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Digital networks – Optical transport networks

Architecture of optical transport networks

Recommendation ITU-T G.872

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TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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Recommendation ITU-T G.872

Architecture of optical transport networks

Summary

Recommendation ITU-T G.872 describes the functional architecture of optical transport networks using the modelling methodology described in Recommendations ITU-T G.800 and ITU-T G.805. The optical transport network (OTN) 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. The optical portion of the network is described in terms of spectrum management entities and maintenance entities.

History

Edition	Recommendation	Approval	Study Group
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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation describes the functional architecture of optical transport networks using the modelling methodology described in [ITU-T G.800] and [ITU-T G.805]. The optical transport network (OTN) 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. The optical portion of the network is described in terms of spectrum management entities and maintenance entities.

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 the scope of this Recommendation.

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

[ITU-T G.694.1] Recommendation ITU-T G694.1 (2012), *Spectral grids for WDM applications: DWDM frequency grid.*

[ITU-T G.698.1] Recommendation ITU-T G.698.1 (2009), *Multichannel DWDM applications with single-channel optical interfaces*.

[ITU-T G.698.2] Recommendation ITU-T G.698.2 (2009), *Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces*.

[ITU-T G.707] Recommendation ITU-T G.707/Y.1322 (2007), *Network node interface for the synchronous digital hierarchy (SDH)*.

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2012), *Interfaces for the optical transport network (OTN)*.

[ITU-T G.798] Recommendation ITU-T G.798 (2010), *Characteristics of optical transport network hierarchy equipment functional blocks*.

[ITU-T G.800] Recommendation ITU-T G.800 (2012), *Unified functional architecture of transport networks*.

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

[ITU-T G.870] Recommendation ITU-T G.870/Y.1352 (2012), *Terms and definitions for optical transport networks (OTN).*

[ITU-T G.873.1] Recommendation ITU-T G.873.1 (2011), *Optical Transport Network (OTN): Linear protection.*

[ITU-T G.873.2] Recommendation ITU-T G.873.2 (2012), *ODUk shared ring protection.*

[ITU-T G.7712] Recommendation ITU-T G.7712/Y.1703 (2010), *Architecture and specification of data communication network.*

[ITU-T G.8080] Recommendation ITU-T G.8080/Y.1304 (2012), *Architecture for the automatically switched optical network.*

3 Terms and definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 adaptation management [ITU-T G.870]: The set of processes for managing client layer network adaptation to/from the server layer network.

3.1.2 administrative domain [ITU-T G.805]: For the purposes of this Recommendation an administrative domain represents the extent of resources which belong to a single player such as a network operator, a service provider or an end-user. Administrative domains of different players do not overlap amongst themselves.

3.1.3 central frequency [ITU-T G.870]: The nominal[1] mid-point of the optical frequency range over which the digital information of a particular OCh-P is modulated.

3.1.4 connection supervision [ITU-T G.805]: The process of monitoring the integrity of a "connection" or "tandem connection" which is part of a "trail".

3.1.5 connectivity supervision [ITU-T G.870]: The set of processes for monitoring the integrity of the routing of the connection between source and sink trail terminations.

3.1.6 continuity supervision [ITU-T G.870]: The set of processes for monitoring the integrity of the continuity of a trail.

3.1.7 effective frequency slot [ITU-T G.870]: The effective frequency slot of a media channel is that part of the frequency slots of the filters along the media channel that is common to all of the filters' frequency slots. It is described by its nominal central frequency and its slot width.

3.1.8 frequency slot [ITU-T G.694.1]: The frequency range allocated to a slot and unavailable to other slots within a flexible grid. A frequency slot is defined by its nominal central frequency and its slot width.

Within this Recommendation a fixed grid device is described in terms of the frequency slots it would have associated with it, if it were a flexible grid device.

3.1.9 inter-domain interface (IrDI) [ITU-T G.870]: A physical interface that represents the boundary between the administrative domains of different network operators. The characteristics are defined in [ITU-T G.709].

[1] Nominal means the intended mid-point of the range. The actual mid-point may be slightly offset by impairments such as long term drift.

3.1.10 intra-domain interface (IaDI) [ITU-T G.870]: A physical interface within the domain of a single network operator. The characteristics are defined in [ITU-T G.709].

3.1.11 maintenance indication [ITU-T G.870]: The set of processes for indicating defects in a connection which is part of a trail in downstream and upstream directions.

3.1.12 management communications [ITU-T G.870]: The set of processes providing communications for management purposes.

3.1.13 media element [ITU-T G.870]: A media element directs the optical signal or affects the properties of an optical signal, it does not modify the properties of the information that has been modulated to produce the optical signal.

3.1.14 network media channel [ITU-T G.870]: A media channel that supports a single OCh-P network connection.

3.1.15 optical channel data unit (ODUk) [ITU-T G.870]: The ODUk is an information structure consisting of the information payload (OPUk) and ODUk-related overhead. See [ITU-T G.709] for the current valid values of k.

3.1.16 optical channel payload unit (OPUk) [ITU-T G.870]: The OPUk is the information structure used to adapt client information for transport over an optical channel. It comprises client information together with any overhead needed to perform rate adaptation between the client signal rate and the OPUk payload rate, and other OPUk overheads supporting the client signal transport. See [ITU-T G.709] for the current valid values of k.

3.1.17 optical channel transport unit (OTUk[V]) [ITU-T G.870]: The OTUk is the information structure used for transport of an ODUk over an OCh trail. See [ITU-T G.709] for the current valid values of k.

3.1.18 optical supervisory channel (OSC) [ITU-T G.870]: The OSC supports the transfer of the non-associated overhead information for the OCh trail, OMS_ME and the OTS_ME.

3.1.19 optical transport hierarchy (OTH) [ITU-T G.870]: The OTH is a hierarchical set of digital transport layers, standardized for the transport of suitably adapted payloads within the OTN.

3.1.20 optical transport network (OTN) [ITU-T G.870]: An optical transport network (OTN) is composed of a set of optical network elements connected by optical fibre links, able to provide functionality of transport, multiplexing, routing, management, supervision and survivability of optical channels carrying client signals, according to the requirements given in [ITU-T G.872].

3.1.21 signal quality supervision See [ITU-T G.870]: The set of processes for monitoring the performance of a connection that is supporting a trail.

3.1.22 slot width [ITU-T G.694.1]: The full width of a frequency slot in a flexible grid.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 media channel: A media association that represents both the topology (i.e., the path through the media) and the resource (frequency slot) that it occupies.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AIS	Alarm Indication Signal
AP	Access Point
APS	Automatic Protection Switching

BDI	Backward Defect Indication
BEI	Backward Error Indication
CP	Connection Point
FDI	Forward Defect Indication
FEC	Forward Error Correction
IaDI	Intra-Domain Interface
IrDI	Inter-Domain Interface
LC	Link Connection
LOC	Loss of Continuity
ME	Maintenance Entity
MI	Management Information
MSI	Multiplex Structure Identifier
NC	Network Connection
NE	Network Element
NIM	Non-Intrusive Monitor
OAM	Operation, Administration and Maintenance
OCh	Optical Channel
OCh_ME	OCh Maintenance Entity
OCh-O	OCh – Overhead
OCh-P	OCh – Payload
OCI	Open Connection Indication
ODU	Optical channel Data Unit
OMS	Optical Multiplex Section
OMS_ME	Optical Multiplex Section Maintenance Entity
OMS-O	Optical Multiplex Section – Overhead
OMS-P	Optical Multiplex Section – Payload
OSC	Optical Supervisory Channel
OTH	Optical Transport Hierarchy
OTM	Optical Transport Module
OTN	Optical Transport Network
OTS	Optical Transmission Section
OTS_ME	Optical Transmission Section Maintenance Entity
OTSn	Optical Transmission Section of order n
OTU	Optical Transport Unit
OTUGn	Optical Transport Unit Group of order n
SDH	Synchronous Digital Hierarchy
SI	Status Information (derived by the monitoring of a signal)

SN	Subnetwork
SNC	Subnetwork Connection
SRP	Shared Ring Protection
STM-N	Synchronous Transport Module level N
TCM	Tandem Connection Monitoring
TCP	Termination Connection Point
TDM	Time Division Multiplexing
TS	Tributary Slot
TT	Trail Termination
TTI	Trail Trace Identifier
(D)WDM	(Dense) Wavelength Division Multiplexing

5 Conventions

This Recommendation uses the diagrammatic conventions defined in [ITU-T G.800] and [ITU-T G.805] with the additional diagrammatic and terminological conventions described in this clause, to distinguish between the topological components and transport processing functions described in [ITU-T G.800] that act on digital signals and media functions described in this Recommendation.

Media elements act on the signals that they convey and have some similarity to the topological components and transport processing functions described in [ITU-T G.800]. However, media elements only direct or affect the physical signal but do not process the information carried in the characteristic information. Given the similarity between these functions, it is convenient to reuse the symbol shapes defined in [ITU-T G.800] with the addition of shading to distinguish between media elements and transport processing functions. These symbols are shown below in Figure 5-1. This Recommendation builds on the familiarity with transport functions while preserving important distinctions by means of its graphical conventions.

A shaded non-intrusive monitor (NIM) only monitors the optical properties of a signal.

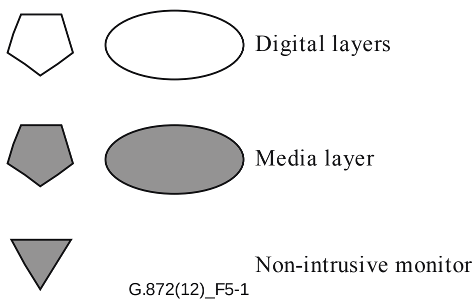

Figure 5-1 – Element shading convention

The following terminological conventions are used to distinguish between signal associations and media associations.

Connection: Is used to denote a signal association as defined in [ITU-T G.800] and [ITU-T G.805].

Media channel: Is used to denote a media association.

6 Functional architecture of optical transport networks

The functionality of optical transport networks comprises of providing transport, aggregation, routing, supervision and survivability of client signals that are processed in both the photonic and digital domains. This functionality for optical transport networks is described from a network level viewpoint using the generic principles defined in [ITU-T G.800] and [ITU-T G.805]. The specific aspects concerning the OTN layered structure, characteristic information, client/server layer associations, network topology and layer network functionality are provided in this Recommendation.

In accordance with [ITU-T G.805] and [ITU-T G.800], the OTN 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 central frequency and the maximum spectral excursion[2] (see [ITU-T G.698.2]). The optical signal is guided to its destination by a network media channel. The nominal central frequency and width of a media channel are defined by its frequency slot. A frequency slot is defined in [ITU-T G.694.1], and within this Recommendation a fixed grid device is described in terms of the frequency slots it would have associated with it if it were a flexible grid device.

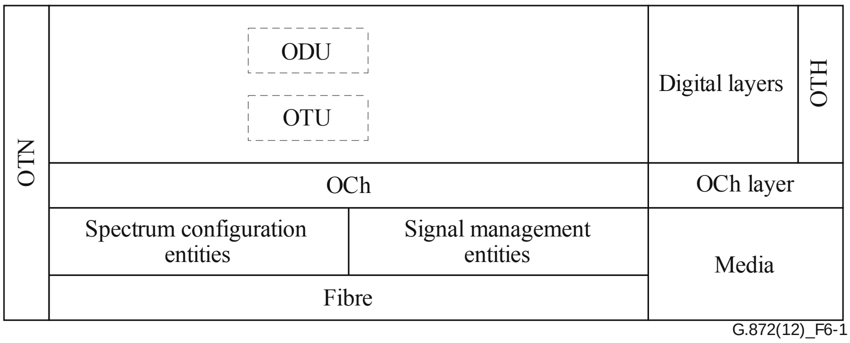

Figure 6-1 – Overview of the OTN

Above the OCh layer are the digital layers (OTU, ODU) that provide for the multiplexing of digital clients and for their maintenance. The OCh termination emits two signals: the OCh-P signal, which is carried in a media channel over media elements (the optical signal is not demodulated by any of the media elements) and the OCh-O signal, which carries OCh overhead information.

The digital layers are described in clause 7 and the OCh layer and media are described in clause 8.

Following the conventions of clause 5, the term "connection" is used to denote a signal association, while the term "media channel" is used to denote a media association. A network media channel is the media association that supports a single OCh-P network connection.

Below the OCh, the entities that provide for configuration of the media channels are described separately from the entities that provide management of the collections of the OCh-P signals that traverse the media[3].

[2] The OCh-P spectrum after the modulation process is out of the scope of this Recommendation.

[3] This separation is necessary to allow the description of media elements that may act on more than a single OCh-P signal. The relationship between the model provided in this Recommendation and the existing functions and processes described in [ITU-T G.798] is provided in Appendix IV.

The effective frequency slot of a media channel is defined by the filters that are in the path of the media channel. The effective frequency slot may be sufficient to support more than one OCh-P signal[4]. The media channel is switched by media matrices (analogue media elements).

The OCh-P signals carried by the media channel are monitored by the OMS and OTS maintenance entities (MEs) (described in clauses 8.2 and 8.3 respectively), which are responsible for non-intrusively inspecting the bulk properties of the OCh-P signals. This inspection results in management information (MI) that is passed to a management system, as well as to the far end of the maintenance entity.

7 OTN digital layers

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 the client, and provides a monitoring capability for the OCh. An ODU path layer may transport a heterogeneous assembly of ODU clients. The heterogeneous multiplexing hierarchy supports various network architectures, including those optimized to minimize stranded capacity, minimize managed entities, support carrier's carrier scenarios, and/or enable ODU0/ODUflex traffic to transit a region of the network that does not support these capabilities.

Figures 7-1 and 7-2 show the client/server relationships without ODU multiplexing and with ODU multiplexing, respectively.

[4] A media channel that may carry multiple OCh-P signals may be used to provide what is commonly called a "waveband" or "express" channel.

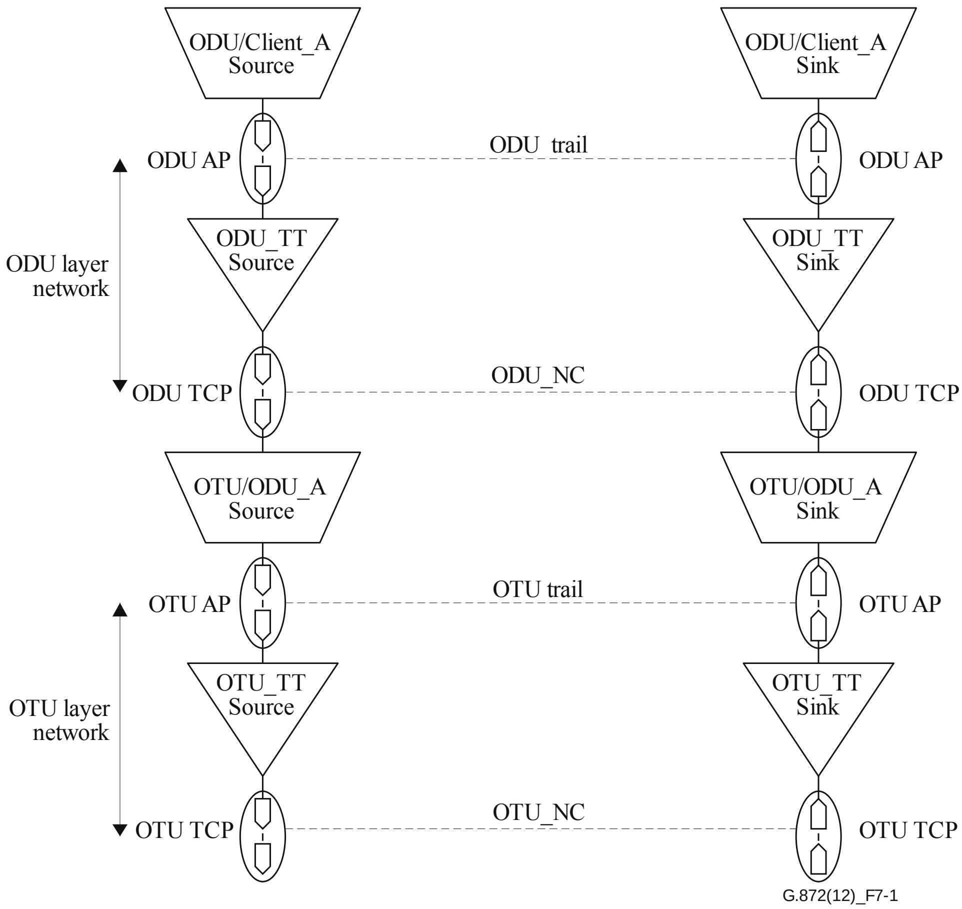

Figure 7-1 – Client/server association of the digital OTN layers without ODU multiplexing

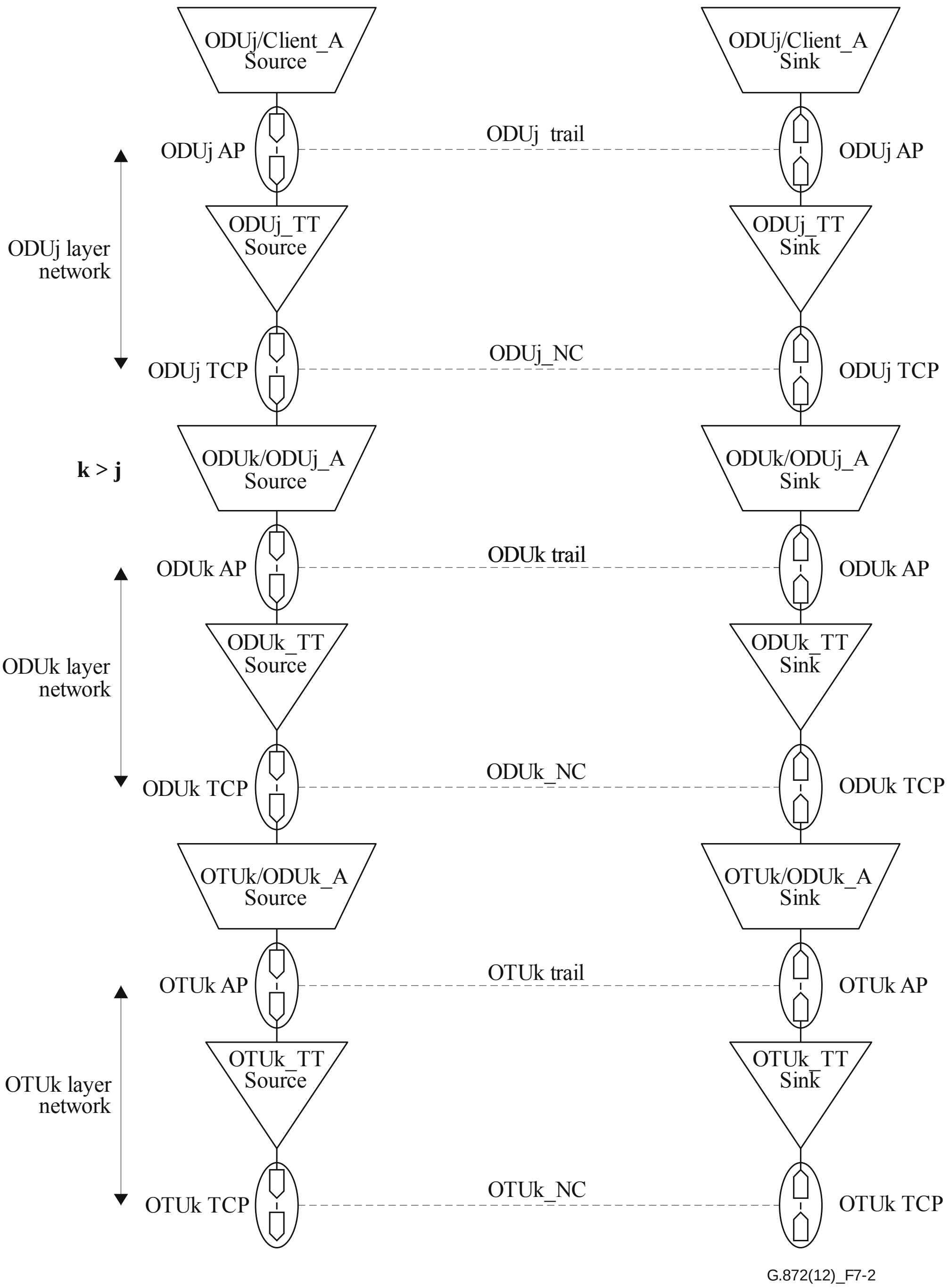

Figure 7-2 – Client/server association of the digital OTN layers with ODU multiplexing

The set of ODU clients and their ODU servers and the set of client ODUs and the server OTU signals, at the time of publication of this Recommendation, are provided in Tables 7-1 and 7-2 respectively. The set of ODU and OTU signals is provided by [ITU-T G.709].

Table 7-1 – Set of ODU clients and their ODU servers

ODU Clients	ODU Server
1.25 Gbit/s bit rate area	ODU0
–	
2.5 Gbit/s bit rate area	ODU1
ODU0	
10 Gbit/s bit rate area	ODU2
ODU0, ODU1, ODUflex	
10.3125 Gbit/s bit rate area	ODU2e
–	
40 Gbit/s bit rate area	ODU3
ODU0, ODU1, ODU2, ODU2e, ODUflex	
100 Gbit/s bit rate area	ODU4
ODU0, ODU1, ODU2, ODU2e, ODU3, ODUflex,	
CBR clients from greater than 2.5 Gbit/s to 100 Gbit/s, or GFP-F mapped packet clients from 1.25 Gbit/s to 100 Gbit/s.	ODUflex
–	

Table 7-2 – ODU clients and their OTU server

ODU client	OTU server
ODU0	–
ODU1	OTU1
ODU2	OTU2
ODU2e	–
ODU3	OTU3
ODU4	OTU4
ODUflex	–

7.1 Optical channel data unit (ODU) layer network

This layer network provides the functionality for end-to-end networking of digital path signals for transparently conveying client information of varying formats as described in Table 7-1. The description of supported client layer networks is outside the scope of this Recommendation. The topological components of the ODU layer network are subnetworks and links. The links are supported by an OTU trail or a server ODU trail. Since the resources that support these topological components support a heterogeneous assembly of ODUs, the ODU layer is modelled as a single layer network that is independent of bit rate. The ODU bit rate is a parameter that allows the number of tributary slots (TS) for the ODU link connection to be determined. 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 the integrity of the ODU adapted information;

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

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.

Details are described in [ITU-T G.709].

The ODU layer network contains the following transport functions and transport entities (see Figure 7-3):

– 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).

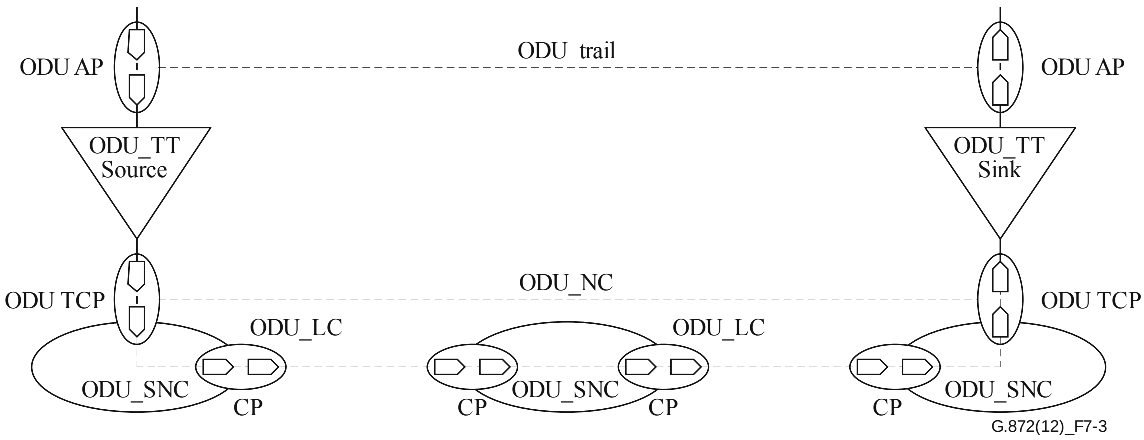

Figure 7-3 – ODU layer network example

7.1.1 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 requirements for these processes are outlined in detail in clause 10.

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.

7.1.2 ODU connection function

The ODU connection function may be used by the network operator to provide routing, grooming, protection and restoration.

NOTE – The ODU connection function may support ODUks with all values of k or only a subset.

7.1.3 ODU transport entities

Network connections, subnetwork connections, matrix connections, link connections, tandem connections and trails are as described in [ITU-T G.805].

7.1.4 ODU topological components

Layer networks, subnetworks, matrices, links, transitional links and access groups are as described in [ITU-T G.805] and [ITU-T G.800].

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.

NOTE – The ODU topological components may support ODUks with all values of k or only a subset.

7.1.5 ODU time division multiplexing

In order to allow the transport of several lower bit rate ODUj signals over a higher bit rate ODUk signal, while maintaining the end-to-end trail for these lower bit rate signals, time division multiplexing (TDM) of ODUs is defined.

Note that the ODUj may be an ODUflex. The tributary slots of the ODUk server may be allocated to any combination of ODUj clients up to the capacity of the ODUk. For the currently defined ODUks the tributary slots according to Table 7-3 are defined.

Table 7-3 – Number of tributary slots (TS) for each ODUk

Nominal TS capacity	1.25 Gbit/s	2.5 Gbit/s
ODU1	2	–
ODU2	8	4
ODU3	32	16
ODU4	80	–

7.1.6 Multi-domain OTN

Domain A may have an OTN network comprised of client ODUi and server ODUj, i < j. The server ODUj may be carried over the network of domain B, interconnected by OTUj. Domain B may carry the ODUj as a client ODU over a server ODUk, j < k. Each of domains A and B sees two hierarchical ODU levels within their respective domains. The ODUj plays the role of a server ODU in domain A and the role of a client ODU in domain B.

A server ODUj of domain A can also be carried as a client ODUj in domain B directly over OTUj in domain B using TCM to manage the segments of the ODUj path in each domain.

Some examples of multi-domain applications are given in Appendix I.

7.1.7 Inverse multiplexing in the OTN

Inverse multiplexing in the OTN is implemented by means of virtual concatenation of X (X ≥ 2) ODU signals (ODU-Xv). The ODU-Xv signal can transport a client signal (e.g., an ODU2-4v may transport an STM-256). The characteristic information of a virtually 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 connection monitoring techniques are applied per data stream on the ODU characteristic information.

In virtually 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 virtually concatenated group of lower rate ODU signals is possible, but results in a non-optimal solution.

Figure 7-4 shows the functional architecture for an ODU-Xv.

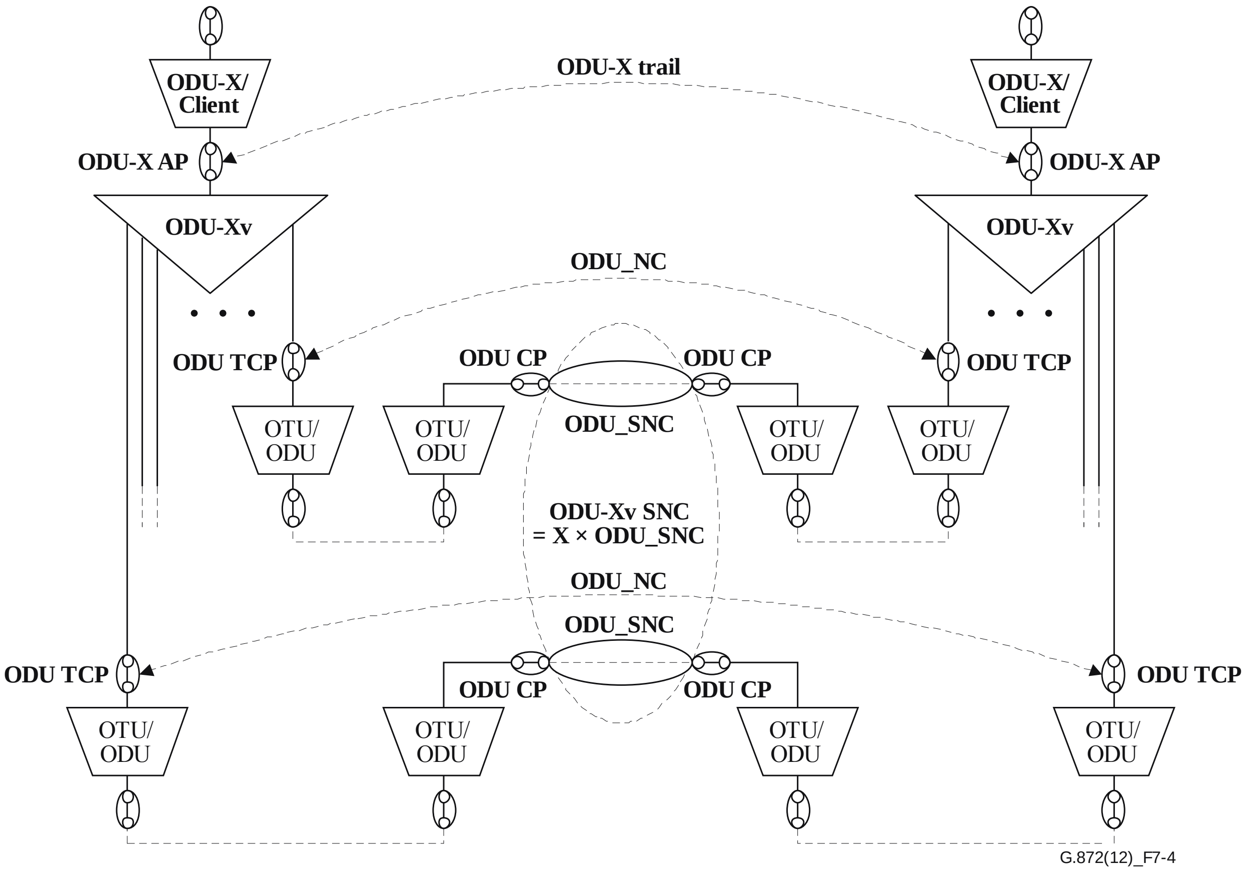

Figure 7-4 – Functional architecture for virtual concatenation of ODUs

The compound function ODU-Xv indicated in Figure 7-4 is further composed from basic atomic functions as shown in Figure 7-5.

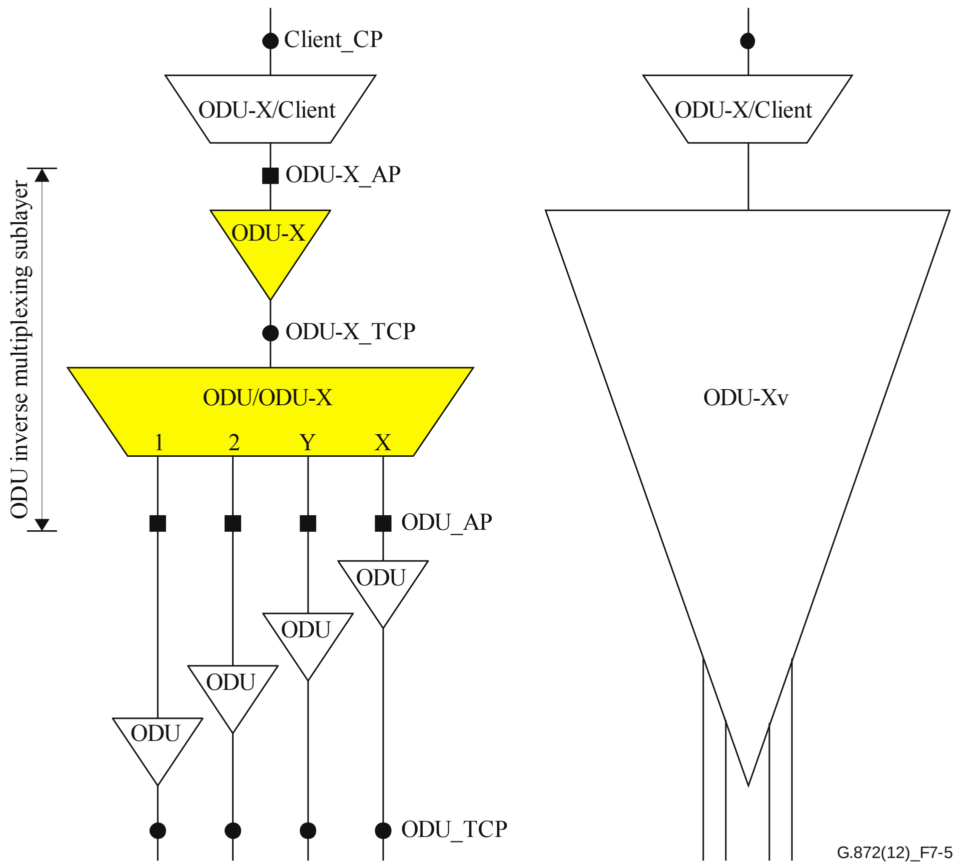

Figure 7-5 – Virtual concatenation model

7.2 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. The capabilities of this layer network include:

– OTU overhead processes for ensuring the integrity of the OTU adapted information and conditioning for its transport over an OCh;
– OTU operations, administration and maintenance functions for enabling section level operations and management functions.

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.

Details are described in [ITU-T G.798].

The OTU layer network contains the following transport functions and transport entities (see Figure 7-6):

– 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).

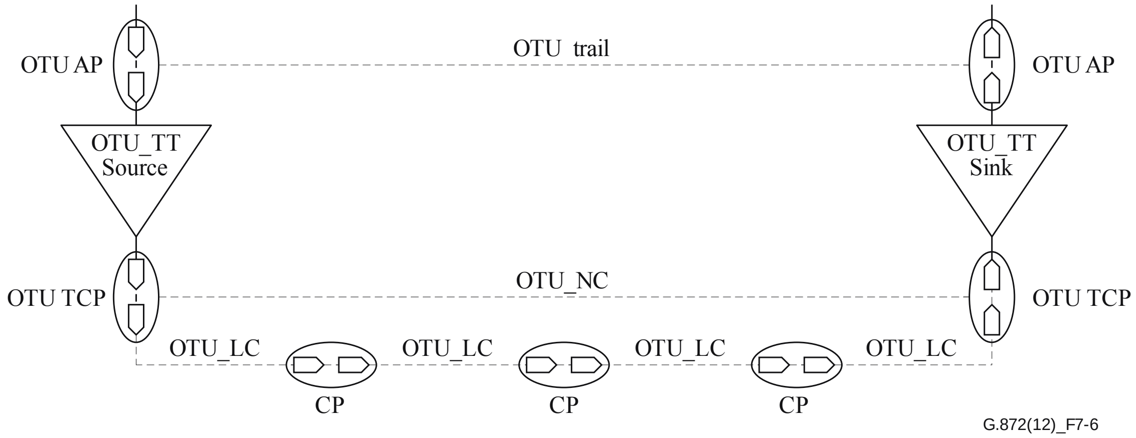

Figure 7-6 – OTU layer network example

7.2.1 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 clause 10.

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.

7.2.2 OTU transport entities

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

7.2.3 OTU topological components

Layer networks, links and access groups are as described in [ITU-T G.805]. When an OTU is carried by an OCh there is a 1:1 correspondence between the OTU and OCh layer networks and access groups.

7.3 Client/server associations

A principal feature of the OTN is the possibility of supporting a wide variety of circuit and packet client layer networks. See [ITU-T G.709].

The structure of the OTN digital layer networks and the adaptation functions are shown in Figures 7-1 and 7-2. For the purposes of description, the interlayer adaptation is named using the server/client relationship.

7.3.1 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 clause 10.

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 clause 10.

A detailed description is provided in [ITU-T G.798].

7.3.2 ODUk/ODUj adaptation

The bidirectional ODUk/ODUj adaptation (ODUk/ODUj_A) function is performed by a collocated pair of source and sink ODUk/ODUj adaptation functions.

The ODUk/ODUj adaptation source (ODUk/ODUj_A_So) performs the following processes between its input and its output:

– ODUj multiplexing to form a higher bit rate ODUk;
– generation and termination of management/maintenance signals as described in clause 10.

The ODUk/ODUj adaptation sink (ODUk/ODUj_A_Sk) performs the following processes between its input and its output:

– ODUj demultiplexing;
– generation and termination of management/maintenance signals as described in clause 10.

A detailed description is provided in [ITU-T G.798].

7.3.3 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.

A detailed description is provided in [ITU-T G.798].

8 OTN optical entities

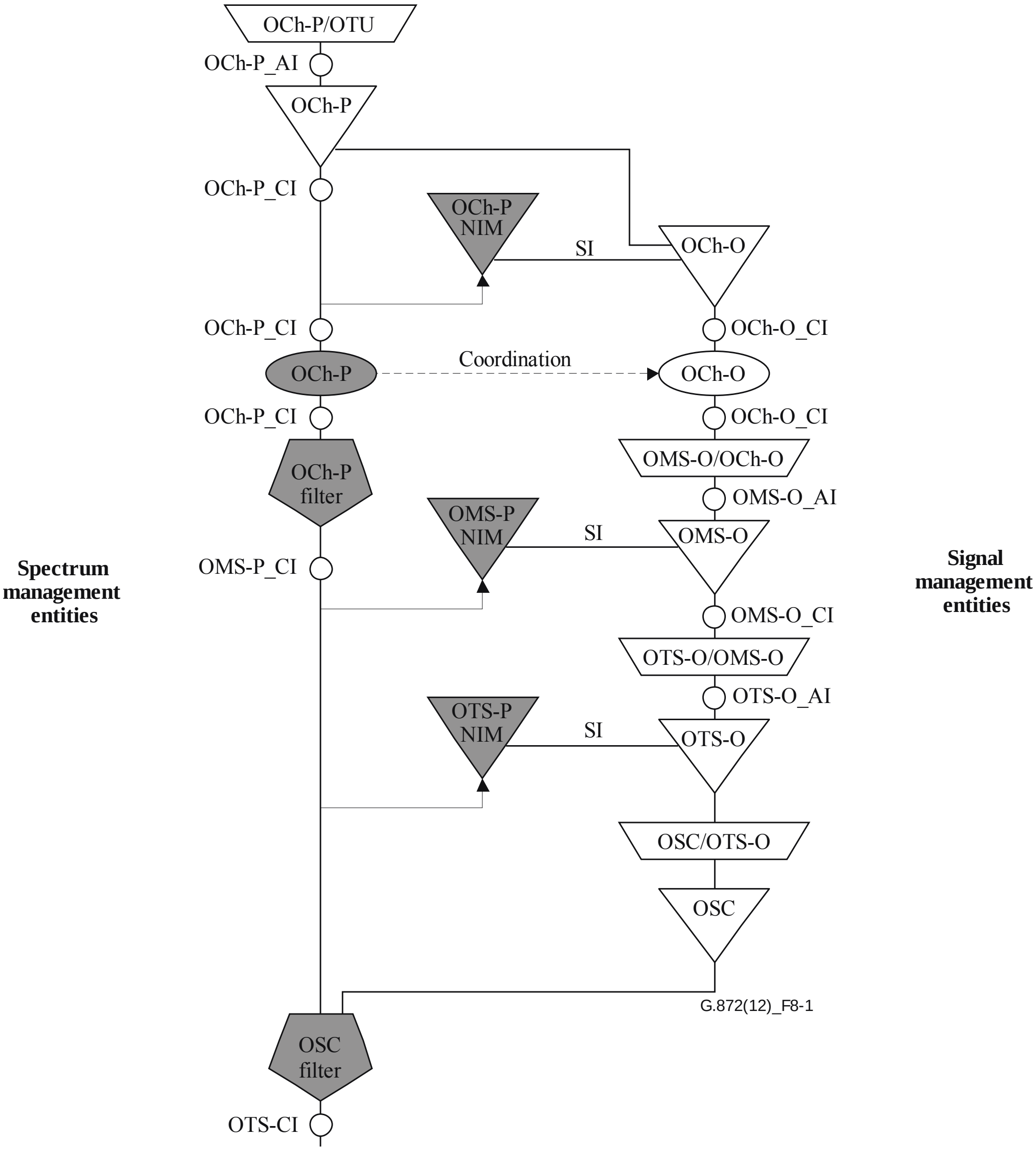

Figure 8-1 – OTN media layer overview

As noted in clause 6, the entities associated with the OTN media layer are distinguished according to whether they provide management of the collections of OCh-P signals traversing the media or whether they provide for configuration of the media channels. The former handle the management of signals via the non-associated overheads and overhead structure defined in [ITU-T G.709]. The latter provide the configuration of the media elements.

Accordingly, the functions for non-associated overhead processing are identified by the -O suffix, and the set of media elements operating on the OCh-P(called the payload) are identified by the -P suffix. The payload processing functions use the processes defined in [ITU-T G.798] and the frame formats of [ITU-T G.709]. The non-associated overhead processing functions use the processes defined in [ITU-T G.798].

Figure 8-1 above provides an overview of the elements of the media layer of the OTN. The only client of the OCh (the OTU) is presented to the OCh-P/OTU adaptation function. The OCh-P termination function sources (or sinks) the OCh-P, which has a specified central frequency, spectral excursion and other parameters. The OCh-P network connection is supported by a network media channel. The optical multiplex section (OMS) and optical transport section (OTS) are described in clauses 8.2 and 8.3 respectively.

The concatenation of all media elements between an OCh-P source and an OCh-P sink is called a network media channel.

The spectrum may be allocated and switched in larger portions than that of a network media channel and therefore may support more than one OCh-P signal.

The OCh layer network provides for the transport of OCh-P that transparently convey OTU information between 3R points of the OTN. In order to do so, the following capabilities are included in the layer network:

– OCh-P signal transport;
– OCh-O overhead processes that monitor the integrity of the OCh AI information; note that these processes may include information obtained directly from the OCh-P termination function (i.e., OCh-P management information);
– OCh (both OCH-P and OCh-O) operations, administration and maintenance functions for enabling network level operations and management functions, such as connection provisioning, quality of service parameter exchange and network survivability;
– OCh-P non-intrusive monitor (OCh-P NIM), monitoring the optical properties of the OCh-P signal.

The OCh-P network connection is supported by a network media channel, which provides for flexible network routing.

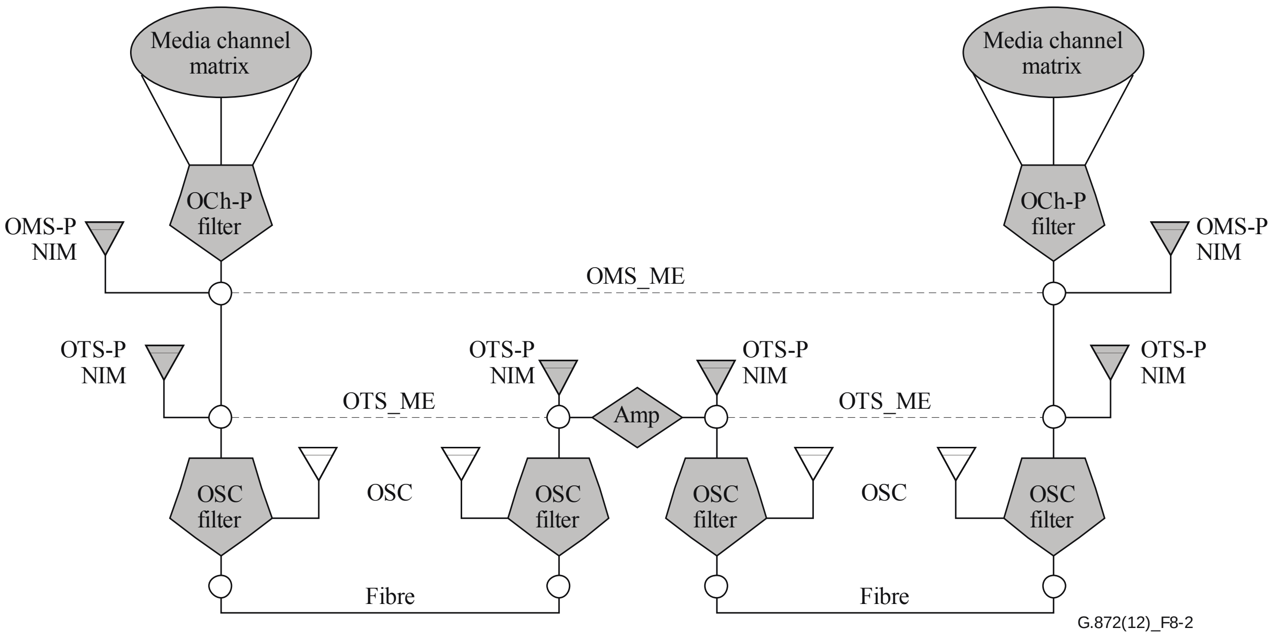

Figure 8-2 – OMS and OTS maintenance entities

Figure 8-2 above shows the location of the OMS and OTS maintenance entities.

The OMS maintenance entity (OMS_ME) monitors all of the OCh-P signals on a fibre between two points of frequency slot flexibility. The OTS maintenance entity (OTS_ME) monitors all of the

OCh-P signals on a fibre between two points of management visibility. These points are usually associated with intermediate amplifier[5] sites.

The optical supervisory channel (OSC) is a signal inserted on the OTS_ME. It is used to carry the non-associated overhead of the OCh_ME, OMS_ME and OTS_ME. An OTN compliant network implementation must support the OSC at its intra-domain interfaces. If the OSC is not supported, then the OMS_ME and OTS_ME are not supported. The OCh-P_NC (see clause 8.1) can exist in the absence of the OMS_ME and OTS_ME, however, some of the alarm management, fault detection and fault isolation capabilities for the OCh trail described in clause 10 will not be supported. The OSC is not supported at the IrDI interface since the media channel between the OCh-P source and sink has no intermediate network elements, the full maintenance capabilities are provided by the OTU layer network.

Optical multiplex section maintenance entity (OMS_ME): This maintenance entity provides:

– bulk monitoring of the OMS-P signal by means of the OMS-P non-intrusive monitor (OMS-P NIM) (see clause 8.2);
– OMS overhead processes for ensuring the integrity of the OMS-P, by means of the OMS-O functions;
– OMS operations, administration 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 the operation and management of optical networks.

Optical transmission section maintenance entity (OTS_ME): This maintenance entity provides:

– bulk monitoring of the OTS-P signal (see clause 8.3) by means of the OTS-P non-intrusive monitor (OTS-P NIM);
– OTS overhead processing for ensuring the integrity of the OTS-P by means of the OTS-O functions;
– OTS operations, administration and maintenance functions for enabling section level operations and management functions.

The media layer network supports network media channels between OCh-P terminations as described in clause 6. A network media channel is constructed from any combination of network elements and fibres as described in clause 8.4.3.

The functional descriptions of the optical layer networks are given in the following clauses. The detailed description of this layer is outside the scope of this Recommendation.

8.1 Optical channel (OCh) layer network

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

– an optical signal defined by a set of parameters. The central frequency, required bandwidth and other analogue parameters such as signal-to-noise ratio associated with the network media channel are of particular interest. The parameters are captured in an application

[5] For distributed optical amplifiers, the location of the amplifier is considered to be the location where the pump wavelength is inserted.

identifier[6], which covers both standardized as well as proprietary applications. Layer processors [ITU-T G.800] in the path may modify these parameters as required.

– A data stream that constitutes non-associated (out-of-band) overhead. This data stream has its own set of functions that process the non-associated overhead independent of the layer processors which affect the OCh-P.

The OCh layer contains the following transport functions and transport entities (see Figure 8-3):

– OCh trail
– OCh-P trail termination source (OCh-P_TT_Source)
– OCh-P trail termination sink (OCh-P_TT_Sink)
– OCh-P network connection (OCh-P_NC).

The OCh layer also contains the following functions associated with the OCh maintenance entity:

– OCh-O trail
– OCh-O trail termination source (OCh-O_TT_Source)
– OCh-O trail termination sink (OCh-O_TT_Sink)
– OCh-O network connection (OCh-O_NC)
– OCh-P non-intrusive monitor (OCh-P NIM).

See clause 8.4 for details of the relationship between the OCh-O matrix and the corresponding media channel matrix.

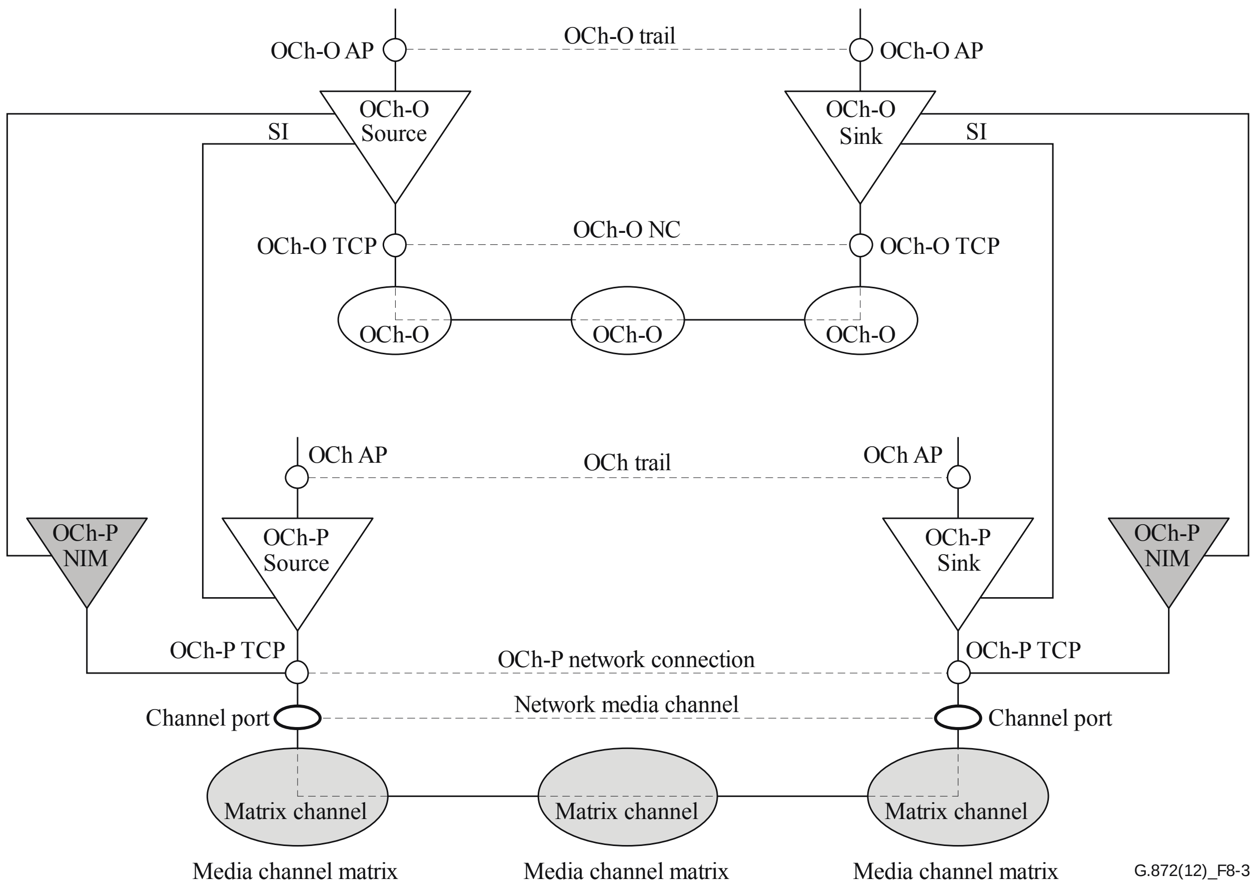

Figure 8-3 – OCh network example

6 Note that an application identifier applies to the transmitter, the network media channel and receiver combination. It does not apply to a single interface.

The signal is emitted or terminated by an OCh-P trail termination. The stream may be modified by a layer processor function, which may be remote from the OCh-P_TT. This allows describing both frequency-specific and frequency-agnostic regions of the OCh layer network.

The central frequency parameter can be used to construct a wavelength-specific routing topology.

The OCh-P characteristic information is formally described as;

CI(oc) = AI+{ <Central Frequency>,<Set of Application Identifiers>}

Note that the client AI determines the client bit rate, and while this may be described by a parameter, that parameter is a part of the client AI and is not an OCh layer parameter.

Table 8-1 – OCh-P CI parameters

Application identifier	The application identifier parameter contains the set of application identifiers supported by the function. (Note)
Central frequency	The central frequency of the emitted signal. This is the nominal mid-point of the optical frequency range over which the digital information of the particular OCh-P is modulated. The OCh-P spectrum after the modulation process is out of the scope of this Recommendation.
NOTE – An application identifier includes the application codes defined in the appropriate optical system Recommendations, as well as the possibility of proprietary identifiers. The identifier covers all aspects of the signal, including forward error correction, baud rate and modulation type.	

8.1.1 OCh trail termination

The following generic processes take place at the OCh trail termination:

– transmission defect detection and indication.

The requirement for these processes is outlined in detail in clause 10.2.

There are three types of OCh trail termination:

– OCh bidirectional trail termination: consists of a pair of collocated OCh trail termination source and sink functions.
– OCh trail termination source: accepts adapted information from the OTU layer network at its input, inserts the OCh trail termination overhead as a separate and distinct logical data stream, modulates AI onto the optical signal and sets its central frequency and presents the characteristic information of the optical channel layer network at its output.
– OCh trail termination sink: accepts the characteristic information of the OCh layer network at its input, demodulates the optical signal[7] and presents the adapted information at its output, processes the separate and distinct logical data stream containing the OCh trail termination overhead[8].

The processes of the OCh trail termination are supported by the following functions:

– OCh-P_TT, handling the OCh-P signal
– OCh-P NIM, monitoring the optical properties of the OCh-P signal
– OCh-O handling the non-associated overhead of the OCh trail.

[7] Note that this process may rely on information extracted by the OCh/OTU adaptation function.

[8] Note that the optical signal may be demodulated if the OAM data stream is absent, however the OAM processing described in clause 10 will not be available.

8.2 Optical multiplex section (OMS)

The characteristic information in an optical multiplex OMS is composed of two separate and distinct logical signals:

– OMS-P signal that consists of a set of n OCh-P signals which, taken as a set, have a defined aggregate optical bandwidth;

– a data stream that constitutes the non-associated OMS overhead (OMS-O). This data stream is processed by OMS-O components. (OMS-O_TT, OMS-O/OCh-O adaptation functions).

The OMS media channel represents the media association between OMS-P end points and is a concatenation of one or more fibres and zero or more amplifiers.

The OMS-P non-intrusive monitor (NIM) monitors the bulk properties of the OMS-P signal at the ingress and egress of the OMS maintenance entity (OMS_ME) and provides information that is carried by the non-associated OMS-O.

The OMS-P signal is assembled by a combination of filter components (see clause 8.4). The filter components and the OMS-P NIM are logically related; however, they may not necessarily be physically co-collocated[9] with the OMS-P NIM (which monitors the signal) or the OMS-O (which operates on the overhead). That is, the OMS NIM and the aggregation or disaggregation of the OCh-P signals may take place in different locations. This means that the span of an OMS media channel may be greater than or equal to the span of the OMS_ME, however, the OMS media channel is not monitored over its full span.

The OMS is the association between the end points of the OMS_ME.

An OCh within an OMS may be either allocated (in-service) or may be unallocated (out-of-service). The OCh-P signal of an in-service OCh may be present or not.

The OMS is supported by the following functions (see Figure 8-4):

– OMS-O source (OMS_ME_Source) handling the non-associated overhead of the OMS_ME;

– OMS-O sink (OMS_ME_Sink) handling the non-associated overhead of the OMS_ME;

– OMS-P NIM, monitoring the optical properties of the OMS-P signal.

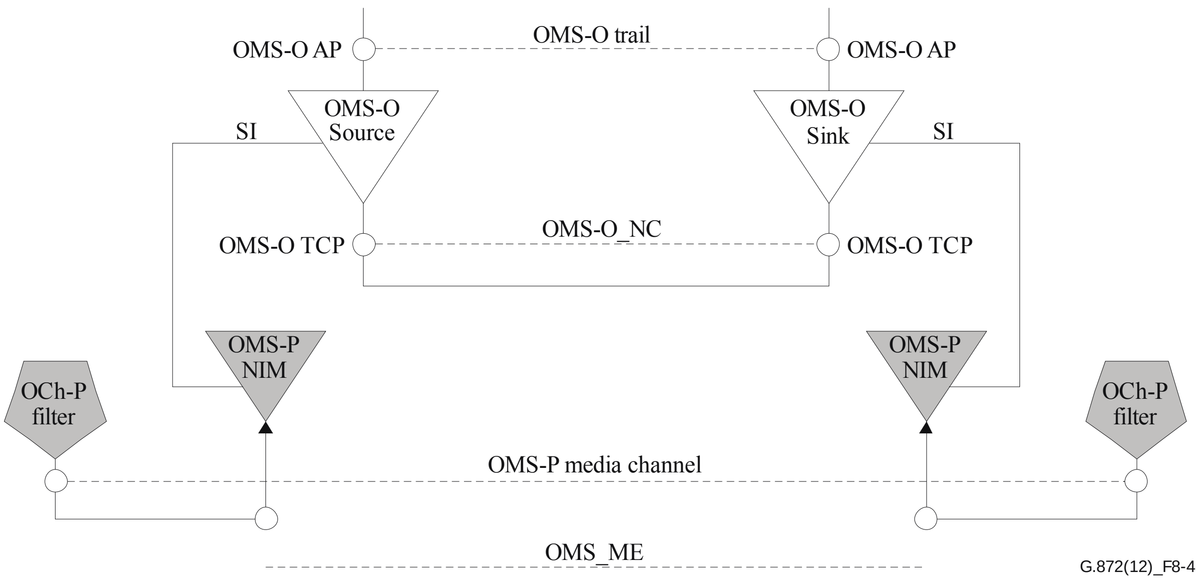

Figure 8-4 – OMS example

[9] Collocated components are on the same network element.

8.2.1 OMS-O overhead termination

The following generic processes are 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 clause 10.2[10].

There are three types of optical multiplex section trail termination:

– OMS-O bidirectional termination: consists of a pair of collocated optical multiplex section termination source and sink functions;

– OMS-O_TT source: accepts the input from the OMS NIM and generates the OMS overhead. That overhead may be carried by out of band means to an OMS-O_TT sink;

– OMS-O_TT sink: processes the OMS overhead and the input from the OMS NIM and generates any OMS management information.

Note that the bulk property monitoring takes place in the co-collocated OMS-P non-intrusive monitor (NIM in the figures).

8.2.2 OMS-O transport entities

The only entity is the OMS-O trail.

8.3 Optical transmission section (OTS)

The OTS is a single unidirectional fibre between points of management visibility. In general, this is the fibre between two network elements, e.g., between amplifiers or between an amplifier and the point where the OMS-P signal is aggregated or disaggregated. The characteristic information of the OTS is composed of two separate and distinct logical signals:

– a data stream that contains an OTS-P signal, which has a defined aggregate optical bandwidth. The OTS-P signal is identical to the OMS-P signal that is being carried[11];

– a data stream that constitutes the OTS management/maintenance overhead (OTS-O). This data stream is processed by OTS-O components. (OTS-O_TT, OTS/OMS-O adaptation functions).

The OTS media channel represents the media association between OTS-P end points.

The OTS-P non-intrusive monitor (NIM) monitors the bulk properties of the OTS-P signal at the ingress and egress of the OTS maintenance entity (OTS_ME) and provides the information that is carried by the non-associated OTS-O. Note that, as described above for the OMS, the span of the OTS media channel may be greater than or equal to the span of the OTS_ME.

The OTS is the association between the end points of the OTS_ME.

Physically the OTS consists of the following signals.

– an OTS-P signal;

– an optical supervisory channel (OSC) signal to carry an OTS, OMS and OCh non-associated overhead. The OSC is terminated at the end of each fibre. The OTS overhead is processed and any OMS overhead is forwarded to the end of the OMS. The OSC is added to the OMS-P signal by an OSC filter component.

This set of signals is called an optical transport module of order n (OTMn).

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[10] Note that these functions are absent if the OAM functions described in clause 10 are not supported.

[11] In this Recommendation, signal power is not considered as a part of the definition of the signal.

The OTS is supported by the following functions (see Figure 8-5):

– OTS-O source (OTS_ME_Source) handling the non-associated overhead of the OTS_ME
– OTS-O sink (OTS_ME_Sink) handling the non-associated overhead of the OTS_ME
– OTS-P NIM monitoring the optical properties of the OTS-P signal.

Additional functions to support a non-associated overhead carried over the OSC are:

– OSC/OTS-O adaptation function
– OSC termination function
– OSC filter.

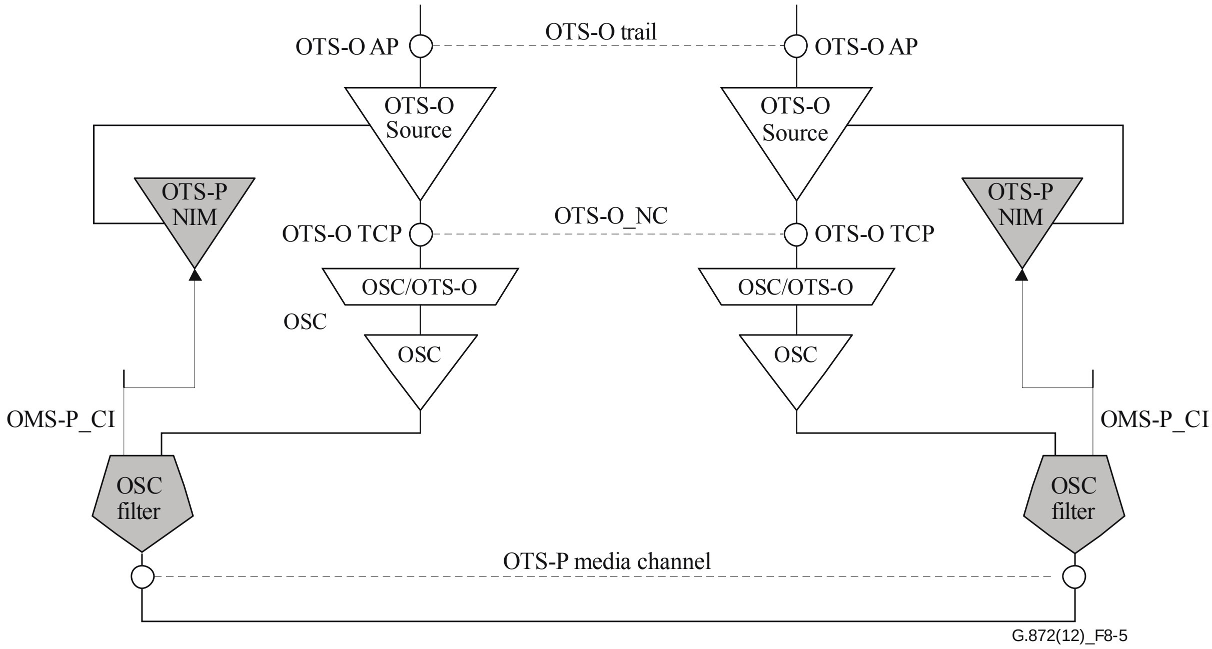

Figure 8-5 – OTS example

8.3.1 OTS-O overhead termination

The following generic processes may be assigned to the OTS-O overhead termination (OTS-O_TT):

– validation of connectivity; note that the OTS-O_TT must arrange for squelching[12] all components of the OTS-P signal in the event of a validation mismatch;
– assessment of transmission quality;
– transmission defect detection and indication.

The means of providing these processes is described in clause 10.2[13].

There are three types of optical transmission section trail termination:

– OTS-O bidirectional trail termination: consists of a pair of collocated optical transmission section trail termination source and sink functions;
– OTS-O source: accept input from the OTS-P NIM and generates the OTS trail termination overhead;

[12] Note that this requirement can be met by a blocking switch at different locations. It is an equipment design matter to place the switch.

[13] Note that these functions are absent if the OAM functions described in clause 10 are not supported.

– OTS-O sink: accepts input from the OTS-P NIM, processes the OTS overhead contained within the optical supervisory channel and generates any OTS management information.

Note that bulk property monitoring takes place in the co-collocated OTS-P NIM.

8.3.2 OTS transport entities

None.

8.4 Media entities

8.4.1 Filter component

The filter component models the ability to pass a defined portion of spectrum from one port to another port. The relationship between the ports on a filter is called a filter channel[14]. The filter channel is specified by the ports that bound it and its frequency slot. The frequency slot is described by its nominal central frequency and its slot width [ITU-T G.694.1]. Within this Recommendation a fixed grid device is described in terms of the frequency slot(s) it would have associated with it if it were a flexible grid device. The frequency slot(s) of some filter components (e.g., devices that support the flexible DWDM grid defined in [ITU-T G.694.1]) can be configured (via the management plane). The filter channel characteristics are made available to a management system. The filter component is represented by a layer processor symbol.

Note that the filter component may be used to represent a concatenation of one or more filter devices, in this case the physical port on one filter device is directly connected to a physical port on another filter device. If this representation is used, the inner detail of the filter devices is hidden within a single filter component.

The filter component is not necessarily an adjunct of the OMS-O functions. It is possible to have spectrum configuration (and hence filter components) without creating an OMS maintenance entity. Conversely, it is possible to source (or sink) an OMS_ME without having any corresponding components that perform spectrum configuration at that location.

In the architecture, filter components are named from their primary signal purpose. The currently named filters are the OCh-P filter (OCh-P_F) which aggregates and disaggregates OCh-P signals, and the OSC filter (OSC_F) which aggregates and disaggregates the OSC and OTS-P signals.

8.4.2 Media channels

The media channel is a topological construct that represents both the path through the media and the resource (frequency slot) that it occupies. A media channel is bounded by ports on media elements. A media channel can span any combination of network elements and fibres. A media channel may not be capable of supporting any OCh-P signal. The size of a media channel is specified by its effective frequency slot, which is described by its nominal central frequency and its slot width [ITU-T G.694.1]. The effective frequency slot width of a media channel is that part of the frequency slots of the filters along the media channel that is common to all of the filter frequency slots. A media channel may be dimensioned to carry more than one OCh-P signal. Also the effective slot width of a media channel may be administratively set to be less than the maximum slot width supported by the filter components on the media channel. A media channel may be configured before it has been decided which OCh-P signals it will be allocated to.

A part of the effective frequency slot of a configured media channel may be allocated to another narrower media channel that extends beyond the original media channel. This sequential allocation does not create a hierarchy of either the media channels or the OCh-P signals which may eventually be carried.

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[14] A filter channel is a specific type of media channel that only exists within a filter component and has a defined frequency slot.

The only component that enforces the frequency slot is the filter component (clause 8.4.1).

The end-to-end channel allocated to transport a single OCh-P signal is called a network media channel and supports a single OCh-P network connection. The effective slot width of the network media channel must be sufficient to accommodate the maximum spectral excursion of the OCh-P signal that it is intended to support. The nominal central frequency of the network media channel should be the same as the central frequency of the OCh-P that it supports. This allows the channel ports on the network media channel to be bound to the connection points on the OCh-P network connection.

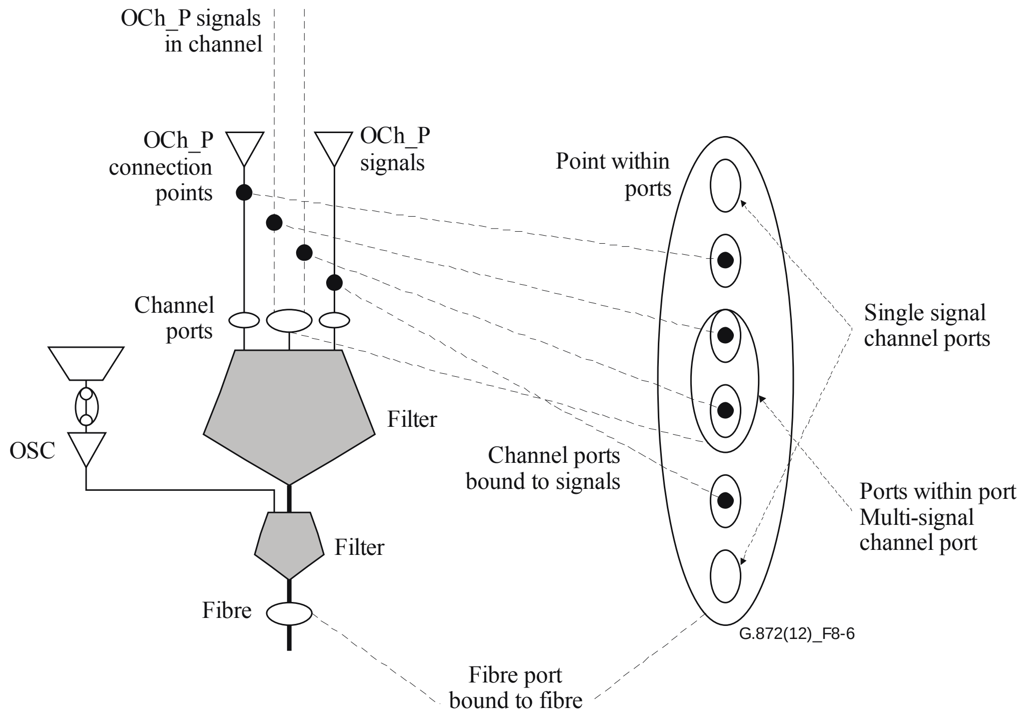


Figure 8-6 – Filter components, ports and points

Figure 8-6 shows the relationship between points on signals, ports on media elements and a management view of the entities within a fibre end. The ports represent channels allocated by a management system and configured by the filter component. The points represent reference points on OCh-P signals being carried over media channels. Note that the apparent containment relationship of the media channels is actually an allocation dependency. No hierarchy is created in either the media channels or the signals carried.

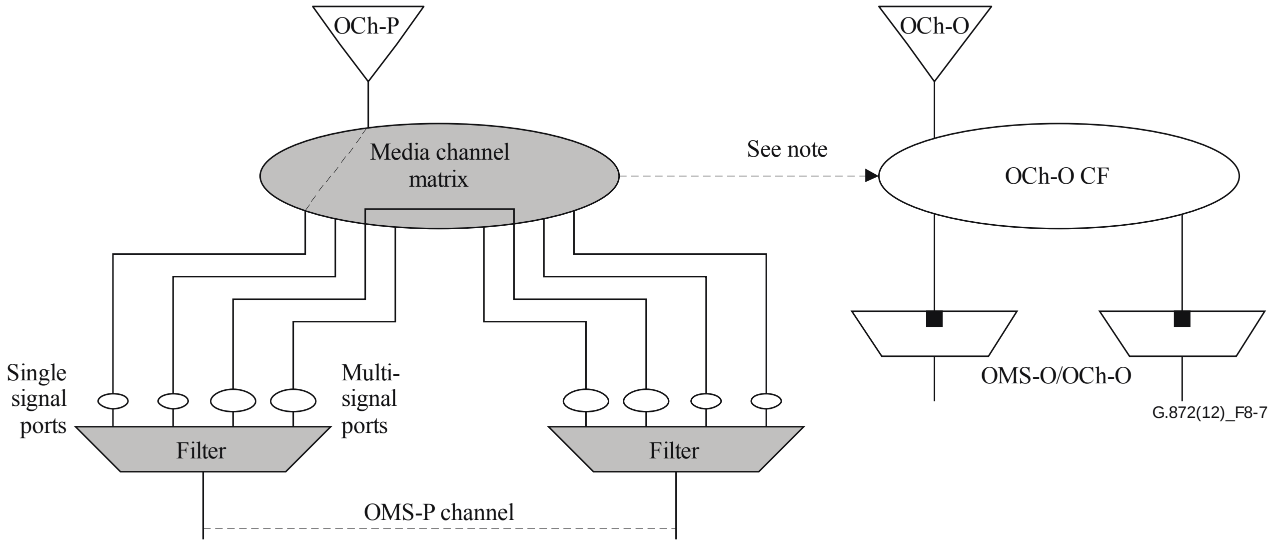
8.4.3 Media channel matrix

The media channel matrix provides flexible connectivity for the media channels. That is it represents a point of flexibility where relationships between the media ports at the edge of a media channel matrix may be created and broken. The relationship between these ports is called a matrix channel. Note that a network element may contain multiple media matrices and filters which together construct the observable behaviour of that network element.

As described in clause 8.4.2 the effective frequency slot of a media channel that is bound to a matrix port may support more than one OCh-P signal. Therefore the matrix channel may carry multiple OCh-P signals and this has significant implications for forwarding OAM information.

NOTE – While both the matrix and the filter support similar port relationships, neither model particular physical devices. The filter allows configuration of the frequency slot of the filter channel between fixed ports, while the matrix allows the port associations to be configured. A single type of physical device may realize the matrix, the filter function or both. The implementation is a design decision for the equipment designer.

The forwarding of OAM information carried on the non-associated overhead is modelled by the OCh-O matrix. Connection points on the OCh-O matrix correspond to those of the OCh-P signals passing through the media channel matrix, and the OAM information flow must follow that of the matrix channel configured in the media channel matrix.



NOTE – The OCh-O connection function must be configured so that the OCh-O connectivity corresponds to the connectivity of the OCh-P signal that is provided by the media channel matrix.

Figure 8-7 – Media channel matrix and OAM switch

8.5 Client/server associations

The structure of the OTN is shown in Figure 8-1.

8.5.1 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 signal. The actual processes required are dependent upon the particular implementation of the client/server. 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 actual processes are dependent upon the particular implementation of the client/server relationship. Forward error correction (FEC) is an optional feature[15].

[15] Some of these processes may rely on information extract from the modulated optical signal by the OCh trail termination sink function.

8.5.2 OMS-O/OCh-O adaptation

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

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

– generation of management/maintenance signals as described in clause 10.2.

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

– termination of management/maintenance signals as described in clause 10.2.

Both adaptation functions process that part of the supervisory channel information that is not processed by the OTS-O_TT.

8.5.3 OTS-O/OMS-O adaptation

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

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

– generation of management/maintenance signals as described in clause 10.2.

This adaptation function processes that part of the supervisory channel information that is not processed by the OTS-O_TT. This is also the case for the sink adaptation function.

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

– termination of management/maintenance signals as described in clause 10.2.

8.5.4 OCh-P filter

The bidirectional OCh-P filter is comprised of a collocated pair of source and sink OCh-P filters.

The OCh-P filter source (OCh-P_F_So) models:

– optical channel aggregation to form an optical multiplex.

The OCh-P filter sink (OCh-P_F_Sk) performs the following processes between its input and its output:

– optical channel disaggregation[16] according to the central frequency.

The OCh-P_F_So and OCh-P_F_Sk are each implemented by one or more filter components. These filter components are not necessarily co-collocated.

8.5.5 OSC filter

The bidirectional OSC filter (OSC_F) function is performed by a collocated pair of source and sink OSC filters.

The OSC filter source (OSC_F_So) performs:

– aggregation of the OSC and the OTS-P.

The OSC filter sink (OSC_F_Sk) performs:

– disaggregation of the OSC and the OTS-P.

[16] Note that this function may also be provided by a coherent receiver.

9 OTN topology

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

Topological component classes comprise access groups, links, transitional links, subnetworks and matrices. All component instances are further qualified by parameters. Media channels of all kinds and optical channel sources and sinks are principally characterized by their frequency slot. ODU's are qualified by their order (k...). The operation of the digital layers is not special and requires no further description in this Recommendation.

The topology is first expressed in a graph, where matrices are represented by vertices and links by edges. The parameters that distinguish topological component instances are attached to the graph as edge semantics and regions of the graph having identical edges semantics are formed. Transitional links appear as edges between regions of different edge semantics, and represent a physical means of transforming between those regions.

The initial network topology of the media layer comprises all available resources. A topology instance is derived from the initial network topology by assigning specific parameters to each topological component. Any links that do not support the selected parameter values are removed from the initial topology graph. Any unreachable matrices are similarly removed. The resulting topology now shows available connectable resources.

For example, selecting a frequency slot and application identifier for a particular OCh-P removes all resources operating at different frequencies from the initial topology graph. The resulting topology now shows available connectable resources at the selected frequency slot. Determining whether a path in this reduced topology will actually support communication between a source and sink, is outside the scope of this Recommendation.

9.1 Unidirectional and bidirectional connections

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 OCh-P may be supported by one optical fibre for both directions (single fibre working), or each direction may be supported by different fibres (two fibre working). For single fibre working, the bi-directional OCh-P connection is realised by a pair of unidirectional media channels, using different frequency slots on the same fibre. For two fibre working, the bi-directional OCh-P connection is supported by two unidirectional media channels, one on each fibre that may use the same frequency slots.

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

9.2 Point-to-multipoint media channels

A unidirectional point-to-multipoint media channel broadcasts the traffic from the source to a number of sinks. This is illustrated in Figure 9-1 where a point-to-multipoint association is provided in the media channel by means of a media multipoint connection point. It is a reference point that binds a port to a set of media channels. It represents the root of a multipoint media channel. The multipoint connection is restricted to unidirectional broadcast multipoint media channels in media networks. This type of media channel can be used by the optical channel layer network.

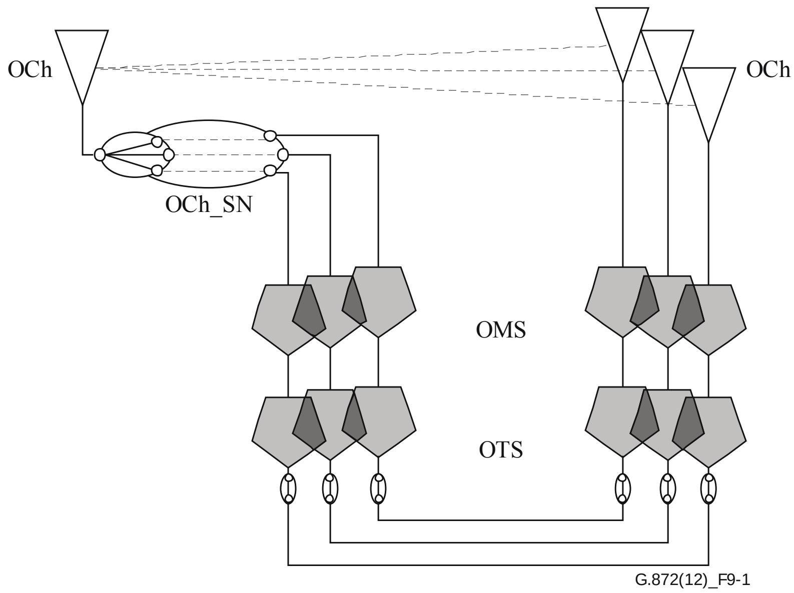


Figure 9-1 – Point-to-multipoint optical channel connection

10 OTN 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 OTN is composed of a set of digital layers (the clients of the optical channel layer) and an optical channel layer. The optical channel layer is supported by spectrum management entities (media channels) and by maintenance entities (OMS and OTS).

From the point of view of monitoring, the media channel is passive and does not contain active components. The digital client layers all contain active OAM which can report on the health of the layer and can be used to infer server health. In most of what follows, digital processes in the OTU overhead perform OCh monitoring. Because the OTU is 1:1 with the OCh, this provides an accurate assessment of the OCh property being monitored. The OMS and OTS entities provide maintenance for the media channels.

The management processes required in each entity are outlined in clause 10.2. This clause also describes techniques for connection supervision.

10.1 Generic requirements

10.1.1 Generic fault, configuration and performance management

The OTN 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 OTN shall provide facilities to:

– ensure the interconnection of transport network entities that have compatible adapted or characteristic information;

– detect faults, isolate faults and initiate recovery actions where applicable. The OTN 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 OTN shall be able to detect performance degradations to avoid failures and verify the quality of service.

10.1.2 Generic management communications

The OTN 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.

10.1.3 Generic client/server interaction management

The OTN shall detect and indicate when a signal is not present at a client layer.

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.

10.2 OTN network management requirements

Requirements for management capabilities with respect to the ODU, OTU, OCh, OMS and OTS are identified and detailed in this clause.

10.2.1 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 is indicated to a client layer through some form of server signal fail indication. The media channels monitored by the OTS maintenance entity are passive, so the OTS-O trail termination will not receive server fail indications. The OTS-O trail termination relies on the OTS-P NIM to detect failures in the optical physical media.

Optical network failures include both 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 perspective. Following a fibre disruption, loss of the aggregate signal may be observed at the first downstream OTS-P NIM, and will be reported by the associated OTS-O trail termination sink. The aggregate signal consists of the aggregated OTS-P and the OSC signal. Loss of the aggregate signal therefore results in loss of continuity of the OTS-P. Subsequently, the detection of the loss of the OTS-P signal will be indicated towards the client layer. Note that loss of continuity of the OSC 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.

In the OTS_ME an optical component failure may lead to the loss of OCh-P signals, however, this may not result in the loss of the optical supervisory channel. This will generate a server signal fail indication to the OMS_ME and a backward defect indication within the OTS_ME, with the same consequent actions as in the fibre disruption case.

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

A server signal fail detected by the OCh-O 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-P trail termination sink will detect a loss of continuity of the OCh-P trail without a loss of continuity being detected in the OTS-O or OMS-O trail. Consequent actions are the same as for the server signal fail case.

Note that failure conditions within the OTN and/or unused (unlit) OCh 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-O 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)

  TTI 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:

  – TTI is necessary in the OTS_ME to ensure proper cable connection.

  – TTI is not needed in the OMS_ME because there is a one-to-one relationship between the OTS_ME and the OMS_ME, i.e., media connectivity in the OMS_ME is fixed; therefore, the OMS-P channel is already covered by the OTS-O TTI. Flexible connectivity in the OMS-P channel is not envisaged. TTI at the OCh-P layer is not needed because there is a one-to-one relationship between the OCh-P trail and the OTU trail;

  – TTI is necessary at the OTU layer to ensure proper OCh connections.

  – TTI is necessary at the ODU layer to ensure proper ODU layer connections.

Detection of connectivity defects will lead to the same consequent actions as those 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 the downstream and upstream directions of a bidirectional trail.

Four maintenance information processes are identified:

- forward defect indication (FDI) and alarm indication signal (AIS)
- backward defect indication (BDI)
- backward error indication (BEI)
- open connection indication (OCI).

These processes enable defect localization and single-ended maintenance.

FDI/AIS are 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 BEI signal the state of the trail at the trail termination sink back to the remote trail termination sink. BDI and BEI support the real-time requirements of bidirectional performance monitoring.

FDI/AIS are applicable at the ODU, OTU, OCh and OMS.

BDI is applicable at the ODU, OTU, OMS and OTS.

BEI is applicable at the ODU and OTU layers.

OCI is applicable at the ODU layer.

10.2.2 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.

Signal quality supervision by means of BIP-8 is applicable at the ODU and OTU layers.

10.2.3 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 ODU/client adaptations. A payload type identifier mismatch detected at source or sink adaptations would indicate an incorrectly provisioned or altered client-ODU server layer ODU/client layer adaptation. The ODU/client layer adaptation may contain client-specific supervision processes. Definition of these processes is outside the scope of this Recommendation.

The PTI process is only applicable at the ODU layer.

10.2.4 Protection control

Protection control refers to the information and set of processes for providing the 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.

Protection processes are applicable at the ODU, OCh and OMS (as described in [ITU-T G.798] and the ITU-T G.873.x-series). Note that OMS protection refers to switching the OMS-P channel as a result of indications received by the OMS-O trail termination.

10.2.5 Subnetwork/tandem/unused connection supervision

Supervision for subnetwork, tandem and unused connections is required for the ODU layer. Connection supervision techniques and applications are listed in clauses 10.3 and 10.4.

10.2.6 Management communications

General management communications that are not associated to a particular OTN layer are transported via a data communications network as specified in [ITU-T G.7712].

10.3 Connection supervision techniques

Connection supervision is the process of monitoring the integrity of a given connection in the digital layers of the OTN. The integrity may be verified by means of detecting and reporting connectivity and transmission performance defects for a given connection. [ITU-T G.805] defines four types of monitoring techniques for connections:

- inherent monitoring
- non-intrusive monitoring
- intrusive monitoring
- sublayer monitoring.

Non-intrusive monitoring of the OCh-P connections is provided by means of monitoring the digital OTU information.

10.4 Connection supervision applications

10.4.1 Monitoring of unused connections

No mechanisms exist for monitoring an unused media channel, so any such information must come from administrative processes on the network element. In order to detect the inadvertent opening of a media channel matrix, the OMS-O overhead must include an indication of whether a slot is occupied or not (OMS multiplex structure identifier (MSI)). This allows a downstream network element to raise an alarm should a persistent unexpected change in slot allocation state occur.

The same situation occurs in the ODU layer necessitating an ODU overhead indication of whether an ODU tributary is occupied or not (ODU MSI). See [ITU-T G.798] for further details.

10.4.2 Connection monitoring

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

OCh-P connection monitoring can be applied at:

– the network connection, establishing the layer network's trail; this monitoring is performed by OCh-P and OTU;
– any subnetwork connection (by non-intrusive monitoring of the OCh-P/OTU).

ODU 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 (by means of the OTU), for fault and performance degradation detection for network maintenance purposes.

ODU 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 G.709]). The number of connection monitoring levels that can be used by each operator/user involved in an ODU connection must be mutually agreed between these operators and users.

11 OTN survivability techniques

Survivability techniques are described in the ITU-T G.873.x-series.

11.1 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.

Currently three types of protection architecture are supported: trail protection, subnetwork connection (SNC) protection and shared ring protection (SRP):

• OMS-P ME protection, see [ITU-T G.798]. Note that OMS_ME protection includes protection of both the OMS-P signal and the OMS-O overhead.

• OCh SNC protection, see [ITU-T G.798]. Note that the OCh trail includes both the OCh-P signal and the OCh-O overhead. Both of these signals must be protected across an OCh SNC.

• ODU SNC protection, see [ITU-T G.873.1].

• ODU SRP, see [ITU-T G.873.2].

11.2 Network restoration

Optical transport network restoration can restore OCh-P or ODU connections. In general, the algorithms used for restoration involve re-routing. Strategies for re-routing are not technology specific and therefore, are outside the scope of this Recommendation. See also [ITU-T G.8080].

12 Subdividing of the OTN

The OTN is subdivided into administrative domains, and may be subdivided into vendor domains, etc. A domain may be further subdivided into smaller portions.

12.1 Domains using the black link approach

The black link approach is described in [ITU-T G.698.1] and [ITU-T G.698.2]. The specification method used in these Recommendations uses a "black link" approach which means that optical interface parameters for only (single-channel) optical tributary signals are specified. Additional specifications are provided for the black link parameters such as residual chromatic dispersion, ripple and polarization mode dispersion. This approach enables transverse compatibility at the single-channel point using a direct wavelength-multiplexing configuration. However, it does not enable transverse compatibility at the multichannel points. The compatibility of the media path, transmitter and receiver is defined by a set of application codes.

The black link approach may be used to provide an OCh network connection between an OCh source/sink pair. The OCh network connection is supported by a network media channel that is terminated by an OCh-P source and an OCh-P sink where each of these components may be provided by different vendors but must all be within the domain of a single network operator. The black link approach is used to control optical impairments; it is not directly related to the subdivision of the OTN network.

The black link approach provides a media path, which is pre-certified for a particular OCh, and its only client is an intra-domain OCh. A black link is terminated by an OCh-P termination (which makes it the path that carries an OCh network connection) and has no internal structure visible from either termination. The terminations may be controlled from a different maintenance domain to that controlling the path through the network. See Figure 12-1.

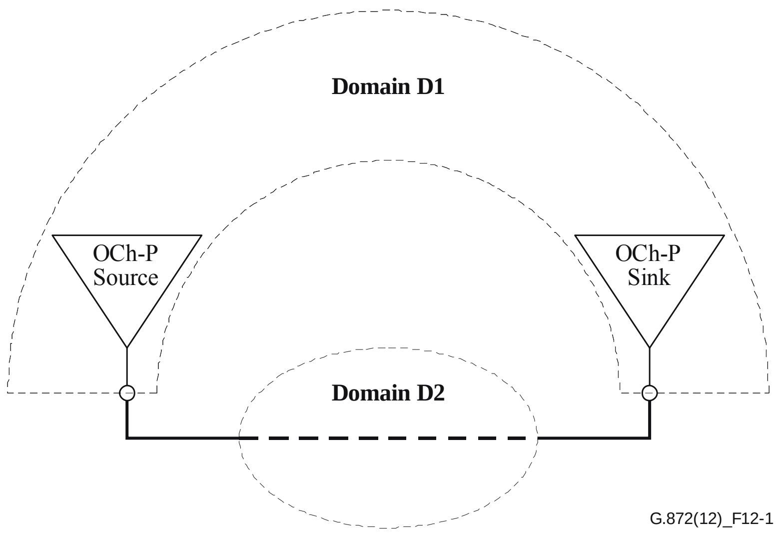


Figure 12-1 – Black link

The domains are considered to be OAM disjoint (i.e., their operations support systems) do not co-operate). OMS maintenance entity group end points at the edge of domain D2 can provide OAM for the network media channel provider but the connections between D1 and D2 are not covered. Also, note that domain D1 has no visibility into the network media channel structure and cannot construct new network media channels using the black link approach to control optical impairments. The interfaces between domains D1 and D2 are not OTN compliant. They are not specified in [ITU-T G.709], and the alarm management, fault detection and fault isolation capabilities for the OCh trail described in clause 10 are not supported.

See Appendix III for a network example of the black link approach.

Appendix I

Examples of multi-domain OTN applications

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

This appendix provides examples of multi-domain OTN applications.

Figure I.1 illustrates the case of interconnection of two disjoint domains (domain A) through another domain (domain B). Domain A has requested an ODUi service from domain B. This ODUi service from domain A's perspective is an HO ODUi, carrying multiple LO ODUk signals. This same ODUi service from domain B's perspective is an LO ODUi of which the end points are outside the domain of domain B. Within domain B's network the LO ODUi is carried over an HO ODUj.

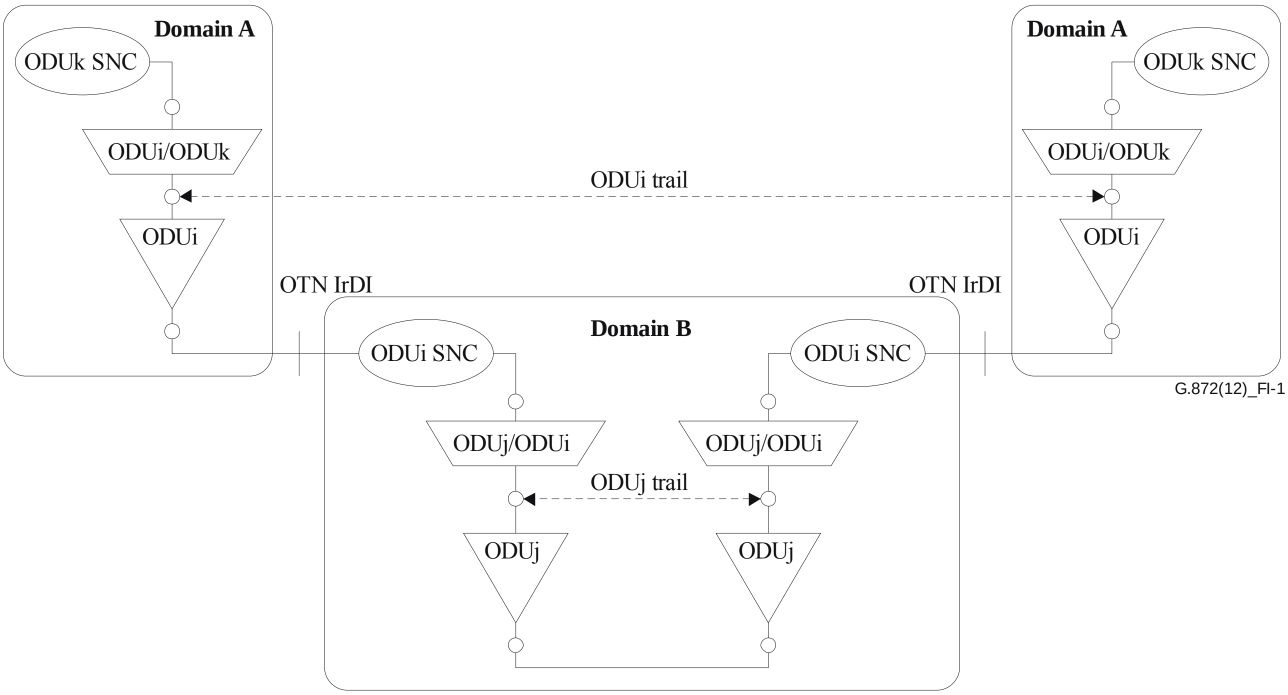


Figure I.1 – Multi-domain OTN scenario 1

Figure I.2 illustrates the above case with additional TCM function.

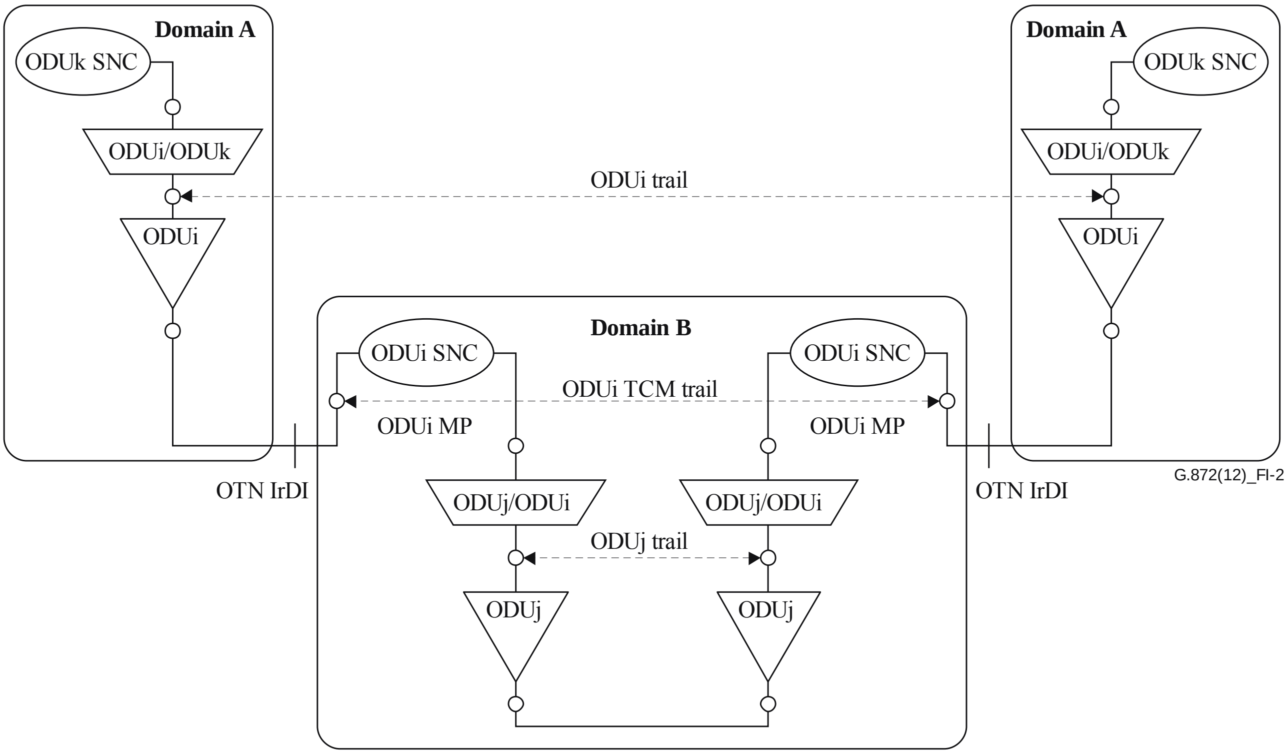


Figure I.2 – Multi-domain OTN scenario 2

Figure I.3 illustrates the case of server ODUi of domain A carried as a client ODUj in domain B directly over OTUj in domain B.

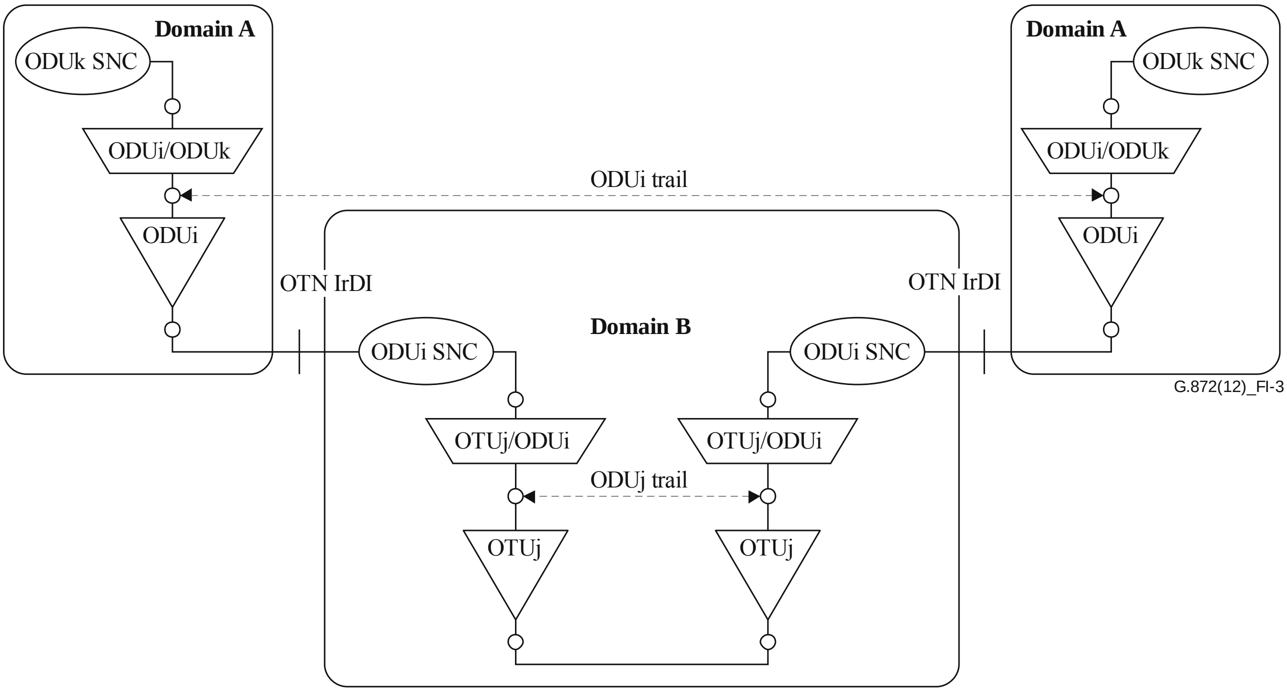


Figure I.3 – Multi-domain OTN scenario 3

Appendix II

Construction of optical channel connections

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

This appendix describes the order of construction of topology entities culminating in the establishment of a network media channel. This description focuses mainly on the spectrum configuration entities and does not discuss establishing all the necessary maintenance entities.

The initial topology is a set of media channel matrices interconnected by fibres. The available media channels are determined by the granularity of the filters around the matrix. In some cases, the granularity can be configured.

Media channel matrix connections are set up to establish a new topology of media channels interconnecting a subset of the matrices. Administratively, the spectrum capacity allocated to the new media channel is removed from the total fibre capacity. By further filter configuration, the media channel capacity can later be administratively allocated for smaller media channels.

The next step is to set up a network media channel across the previously constructed topology. When a media matrix channel request traverses a matrix in a previously established media matrix channel, no action is required to configure the matrix; however, the request should be verified against the existing media matrix channel. When the new channel request traverses an un-configured matrix, the media matrix channel must be set up. In both cases an OCh-O OAM forwarding relationship must be set up on the network element so that an OCh-O non-associated overhead can be correctly forwarded. While configuring OAM forwarding and switching the network media channel could occur at different times, it is most likely that a single configuration request will perform both OAM and media matrix operations at the same time.

Now that a network media channel exists across the network, an OCh-P signal can now be launched and any non-associated overhead will be forwarded to the OCh-O sink.

Note that this description refers to information needed to manage resource usage in the network. There is no implication as to where this information resides in the network.

Appendix III

An example of the use of the black link approach

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

The black link approach to the specification of the compatibility of transmitters, receivers and optical links is described in [ITU-T G.698.1] and [ITU-T G.698.2].

The "black link" approach provides single-channel optical interface specifications for DWDM optical signals. Additional specifications are provided for the black link parameters such as residual chromatic dispersion, ripple and polarization mode dispersion. This approach enables transverse compatibility at the single-channel point using a direct wavelength-multiplexing configuration. However, it does not enable transverse compatibility at the multichannel points. The use of the black link approach to define transverse compatibility requires that the transmitter (OCh-P_TT source), receiver (OCh-P_TT sink) and optical link (network media channel) are configured to support the same application code.[17]

An example of a unidirectional OCh-P network connection using the black link approach is illustrated in Figure III.1.

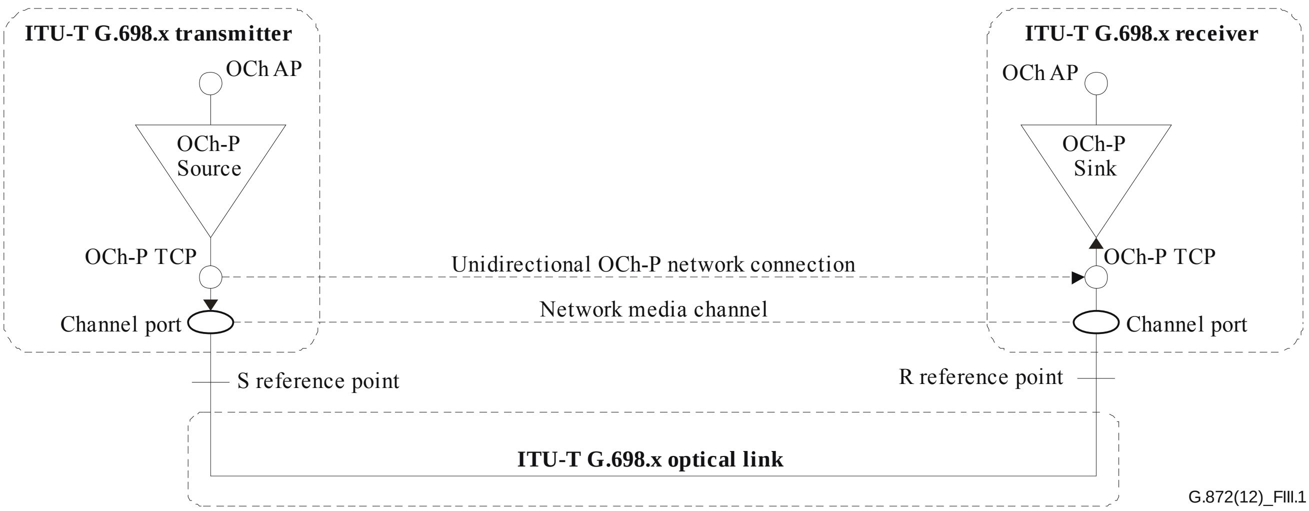


Figure III.1 – Unidirectional OCh network connection using the black link approach

It is possible to use an OCh-P NIM to monitor the OCh-P signal at the boundary of the optical link as illustrated in Figure III.2. If the OCh-P NIMs, the OMS_ME and OTS_ME are instantiated for the optical link, monitoring of performance degradations may be supported (see clause 10). The S and R reference points defined in [ITU-T G.698.1] and [ITU-T G.698.2] define the parameters of the OCh-P. No interface specification is provided for the OCh-O. The alarm management, fault detection and fault isolation capabilities for the OCh trail described in clause 10 are not supported, since, as illustrated in Figure III.2, the required information is not available.

[17] Application codes are defined in [ITU-T G.698.1] and [ITU-T G.698.2].

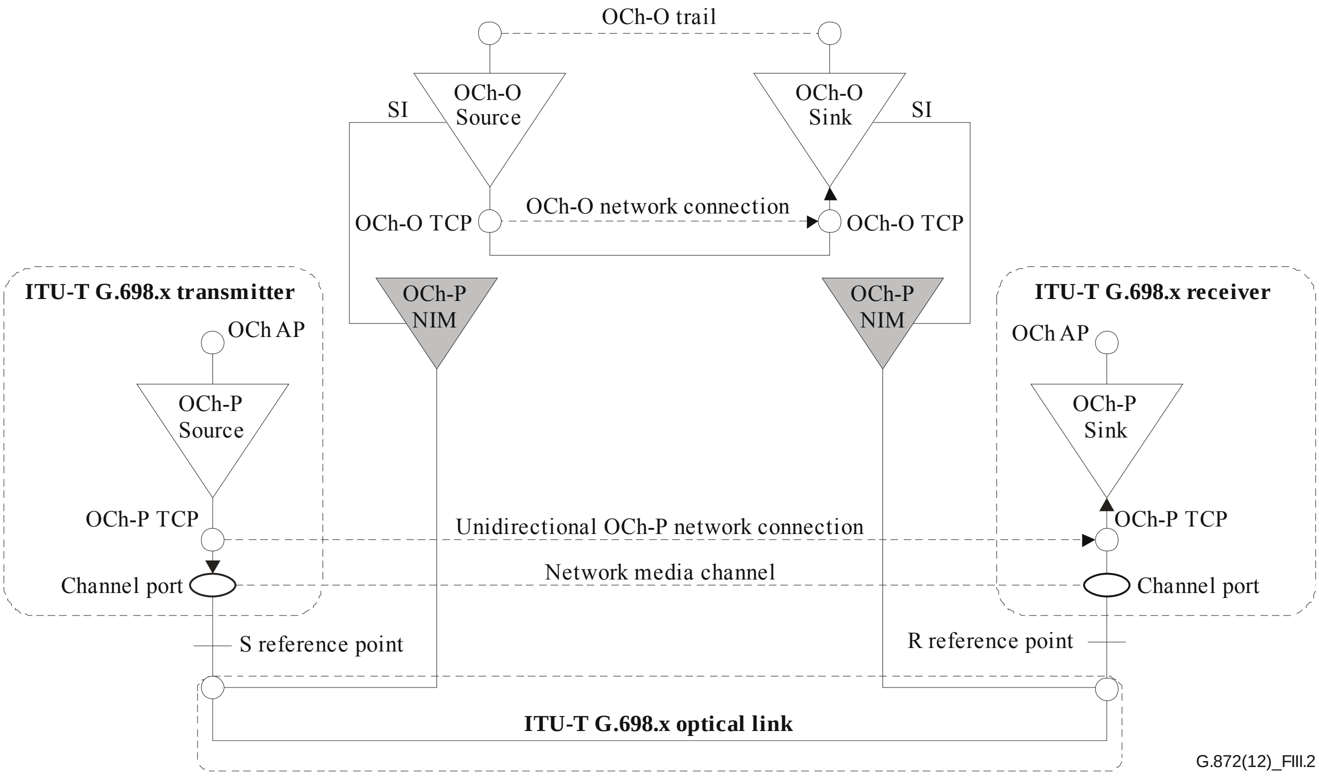


Figure III.2 – Unidirectional OCh network connection using the black link approach with a monitored optical link

Appendix IV

Relationship between Recommendations ITU-T G.872 and ITU-T G.798

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

This appendix describes the relationship between the model provided in this Recommendation and the existing functions and processes described in [ITU-T G.798]. Figure IV.1 illustrates that the additions to this Recommendation that support configurable media elements and the ability to manage the media at a granularity that is greater than a single OCh-P have no effect on processes defined in [ITU-T G.798].

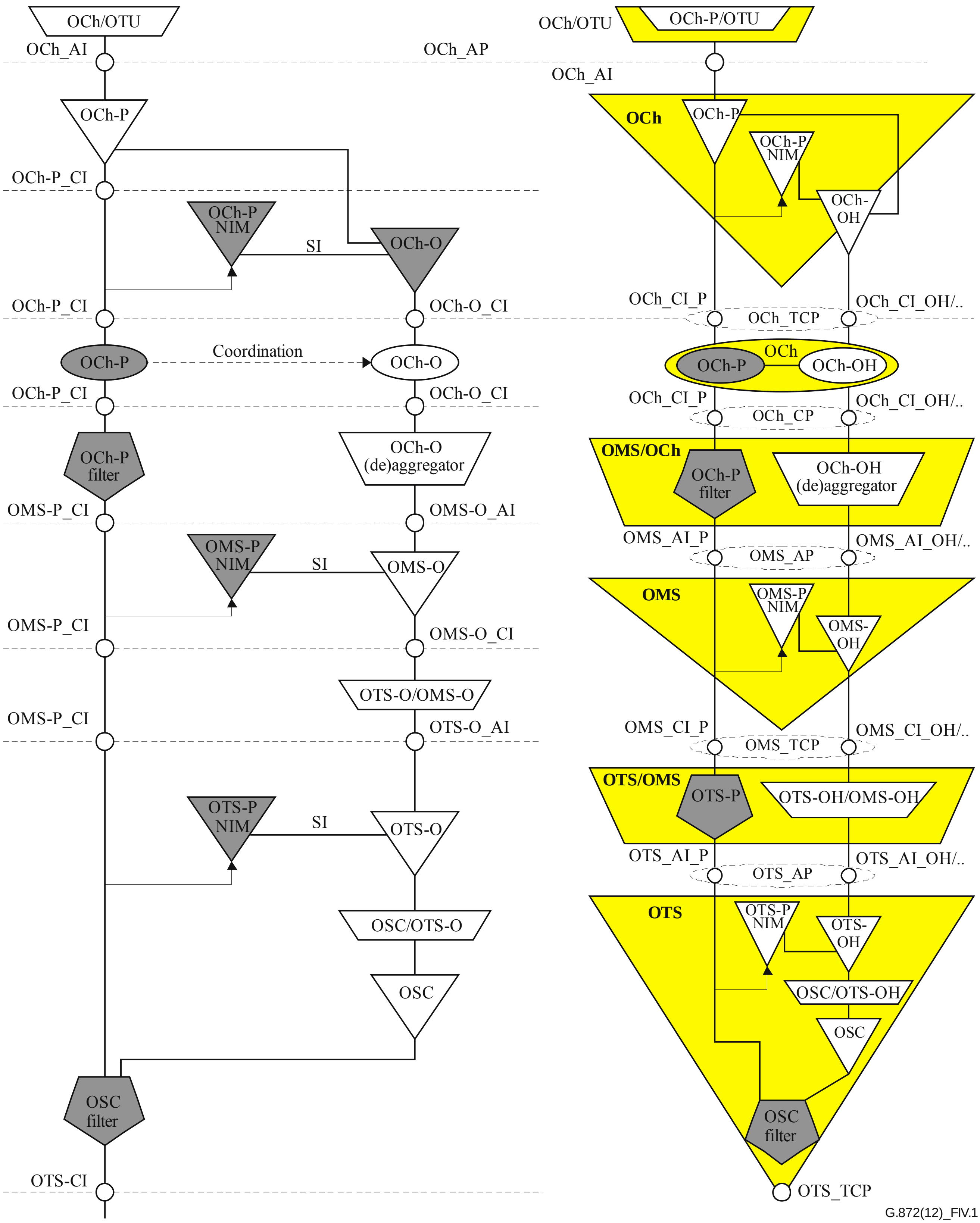


Figure IV.1 – Relationship between ITU-T G.872 and ITU-T G.798

Note that the reference points in the right hand (ITU-T G.798) column are references in both the signal and OAM paths. The ITU-T G.798 reference point is shown dotted, with the two components inside it.

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