayer trail monitored connections.

Optical channel layer (network, subnetwork, tandemed link and link) connections may be directly monitored by means of insertion of connection monitoring overhead at the ingress of the connection and extraction and processing of this overhead at the egress of the connection.

Sublayer monitoring is not available for optical multiplex sections and optical transmission sections.

6.4 Connection supervision applications

6.4.1 Monitoring of unused connections

Optical channels are either in-service or not (as described in 5.4). Furthermore, out-of-service channels are either lit or unlit. Lit out-of-service channels shall generate a valid optical channel overhead with an appropriate payload (e.g. a NULL client with an all-0s pattern or a PRBS test signal, and a payload type identifier. For such, a signal monitoring is the same as for in-service channels.

6.4.2 Connection monitoring

The intended role of optical channel connection monitoring is to represent that portion of an optical channel connection that requires independent monitoring from other parts of the optical channel connection.

Optical channel connection monitoring can be applied at:

- the network connection, establishing the layer network's trail;
- any subnetwork connection, establishing a serving operator administrative domain tandem connection;
- any tandem link connection or link connection, establishing a service requesting administrative domain tandem connection or a protected domain tandem connection;
- any link connection, for fault and performance degradation detection for network maintenance purposes.

Optical channel connection monitoring can be established for a number of nested connections, up to the maximum level defined by implementation-specific Recommendations (e.g. ITU-T Rec. G.709). The number of connection monitoring levels that can be used by each operator/user involved in an optical channel connection must be mutually agreed between these operators and users.

An example (with five levels of nested connection monitoring) is presented in Figure 7. An optical channel signal generated in user network 1 is transported via the networks of 3 network operators to user network 2. Both user networks contain multiple OTN network elements.

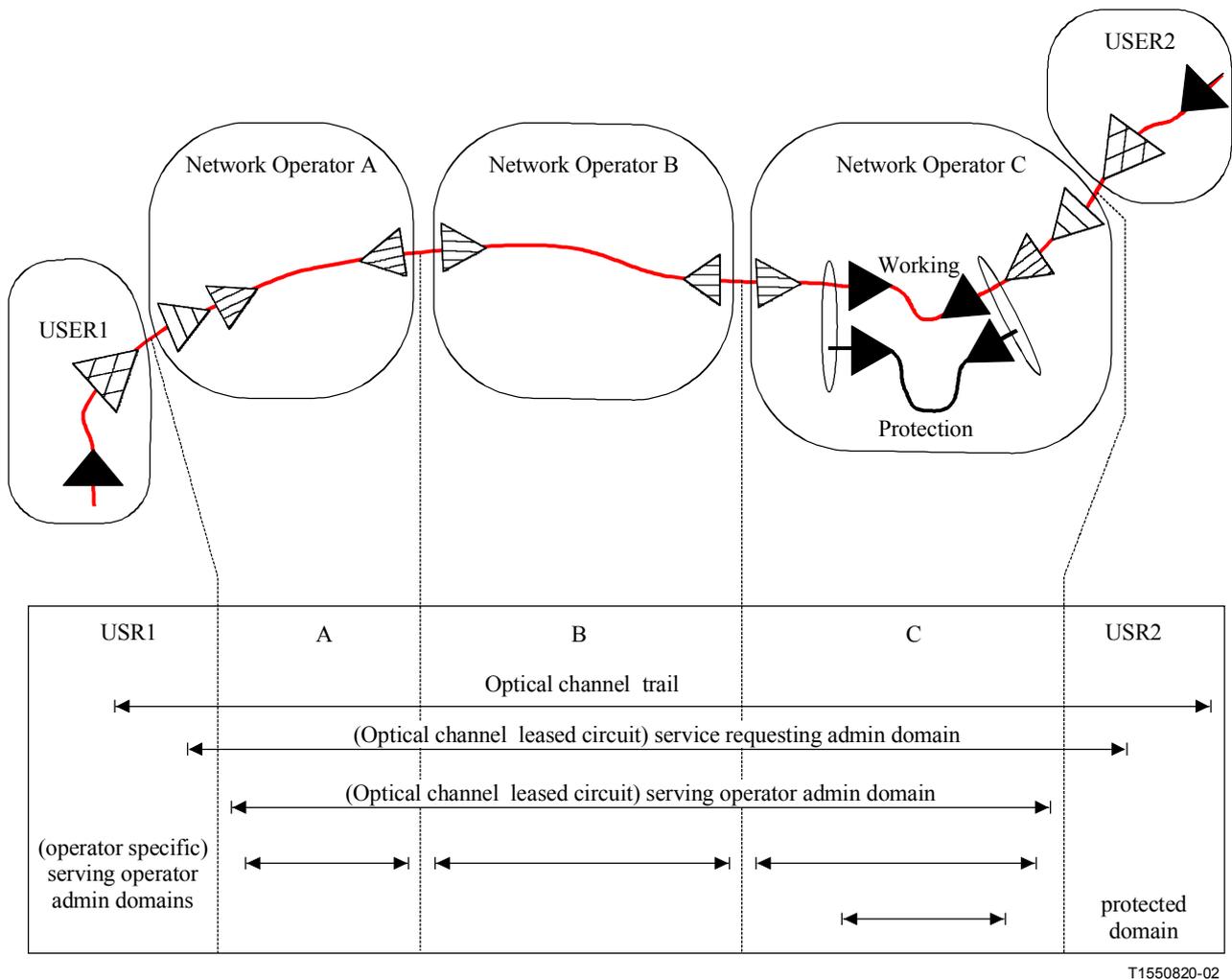


Figure 7/G.872 – Example of OCh connection monitoring

The three network operators offer an optical channel leased circuit to the user network. The user network is capable to monitor the quality of service of the optical channel at an end-to-end basis and between the edges of the two user networks. The network operators monitor the quality of service of the jointly offered optical channel leased circuit, of the optical channel connection in each network operator domain and of a working and protection connection in a protected domain within the network of network operator C.

Monitoring the interconnection between any two adjacent networks (USR1-NO A, NO A-NO B, NO B-NO C, NO C-USR2) can be performed by means of the activation of additional connection monitors at each end of the interconnection (not illustrated). This will prevent white spots (unmonitored portion) to be present in the connection.

Connection monitoring provides the following functions (between the ends of the connection):

- connection near-end fault management and performance monitoring (error performance and failure/alarm conditions):
 - connection server signal fail verification (i.e. FDI/AIS);

- connection continuity verification (i.e. loss of continuity);
- connection connectivity verification (i.e. trace);
- connection error verification (i.e. error detection code);
- connection far-end fault management and performance monitoring (error performance and failure/alarm conditions):
 - connection backward defect indication;
 - connection backward error indication;
- connection monitoring independent of the content/status of the incoming signal itself;
- addition or tearing down of a connection monitoring level without interruption of the traffic, and (as an objective) without introducing of monitoring errors at the other connection monitoring levels;
- non-intrusive monitoring of any connection monitoring level at any intermediate point within the specific connection for:
 - monitoring the total connection from this point based on the backward indications (note that this is possible only in case of bidirectional connections);
 - monitoring of the status of the connection at this point.

Optical channel connection monitoring can be applied to unidirectional and bidirectional connections. For the case of unidirectional connections, far-end fault management and performance monitoring is not supported and the addition or tearing down of a connection monitor level may introduce a traffic interruption.

7 Optical network survivability techniques

This clause describes the architectural features of network strategies that may be applied to enhance the survivability of optical transport networks from network link and node impairments. The survivability techniques considered for optical transport networks encompass both protection and network restoration capabilities.

The following network objectives for the selection of self-healing architectures are seen as the predominant ones:

- Heal quickly (on the order of SDH rings).
- Coexist in harmony with possible client layer schemes (e.g. SDH rings). An example would be the ability to enable/disable the OTN protection scheme on a per Optical Channel basis.
- Heal single points of failure.
- Minimize the rerouting distance (to avoid physical layer impairments on the signals).
- Gracefully accommodate multiple failures.
- Avoid hits on traffic unaffected by the failure.
- Minimize the amount of protection bandwidth required.
- Minimize the amount of signalling complexity required.
- Support prior path verification.
- Take into account OTN ring interworking.
- Take into account optical channel layer mesh networks and interworking.

7.1 Protection techniques

A protection application makes use of pre-assigned capacity between nodes. The simplest architecture has 1 working and 1 protection capacity (1+1); the most complex architecture has n working and m protection capacities (m:n).

Unidirectional protection is defined as a protection switching method which switches only the affected traffic direction in the event of a unidirectional failure. Bidirectional protection switches both directions of traffic in the event of a unidirectional failure.

Three types of protection architecture are considered: trail protection, subnetwork connection protection, and shared protection rings.

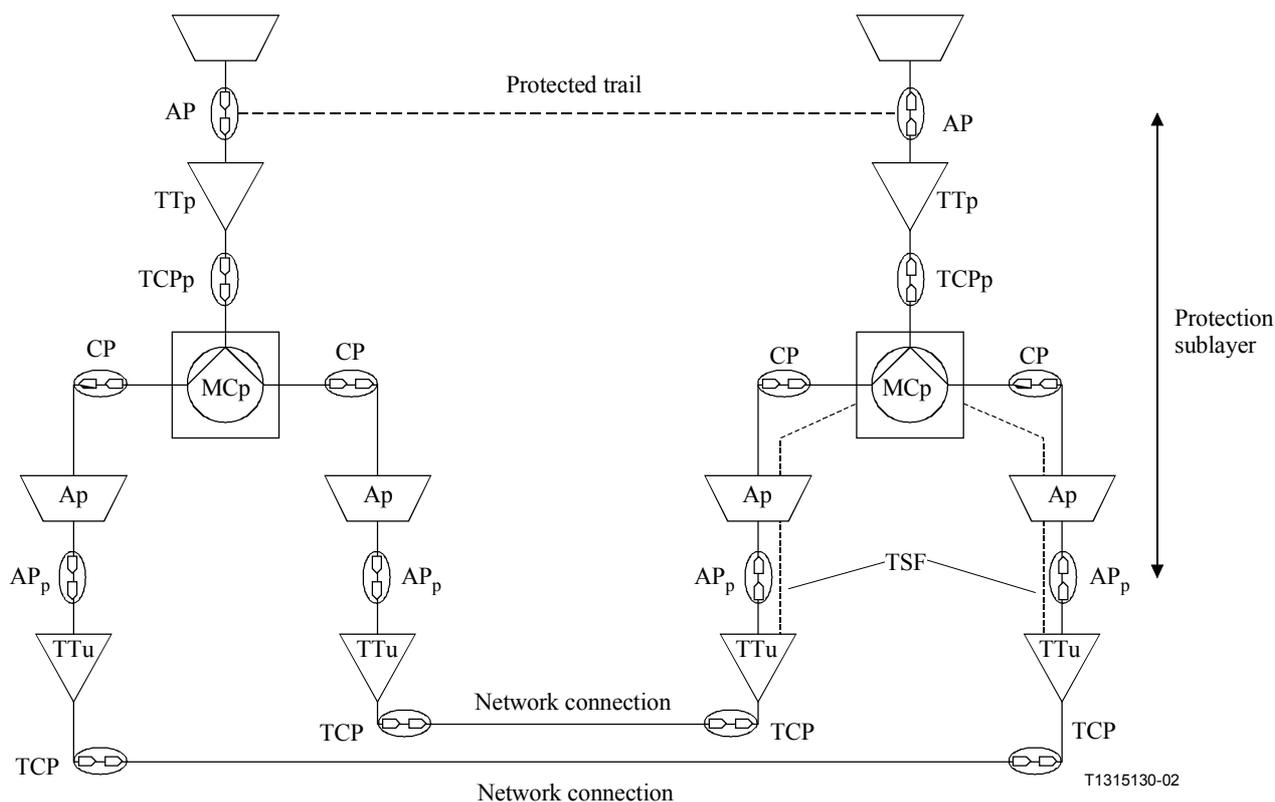
7.1.1 Trail protection

Trail protection is a dedicated end-to-end protection mechanism that can be used on any physical structure (i.e. meshed, ring, or mixed). A working trail is replaced by a protection trail if the working trail fails or if the performance falls below the required level. Trail protection can operate in a unidirectional or bidirectional manner.

Trail protection may also be 1+1, where the dedicated protection trail is only used for protection purposes, or 1:N where extra traffic may be supported.

The following type of trail protection may be used in optical transport layers:

- *1+1 unidirectional trail protection*
In this architecture, a permanent bridge is utilized at the transmit end. At the receive end of the trail, a protection switch is effected by selecting one of the signals based on purely local information. This architecture is illustrated in Figure 8. It may be used without an automatic protection switching protocol.
- *1:N trail protection*
In this architecture, N working trails that are to be protected share an additional trail for protection purpose. In a normal condition, this protection capacity can be used to carry lower priority “extra traffic”. This extra traffic itself is not protected and is to be replaced by higher priority working traffic under failure conditions. This architecture requires an APS protocol as described in 6.2.4 (protection control).



Ap	Protection adaptation	TSF	Trail signal fail
AP _p	Protection access point	TTp	Protected trail termination
MC _p	Protection matrix connection	TTu	Unprotected trail termination
TCP _p	Protection TCP		

Figure 8/G.872 – 1+1 unidirectional trail protection

7.1.2 Subnetwork connection protection

Subnetwork connection protection is a dedicated protection mechanism that may be used on any physical structure (i.e. meshed, ring, or mixed). It may be used to protect part or all of a network connection. Subnetwork connection protection using inherent monitoring (SNC/I) protects against failures and degradations in the server layer. The switching process and defect detection process are performed by two adjacent layers, with the server layer providing the defect and degradation detection process and the client layer performing the protection switching based on the server layer information.

Note that SNC/I is normally limited to a single server layer trail for the working and protection connection between the sink and source protection switch as only information about the locally terminated server layer trail is available. Information about further upstream server layer trails is normally not available at the protection switching selector.

Subnetwork connection protection using non-intrusive monitoring (SNC/N) uses client layer information to protect against failures in the server layer and failures and degradations in the client layer. Subnetwork connection protection using sublayer trail monitoring (SNC/S) uses a trail created in a sublayer to protect against failures. Some portion of original trail's capacity is overwritten such that the part of connection that is of interest can be directly monitored by the trail created in a sublayer.

The following SNC protection architectures have been identified for optical networks:

- *1+1 unidirectional SNC/I, SNC/N and SNC/S*

In these architectures, a permanent bridge is utilized at the transmit end. At the receive end, a protection switch is effected by selecting one of the signals based on purely local information. For protection-switching criteria, inherent, non-intrusive or sub-layer monitoring as defined in 6.3 can be used.

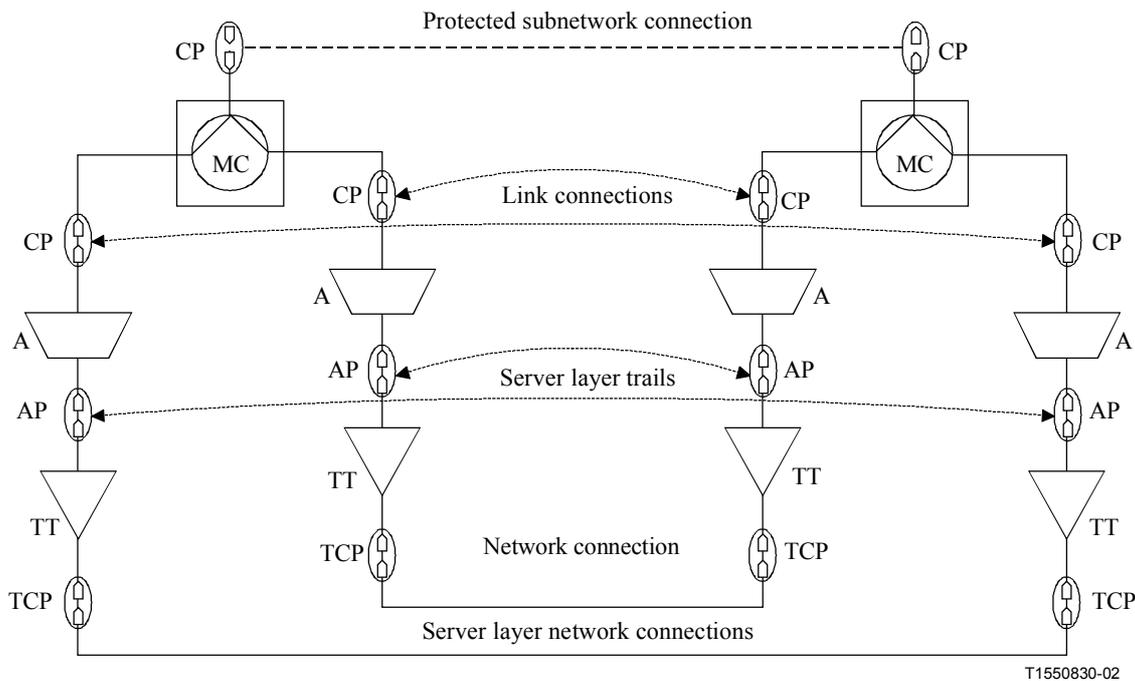
These architectures are illustrated in Figures 9, 10, and 11. They may be used without an automatic protection switching protocol.

- *1:N SNC/S protection*

In this architecture, N working subnetwork connections that are to be protected share an additional subnetwork connection for protection purpose. In a normal condition, this protection capacity can be used to carry lower priority “extra traffic”. This extra traffic itself is not protected and is to be replaced by higher priority working traffic under failure conditions. This architecture requires an APS as described in 6.2.4 (protection control).

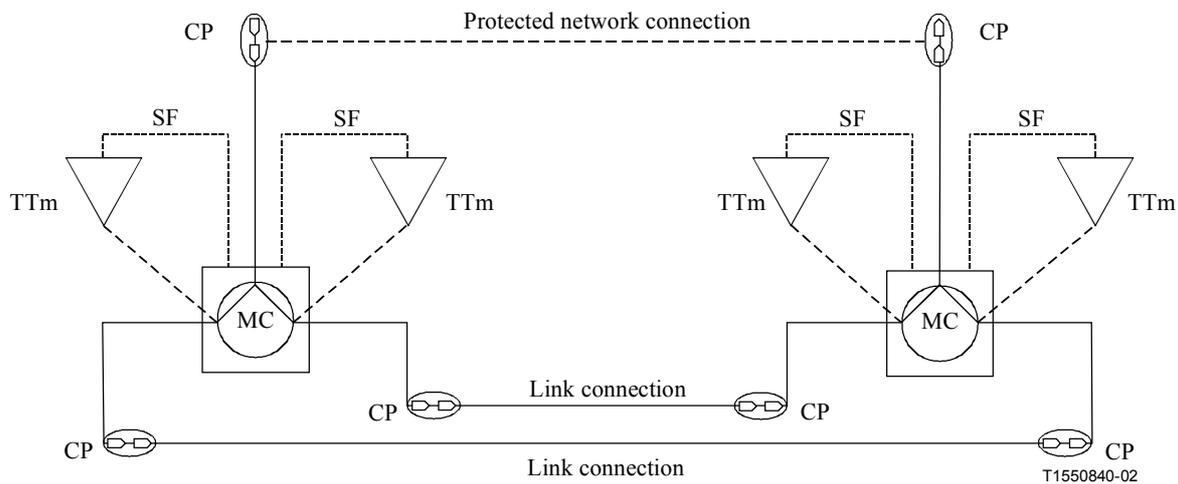
For protection-switching criteria, sub-layer monitoring as defined in 6.3 can be used.

Other architectures are for further study.



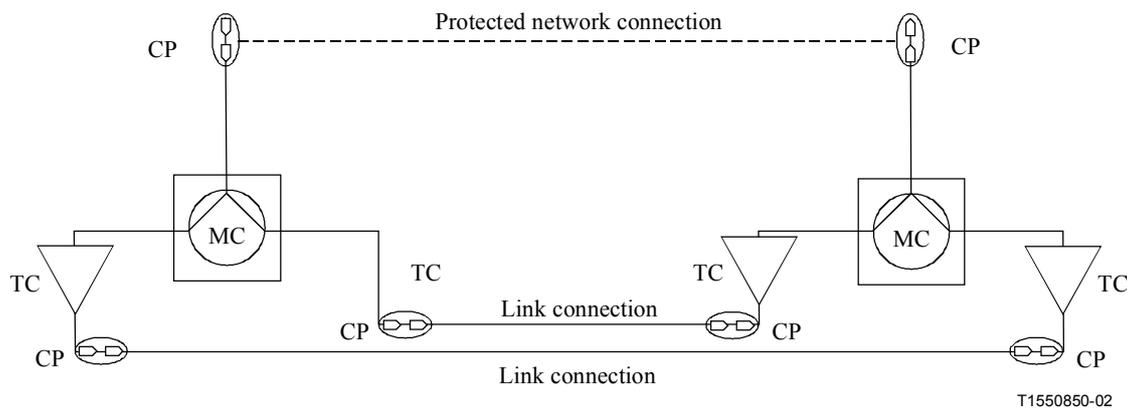
A	Adaptation	MC	Matrix connection
AP	Access point	TCP	Termination connection point
CP	Connection point	TT	Trail termination

Figure 9/G.872 – Subnetwork connection protection with inherent monitoring



- AP Access point
- CP Connection point
- MC Matrix connection
- SF Signal fail
- TTm Non-intrusive trail termination monitor

Figure 10/G.872 – Subnetwork connection protection with non-intrusive monitoring



- CP Connection point
- MC Matrix connection
- TC Tandem connection termination

Figure 11/G.872 – Subnetwork connection protection with sublayer monitoring

7.1.3 Shared protection rings

This architecture virtually provides each connection to be protected with a pre-assigned 1:1 protection route and capacity. The protection connection itself does not carry a copy of the working connection under non-failure conditions; therefore, the capacity is not occupied and can be used for the extra traffic with a lower priority. The extra traffic itself is not protected. This protection capacity can be shared by other protection connections on a link-by-link basis. To restore a network failure, the affected working connections are switched to counter-directional routes on an end-to-end basis with pre-assigned wavelengths. This architecture requires an APS protocol.

7.2 Network protection applicability in the optical transport network

In the optical transport network the protection techniques described above can be applied as illustrated in Table 2.

Table 2/G.872 – Protection techniques for the optical transport network

Protection technique	OTS layer	OMS layer	OCh layer
1+1 trail protection	NA	A	A
1:N trail protection	NA	A	NA
1+1 SNC/N, SNC/S and SNC/I	NA	NA	A
1:N SNC/S	NA	NA	A
Shared protected ring	NA	A	A
A Applicable			
NA Not Applicable			

7.3 Network restoration

Optical network restoration techniques are based on optical channel cross-connection. In general, the algorithms used for restoration involve re-routing. Strategies for re-routing are not technology specific and, therefore, outside the scope of this Recommendation.

8 Interconnection and interworking between different administrative domains

As optical networking technology is evolving, so will the methods by which interconnection and interworking between different administrative domains takes place. In this context we refer to interconnection to describe a physical interface between two administrative domains. Interworking refers to the agreed networking level between domains and is described in terms of the characteristic information that is transferred transparently across domains. The following scenarios are foreseen:

- a) Initially as WDM point-to-point line systems and more complex optical network elements are introduced, they will be operated as OTN islands contained within administrative domains. Interconnection with existing transport networks (e.g. PDH and SDH networks) may take place at one of the physical interfaces which have been standardized for these networks. Such interconnection generally involves modifying the physical characteristics of the signal which is passed over an inter-domain interface, such as a G.957 optical signal for SDH-based transport networks, so that the adapted information of the signal is OTN compliant. This method of interconnection is illustrated in Figure 12 with a non-OTN Inter-Domain Interface (non-OTN_IrDI) between administrative domains A and B. Domain B contains an OTN while domain A may or may not. Also shown in Figure 12 is an OTN Intra-Domain Interface (OTN_IaDI). For Intra-Domain applications, no need is currently foreseen for the standardization of fully transverse compatible interfaces.

Interworking takes place at some agreed-upon client layer and its supervision is based upon client-specific maintenance signals. No optical supervisory channel is required for this application.

- b) As a second step, as capacity for interconnect increases, OTN compliant systems may be applied to interconnect administrative domains. This is depicted in Figure 13. The interconnection point is referred to as an OTN Inter-Domain Interface (OTN_IrDI). This interface may be single channel or multichannel.

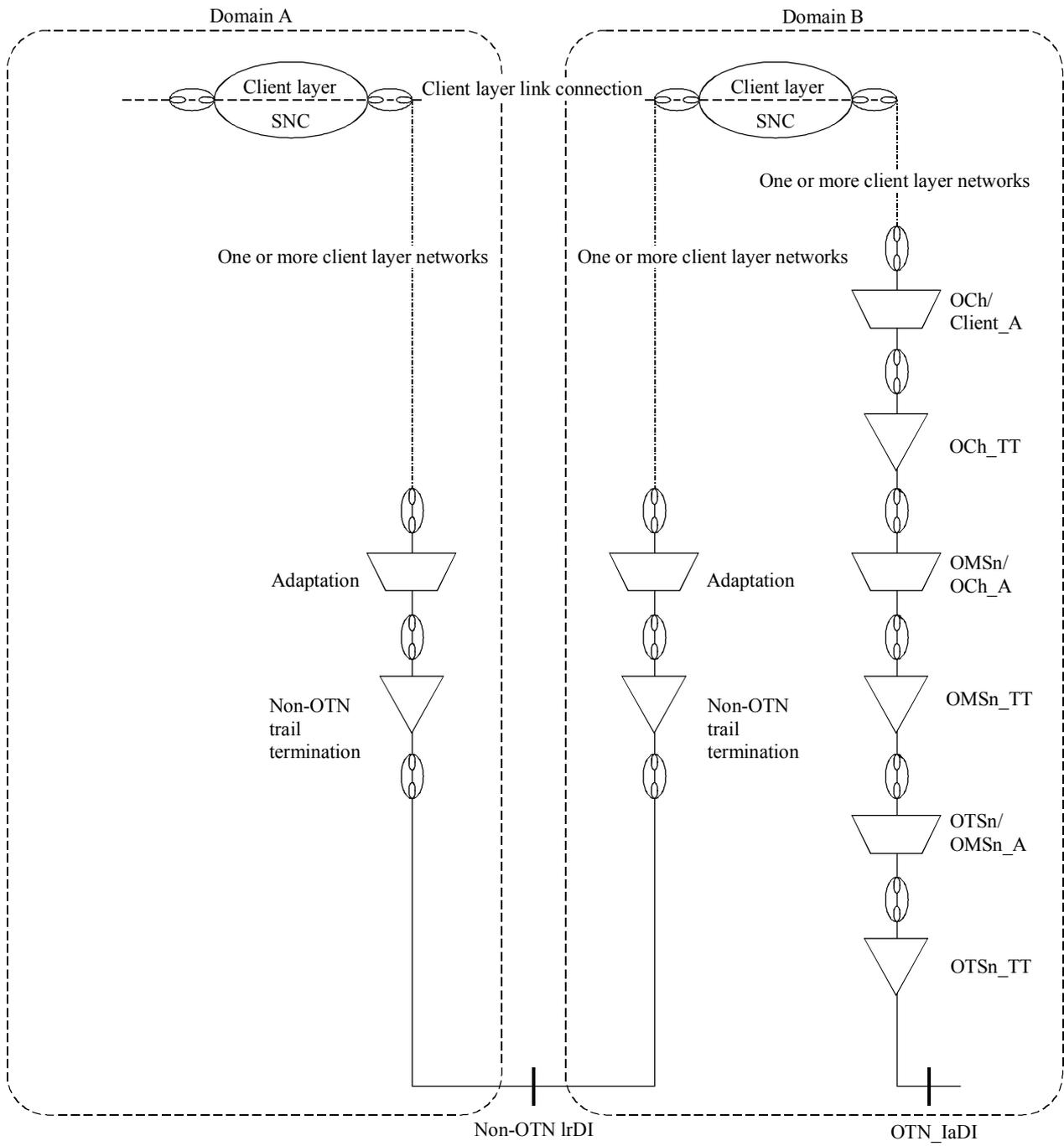
For this first application, standardization of a transverse compatible short distance (e.g. <40 km) interface has first priority. No optical supervisory channel is required for this application.

Second priority should be given to transverse compatible interfaces that span longer distances. No optical supervisory channel is required if there are no intermediate network elements between the IrDI point and the network element providing interworking.

Obviously such OTN_IrDIs may also be applied to Intra-Domain applications (OTN_IaDI).

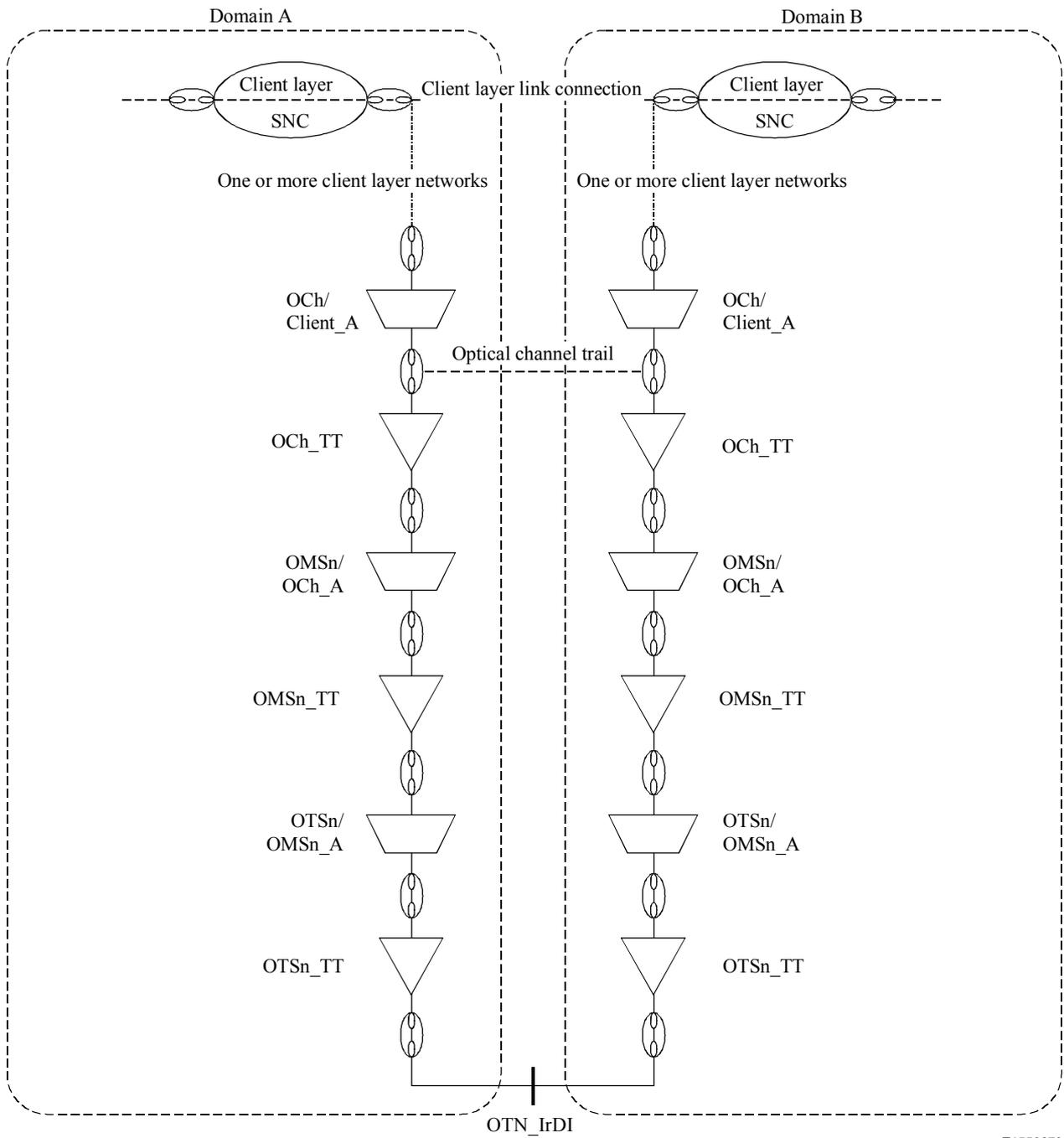
For this step, limited optical channel overhead may be applied. Interworking will continue to take place at some agreed upon client layer as in case a).

- c) Finally, when the standards for the overhead are in place and implemented, it will become possible to provide continuity for the OCh at the interconnection point between different administrative domains as shown in Figure 14. The OTN_IrDI is intended to be used for this purpose. This use of an OTN compliant interface is driven by the need to provide OCh continuity. Therefore, the IrDI may be a single-channel or a multi-channel interface. For the purpose of OMS/OTS maintenance, no optical supervisory channel is required if there are no intermediate network elements between the IrDI point and the network element providing interworking. In this case the OMS/OTS layer networks are collapsed into a single OPS layer network (refer to ITU-T Recs. G.709 and G.798). New applications that may require the use of the OSC are for further study.



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Figure 12/G.872 – Scenario 1: Interconnection of different administrative domains via a non-OTN interface



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Figure 13/G.872 – Scenario 2: Interconnection of different administrative domains via an optical island with an OTN inter-domain interface

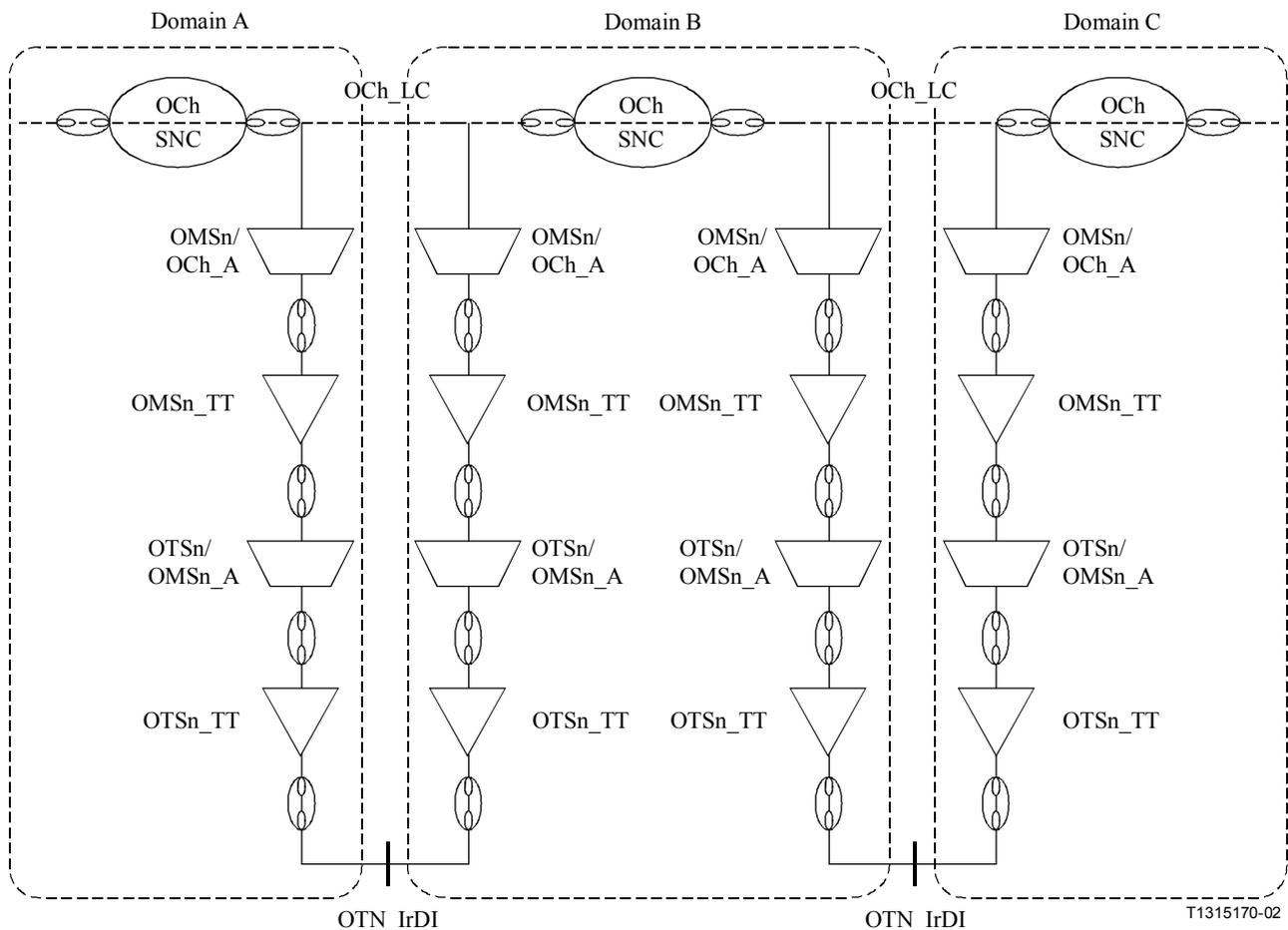


Figure 14/G.872 – Scenario 3: Interconnection of OTN subnetworks in different administrative domains via an OTN inter-domain interface supporting OCh interworking

9 Implementation aspects of the optical channel

9.1 Introduction

Table 1 presents the maintenance requirements for each layer of the OTN, and for the OCh layer in particular. Clause 6.2.1 discusses the requirements for continuity and connectivity supervision, while clause 6.2.2 discusses the requirements for signal quality supervision. In brief, the requirements for connectivity supervision were assigned to associated overhead, overhead that cannot be separated from the payload.

During the development of ITU-T Rec. G.709, (implementation of the Optical Channel Layer according to ITU-T Rec. G.872 requirements), it was realized that the only techniques presently available that could meet the requirements for associated OCh trace, as well as providing an accurate assessment of the quality of a digital client signal, were digital techniques. Because the scope of ITU-T Rec. G.872 is restricted to the functional description of optical transport networks that support digital signals, this did not seem to be a serious limitation.

Furthermore, due to the limitations of the current optical technology it is not possible to build a worldwide pure optical network. 3R regeneration of the optical channel signals is required after a certain distance and it will be used at domain borders in order to decouple the domains concerning optical signal impairments and to get an accurate assessment of the signal quality.

For this reason ITU-T Rec. G.709 chose to implement the Optical Channel by means of a digital framed signal with digital overhead that supports the management requirements for the OCh listed in clause 6. Furthermore this allows the use of Forward Error Correction for enhanced system performance. This results in the introduction of two digital layer networks, the ODU and OTU. The intention is that all client signals would be mapped into the Optical Channel via the ODU and OTU layer networks.

In order to allow optimization of the OTN for different applications, ODU and OTU signals for three bit rate areas are defined:

- ODU1 and OTU1 for the 2.5 Gbit/s bit-rate area;
- ODU2 and OTU2 for the 10 Gbit/s bit-rate area;
- ODU3 and OTU3 for the 40 Gbit/s bit-rate area.

Support for entities at higher bit rates is for further study.

In the meantime, the desire remains for this Recommendation to describe an Optical Channel without any digital processing, so that this Recommendation remains valid should technology become available that allows for the implementation of this Recommendation without digital processing. To this end, the Optical Channel requirements of this Recommendation remain in force, and the OTU could be considered just another client of the OCh.

Currently, the only client of the Optical Channel that meets all the requirements of this Recommendation is the OTU. Other clients can be directly mapped into the OCh, with a corresponding loss of functionality, and without support from any standard.

9.2 Digital OTN layered structure

The digital OTN layered structure is comprised of digital path layer networks (ODU) and digital section layer networks (OTU).

An OTU section layer supports one ODU path layer network as client layer.

An ODU path layer supports the various OTN client signals and ODU_j ($j < k$) path layer networks with lower bit rates (see ODU TDM in 9.6) as client layers. For the later case it is recommended that the number of visible hierarchical levels of ODU path layer networks that are supported within a domain be limited to two (one multiplexing stage) in order to reduce the overall network complexity.

Example (see Figure 15): Within an administrative domain that supports ODU1 and ODU2 services over ODU3, only one-stage multiplexing (ODU1 → ODU2) or (ODU1, ODU2 → ODU3) is used. An ODU2 with ODU1 that are individually networked within the domain (ODU1 services) has to be terminated and the ODU1s have to be multiplexed directly into the ODU3 in case of transport via an ODU3. Transport of the ODU1s in the ODU2s via the ODU3 is not supported.

NOTE – This limitation does not apply to transparent transport of an ODU (e.g. ODU2 service) with any kind of client signals including lower bit rate ODUs (e.g. ODU1) over a higher bit rate ODU (e.g. ODU3) through a domain. Only if access to the lower bit rate ODUs (e.g. ODU1 service) is required within the domain does the limitation apply.

Figures 16 and 17 show the client/server relationships without and with ODU multiplexing.

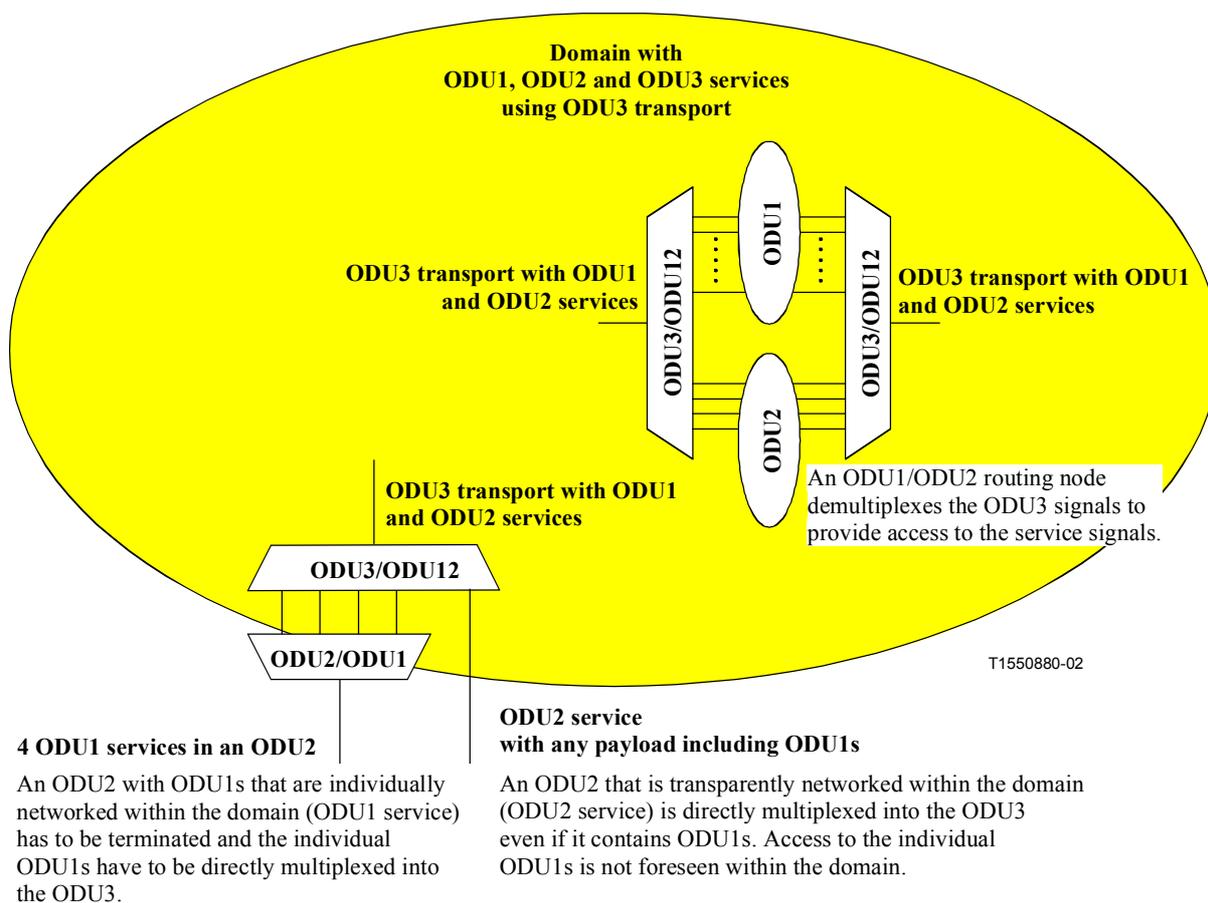


Figure 15/G.872 – Visible hierarchical ODU path layer network levels within a domain

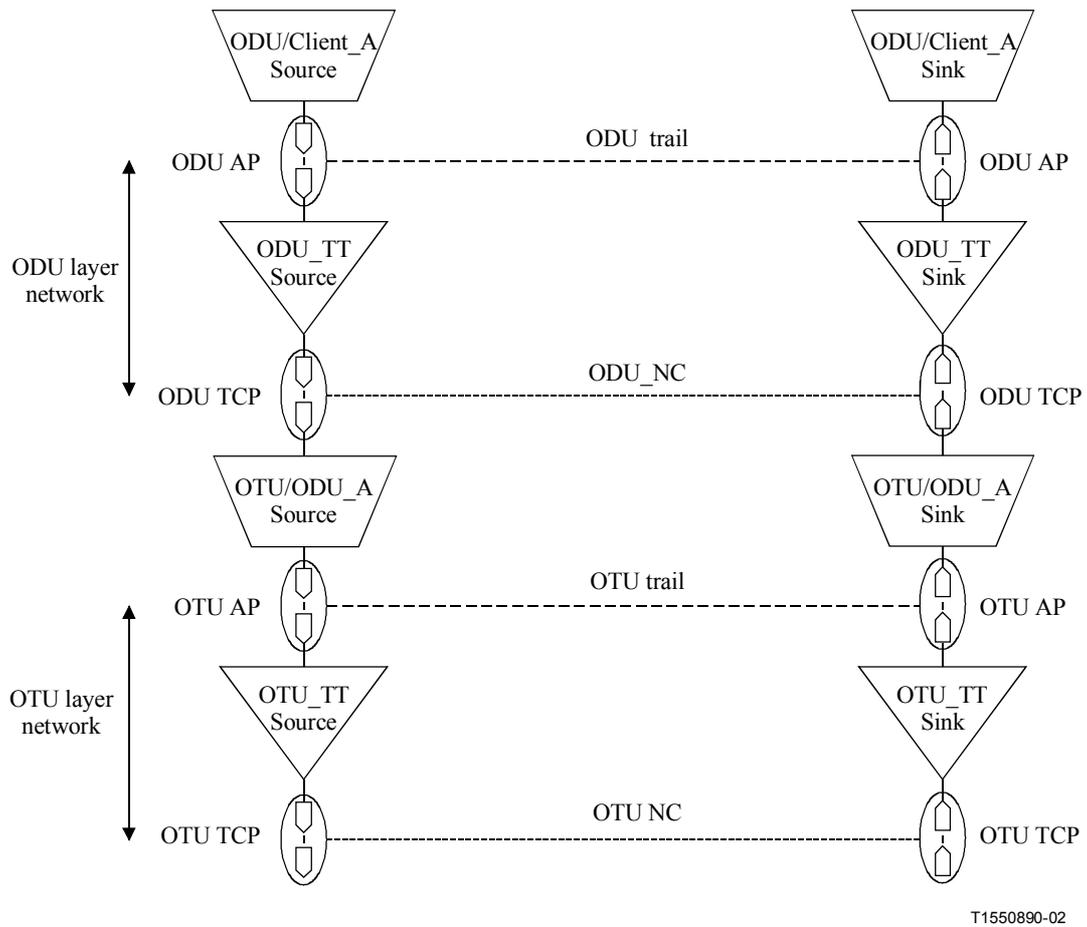


Figure 16/G.872 – Client server association of the digital OTN layers without ODU multiplexing

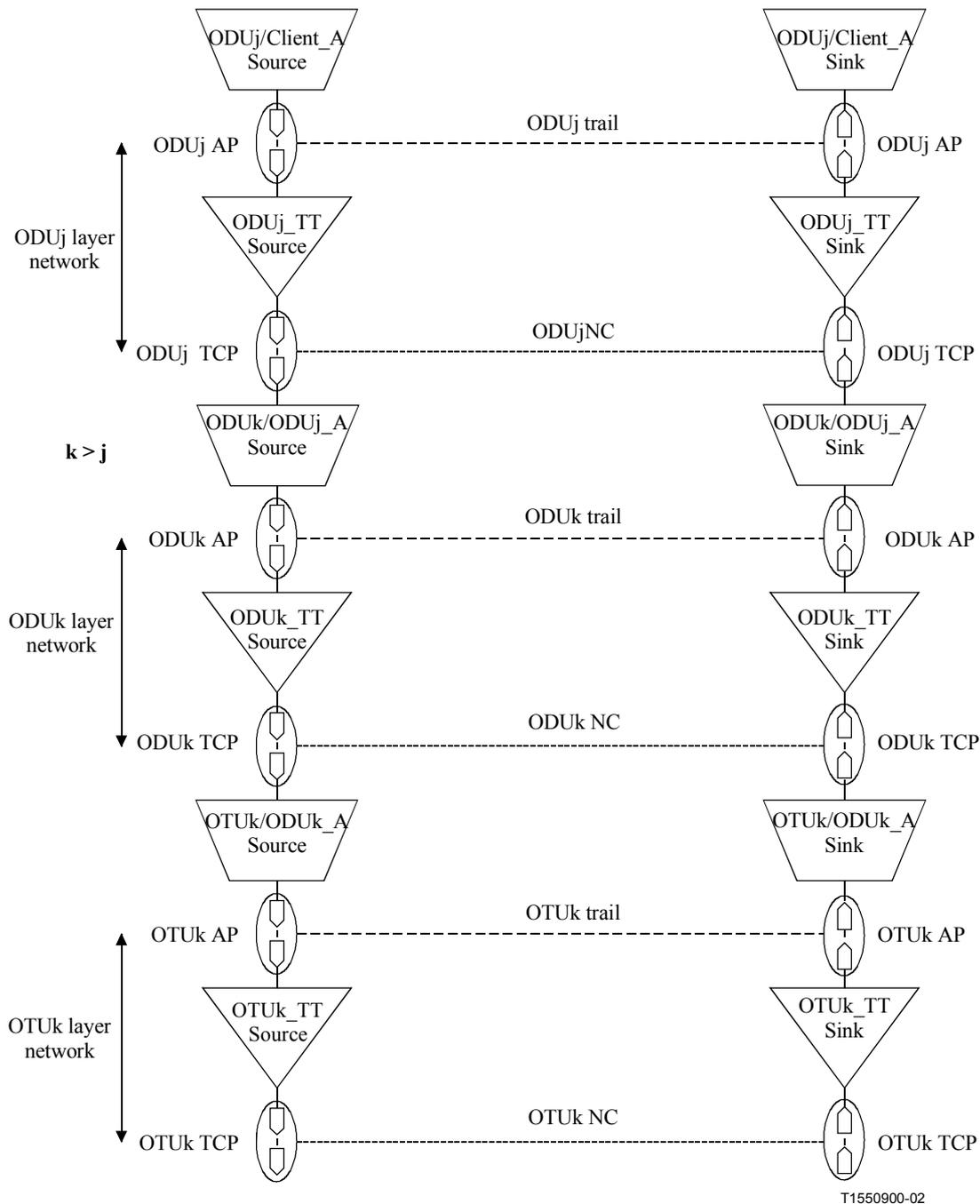


Figure 17/G.872 – Client server association of the digital OTN layers with ODU multiplexing

Motivation for this layer structure is as follows:

ODU layer network: This layer network provides functionality for end-to-end networking of digital path signals for transparently conveying client information of varying format (e.g. ATM, Ethernet, IP, SDH ATM, ODU, etc.). The description of supported client layer networks is outside the scope of this Recommendation. To provide end-to-end networking, the following capabilities are included in the layer network:

- ODU connection rearrangement for flexible network routing;
- ODU overhead processes for ensuring integrity of the ODU adapted information;

- ODU operations, administrations, and maintenance functions for enabling network level operations and management functions, such as connection provisioning, quality of service parameter exchange and network survivability.

OTU layer network: This layer network provides functionality for networking of digital section signals. The capabilities of this layer network include:

- OTU overhead processes and conditioning for the transport over optical channels for ensuring integrity of the OTU adapted information;
- OTU operations, administrations, and maintenance functions for enabling section level operations and management functions, such as OTU survivability.

The detailed functional description of the layer networks is given in the following clauses.

9.3 Optical channel layer network (OCh)

With the introduction of the ODU and OTU the OCh as described in 5.3 is limited to the analogue transport of the digital client payload signal between 3R points of the OTN. It supports in this case only a subset of the OCh management requirements defined in clause 7 (see Table 3).

Tableau 3/G.872 – Management requirements for the ITU-T G.709-based OCh

Management capability	Process	Function	Layer network				Comments
			ODU-Path	ODU-TC	OTU	OCh	
Continuity supervision	<ul style="list-style-type: none"> • Loss of continuity detection 	TT	R	R	R	R	See 6.2.1.
Connectivity supervision	<ul style="list-style-type: none"> • Trail trace identification 	TT	R	R	R	FFS	See 6.2.1.
Maintenance information	<ul style="list-style-type: none"> • Forward defect indication^{a)} 	TT	R	R	R	R	See 6.2.1.
	<ul style="list-style-type: none"> • Open connection indication^{a)} 	TT	R	R	–	R	
	<ul style="list-style-type: none"> • Backward defect indication 	TT	R	R	R	–	
	<ul style="list-style-type: none"> • Backward quality indication 	TT	R	R	R	–	
	<ul style="list-style-type: none"> • Incoming alignment error (IAE) indication 	TT	–	R	R	–	
	<ul style="list-style-type: none"> • Backward IAE indication 	TT	–	R	R	–	
Signal quality supervision	<ul style="list-style-type: none"> • Performance monitoring based on BIP calculation 	TT	R	R	R	–	See 6.2.2.
	<ul style="list-style-type: none"> • Performance monitoring based on analogue parameters 	TT	–	–	–	FFS	
Protection control	<ul style="list-style-type: none"> • Automatic protection switching protocol 	A/T	R*		R*	R*	See 6.2.4.

Tableau 3/G.872 – Management requirements for the ITU-T G.709-based OCh

Management capability	Process	Function	Layer network				Comments
			ODU-Path	ODU-TC	OTU	OCh	
Management communications	• Message-based channel	A	R*		R*	FFS	See 6.2.5.
	• Operator-specific	A	R*		R	FFS	
– Not applicable		R	Required				
A Adaptation function		R*	Required (if management capability has to be supported)				
FFS For further study		TT	Trail termination function				
a) OCh-FDI/OCI as non-associated OCh OH may also be used.							

9.4 Optical channel Transport Unit (OTU) layer network

The OTU layer network provides for the transport of ODU client signals through an OTU trail between 3R points of the OTN. It is the digital counterpart to the analogue OCh layer network. The characteristic information of an OTU layer network is composed of:

- the OTU payload area for the transport of the ODU client signal;
- the OTU overhead area for the transport of the associated overhead.

The OTU layer network contains the following transport functions and transport entities (see Figure 18):

- OTU trail;
- OTU trail termination source (OTU_TT_Source);
- trail termination sink (OTU_TT_Sink);
- OTU network connection (OTU_NC);
- OTU link connection (OTU_LC);

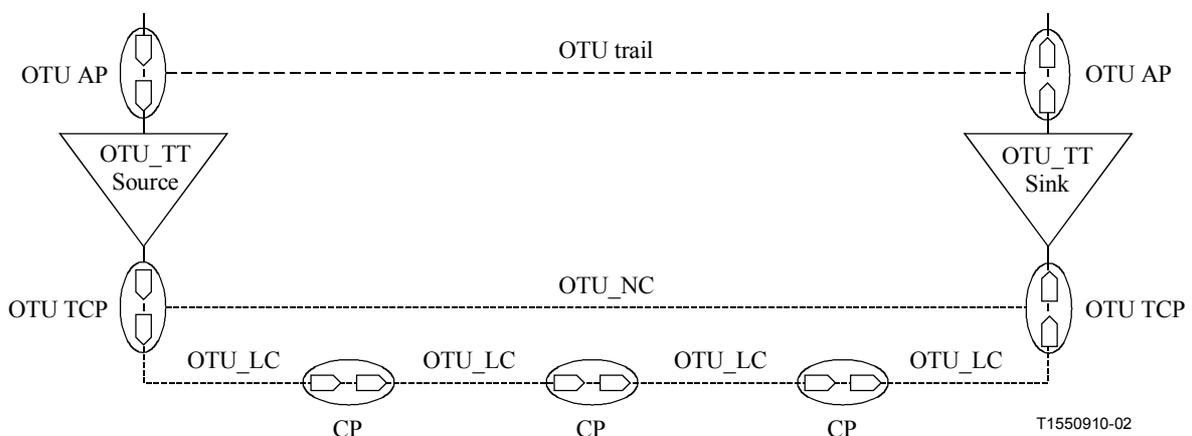


Figure 18/G.872 – OTU layer network example

9.4.1 OTU trail termination

The following generic processes may be assigned to the OTU trail termination:

- validation of connectivity integrity;
- assessment of transmission quality;
- transmission defect detection and indication.

The requirement for these processes is outlined in detail in 9.5.

There are three types of OTU trail termination:

- OTU bidirectional trail termination: consists of a pair of collocated OTU trail termination source and sink functions.
- OTU trail termination source: accepts adapted information from an ODU network at its input, inserts the OTU trail termination overhead as a separate and distinct logical data stream and presents the characteristic information of the OTU layer network at its output.
- OTU trail termination sink: accepts the characteristic information of the OTU layer network at its input, extracts the separate and distinct logical data stream containing the OTU trail termination overhead and presents the adapted information at its output.

9.4.2 OTU transport entities

Network connections, link connections and trails are as described in ITU-T Rec. G.805.

9.5 Optical channel Data Unit (ODU) layer network

The ODU layer network provides for the end-to-end transport of digital client signals through the OTN. The characteristic information of an ODU layer network is composed of:

- the ODU payload area for the transport of the digital client signals;
- the ODU overhead area for the transport of the associated overhead.

The ODU layer network contains the following transport functions and transport entities (see Figure 19):

- ODU trail;
- ODU trail termination source (ODU_TT_Source);
- ODU trail termination sink (ODU_TT_Sink);
- ODU network connection (ODU_NC);
- ODU link connection (ODU_LC);
- ODU subnetwork (ODU_SN);
- ODU subnetwork connection (ODU_SNC).

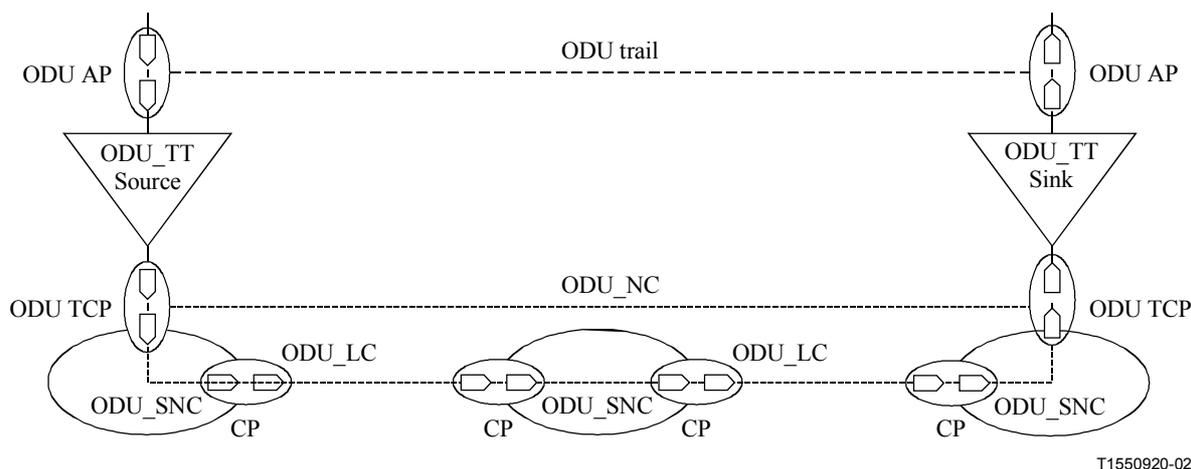


Figure 19/G.872 – ODU layer network example

9.5.1 ODU trail termination

The following generic processes may be assigned to the ODU trail termination:

- validation of connectivity integrity;
- assessment of transmission quality;
- transmission defect detection and indication.

The requirement for these processes is outlined in detail in 9.5.

There are three types of ODU trail termination:

- ODU bidirectional trail termination: consists of a pair of collocated ODU trail termination source and sink functions.
- ODU trail termination source: accepts adapted information from a client layer network at its input, inserts the ODU trail termination overhead as a separate and distinct logical data stream and presents the characteristic information of the ODU layer network at its output.
- ODU trail termination sink: accepts the characteristic information of the ODU layer network at its input, extracts the separate and distinct logical data stream containing the ODU trail termination overhead and presents the adapted information at its output.

9.5.2 ODU transport entities

Network connections, link connections, tandem connections, and trails are as described in ITU-T Rec. G.805.

The ODU subnetwork, ODU_{SN}, provides flexibility within the ODU layer. Characteristic information is routed between input (termination) connection points [(T)CPs] and output (T)CPs. The connection function may be used by the network operator to provide routing, grooming, protection and restoration.

9.6 ODU Time Division Multiplexing

In order to allow transport of several lower bit-rate Optical Channel signals over a higher bit-rate Optical Channel and maintain the end-to-end trail for these lower bit-rate channels, Time Division Multiplexing (TDM) of ODUs is defined.

Lower bit-rate ODU_j can be clients of higher bit-rate ODU_k ($k > j$). For the currently defined ODU_ks the following client/server relationships are defined:

- An ODU₂ can transport 4 ODU₁s.

- An ODU3 can transport 16 ODU1s, or 4 ODU2s, or any mixture of ODU1 and ODU2 within these limits, where an ODU2 is the equivalent of 4 ODU1s.

For limitations on the number of visible hierarchical levels of ODU path layer networks within an domain, see 9.2.

9.7 Client/server associations

A principal feature of optical transport networks is the possibility of supporting a wide variety of client layer networks. Examples of these client layer networks include an SDH STM-N, and a contiguous ATM cell stream. Restrictions or rules that limit the capability of an optical channel to transfer a particular client layer network are for further study.

The structure of the optical layer networks and the adaptation functions are shown in Figures 16 and 17. For the purposes of description of the optical transport network, the interlayer adaptation is named using the server/client relationship.

9.7.1 ODU/Client adaptation

The ODU/Client adaptation (ODU/Client_A) is considered to consist of two types of processes: client-specific processes and server-specific processes. The description of the client-specific processes is outside the scope of this Recommendation.

The bidirectional ODU/Client adaptation (ODU/Client_A) function is performed by a collocated pair of source and sink ODU/Client adaptation functions.

The ODU/Client adaptation source (ODU/Client_A_So) performs the following processes between its input and its output:

- all the processing required to adapt the client signal to the ODU payload area. The processes are dependent upon the particular client signal.
- generation and termination of management/maintenance signals as described in 9.7.

The ODU/Client adaptation sink (ODU/Client_A_Sk) performs the following processes between its input and its output:

- recovery of the client signal from the ODU payload area. The processes are dependent upon the particular client/server relationship.
- generation and termination of management/maintenance signals as described in 9.7.

9.7.2 ODU_k/ODU_j adaptation

The bidirectional ODU_k/ODU_j adaptation (ODU_k/ODU_j_A) function is performed by a collocated pair of source and sink ODU_k/ODU_j adaptation functions.

The ODU_k/ODU_j adaptation source (ODU_k/ODU_j_A_So) performs the following processes between its input and its output:

- ODU_j multiplexing to form an higher bit rate ODU_k;
- generation and termination of management/maintenance signals as described in 9.7.

The ODU_k/ODU_j adaptation sink (ODU_k/ODU_j_A_Sk) performs the following processes between its input and its output:

- ODU_j demultiplexing;
- generation and termination of management/maintenance signals as described in 9.7.

9.7.3 OTU/ODU adaptation

The bidirectional OTU/ODU adaptation (OTU/ODU_A) function is performed by a collocated pair of source and sink OTU/ODU adaptation functions.

The OTU/ODU adaptation source (OTU/ODU_A_So) performs the following processes between its input and its output:

- all the processing required to adapt the ODU signal to the OTU payload area. The processes are dependent upon the particular implementation of the client/server relationship.

The OTU/ODU adaptation sink (OTU/ODU_A_Sk) performs the following processes between its input and its output:

- recovery of the ODU signal from the OTU payload area. The processes are dependent upon the particular implementation of the client/server relationship.

9.7.4 OCh/OTU adaptation

The bidirectional OCh/OTU adaptation (OCh/OTU_A) function is performed by a collocated pair of source and sink OCh/OTU adaptation functions.

The OCh/OTU adaptation source (OCh/OTU_A_So) performs the following processes between its input and its output:

- all the processing required to generate a continuous data stream that can be modulated onto an optical frequency carrier. The processes required are dependent upon the particular implementation of the client/server relationship and include processing such as scrambling and channel coding (e.g. NRZ). Forward error correction is an optional feature.

The OCh/OTU adaptation sink (OCh/OTU_A_Sk) performs the following processes between its input and its output:

- recovery of the OTU signal from the continuous data stream. The processes are dependent upon the particular implementation of the client/server relationship and include processes such as timing recovery, channel decoding, framing and descrambling. Forward error correction is an optional feature.

9.8 Inverse multiplexing in the OTN

Inverse multiplexing in the OTN is implemented by means of virtual concatenation of X ($X \leq 2$) ODU signals (ODU-Xv). The ODU-Xv signal can transport a client signal (e.g. an ODU2-4v may transport a STM-256). The characteristic information of a virtual concatenated ODU (ODU-Xv) layer network is transported via a bundle of X ODU network connections, each having its own transfer delay. The ODU-Xv trail termination sink function has to compensate this differential delay in order to provide a contiguous payload at its output.

The differential delay that has to be compensated for, for ODU-Xv, is at least xxx μ sec (this value is to be determined).

The connection monitoring techniques are applied per data stream on the ODU characteristic information.

In virtual concatenated ODU connections which extend across several networks, care should be taken during path set-up to ensure that the worst-case differential delay (e.g. during a protection switch in one of the intermediate networks) does not exceed the chosen compensation range.

Performance monitoring and protection are carried out on the individual ODU signals which make up the virtually concatenated group. Performance monitoring on the group as an entity is for further study.

NOTE – The transport of higher rate ODU signals via a virtual concatenated group of lower rate ODU signals is possible, but results in a non-optimal solution.

Figure 20 shows the functional architecture for a ODU-Xv.

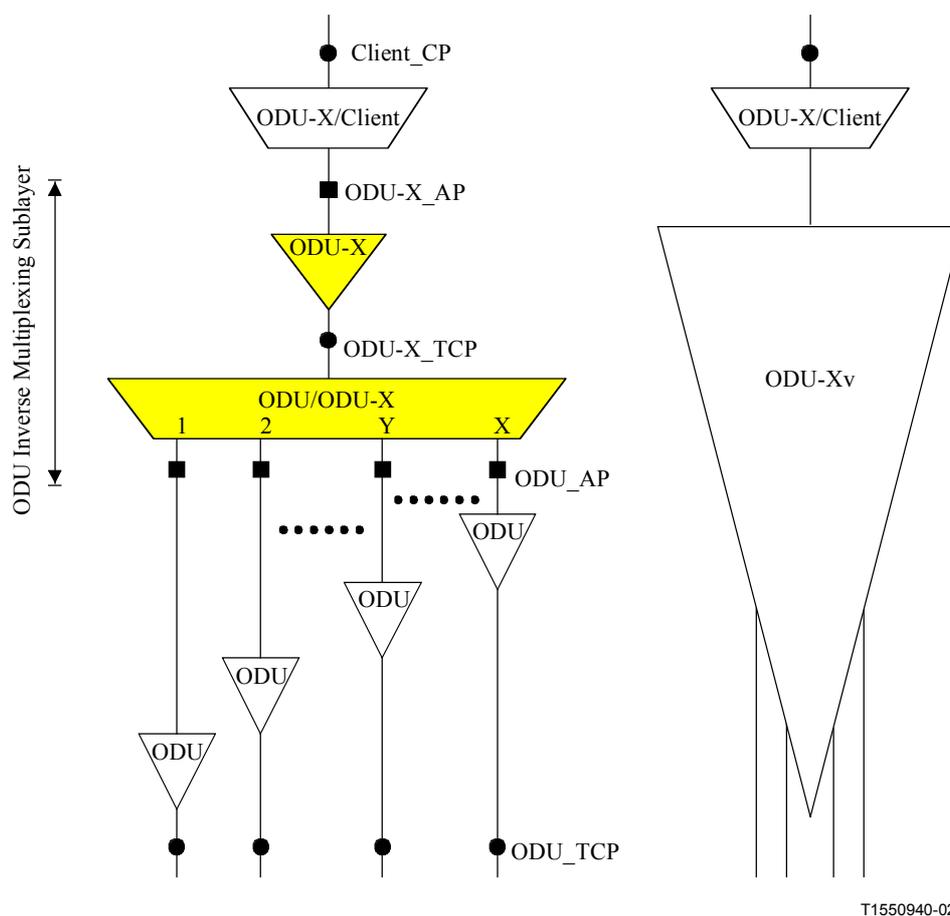


Figure 21/G.872 – Virtual concatenation model

9.9 Transport of OTN elements over non-OTN layer networks

When the OTN is introduced, it may be that not all parts of a network infrastructure are capable of carrying ODUs. For the interconnection of OTN islands, it may be necessary to transport them over existing layer networks, e.g. by mapping of ODUs into SDH higher-order VCs. For additional information, see also Appendix III.

9.10 Optical layer network management requirements

Requirements for management capabilities with respect to ODU and OTU layer networks are identified in this clause. A summary of the optical layer network management requirements is given in Table 3.

9.11 Survivability techniques

The protection techniques described in 7.1 also apply to the digital layered structure of the optical transport network both at OTU and ODU layer. Table 4 reports the applicability of the different protection techniques for the OTU and ODU layers.

Table 4/G.872 – Protection techniques for the digital OTN

Protection technique	OTU layer	ODU layer
1+1 trail protection	A	NA
1:N trail protection	FFS	NA
1+1 SNC/N, SNC/S and SNC/I	NA	A
1:N SNC/S	NA	A
Shared protected ring	NA	A
A Applicable FFS For further study NA Not applicable		

9.12 Interconnection between different domains

Following the considerations presented in 9.1, the methods by which interconnection and interworking between different domains takes place involves 3R regeneration; refer to ITU-T Recs. G.709 and G.798. The following cases are foreseen:

- a) Non-OTN domain interconnects with OTN domain via non-OTN IrDI (Figure 22).
- b) Two OTN domains interconnect via non-OTN IrDI (Figure 23).
- c) Two OTN domains interconnect via OTN IrDI (Figure 24).
- d) Non-OTN domain interconnects with OTN domain via OTN IrDI (Figure 25).
- e) Two OTN domains interconnect via a SDH network (deploying a modem) via OTN IrDIs (Figure 26; see also 9.9).

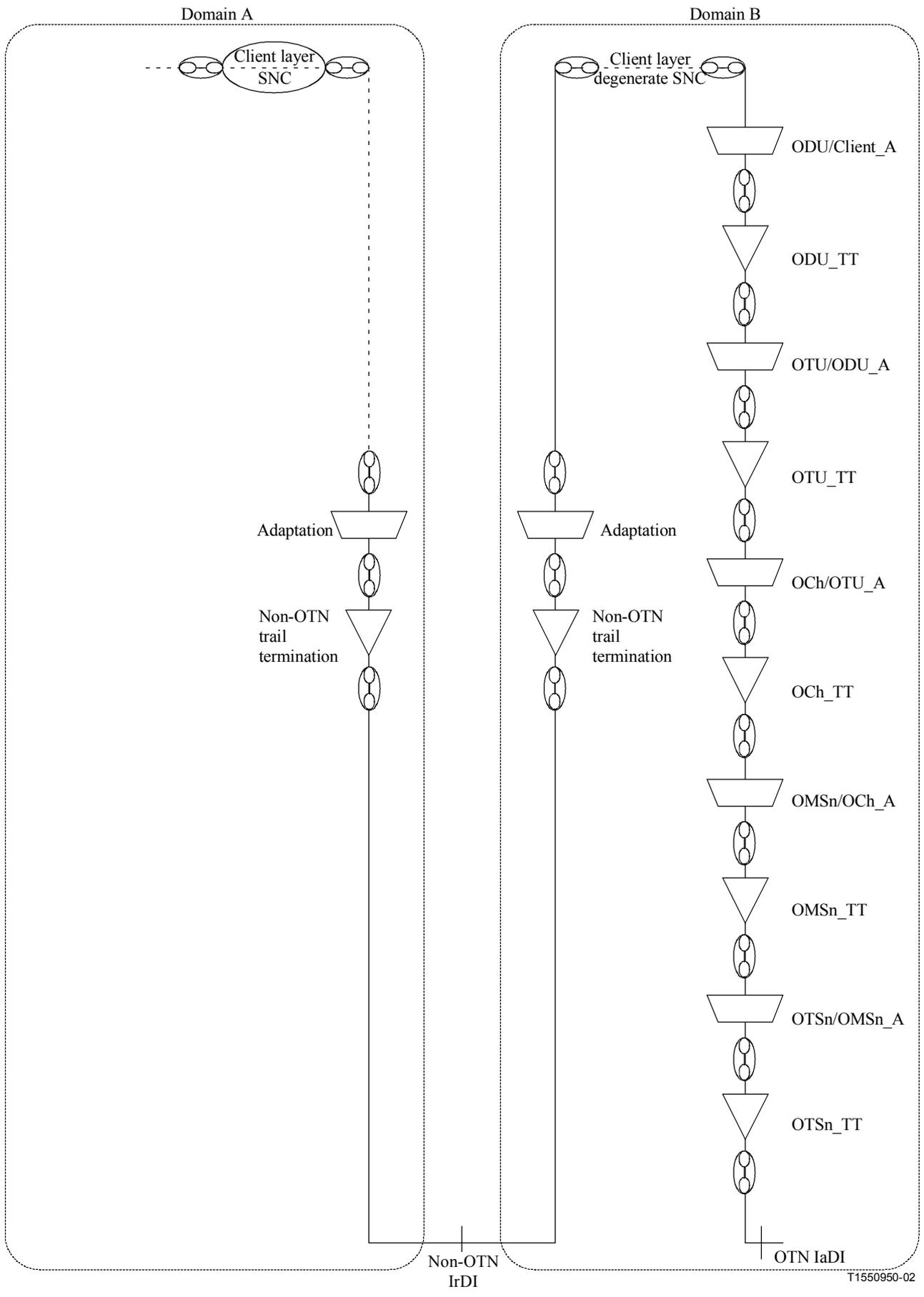
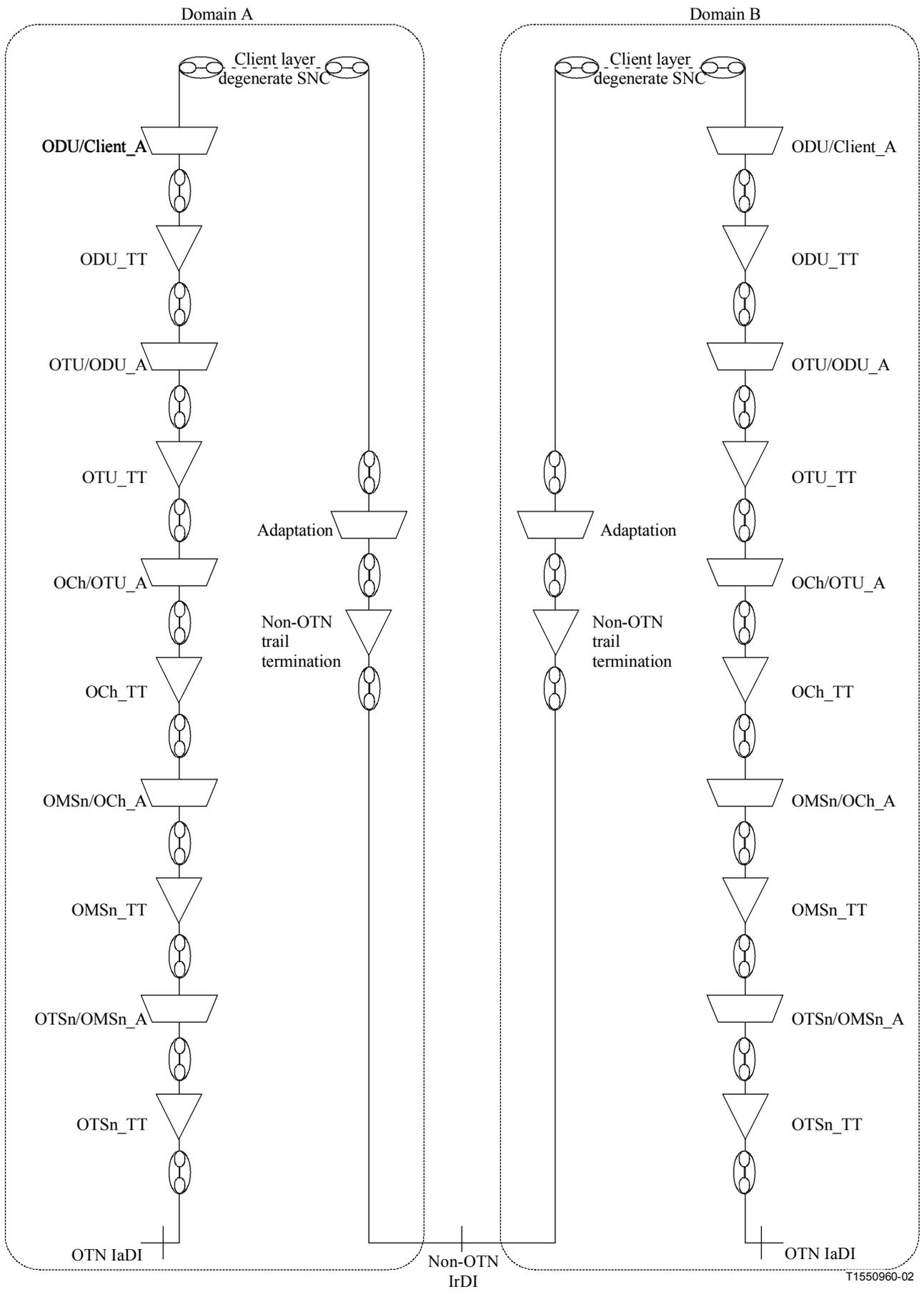
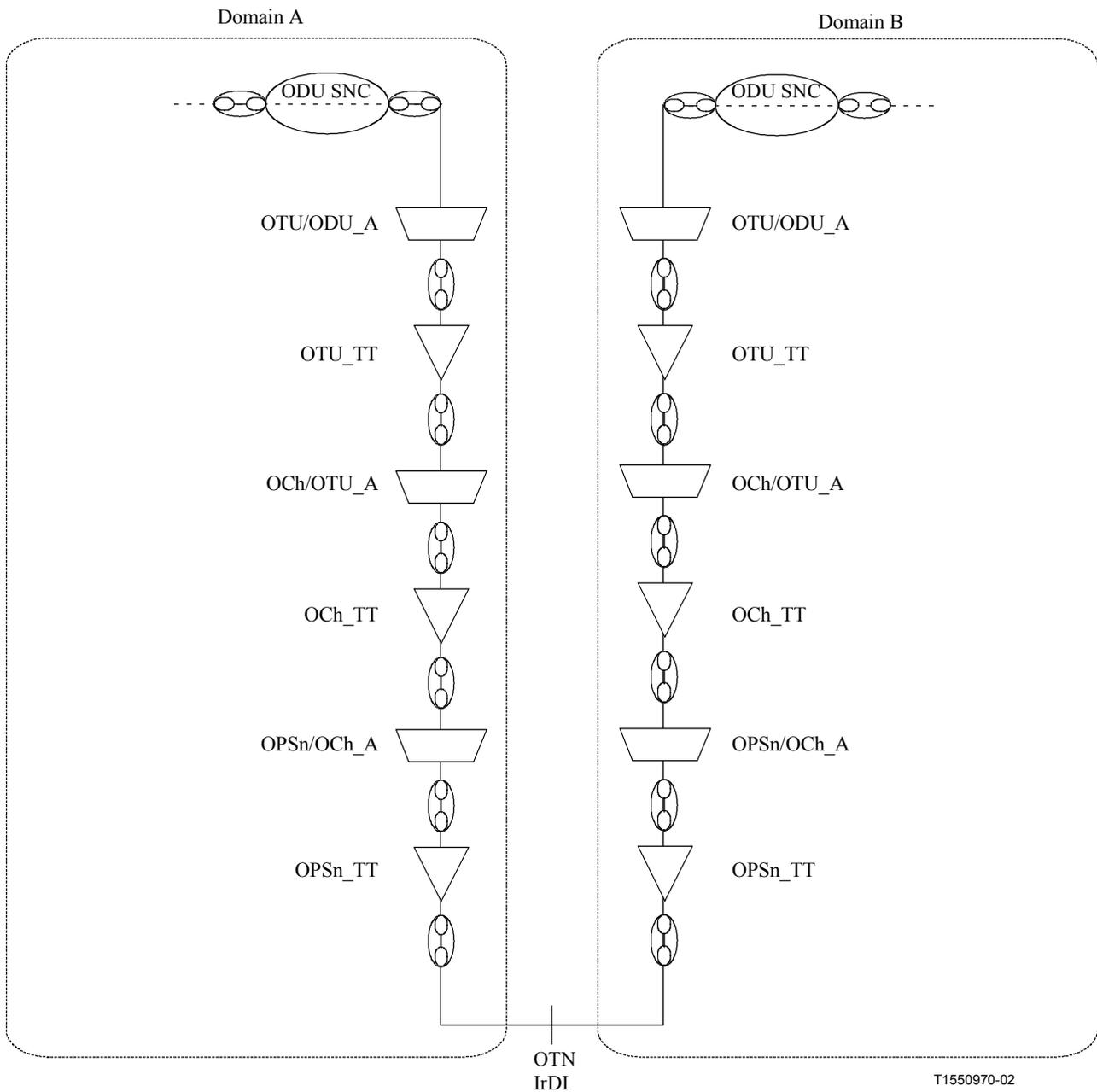


Figure 22/G.872 – Non-OTN domain interconnects with OTN domain via non-OTN IrDI



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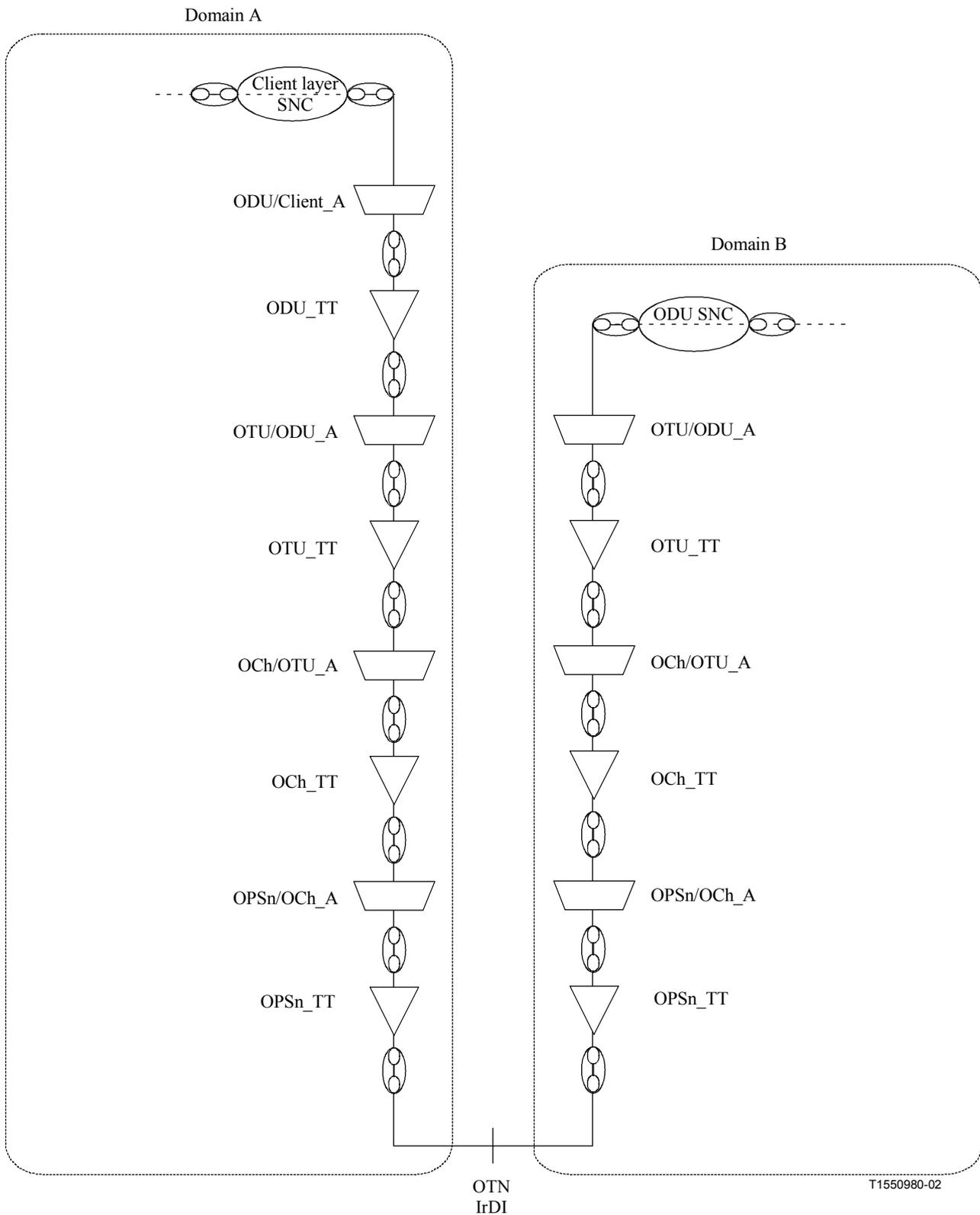
Figure 23/G.872 – Two OTN domains in Two OTN domains interconnect via non-OTN IrDI



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NOTE – An OPSn layer network is a collapsed version of OMSn/OTSn layer networks; collapsing is possible if there are no intermediate network elements between the IrDI point and the network element providing interworking. For such case, maintenance is provided by the OTU layer network.

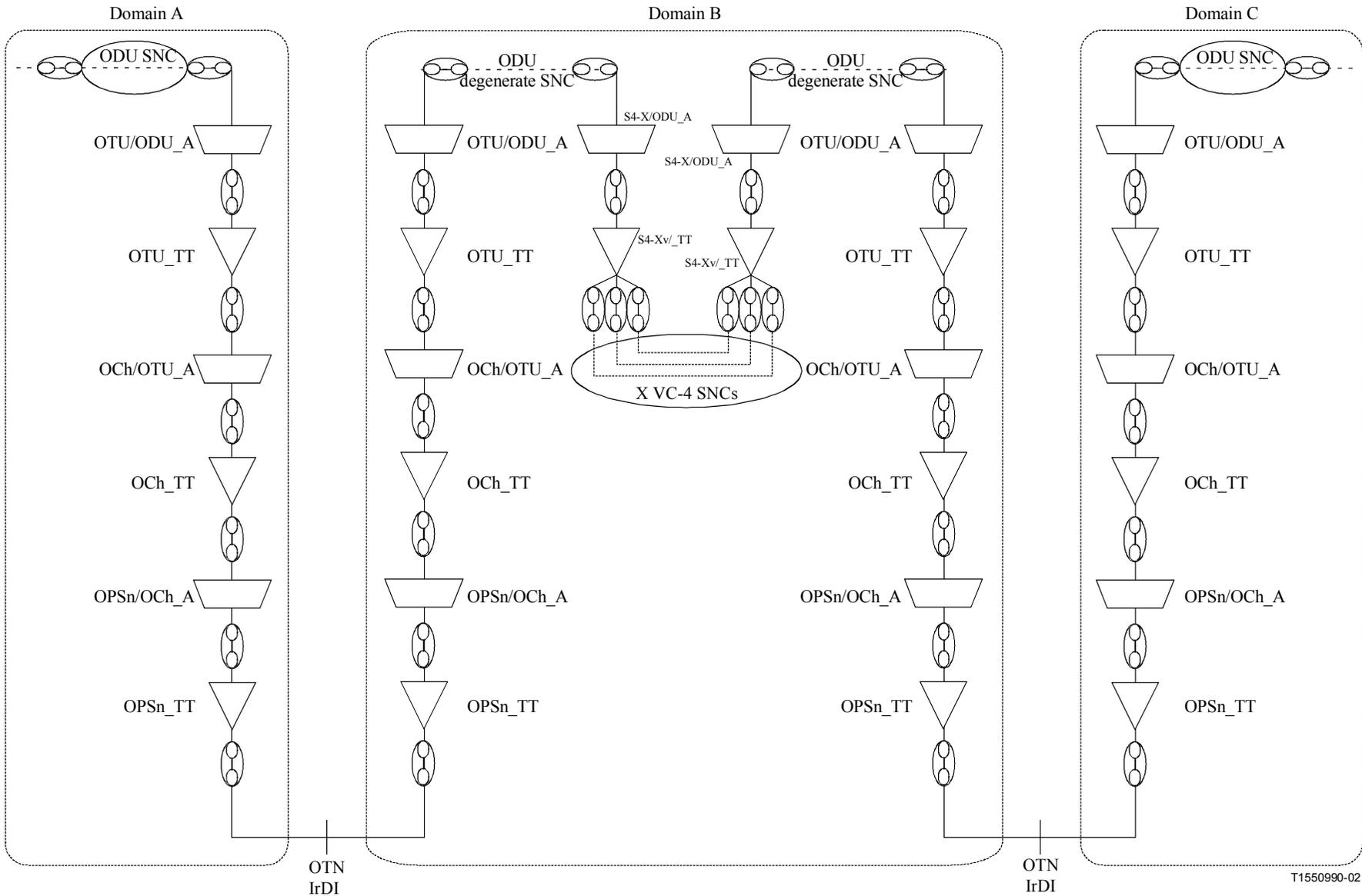
Figure 24/G.872 – Two OTN domains interconnect via OTN IrDI



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NOTE – An OPSn layer network is a collapsed version of OMSn/OTSn layer networks; collapsing is possible if there are no intermediate network elements between the IrDI point and the network element providing interworking. For such case, maintenance is provided by the OTU layer network.

Figure 25/G.872 – Non-OTN domain interconnects with OTN domain via OTN IrDI



NOTE – An OPSn layer network is a collapsed version of OMSn/OTSn layer networks; collapsing is possible if there are no intermediate network elements between the IrDI point and the network element providing interworking. For such case, maintenance is provided by the OTU layer network.

Figure 26/G.872 – Two OTN domains interconnect via a SDH network (deploying a modem) via OTN IrDIs

10 Subdividing of the optical transport network

The OTN is subdivided into administrative domains, and may be subdivided into vendor domains, etc. For interworking and interconnection of domains refer to clause 8. A domain may be further subdivided into smaller portions.

10.1 Subdividing of domains

A client signal that is transported over a domain may need to be regenerated (3R regeneration). The OCh layer network is terminated for 3R regeneration, i.e. the processes of 3R regeneration are allocated to the OCh/Client adaptation sink and source functions. Whether further layer networks of the digital clients are terminated depends on the type of the digital client.

The OTU layer network shall be terminated when the client is the digital OTN. OCh and OTU layer network are coincident, i.e. the OTU digital sections form a 3R span. This is illustrated in Figure 27.

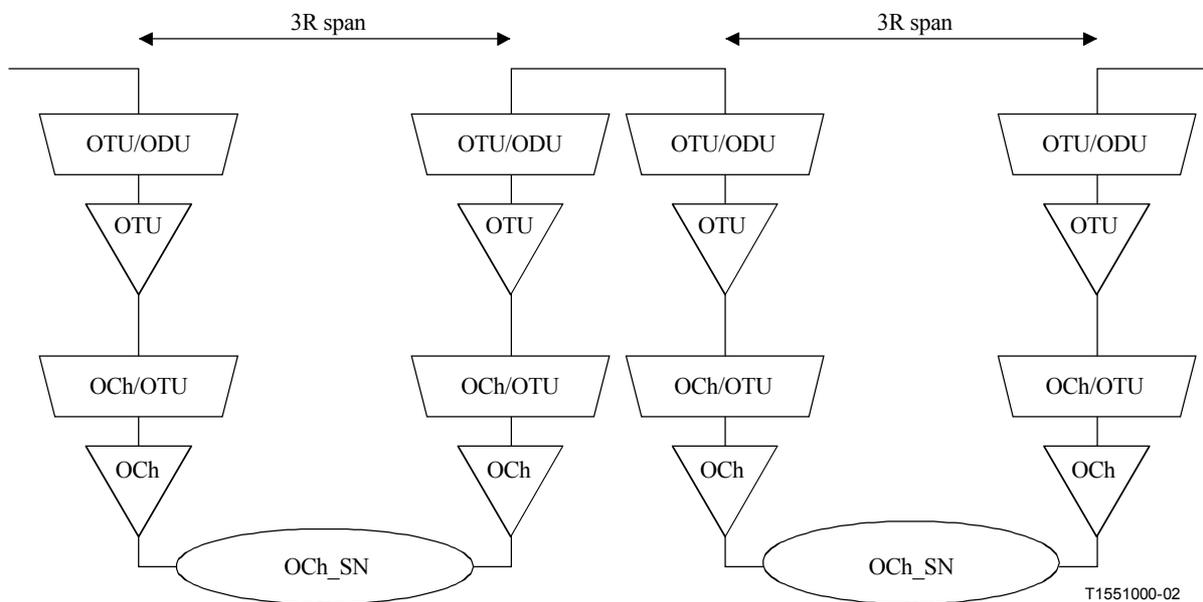


Figure 27/G.872 – Example of 3R spans for the digital OTN

In case of other digital clients there is no requirement to terminate a layer network of the digital client. Figure 28 illustrates 3R spans for Constant Bit Rate (CBR) signals, such as SDH, where 3R regeneration is carried out without further processing of a SDH layer network.

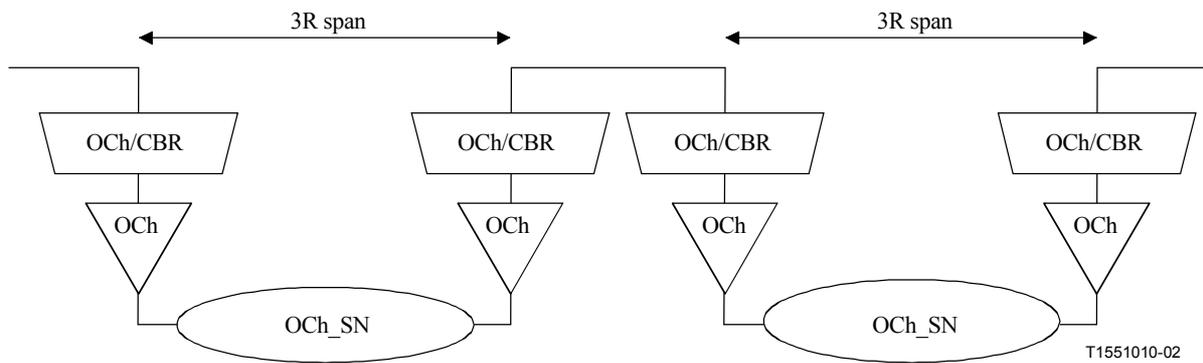


Figure 28/G.872 – Example of 3R spans for clients others than the digital OTN

10.2 Subdividing of 3R spans

A 3R span is characterized by 3R regeneration functions at both ends. The 3R processes are allocated to the OCh/Client adaptation function. A 3R span may be subdivided into smaller portions. Dimensioning rules for such partitioning are outside the scope of this Recommendation. However, when the OCh layer network provides routing flexibility, a 3R span should be dimensioned such that full routing flexibility exists.

Annex A

Impairment mitigation and regeneration

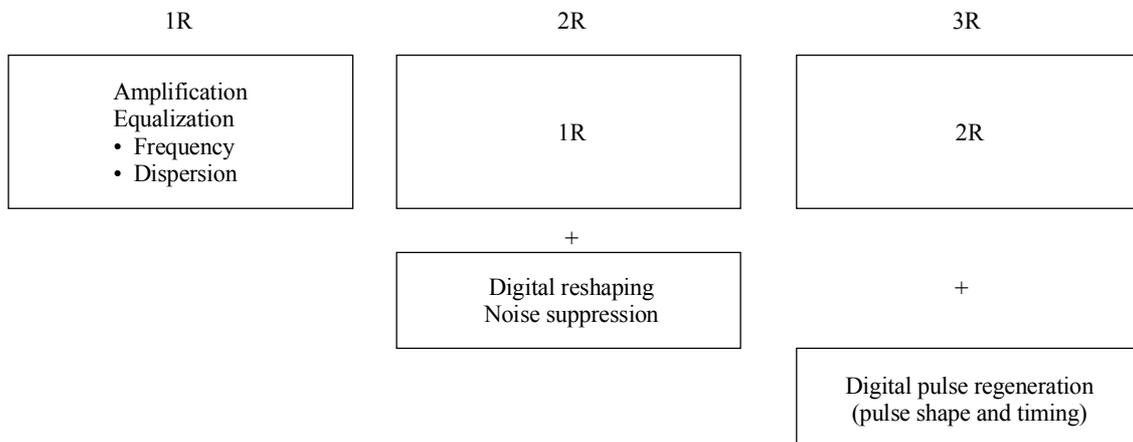
The transmission of information over an optical network is hindered by the accumulation of impairments that need to be mitigated against to maintain signal quality. It is recognized from a modelling viewpoint that these compensations need to be described in terms of processes. In particular the description of processes involved in so-called 1R, 2R and 3R regeneration are of interest. A transport function must be described in terms of the processes associated with the relevant adaptation and termination functions in each layer and a simple statement of 1R, 2R or 3R regeneration is insufficient. However, because 1R, 2R and 3R regeneration are commonly used terms, the following classification is provided as an aid to understanding them.

These forms of regeneration are composed of a combination of the following processes:

- a) Equal amplification of all frequencies within the amplification bandwidth. There is no restriction upon client layers.
- b) Amplification with different gain for frequencies within the amplification bandwidth. This could be applied to both single-channel and multi-channel systems.
- c) Dispersion compensation (phase distortion). This analogue process can be applied in either single-channel or multi-channel systems.
- d) Noise suppression.
- e) Digital reshaping (Schmitt Trigger function) with no clock recovery. This is applicable to individual channels and can be used for different bit rates but is not transparent to line coding.
- f) Complete regeneration of the pulse shape including clock recovery and retiming within required jitter limits.

As can be seen in Figure A.1, 1R regeneration is described as any combination of processes a) to c). 2R regeneration is considered to be 1R regeneration together with processes d) and e), whilst 3R regeneration is considered to be 2R regeneration together with process f).

An informal description of 1R regeneration is that 1R regeneration is based on analogue techniques; 2R involves digital processing of the signal levels while 3R regeneration also involves digital processing of the signal timing information.



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Figure A.1/G.872 – Regeneration classification

Appendix I

Examples of optical network functionality

This appendix describes examples of functional groupings that may be applied to the optical network.

I.1 Wavelength conversion

Figure I.1 shows the functional model for single channel wavelength conversion. The OTS and OMS trails are terminated and the wavelength conversion is performed by the OMS/OCh adaptation function. At the OCh layer the wavelength is undefined. The OMS/OCh_A source assigns a specific wavelength to the optical channel.

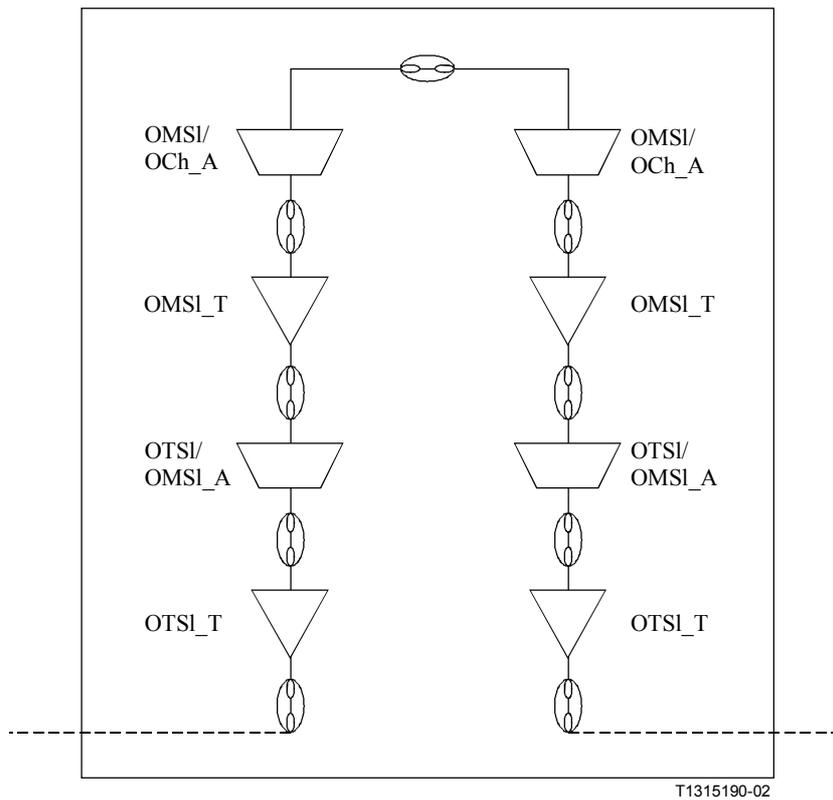
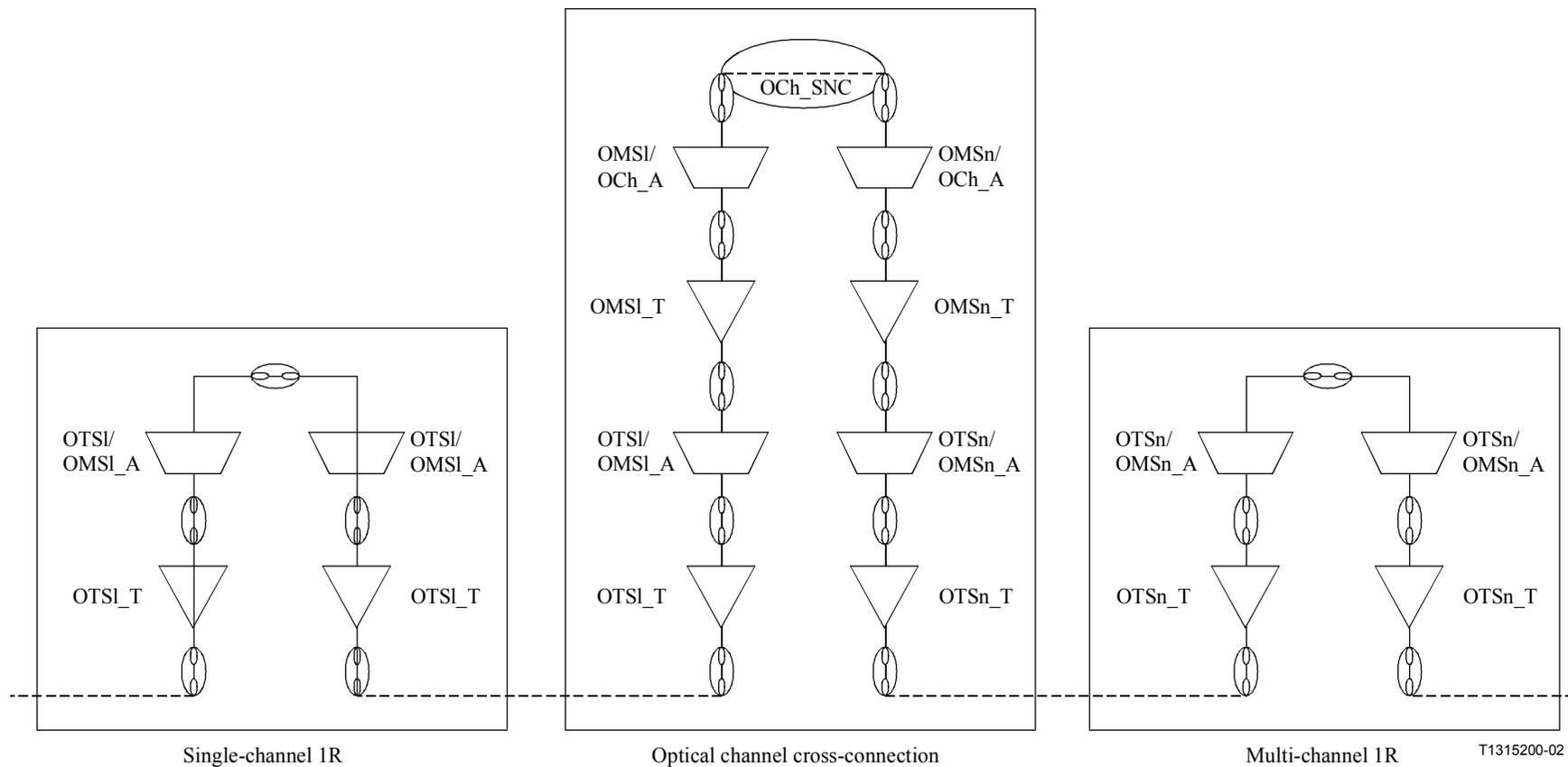


Figure I.1/G.872 – Example of optical wavelength conversion

I.2 Cross-connect

Figure I.2 shows the functional model of a cross-connect and two optical amplifiers, one single channel and one multi-channel. The OCh layer signals can be cross-connected between OTN interfaces or to appropriate client layer interfaces. The cross-connect may also include wavelength/frequency conversion.



NOTE – Line terminals and trails, etc., are not shown for simplification.

Figure I.2/G.872 – Application of functional architecture to cases of single and multi-channel 1R regeneration (amplification) and channel cross-connection

I.3 Regeneration

The processes involved in 1R, 2R and 3R regeneration are as detailed in Annex A. Their assignment to the appropriate optical transport network function(s) is outside the scope of this Recommendation.

Appendix II

Relationship between OTN and existing WDM networks

An optical channel provides an optical signal to the underlying OMS layer network. This hides the digital format carried on the optical signal, which is of no interest to the OMS. The optical channel can then be frequency division multiplexed with other optical channels resulting in an OTM-n signal.

Current optical technology does not provide all of the functionality required for the management and maintenance of optical channels in a manner that is independent of the digital client layer. This is overcome by the use of the optical transport unit as a common encapsulation technique for digital clients and as a mechanism for supporting those aspects of management and maintenance information that cannot currently be supported by optical channel trail termination functions. As such the OTU layer network is the recommended client layer network of the optical channel. However, it is also possible to transport other digital clients directly on an optical channel, albeit with some limitations.

STM-N and Gigabit Ethernet clients, for example, may also be carried over the optical channel, without encapsulating their frames into an optical transport unit. Such a signal, without encapsulation, has the same form of characteristic information as an optical channel. As such it can pass through a cross-connect that is capable of supporting an optical channel connection. However, it does not provide the OAM functions that are associated with an OTU. Transport of such signals over the OTN may result in network management limitations and any limitations are technology specific and are dependent upon the capabilities of the optical channel client. It is also necessary to define adaptation and termination functions for an optical channel that convert, for example, an STM-N frame from a logical signal into an optical signal of defined bandwidth and signal-to-noise ratio, and in the sink direction recover bit and frame timing that can be transported by an optical multiplex section. In the case of SDH such an optical channel is analogous to an SDH optical section with only the optical bandwidth and signal-to-noise ratio from the set of optical parameters defined. The description of client-to-optical channel adaptation functions for this form of transport are outside the scope of this Recommendation and are not part of the OTN.

In the case where only one optical channel is carried on a fibre, the OMS and OTS can be collapsed to create a single layer network – an optical physical section (OPS). This is an OTM-0 level signal as shown in Figure II.1.

Existing pre-OTN WDM systems are currently deployed in networks to carry clients such as SDH and GbE. These systems are also shown.

The relationship between the OTN and the existing WDM and pre-OTN WDM interfaces is shown in Figure II.1.

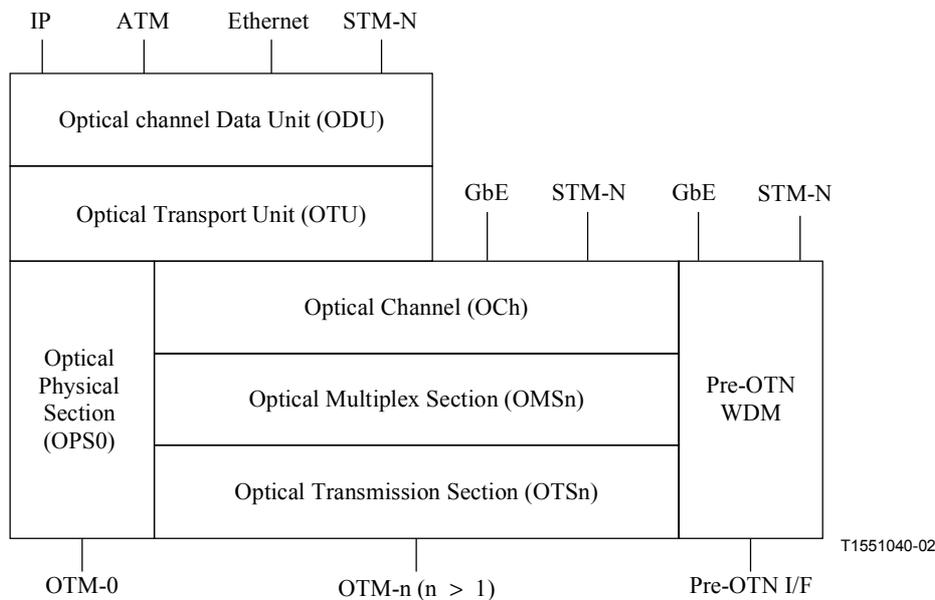


Figure II.1/G.872 – Relationship between OTN and WDM

Appendix III

Introduction of OTN-based transport networks

III.1 General

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

This appendix first identifies the types of client layer signals that can be supported on OTN paths and the types of client layer signals that can be supported on SDH paths. It then describes the three basic introductory scenarios for OTN-based equipment. For each type of OTN client layer signal and introductory scenario, this appendix describes the consequences on networking, SDH/OTN interworking and subsequent transport evolution.

Figure III.1 shows the introductory paths that are available and illustrates the basic choices and provides a reference during the following discussion.

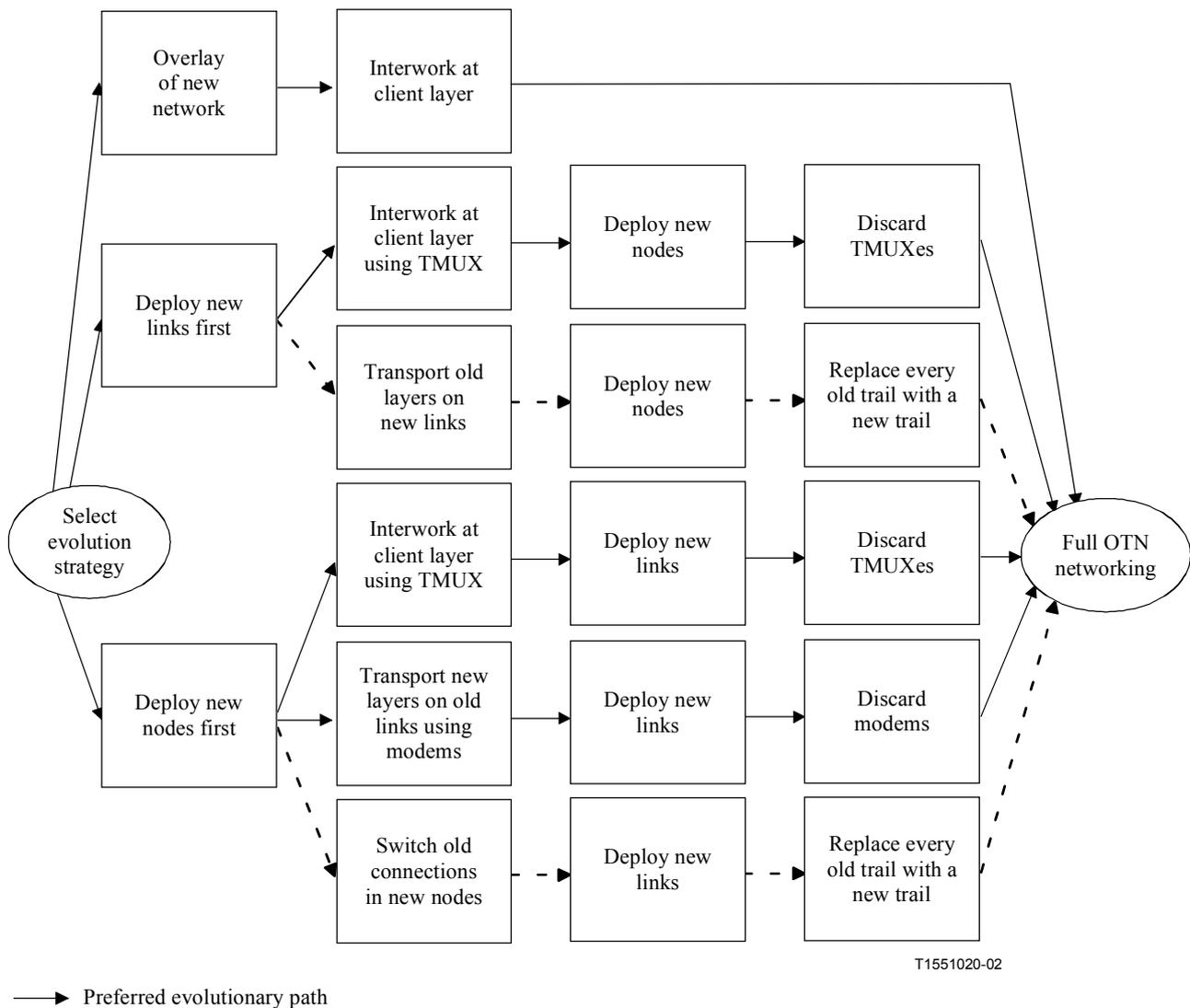


Figure III.1/G.872 – OTN evolution paths

III.2 Types of client layer signals

III.2.1 OTN case

OTN path layers (ODU transport entities) support the following client layer signals in accordance with the mappings defined in ITU-T Rec. G.709. For the purpose of interworking two cases must be considered:

- a) client layer signals such as:
 - i) a constant bit rate ATM cell stream;
 - ii) variable length Generic Frame Procedure (GFP) frames. These may be used to transport IP, for example;
 - iii) a non-specific client mapping is specified for support of any (set of) client signal(s), into a continuous bit stream.
- b) STM-N regenerator section layer signals which, in turn support:
 - i) SDH higher order path layers;

OTN-based transport network equipment is concerned with control of connectivity of ODU paths and optical channels and not with control of connectivity of the client layer. Therefore in case b)

above, the OTN-based equipment cannot be used to individually network the SDH path layers associated with b) or the client layers associated with the SDH path layers.

This constraint could be significant in cases where OTN-based transport networks become widespread. Where this is likely to be the case, it is recommended that the support of such a signal is minimized from the outset or, that during subsequent stages of transport network evolution, steps are taken to minimize the redundant STM-N section layer signals

III.2.2 SDH case

In this case the SDH path layers support the following client layer signals in accordance with the mappings defined in ITU-T Rec. G.707. The following two types of client layer signals which must be considered for interworking:

- a) client layer signals such as:
 - i) a constant bit rate ATM cell stream
 - ii) variable length Generic Frame Procedure (GFP) frames. These may be used to transport IP, for example.
- b) OTN path layer signals (ODU1 and ODU2), that in turn support the client layer signals identified in III.2.1 (see Note).

NOTE – These mappings of ODU path layer into SDH higher order layer signals outline a possible transitional stage of transport network evolution. The functionality required to provide these mappings is referred to below as “modem” functionality (since it is analogous to the transition from the “old” analogue network to the “new” digital network where modems allowed signals from the “new” network to be supported over the “old” network). An optical modem may for example be used to interconnect OTN islands using the SDH network.

III.3 Initial introduction of OTN-based equipment

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

- a) Deployment of an overlay network comprising the simultaneous deployment of OTN line systems and ODU/OCh cross-connect functionality to provide widespread path layer connectivity (see Note). In addition, to increase geographical coverage in such an overlay network, the link connections in the OTN path layer could be adapted into SDH paths using the modem functionality as mentioned in III.2. Initially, this overlay network is likely to be “thin” and might be targeted at supporting particular client layer types but later “thickened” to include other services.

NOTE – ODU and/or OCh cross-connect functionality is realized in OTN cross-connect equipment and/or add/drop multiplex equipment (ADM). Such functionality is referred to below as XC/ADM.

- b) Deployment of OTN XC/ADMs only. This is likely to take the form of cross-connects in central locations where control of the connectivity of STM-N regenerator sections at the site is the desired initial benefit. In terms of the functional architecture, ODU/OCh paths in the XC/ADMs provide subnetwork connections in the STM-N regenerator section layer. OTN line systems could be deployed at a later stage to provide more widespread ODU connectivity. Similarly, higher order SDH paths with the modem functionality could be used as mentioned in a) above to provide more widespread ODU connectivity.
- c) Deployment of OTN line systems only. Such systems are functionally similar to SDH line systems in that they support link connections in the STM-N regenerator section layer. In terms of the functional architecture, ODU paths in the OTN line systems provide link connections in the SDH STM-N regenerator section. OTN XC/ADMs could be deployed at a later date to provide more ODU connectivity.

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

III.4 Interworking between SDH and OTN-based transport networks

III.4.1 Interworking levels

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

- a) at the client layer for signals identified in III.2.1 a) and III.2.2 a): Such interworking generally requires the termination of the respective SDH and OTN paths and the adaptation functions between the respective path layers and the client layer. This combination of functions is referred to as transmultiplexing (TMUX). This approach does not necessarily imply additional physical interfaces.
- b) at the SDH STM-N regenerator section level for signals identified in III.2.1 b): Such interworking requires the adaptation of the STM-N regenerator section layer signal into appropriate ODU path layers using the mappings described in ITU-T Rec. G.709.
- c) at the OTN path level where the OTN path layer signals, described in III.2.2 b), are adapted into SDH higher order paths using the modem functionality.

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

III.4.2 OTN overlay

The two interworking levels are considered as follows:

- a) The requirements for interworking at the client level are given in III.4.1 a)

In cases where SDH higher order paths are used to provide ODU connectivity “modem” functionality will be required for adaptation to the SDH higher order path layer.

In cases where subsequently OTU interfaces are provided on network elements which process the client layer signals identified in III.2.1 a), there are no interworking requirements between such network elements and the OTN transport network.

- b) The requirements for interworking at the STM-N level are given in III.4.1 b). SDH higher and/or lower order path layer multiplexing functionality will continue to be required in the SDH based transport network.

In cases where SDH higher order paths are used to provide ODU connectivity “modem” functionality will be required for adaptation to the SDH higher order path layer.

In cases where it is subsequently desired to interwork at the client level, it will be necessary to cease the OTN paths supporting STM-N regenerator sections and provide new OTN paths which directly support the client layer. SDH lower and higher order path multiplexing functionality will not be required.

III.4.3 OTN XCs, ADMs, and line systems

The two interworking levels are considered as follows:

- a) The requirements for interworking at the client level are given in III.4.1 a).

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

- b) The requirements for interworking at the STM-N regenerator section level are given in III.4.1 b).

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

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