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

Digital transmission systems – Digital networks – Optical transport networks

Architecture of optical transport networks

ITU-T Recommendation G.872

(Previously CCITT Recommendation)

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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 Recommendation 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 prepared by ITU-T Study Group 13 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 26th of February 1999.

FOREWORD

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

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

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 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

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

CONTENTS

Recommendation G.872

ARCHITECTURE OF OPTICAL TRANSPORT NETWORKS

(Geneva, 1999)

1 Scope

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; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

– ITU-T Recommendation G.652 (1997), *Characteristics of a single-mode optical fibre cable.*

– ITU-T Recommendation G.653 (1997), *Characteristics of a dispersion-shifted single-mode optical fibre cable.*

– ITU-T Recommendation G.655 (1996), *Characterization of a non-zero dispersion shifted single-mode optical fibre cable.*

– ITU-T Recommendation G.681 (1996), *Functional characteristics of interoffice and long-haul line systems using optical amplifiers, including optical multiplexing.*

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

– ITU-T Recommendation G.803 (1997), *Architecture of transport networks based on the synchronous digital hierarchy (SDH).*

– ITU-T Recommendation G.805 (1995), *Generic functional architecture of transport networks.*

– ITU-T Recommendation G.957 (1995), *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.*

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 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.

3.3 connectivity supervision: The set of processes for monitoring the integrity of the routing of the connection between source and sink trail terminations.

3.4 continuity supervision: The set of processes for monitoring the integrity of the continuity of a trail.

3.5 Inter-Domain Interface (IrDI): A physical interface that represents the boundary between two administrative domains.

3.6 Intra-Domain Interface (IaDI): A physical interface within an administrative domain.

3.7 maintenance indication: The set of processes for indicating defects in a connection which is part of a trail in downstream and upstream directions.

3.8 management communications: The set of processes providing communications for management purposes.

3.9 OTN compliant interface: An interface for the optical transport network based on the architecture defined in this Recommendation (G.872).

3.10 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).

3.11 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 for national use.

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.

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

3.13 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.

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

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

3.16 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 Recommendation G.805)
APS	Automatic protection switching
ATM	Asynchronous transfer mode (see Recommendation I.326)
BDI	Backward defect indication
CP	Connection point (see Recommendation 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
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 Recommendation G.803)
SDH	Synchronous digital hierarchy (see Recommendation G.707)
SNC	Subnetwork connection (see Recommendation 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 Recommendation G.707)
TCP	Termination connection point (see Recommendation 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. This functionality for optical networks is described from a network level viewpoint using the generic principles defined in Recommendation 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. This

Recommendation uses the terminology, functional architecture and diagrammatic conventions defined in Recommendation G.805.

In accordance with Recommendation 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. optical code division multiplexing) 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 supervisory 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 supervisory 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 supervisory 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 subclause.

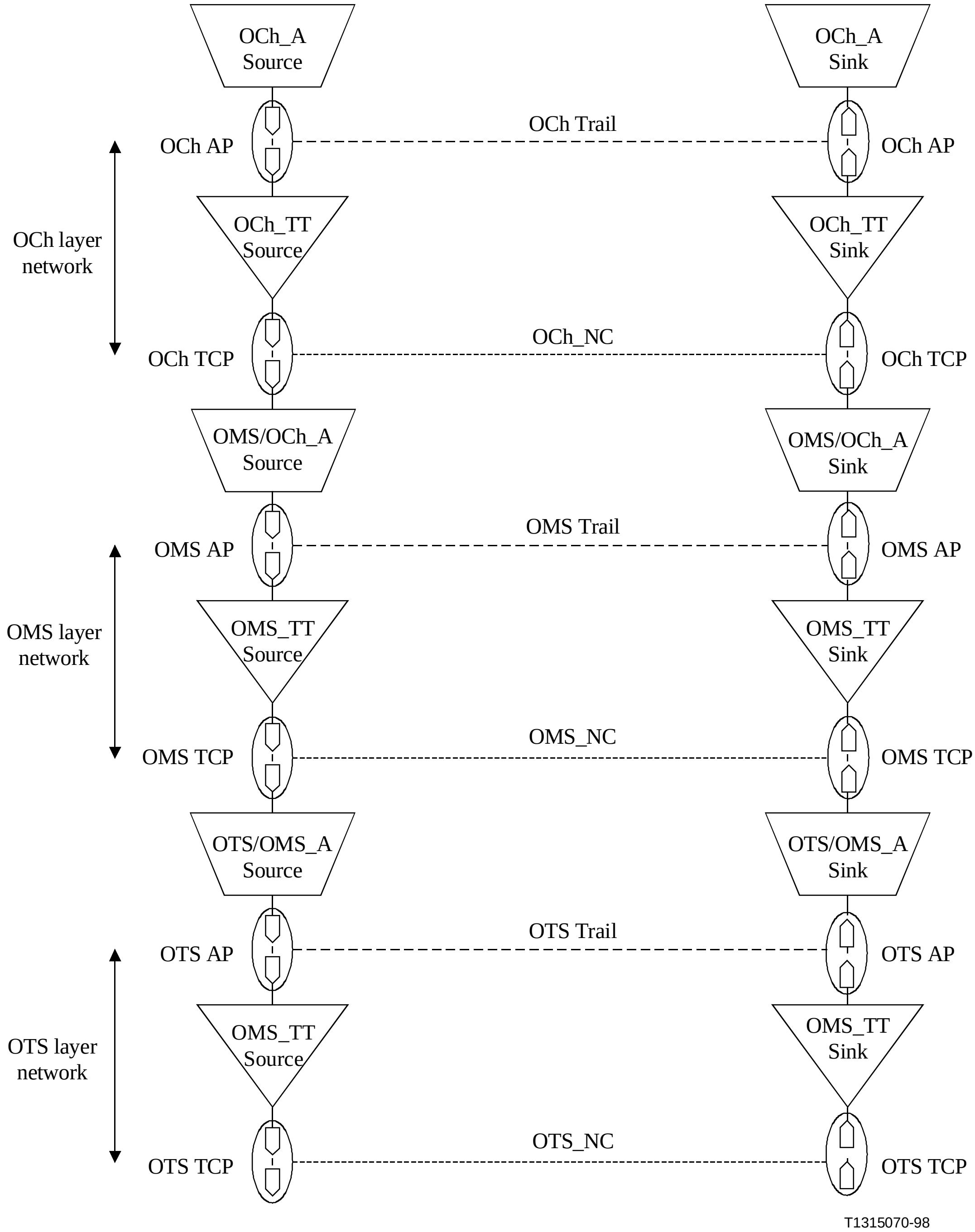


Figure 1/G.872 – Client server associations in an optical transport network

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:

– a data stream that constitutes the adapted information of a client layer network;

– a data stream that constitutes the optical channel trail termination overhead.

This characteristic information is an Optical Transport Unit (OTU). 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).

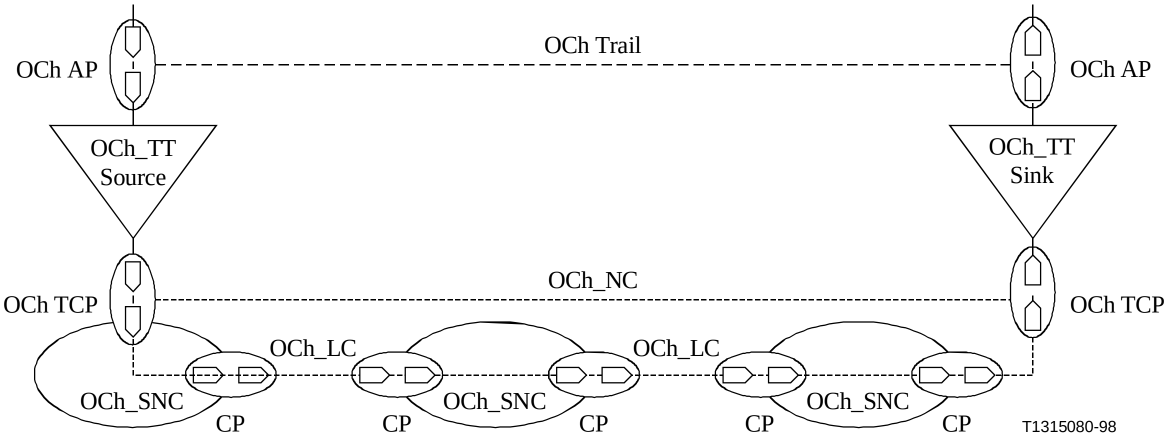


Figure 2/G.872 – OCh layer network example

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 co-located 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 Recommendation 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 Transport Unit Group of order n (OTUGn).

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).

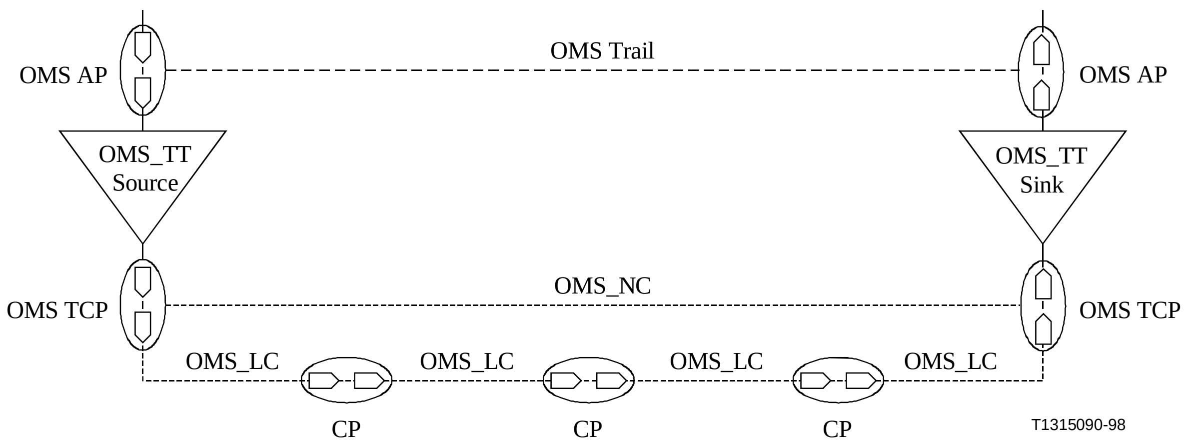


Figure 3/G.872 – OMS layer network example

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 co-located 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 Recommendation 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 (OTMn).

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.

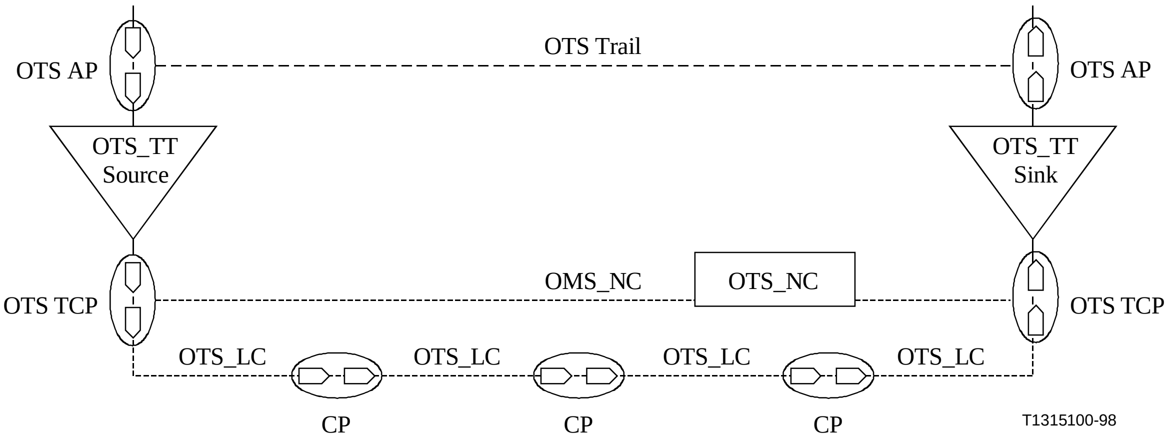


Figure 4/G.872 – OTS layer network example

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 co-located 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 Recommendation 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 co-located 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 co-located 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 transport unit 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 transport unit;

– 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 co-located 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 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 and is for further study.

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.

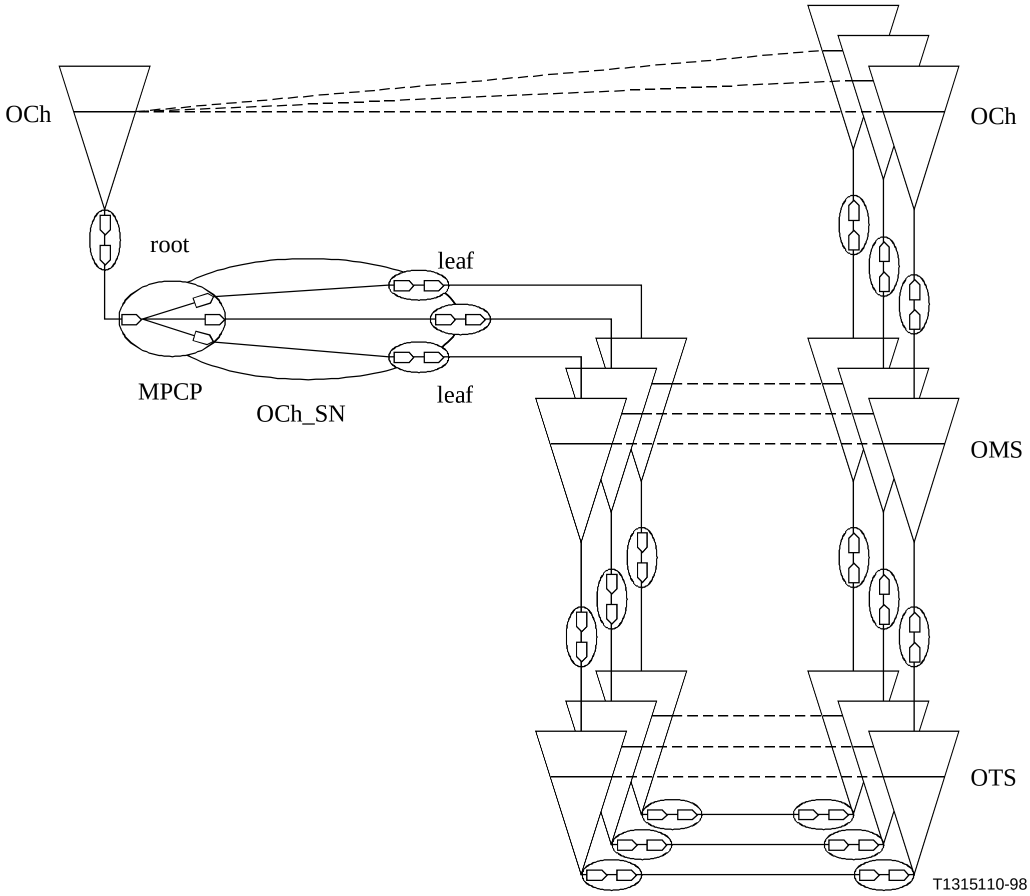


Figure 5/G.872 – Point-to-multipoint optical channel connection

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 subclause. 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	• Loss of continuity detection	TT	R	R	R	See 6.2.1
Connectivity supervision	• Trail trace identification	TT	R[a)]	NR	R	See 6.2.1
Maintenance information	• Forward defect indication	TT	R	R	R	See 6.2.1
	• Backward defect indication	TT	R	R	R	
	• Backward quality indication	TT	FFS	FFS	FFS	

Table 1/G.872 – Optical transport network – Network level management requirements *(concluded)*

Management capability	Process	Function	Layer network			Comments
			OCh	OMS	OTS	
Signal quality supervision	• Performance monitoring (parameters are for further study)	TT	R	FFS	R	See 6.2.2
Adaptation management	• Payload type indication	A	R	FFS	NA	See 6.2.3
Protection control	• Automatic protection switching protocol	A/T	FFS	FFS	NR	See 6.2.4
Subnetwork/tandem/ unused connection supervision	• Connection supervision	A/T	FFS	FFS	FFS	See 6.3
Management communications	• Message-based channel • Auxiliary channel	A A	NR NR	FFS NR	R O	See 6.2.5
Other communication needs	• Operator-specific • National use	A A	NR NR	NR NR	R FFS	See 6.2.6

R Required
A Adaptation function
FFS For further study
TT Trail termination function
NA Not applicable
A/T Process may be assigned to one or both functions; allocation is for further study.
NR Not required
O Optional
[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 defection 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*

  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 indication

Maintenance indication 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.

Two maintenance indication processes are identified:

- Forward Defect Indication (FDI).
- Backward Defect Indication (BDI).

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 signals 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 8). In addition, BDI supports 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.

NOTE – FDI and BDI terminology is used instead of the traditional AIS and RDI terminology in order not to prejudge 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 for backward quality indication 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 Identifier (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.

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.

The OCh/Client adaptation may contain client-specific supervision processes. Definition of these processes is outside the scope of this Recommendation.

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.

Subclause 7.1 describes only protection architectures that are controlled by local information of the NE. An automatic protection switching (APS) protocol is not required for these protection architectures. The need for an APS protocol supporting additional protection architectures is for further study.

6.2.5 Management communications

Two types of management communication processes are identified:

- message-based channel for supporting a data communications network;
- auxiliary channel for supporting personnel voice and voiceband data communications.

A message-based channel is required at the OTS layer to support OTN-related data communications for, for example, management of line optical amplifiers. The need for an additional channel at the OMS layer to support, for example, OMS layer management information exchange, is for further study. A message-based channel at the OCh layer is not required.

The need for an auxiliary channel at the OTS layer supporting, for example, an engineering orderwire, is optional. Additional auxiliary channels at the OMS and OCh layers are not envisaged.

6.2.6 Other communication needs

Capacity needs to be made available for other communication channels, e.g. for operator-specific overhead, and/or national use.

6.3 Connection supervision techniques and applications

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. Recommendation 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.

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.

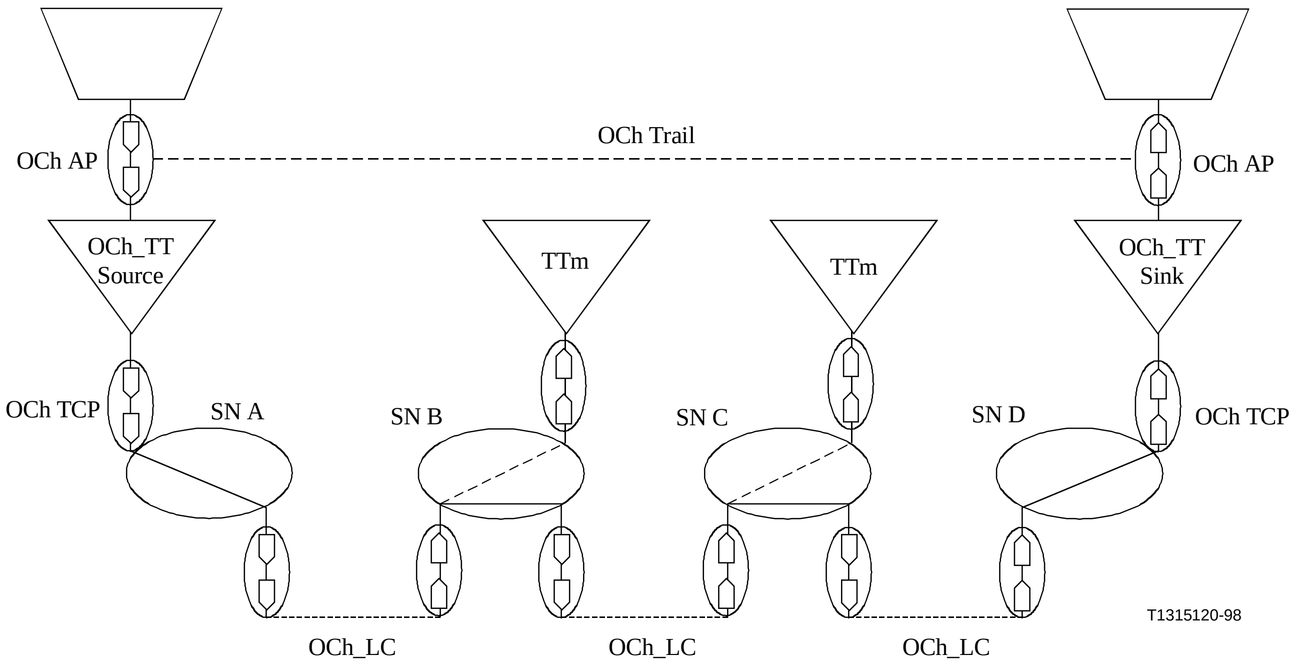


Figure 6/G.872 – Example of subnetwork connection supervision using non-intrusive monitoring

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

The application of this technique to optical network transport layers is for further study.

6.3.5 Monitoring of unused connections

Monitoring the integrity of unused connections in optical transport network layers is for further study.

6.3.6 Tandem connection monitoring

The intended role of tandem connections is to represent that portion of a trail that exists within a particular administrative region. Tandem connection monitoring in optical transport network layers is for further study.

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.

7.1 Protection

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.

Two types of protection architecture are considered: trail protection and subnetwork connection protection.

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). It can be applied in both the OCh and OMS layers. Trail protection is not recommended for use in the OTS layer. 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 1:1 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 can be applied in either the OMS or OCh layers. This architecture is illustrated in Figure 7. It may be used without an automatic protection switching protocol.

All other types of trail protection including OMS and OCh trail protection in other configurations is for further study.

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 in the server layer. The switching process and defect detection process are performed by two adjacent layers, with the server layer providing the defect detection process and the client layer receives Server Signal Fail (SSF) generated by the server layer. 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.

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

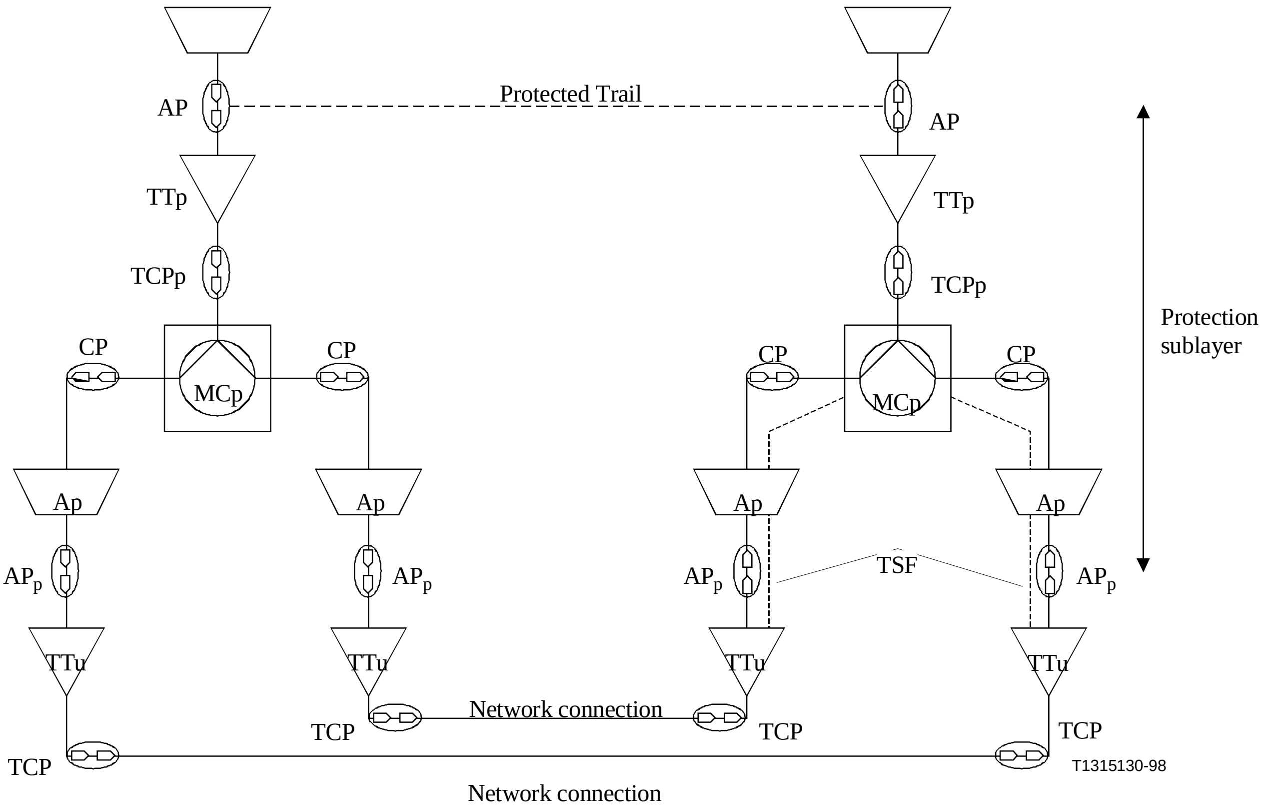
1+1 unidirectional SNC/N

In this architecture, 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. This architecture can be applied in the OCh and OTS network layers. In the latter case, its application is restricted to network connection protection rather than subnetwork connection protection and is therefore suitable for short-haul optical line systems without in-line amplifiers. This architecture is illustrated in Figure 8. It may be used without an automatic protection switching protocol.

1+1 unidirectional SNC/I

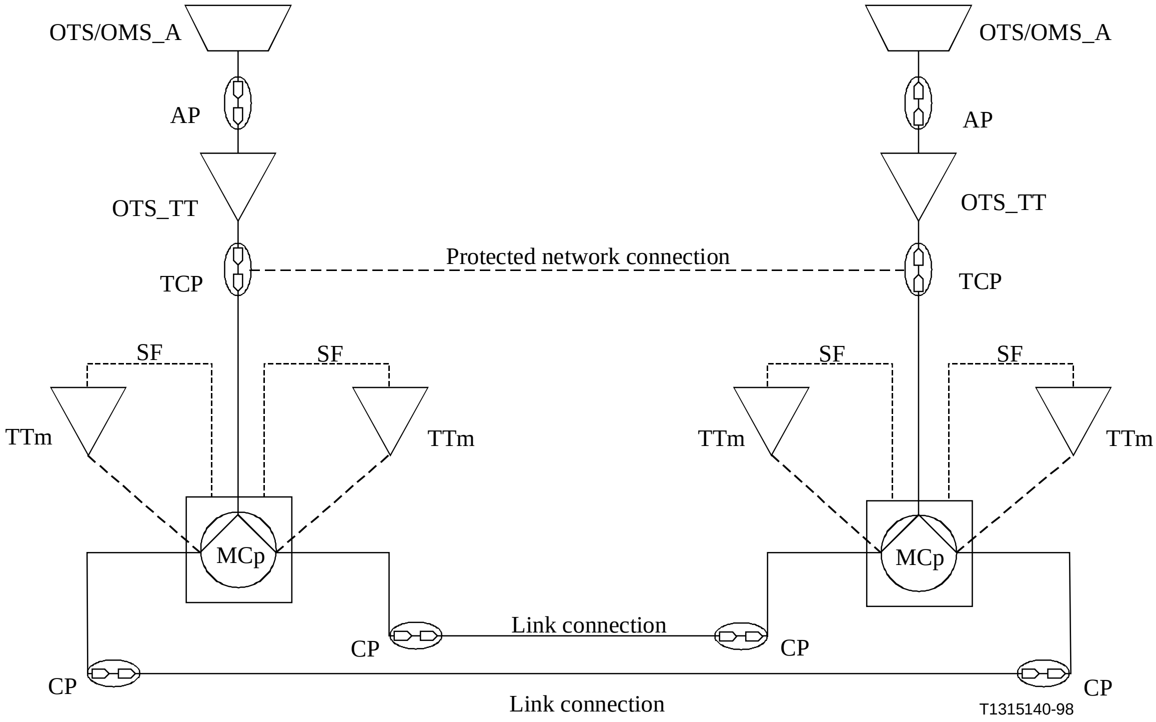
This architecture can be applied in the optical channel layer network.

Other architectures are for further study.



TSF Trail signal fail
TTp Protected trail termination
TTu Unprotected trail termination
Ap Protection adaptation
MCp Protection matrix connection
TCPp Protection TCP
AP_p Protection access point

Figure 7/G.872 – 1+1 unidirectional trail protection



SF Signal fail
MCp Protection matrix connection
TTm Non-intrusive trail termination monitor
TCP Termination connection point
AP Access point
CP Connection point

Figure 8/G.872 – Network connection protection with non-intrusive monitoring in the optical transmission section layer network

7.2 Network restoration

Optical network restoration techniques are based on optical channel cross-connection. In general, the algorithms used for restoration involve rerouting. To restore an impaired connection, alternative facilities may be chosen among the available capacity of the optical layer network.

Optical transport network restoration techniques require further study.

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 9 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 9 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.

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 10. 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. Second priority should be given to transverse compatible interfaces that span longer distances.

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 11. 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 multichannel interface.

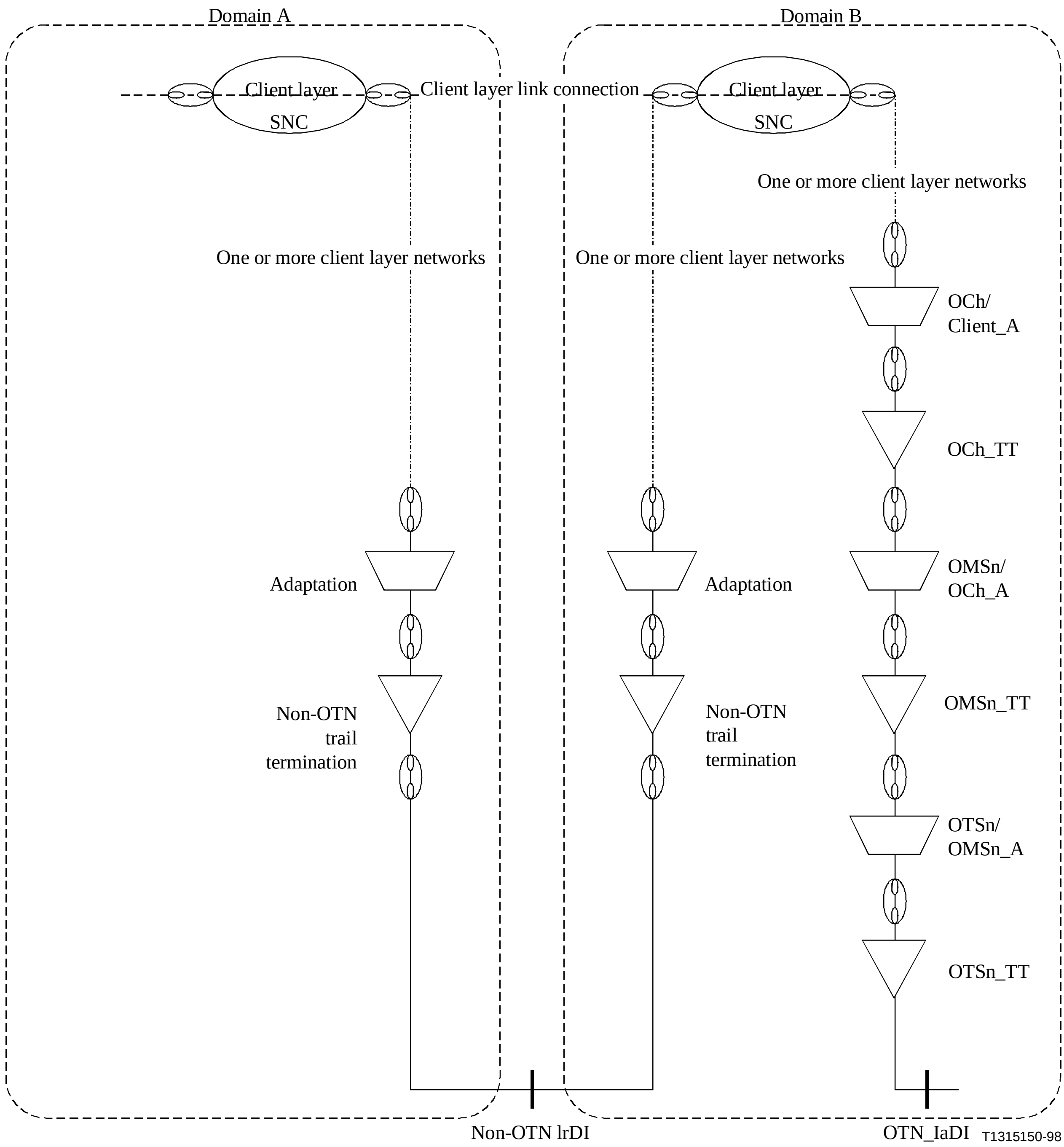


Figure 9/G.872 – Scenario 1: Interconnection of different administrative domains via a non-OTN interface

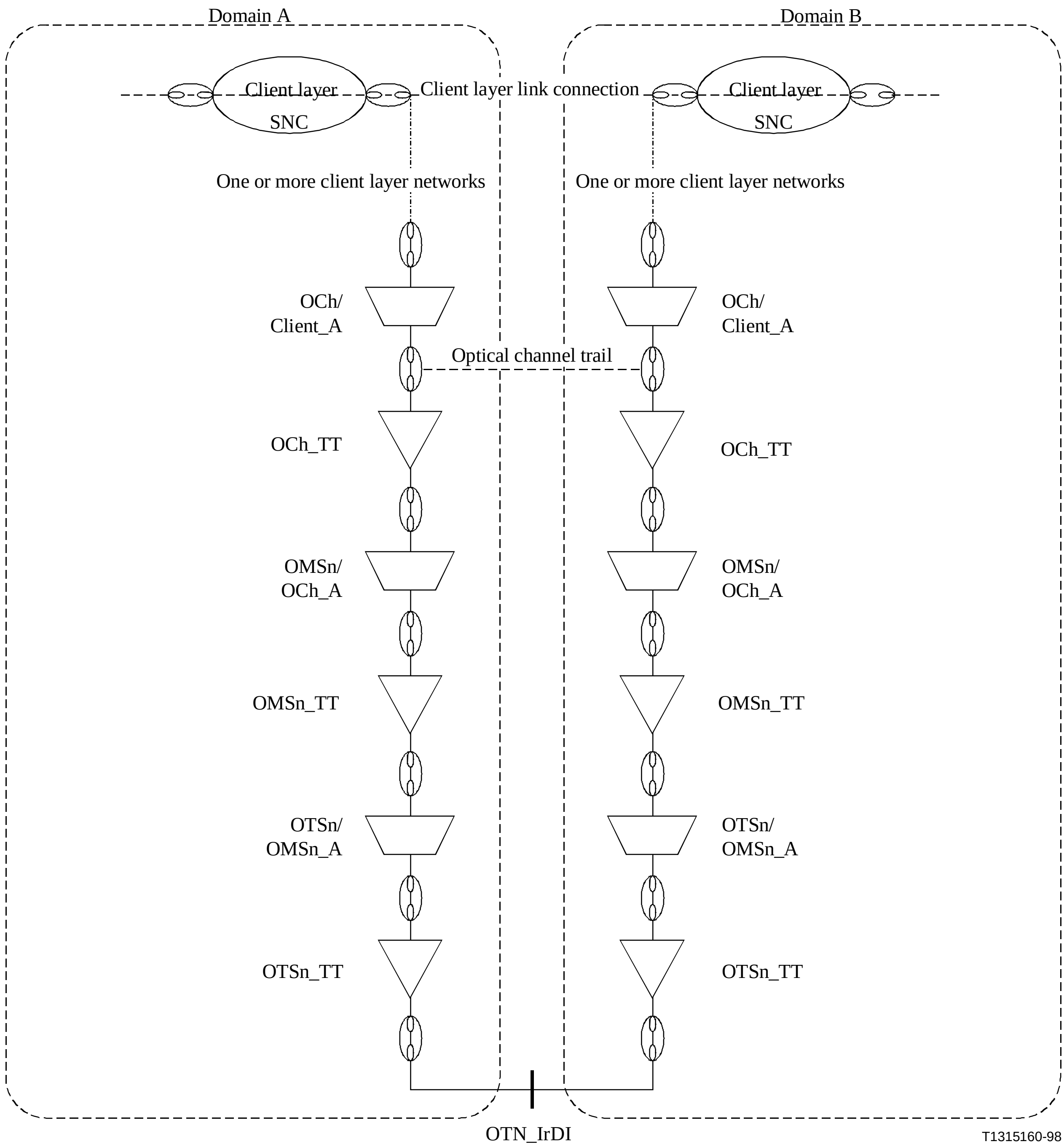


Figure 10/G.872 – Scenario 2: Interconnection of different administrative domains via an optical island with an OTN inter-domain interface

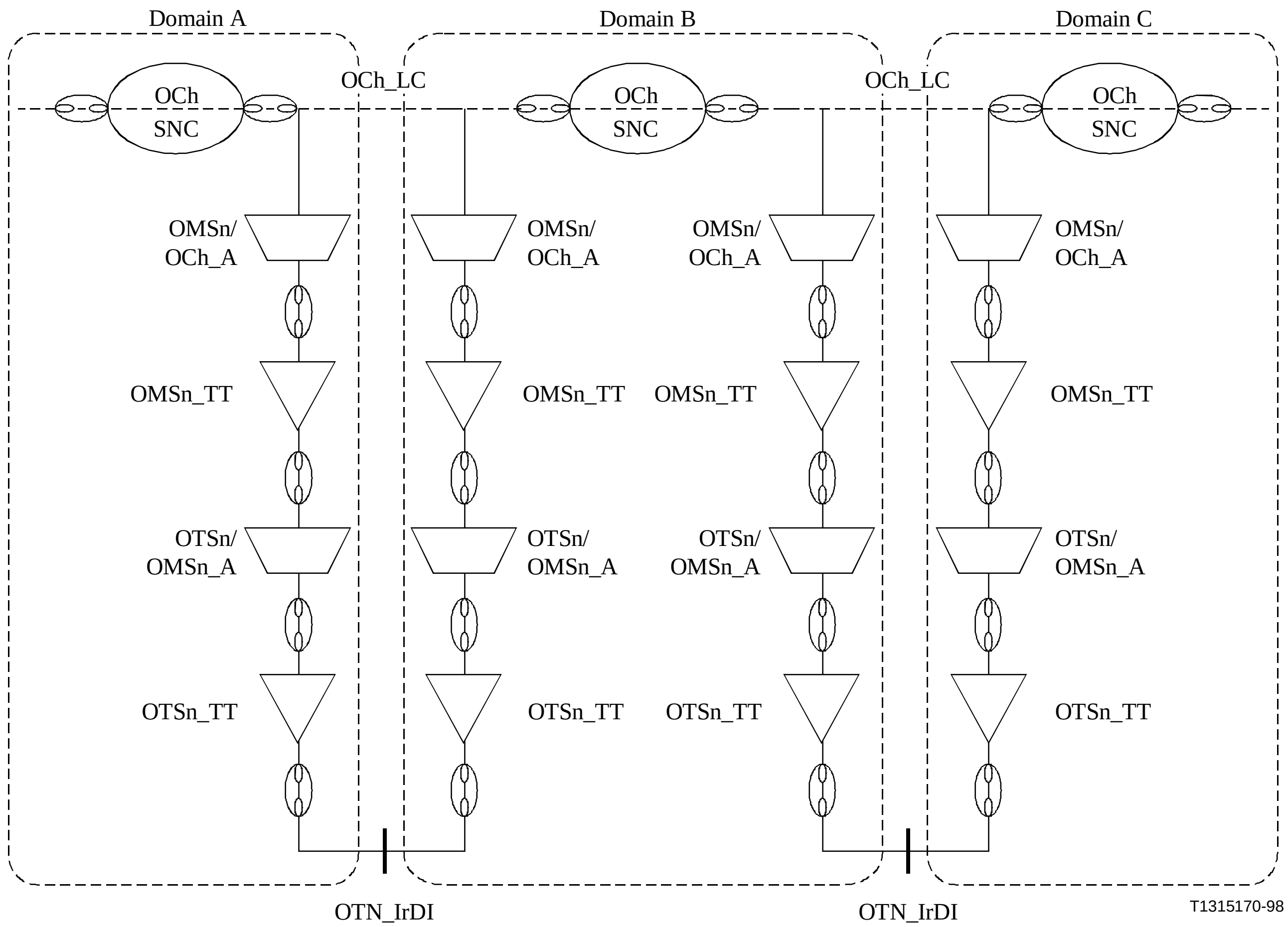


Figure 11/G.872 – Scenario 3: Interconnection of OTN subnetworks in different administrative domains via an OTN inter-domain interface supporting OCh interworking

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 multichannel systems.

c) Dispersion compensation (phase distortion). This analogue process can be applied in either single-channel or multichannel 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.

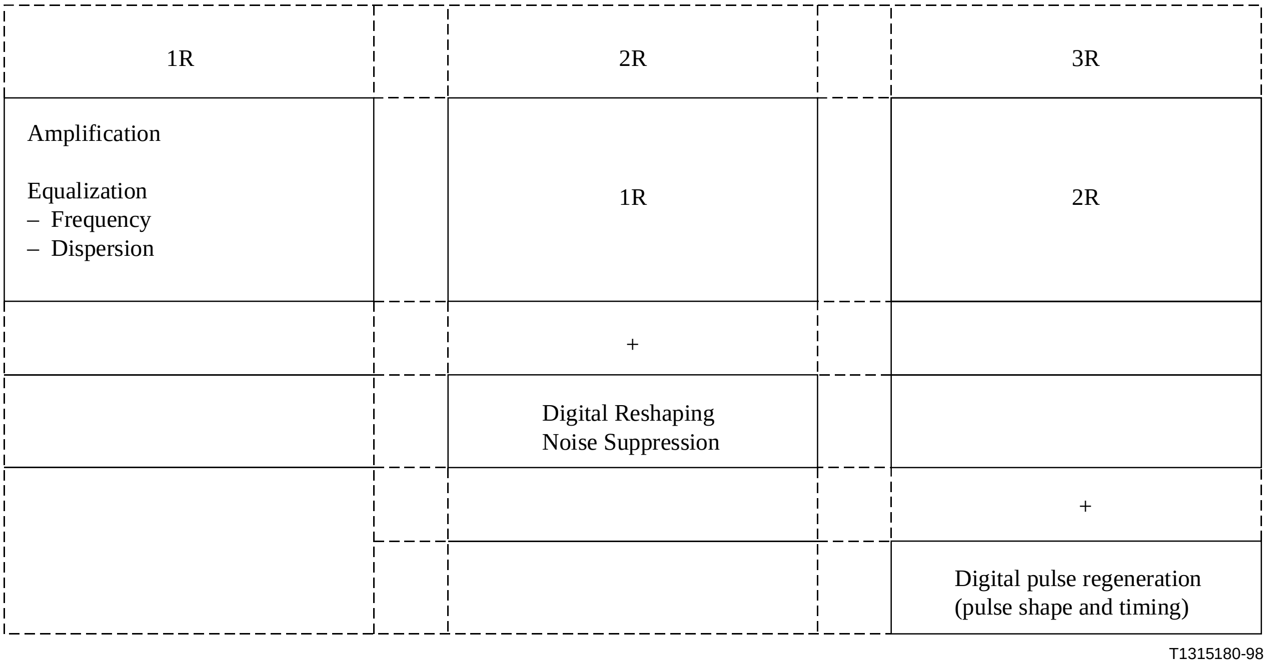


Figure A.1/G.872 – Regeneration classification

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.

I.2 Cross-connect

Figure I.2 shows the functional model of a cross-connect and two optical amplifiers, one single channel and one multichannel. 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.

I.3 Regeneration

The processes involved in 1R, 2R and 3R regeneration as detailed in Annex A and their assignment to the appropriate optical transport network function are for further study.

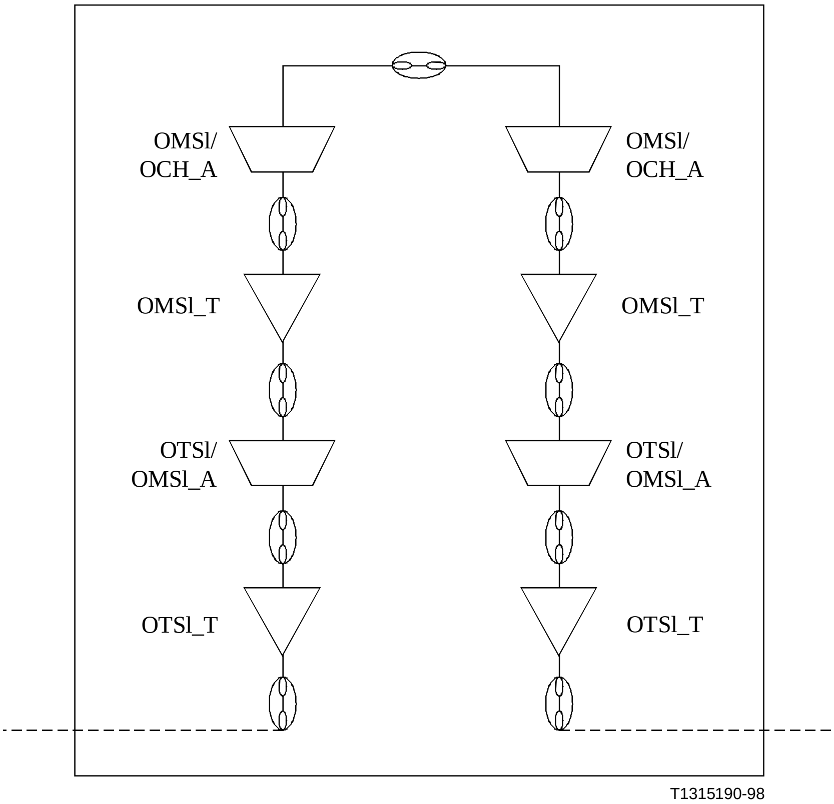
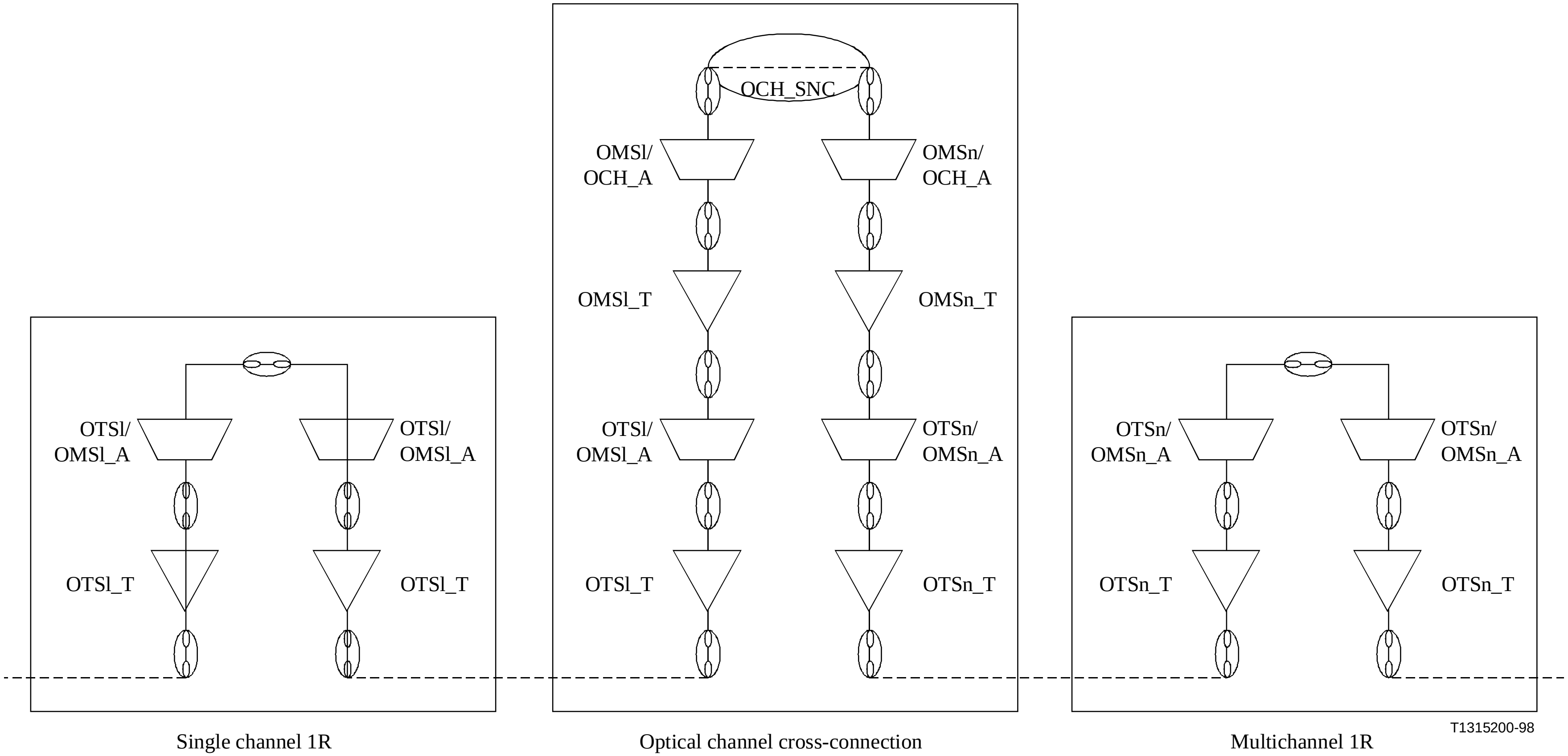


Figure I.1/G.872 – Example of optical wavelength conversion



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 multichannel 1R regeneration (amplification) and channel cross-connection

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