International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.872
Amendment 1
(01/2021)

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

Digital networks – Optical transport networks

Architecture of the optical transport network

Amendment 1

Recommendation ITU-T G.872 (2019) – Amendment 1

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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Recommendation ITU-T G.872

Architecture of the optical transport network

Amendment 1

Summary

Recommendation ITU-T G.872 describes the functional architecture of the optical transport network (OTN) using the modelling methodology described in Recommendations ITU-T G.800, ITU-T G.805 and ITU-T G.807. The OTN functionality is described from a network level viewpoint, taking into account, the characteristic information of clients of OTN, client/server layer associations, networking topology, layer network functionality and optical media network structure, which provide multiplexing, routing and supervision of digital clients. The digital layers of the OTN use the frame formats defined in ITU-T G.709. The media portion of the network is described in terms of media constructs, media elements and optical signal maintenance entities.

Amendment 1 updates ITU-T G.872 (2019) to align with ITU-T G.807 (2020) Amendment 1. It also adds a description of the OTU25 and OTU50 interfaces, and enhances the description of flexible OTN interfaces.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T G.872	1999-02-26	13	11.1002/1000/4576
2.0	ITU-T G.872	2001-11-29	15	11.1002/1000/5606
2.1	ITU-T G.872 (2001) Amd. 1	2003-12-14	15	11.1002/1000/7064
2.2	ITU-T G.872 (2001) Cor. 1	2005-01-13	15	11.1002/1000/7483
2.3	ITU-T G.872 (2001) Amd. 2	2010-07-29	15	11.1002/1000/10880
3.0	ITU-T G.872	2012-10-29	15	11.1002/1000/11786
3.1	ITU-T G.872 (2012) Amd. 1	2013-11-06	15	11.1002/1000/11986
4.0	ITU-T G.872	2017-01-12	15	11.1002/1000/13086
5.0	ITU-T G.872	2019-12-22	15	11.1002/1000/13999
5.1	ITU-T G.872 (2019) Amd. 1	2021-01-13	15	11.1002/1000/14522

Keywords

Optical transport network (OTN), OTN functional architecture.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Amendment 1

Editorial note: This is a complete-text publication. Modifications introduced by this amendment are shown in revision marks relative to Recommendation ITU-T G.872 (2019).

1 Scope

This Recommendation describes the functional architecture of the optical transport network~~s~~ (OTN~~s~~) using the modelling methodology described in [ITU-T G.800], [ITU-T G.805] for the digital layer networks and [ITU-T G.807] for the optical media network. The OTN functionality is described from a network-level viewpoint. This takes into account the characteristic information (CI) of the clients of the OTN, the client/server layer associations, network topology, the optical media network structure, and the layer network functionalities that provide multiplexing, routing, supervision, performance assessment and network survivability for digital clients. The digital layers of the OTN use the frame formats defined in ITU-T G.709. The media portion of the network is described in terms of media constructs, media elements and optical signal maintenance entities described in [ITU-T G.807]. This Recommendation provides the functional description of OTN that support digital clients. The support of analogue signals as clients 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 G.694.1 (2020), *Spectral grids for WDM applications: DWDM frequency grid.*

[ITU-T G.694.2] Recommendation ITU-T G.694.2 (2003), *Spectral grids for WDM applications: CWDM wavelength grid.*

[ITU-T G.695] Recommendation ITU-T G.695 (2018), Optical interfaces for coarse wavelength division multiplexing applications.

[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 (2018), *Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces.*

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2020~~16~~), *Interfaces for the optical transport network (OTN).*

[ITU-T G.709.1] Recommendation ITU-T G.709.1/Y.1331.1 (2018), *Flexible OTN short reach interfaces.*

[ITU-T G.709.2] Recommendation ITU-T G.709.2/Y.1331.2 (2018), *OTU4 long-reach interface*.

[ITU-T G.709.3] Recommendation ITU-T G.709.3/Y.1331.3 (~~2018~~2020), *Flexible OTN long reach interfaces.*

[ITU-T G.709.4] Recommendation ITU-T G.709.4/Y.1331.4 (2020), *OTU25 and OTU50 short-reach interfaces.*

[ITU-T G.798] Recommendation ITU-T G.798 (2017), *Characteristics of optical transport network hierarchy equipment functional blocks.*

[ITU-T G.800] Recommendation ITU-T G.800 (2016), *Unified functional architecture of transport networks.*

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

[ITU-T G.807] Recommendation ITU-T G.807 (2020), *Generic functional architecture of the optical media network.*

[ITU-T G.873.1] Recommendation ITU-T G.873.1 (2017), *Optical transport network: Linear protection.*

[ITU-T G.873.2] Recommendation ITU-T G.873.2 (2015), *ODUk shared ring protection.*

[ITU-T G.873.3] Recommendation ITU-T G.873.3 (2017), *Optical transport network – Shared mesh protection.*

[ITU-T G.874] Recommendation ITU-T G.874 (2020~~17~~), *Management aspects of optical transport network elements.*

[ITU-T G.875] Recommendation ITU-T G.875 (2020~~18~~), *Optical transport network: Protocol-neutral management information model for the network element view.*

[ITU-T G.959.1] Recommendation ITU-T G.959.1 (2018), *Optical transport network physical layer interfaces.*

[ITU-T G.7712] Recommendation ITU-T G.7712/Y.1703 (2019), *Architecture and specification of data communication network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 access point: [ITU-T G.805].

3.1.2 adaptation: [ITU-T G.805].

3.1.3 adapted information (AI): [ITU-T G.805].

3.1.4 administrative domain: [ITU-T G.805].

3.1.5 characteristic information (CI): [ITU-T G.805].

3.1.6 connection supervision: [ITU-T G.805].

3.1.7 connection: [ITU-T G.805].

3.1.8 forwarding point: [ITU-T G.80~~0~~5].

3.1.9 layer network: [ITU-T G.805].

3.1.10 link: [ITU-T G.805].

3.1.11 media channel: [ITU-T G.807].

3.1.12 media channel assembly: [ITU-T G.807].

3.1.13 media channel group: [ITU-T G.807].

3.1.14 media subnetwork: [ITU-T G.807].

3.1.15 media layer access point (M-AP): [ITU-T G.807].

3.1.16 media layer adapted information (M-AI): [ITU-T G.807].

3.1.17~~5~~ network connection: [ITU-T G.805].

3.1.18~~6~~ network media channel: [ITU-T G.807].

3.1.19~~7~~ optical data unit (ODU): [ITU-T G.709].

3.1.20~~18~~ optical payload unit (OPU): [ITU-T G.709].

3.1.21~~19~~ optical transport network (OTN): [ITU-T G.709].

3.1.22~~0~~ optical transport unit (OTU): [ITU-T G.709].

3.1.23~~1~~ optical tributary signal (OTSi): [ITU-T G.959.1].

3.1.24~~2~~ optical tributary signal assembly (OTSiA): [ITU-T G.807].

3.1.25~~3~~ optical tributary signal group (OTSiG): [ITU-T G.807].

3.1.26~~4~~ optical tributary signal overhead (OTSiG-O): [ITU-T G.807].

3.1.27~~5~~ OSC: [ITU-T G.807].

3.1.28~~6~~ subnetwork: [ITU-T G.805].

3.1.29~~7~~ topological component: [ITU-T G.805].

3.1.30~~28~~ trail: [ITU-T G.805].

3.1.31~~29~~ transitional link: [ITU-T G.800].

3.1.32~~0~~ transport entity: [ITU-T G.800].

3.1.33~~1~~ transport processing function: [ITU-T G.805].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI Adapted Information

AP Access Point

ASON Automatically Switched Optical Network

~~BDI Backward Defect Indication~~

CI Characteristic Information

~~FDI Forward Defect Indication~~

FEC Forward Error Correction

FlexE Flex Ethernet

FlexO Flexible Optical Transport Network

FP Forwarding Point

~~MCA Media Channel Assembly~~

M-AI Media layer adapted information

M-AP Media layer access point

MCG Media Channel Group

NMCG Network Media Channel Group

OAM Operation, Administration and Maintenance

OCI Open Connection Indication

ODU Optical Data Unit

OMS Optical Multiplex Section

OMS-O OMS Overhead

OPU Optical Payload Unit

OSME Optical Signal Maintenance Entity

OTN Optical Transport Network

OTS Optical Transmission Section

OTS-O OTS Overhead

OTSi Optical Tributary Signal(s)

OTSiA Optical Tributary Signal Assembly

OTSiG Optical Tributary Signal Group

OTSiG-O Optical Tributary Signal Group Overhead

OTU Optical Transport Unit

PMI Payload Missing Indication

~~ROADM Reconfigurable Optical Add/Drop Multiplexer~~

SDN Software Defined Network

~~SSF Server Signal Fail~~

TCM Tandem Connection Monitoring

TS Tributary Slot

TTI Trail Trace Identifier

5 Conventions

5.1 Notational

The forwarding point (FP), defined in [ITU-T G.800], is used in this Recommendation and is equivalent to the connection point (CP), defined in [ITU-T G.805] that is used in [ITU-T G.709] and [ITU-T G.798].

The term modulator/demodulator is used to describe a bidirectional function that consists of a pair of collocated modulator and demodulator functions.

The term media layer access point (M-AP), defined in [ITU-T G.807], is used in this Recommendation to identify the reference point between an adaptation function and a modulator/demodulator function. [ITU-T G.798] uses the term access point (AP) to identify this reference point.

~~To distinguish between the optical signals and the corresponding non-associated overhead, t~~The suffix -O ~~suffix~~ is used to identify the non-associated overhead that corresponds to a group of optical signals, for example optical tributary signal group overhead (OTSiG-O), or optical multiplex section overhead (OMS-O).

The following conventions are used for optical data unit (ODU):

– ODUk is used to indicate an ODU0, ODU1, ODU2, ODU2e, ODU3, ODU4,~~ or~~ ODUflex, ODU25u, ODU25, ODU50u or ODU50
– ODUj is used to indicate an ODUk where k>j. This convention is used when two ODUk information structures are described (e.g., for ODUk multiplexing)
  – ODU25u, ODU25, ODU50u and ODU50 are only ODUk
– ODUCn is used to indicate an ODUCn
  – n is a~~n~~ positive integer
– ODU is used to indicate either an ODUk or ODUCn

The following conventions are used for the optical transport unit (OTU):

– OTUk is used to indicate an OTU1, OTU2, OTU3 or OTU4
– OTUCn is used to indicate an OTUCn
  – n is a~~n~~ positive integer
– OTU is used to indicate ~~either~~ an OTUk, OTU25u, OTU25, OTU50u, OTU50 or OTUCn

5.2 Diagrammatic

This Recommendation uses diagrammatic conventions described in [ITU-T G.800], [ITU-T G.805] and [ITU-T G.807].

6 Functional architecture of OTN

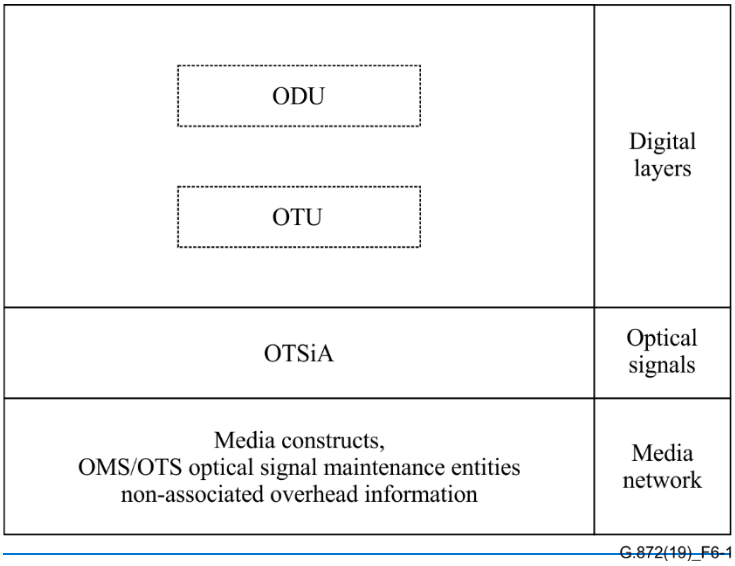
The optical transport network (OTN) provides transport, aggregation, routing, supervision and survivability for digital clients that are processed in the digital domain and carried across the optical media. These OTN functions are described from a network level viewpoint using the generic principles defined in [ITU-T G.800], [ITU-T G.805] for the digital layers and [ITU-T G.807] for the media network. The specific aspects concerning the OTN layered structure, characteristic information (CI), client/server layer associations, network topology, layer network functionality and media are provided in this Recommendation. A number of other ITU-T Recommendations provide detailed information on the implementation of the OTN. For example:

– [ITU-T G.709], [ITU-T G.709.1], [ITU-T G.709.2], ~~and~~ [ITU-T G.709.3] and [ITU-T G.709.4] provide the rates and formats used in the OTN;
– [ITU-T G.798] defines the equipment functional blocks;
– [ITU-T G.873.1], [ITU-T G.873.2] and [ITU-T G.873.3] describe linear, ring and shared mesh protection respectively;
– [ITU-T G.874] and [ITU-T G.875] define the management interface;

– [ITU-T G.695], [ITU-T G.698.1], [ITU-T G.698.2] and [ITU-T G.959.1] define the physical interfaces~~.~~;

– [ITU-T G.694.1] and [ITU-T G.694.2] define the frequency grid for DWDM interfaces and the wavelength grid for CWDM interfaces respectively.

In accordance with [ITU-T G.805] and [ITU-T G.800], the digital layers of the OTN are decomposed into independent transport layer networks, where each layer network can be separately partitioned in a way that reflects the internal structure of that layer network. The OTN consists of the digital layers, optical signals and the media network all of which may be managed as a single multi-layer entity. The structure of the OTN is provided in Figure 6-1 below.



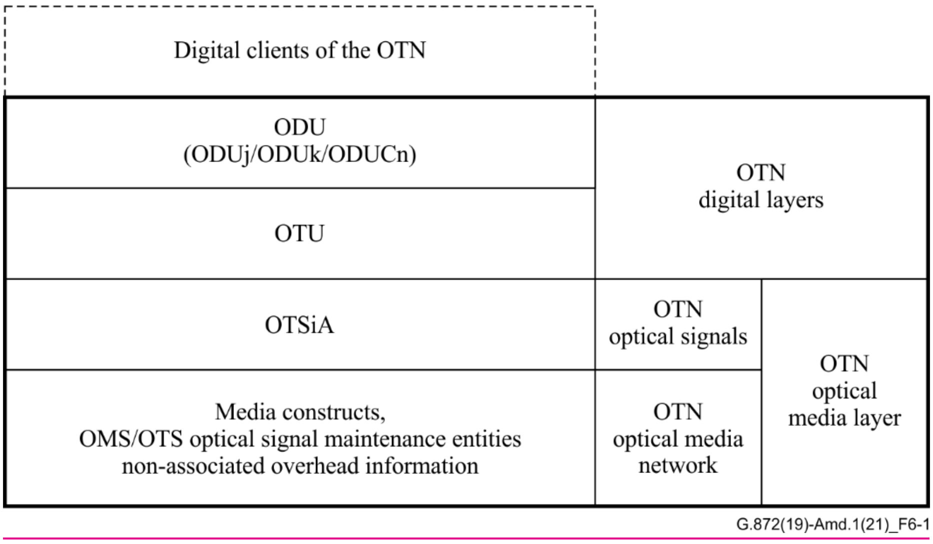


Figure 6-1 – Overview of the OTN

The digital layers of the OTN (optical data unit (ODU), optical transport unit (OTU)) provide the capability to multiplex~~ing of~~ and maintain digital clients~~ and for their maintenance~~. An OTU is supported by one optical tributary signal assembly (OTSiA)[1] and the OTSiA supports one OTU. The OTSiA is a management/control abstraction that represents the optical tributary signal group (OTSiG) management/control abstraction and the non-associated overhead (OTSiG-O); see [ITU-T G.807]. The OTSiG represents one or more optical tributary signals (OTSi).

[1] The mapping between the OCh terminology and the OTSi terminology is provided in Appendix I.

Below the OTSi ~~are~~is the optical media network, which contains the media constructs that provide the ability to configure the media channels that guide the OTSi through the media network, see [ITU-T G.807].

The OTSiA, together with the associated media channels, that supports the OTU, ~~and~~ may be managed as a part of an OTN network. While the optical media layer (OTSiA and media network) described in [ITU-T G.807] may support other clients, such clients are not ~~considered to be~~ a part of the OTN ~~network since OTU monitoring capabilities are not necessarily supported by such clients.~~. In some cases, the OTSiA ~~relies on the OTU for~~ may not support certain monitoring functions (e.g., path trace~~) to support~~). In this case, the OTU monitoring functions may be used to provide the full operation, administration, maintenance (OAM) and fault management capabilities of the OTN.

The configuration of the media channels to support an OTSiA and monitoring of ~~those signals~~ the OTSiA is described in [ITU-T G.807].

The OTN digital layers are described in clause 7. The generic aspects of the media layer (OTSiA and ~~the OTSiA~~ media network) are described in [ITU-T G.807], and the OTN specific aspects of the media layer are described in clause 8 ~~and [ITU-T G.807]~~.

7 OTN digital layers

The digital layers of the OTN are divided into the OTU layer and a hierarchy of one or more ODU layers. An OTU layer supports one ODU layer network as the client, and provides monitoring capability for the OTSiG[2]. The relationship between the ODUk and OTUk is shown in Figure 7-1.

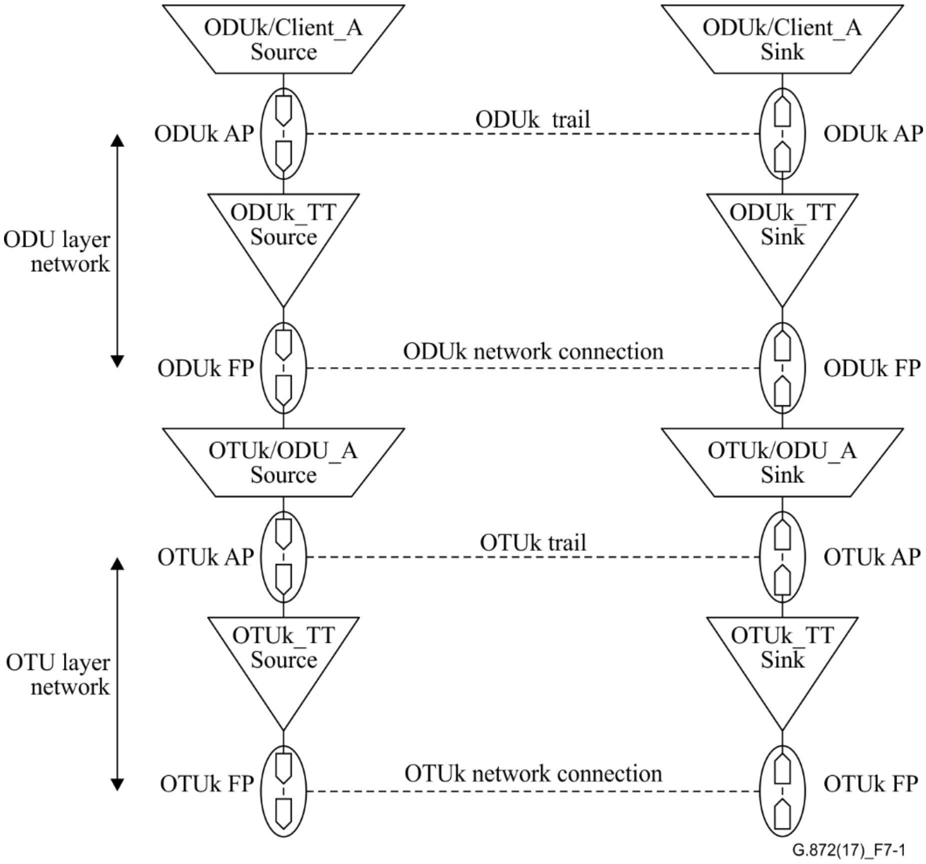


Figure 7-1 – Client/server association of the digital OTN layers without ODU multiplexing

[2] The OTSiG is described in [ITU-T G.807], the mapping between the OTSi terminology and the OCh terminology is provided in Appendix I.

NOTE – As described in clause 5.1 the forwarding point (FP) defined in [ITU-T G.800] is used in this Recommendation and is equivalent to the connection point (CP), defined in [ITU-T G.805] that is used in [ITU-T G.709] and [ITU-T G.798].

An ODUk may support a single (non-OTN) client as shown in Figure 7-1. An ODU (ODUk or ODUCn as described in clause 5.1) may support a heterogeneous assembly of lower rate ODUk clients using ODUk multiplexing as shown by the adaptation between the ODU and ODUj layer networks in Figure 7-2. ODUk multiplexing is described in clause 7.1.1.

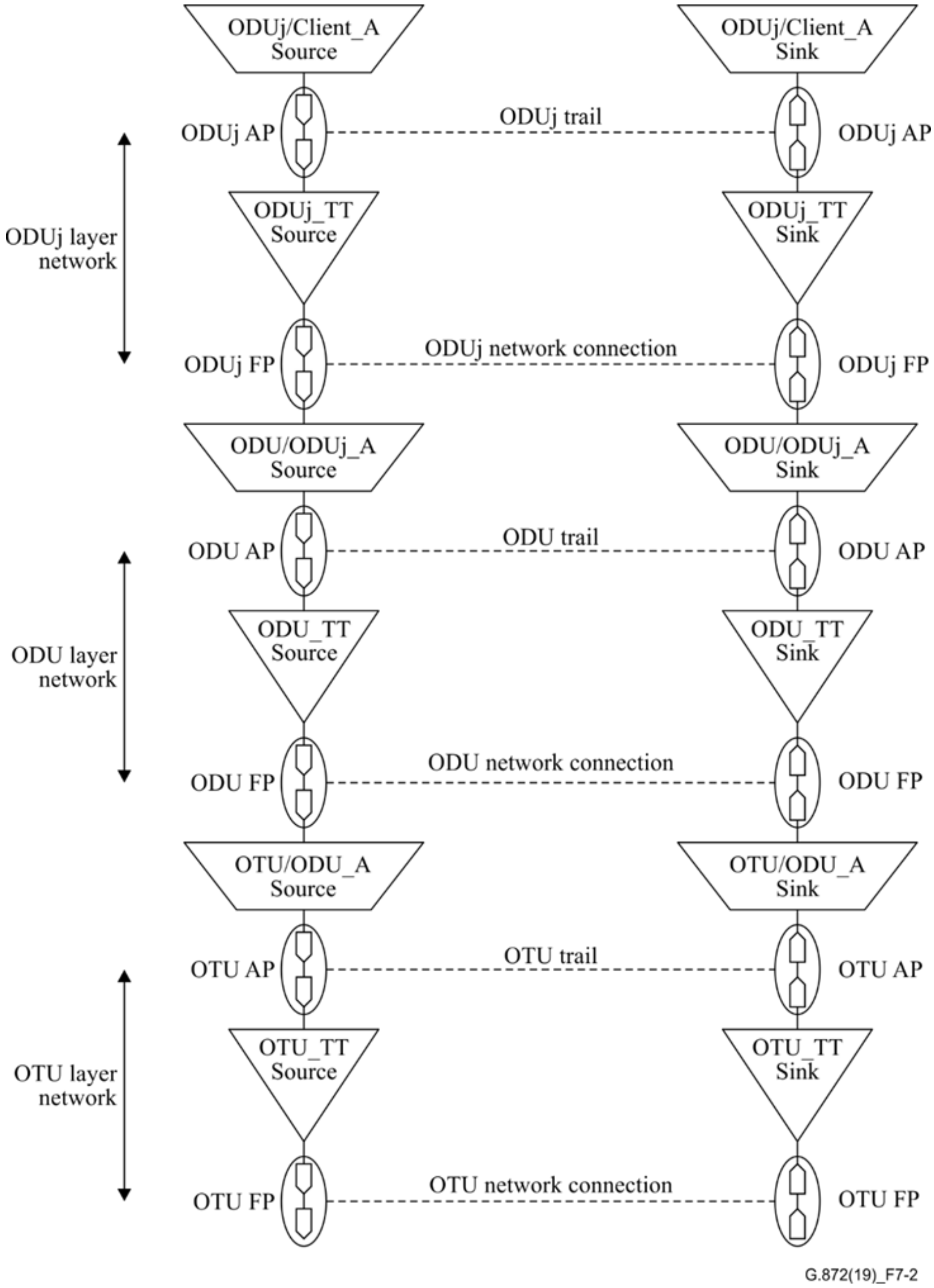


Figure 7-2 – Client/server association of the digital OTN layers with ODU multiplexing

The currently supported set of clients and servers is provided in clause 7.1.2.

7.1 Optical data unit (ODU) layer network

The optical data unit (ODU) layer network provides end-to-end transport of digital client information across the OTN. The description of the supported client layer networks is outside the scope of this

Recommendation. A description of the use of the OTN to carry Flex Ethernet (FlexE) is provided in Appendix II.

The characteristic information (CI) of an ODU layer network is described in terms of the frame structure defined in [ITU-T G.709], and is composed of:

– the optical payload unit (OPU) which is the ~~ODU~~ payload area of the ODU that is used to transport the digital client(s) ~~(the OPU)~~; and

– the ODU and OPU overhead area for the transport of the associated overhead.

NOTE – An ODUCn consists of n interleaved ODUC frame structures that support a single OPUCn payload area and n instances of the ODUC overhead and OPUC overhead.

Details of the format are provided in [ITU-T G.709].

The topological components of the ODU layer network are ODUk subnetworks and ODU links. The links are supported by either an OTU trail or a server ODU trail. As described in clause 7.1.1 an ODU server supports a heterogeneous assembly of ODUks. The ODUk subnetwork may provide connections for any ODUk. The tributary slot (TS) size supported by a server ODU and the bitrate of the client ODUk are modelled as parameters. This allows the ODU layer network to be viewed as a single layer network. When attempting to find a route for a particular ODUk, these parameters are used to identify the subset of the topological components in the ODU layer network that may be used[3] to support that ODUk[4], this is illustrated in Appendix III. These parameters also allow the number of tributary slots (TS) that an ODU will occupy on an ODU link connection (i.e., within a server ODU) to be determined. Each client ODU is mapped into an integer number of server ODU TS[5].

To provide end-to-end networking, the following capabilities are included in the ODU layer network:

– ODUk connection rearrangement for flexible network routing;

– ODU overhead processes to verify the integrity of the client adapted information (AI);

– ODU operations, administration and maintenance functions, including network survivability.

The ODU layer network contains the following topological components, transport processing functions and transport entities (see Figure 7-3 for the ODUk and Figure 7-4 for the ODUCn). The interlayer adaptation functions are described in clause 7.3.

Topological components:

– ODUk subnetwork

– ODU link.

Transport processing functions:

– ODU trail termination source

– ODU trail termination sink.

Transport entities:

– ODU trail

– ODU network connection

– ODU link connection

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[3] The restriction may be based on the capability of the resource (e.g., a link with 2.5 Gbit/s TS cannot support an ODU0 connection) or the restriction may be based on management policy (e.g., only ODU4 connections are allowed to use an ODUCn link).

[4] This approach allows the topology of an ODUk specific layer network to be generated from the topology of the ODU layer network.

[5] This may lead to inefficient use of bandwidth when the bit rate of the client ODU is less than the bit rate of a TS in the server ODU. (See Tables 7-2 and 7-4.)

– ODUk subnetwork connection.

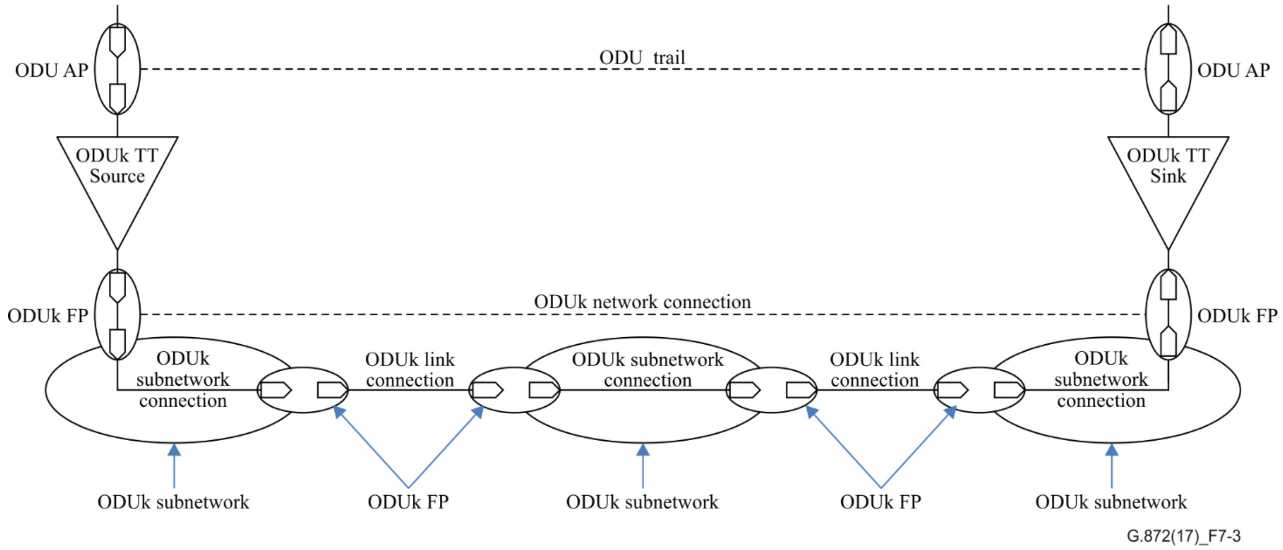

Figure 7-3 – ODUk layer network example

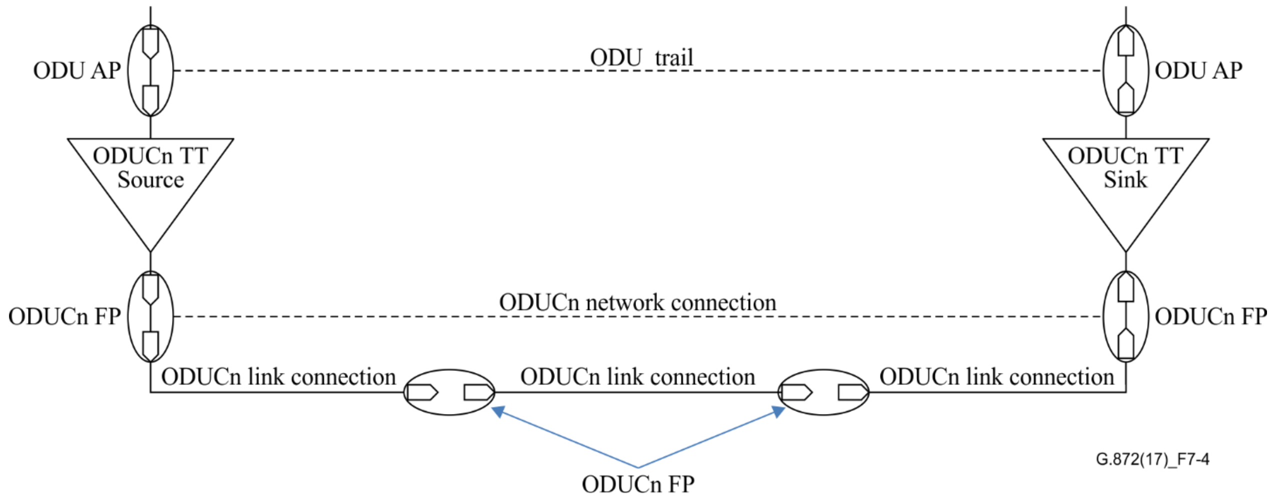

Figure 7-4 – ODUCn layer network example

The ODUCn forwarding point (FP)[6] represents the location of ODUCn regeneration and allows ODUCn tandem connection monitoring (TCM).

7.1.1 ODUk multiplexing

In order to allow the transport of several lower bit rate ODUk clients over a higher bit rate ODU server, time division multiplexing of ODUks is defined. The ODU clients and servers are described in Table 7-2.

The TS of the ODU server may be allocated to any combination of ODUk clients up to the capacity of the server ODU.

The heterogeneous multiplexing of ODUks supports various network architectures, including those that are optimized to minimize stranded capacity, and/or to minimize the number of managed entities, and/or support carrier's carrier scenarios, and/or enable ODU0/ODUflex traffic to transit a region of

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[6] As described in clause 5.1 the forwarding point (FP) defined in [ITU-T G.800] is used in this Recommendation and is equivalent to the connection point (CP), defined in [ITU-T G.805], that is used in [ITU-T G.709] and [ITU-T G.798].

the network that do not support these capabilities. Some examples of carrier's carrier (multi-domain) applications are given in Appendix IV.

7.1.2 ODU clients and servers

The information in this sub clause was correct at the time of publication of this Recommendation, the current set of ODUs and OTUs and TS is provided in [ITU-T G.709].

The set of ODU servers and their non-OTN clients is provided in Table 7-1.

Table 7-1 – ODU servers and their non-OTN clients

ODU server	non-OTN clients
ODU0	1.25 Gbit/s bit rate area
ODU1	2.5 Gbit/s bit rate area
ODU2	10 Gbit/s bit rate area
ODU2e	10.3125 Gbit/s bit rate area
ODU25u	none
ODU25	none
ODU3	40 Gbit/s bit rate area
ODU50u	none
ODU50	none
ODU4	100 Gbit/s bit rate area
ODUflex	CBR clients greater than 2.5 Gbit/s, or GFP-F mapped packet clients greater than 1.25 Gbit/s, or IMP mapped 64B/66B encoded clients
ODUCn	None
NOTE – ODU25u, ODU25, ODU50u, ODU50 and ODUCn support a limited set of non-OTN clients (e.g., NULL, PRBS and proprietary use clients) as defined in [ITU-T G.709]	

The set of ODU servers and their ODU clients is provided in Table 7-2.

Table 7-2 – ODU servers and their ODU clients

ODU server	ODU clients
ODU1	ODU0
ODU2	ODU0, ODU1, ODUflex
ODU25u	ODU0, ODU1, ODU2, ODU2e, ODUflex
ODU25	ODU0, ODU1, ODU2, ODU2e, ODUflex
ODU3	ODU0, ODU1, ODU2, ODU2e, ODUflex
ODU50u	ODU0, ODU1, ODU2, ODU2e, ODU3, ODUflex
ODU50	ODU0, ODU1, ODU2, ODU2e, ODU3, ODUflex
ODU4	ODU0, ODU1, ODU2, ODU2e, ODU3, ODUflex
ODUCn	ODU0, ODU1, ODU2, ODU2e, ODU3, ODU4, ODUflex
NOTE 1 – The ODU2 and ODU3 servers only support ODU0 and ODUflex clients if the ODU2 or ODU3 server has 1.25Gbit/s TS (see Table 7-4). NOTE 2 – ODU0, ODU2e and ODUflex cannot be used as a server. NOTE 3 – An ODU server does not support ODU25u, ODU25, ODU50u, ODU50 or ODUCn clients.	

The set of OTU servers and their ODU clients is provided in Table 7-3.

Table 7-3 – OTU servers and their ODU clients

OTU server	ODU client
OTU1	ODU1
OTU2	ODU2
OTU25u	ODU25u
OTU25	ODU25
OTU3	ODU3
OTU50u	ODU50u
OTU50	ODU50
OTU4	ODU4
OTUCn	ODUCn
OTUCn-M	ODUCn

NOTE 1 – The OTUCn-M is described in clause 7.2.
NOTE 2 – OTU servers have not been defined for ODU0, ODU2e or ODUflex.

The total number of TS available in a server ODU (when carrying one or more ~~an~~ ODUk~~i~~ client(s)), is provided in Table 7-4.

Table 7-4 – Number of tributary slots (TS) for each ODU

ODU server	Nominal TS capacity		
	1.25 Gbit/s	2.5 Gbit/s	5 Gbit/s
ODU1	2	not applicable	not applicable
ODU2	8	4	not applicable
ODU25u	20	not applicable	not applicable
ODU25	20	not applicable	not applicable
ODU3	32	16	not applicable
ODU50u	40	not applicable	not applicable
ODU50	40	not applicable	not applicable
ODU4	80	not applicable	not applicable
ODUCn	not applicable	not applicable	20×n

NOTE 1 – An ODUCn supports a maximum of 10×n ODUk clients.
NOTE 2 – ODU0, ODU2e or ODUflex do not support ODU clients and therefore do not support tributary slots.

7.1.3 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 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 (AI) 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 CI of the ODU layer network at its output;

– ODU trail termination sink: accepts the CI 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 AI at its output.

7.1.4 ODU transport entities

Network connections, subnetwork connections, link connections, tandem connections and trails are as described in [ITU-T G.800].

7.1.4.1 ODU tandem connections

The ODU overhead includes information to support monitoring the end-to-end ODU trail and up to six levels of tandem connections. The ODU path OH is terminated where the ODU is assembled and disassembled. The tandem connection overhead is added and terminated at the end of each tandem connection.

NOTE – In normal operation, the monitored tandem connections may be nested, cascaded or both. For test purposes the monitored tandem connections may overlap. Overlapped monitored connections must be operated in a non-intrusive mode.

7.1.5 ODU topological components

Layer network, subnetworks, links (including transitional links) and access groups are as described in [ITU-T G.800].

The ODUk subnetwork provides flexibility within the ODUk layer network. ODUk CI is routed between input forwarding points (FPs) and output FPs.

The ODU layer does not provide flexible connectivity for ODUCn; as such there is no ODUCn subnetwork.

7.2 Optical transport unit (OTU) layer network

The OTU layer network provides for the transport of ODU client signals through an OTU trail.

The CI of an OTU layer network is composed of:

– the OTU payload area that carries a single ODU as a client;

– the OTU overhead area.

NOTE 1 – An OTUCn carries n instances of the OTUC overhead.

An OTUCn with a bit rate that is not an integer multiple of 100 Gbit/s is described as an OTUCn-M carries n instances of OTUC overhead, ODUC overhead and OPUC overhead, together with M 5Gbit/s OPUCn TS. An ODUCn-M and OPUCn-M are not defined. When an OTUCn-M is used to carry an ODUCn (20n–M), TS are marked as unavailable in the OPUCn multiplex structure identifier (MSI), to limit the bandwidth available to that supported by the OTUCn-M~~since they cannot be used to carry a client~~.

Details of the format are provided in [ITU-T G.709].

The capabilities of this layer network include:

– OTU overhead processes to confirm the integrity of the client AI and conditioning for its transport over an OTSiG;

– OTU operations, administration and maintenance functions.

NOTE 2 – Flexible connectivity of an OTU may be provided by the media network described in clause 8.

The OTU layer network contains the following transport processing functions and transport entities (see Figure 7-5 for the OTU and Figure 7-6 for the OTUCn). The interlayer adaptation functions are described in clause 7.3.

Transport processing functions:

– OTU trail termination source;

– OTU trail termination sink.

Transport entities:

– OTU trail;

– OTU network connection;

– OTUCn link connection.

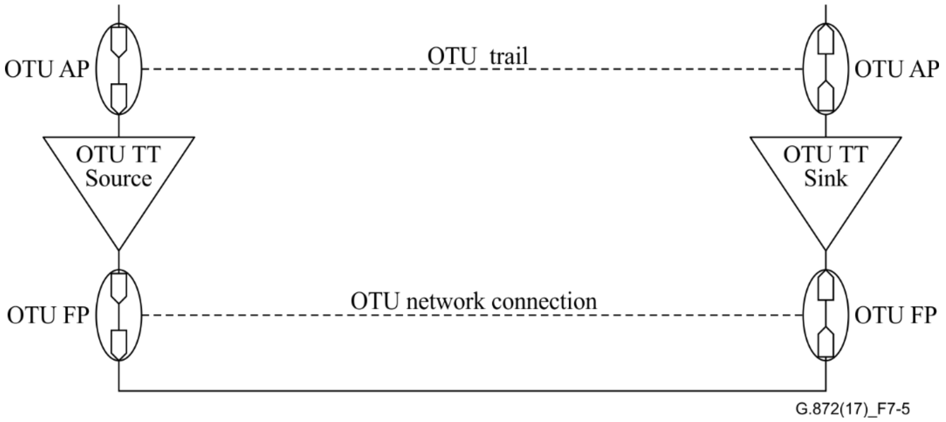


Figure 7-5 – OTU layer network example

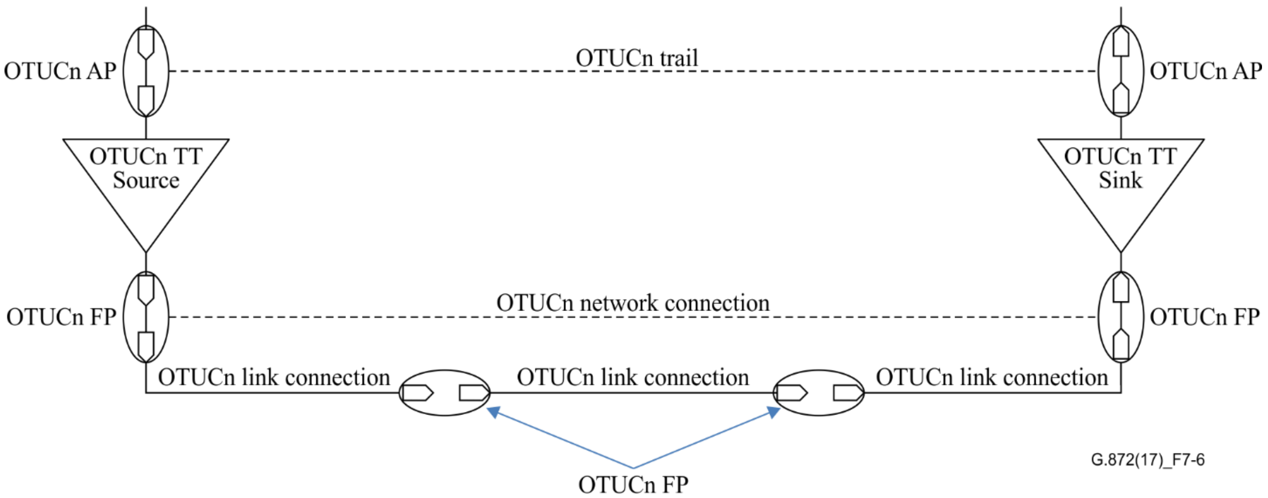


Figure 7-6 – OTUCn layer network example

Figure 7-6 shows the case where regeneration is performed below the OTUCn layer, in this case ODUCn TCM is not supported.

7.2.1 OTU trail termination

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

– validation of connectivity integrity;

– assessment of transmission quality;

– transmission defect detection and indication.

The capabilities of these processes are outlined 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 AI from an ODU network at its input, inserts the OTU trail termination overhead as a separate and distinct logical data stream and presents the CI of the OTU layer network at its output;

– OTU trail termination sink: accepts the CI 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 AI at its output.

7.2.2 OTU transport entities

Network connections, link connections and trails are as described in [ITU-T G.800].

7.2.3 OTU topological components

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

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. The current set of supported clients is provided in [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. A full description of the adaptation functions is provided in [ITU-T G.798].

7.3.1 ODU/client adaptation

The ODU/client adaptation 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 ODU servers are defined in Table 7-1.

The bidirectional ODU/client adaptation function is performed by a collocated pair of source and sink ODU/client adaptation functions.

The ODU/client adaptation source 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 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 ODU/ODU adaptation

The bidirectional ODU/ODU adaptation function is performed by a collocated pair of source and sink ODU/ODU adaptation functions. The ODU/ODU adaptations are defined in Table 7-2.

The ODU/ODU adaptation source performs the following processes between its input and its output:

– multiplexing lower rate ODUk clients to form a higher bit rate ODU server;

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

The ODU/ODU adaptation sink performs the following processes between its input and its output:

– demultiplexing the lower rate ODUk clients from the higher rate ODU server;

– 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 function is performed by a collocated pair of source and sink OTU/ODU adaptation functions. The OTU servers are defined in Table 7-3.

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

– mapping the ODU into the OTU payload area. The processes are dependent upon the particular implementation of the client/server relationship.

The OTU/ODU adaptation sink 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 Architecture of the media network supporting the OTN digital layers

The architecture of the media network is described using media constructs (see clause 8.1) to represent the different functions that are present in the media network. Media constructs operate on the signal envelope (e.g., amplify or attenuate the signal, constrain or direct the media channel, etc.) and are not aware of the information being carried. Media constructs do not modulate or demodulate the signal and therefore do not process the digital information that is carried by the signal.

A full description of the generic functional architecture of the media network is provided in [ITU-T G.807].

8.1 Media constructs

The following media constructs used to describe the architecture of the media network are described in [ITU-T G.807]:

– media port;

– media channel;

– media channel group;

– media channel assembly;

– media subnetwork;

– optical amplifier;

– fibre;

– optical parameter monitor (OPM-x);

– optical signal maintenance entity (OSME).

8.2 Media element

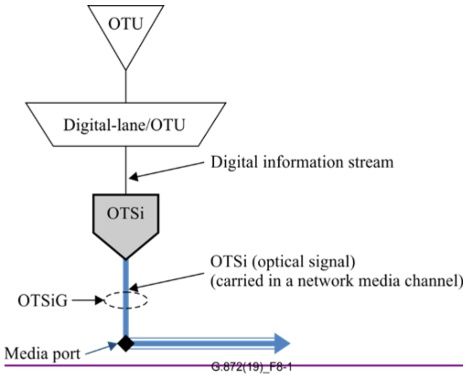
For the purposes of management and control, the media network is represented by a set of media elements. An instance of a media element encompasses the functionality represented by one or more of the media constructs. The media element is described in clause 7.2 of [ITU-T G.807].

8.3 Optical tributary signals (OTSi)

~~The media network described in clause 7 of [ITU-T G.807] is used to carry the OTSi that convey the digital information of the OTN. The OTSi is the signal that is carried between an OTSi modulator and an OTSi demodulator that is carried by a network media channel.~~

As described in clause 10~~.1~~ of [ITU-T G.807], an OTU is supported by a set of one or more OTSi that are represented by the OTSiG management/control abstraction together with non-associated overhead (OTSiG-O). The OTSiG and OTSiG-O are represented by the OTSiA management/control abstraction – an OTSiA carries one OTU. As described in clause 10.1 of [ITU-T G.807], each uni-directional OTSi is carried in an independent network media channel (NMC) between the media port of a modulator and the media port of a demodulator. The set of media channels that support the members of the OTSiG may be represented as a network media channel group (NMCG).

The case where the OTU is carried by a single OTSi is shown in Figure 8-1.



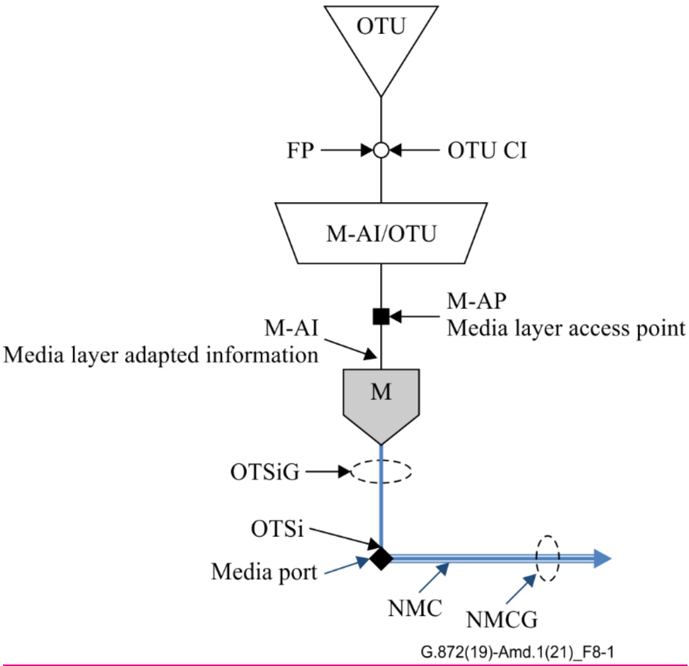
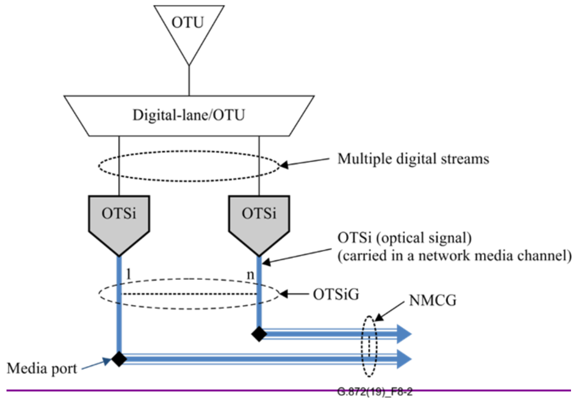


Figure 8-1 – Mapping an OTU to an OTSiG that contains one OTSi

The case where an OTU is carried by more than one OTSi is illustrated in Figure 8-2.



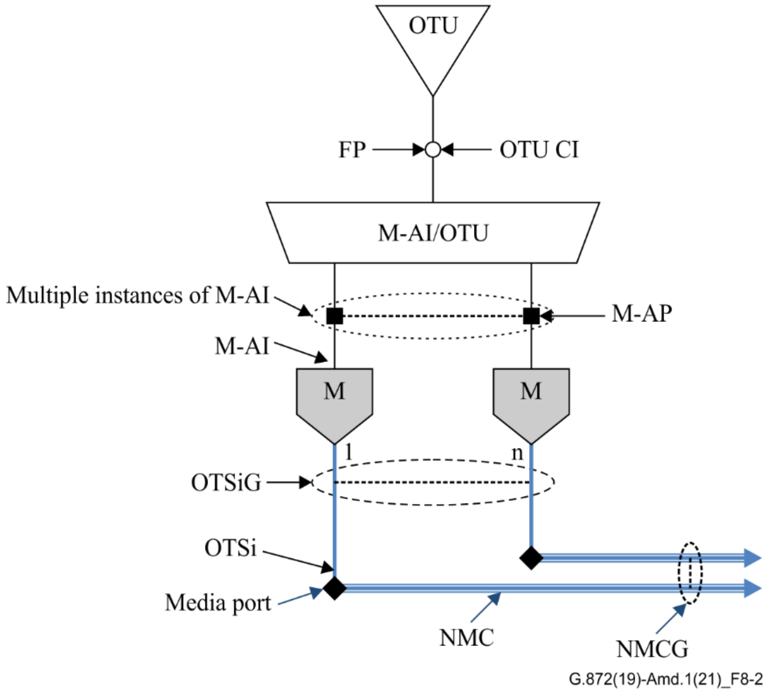
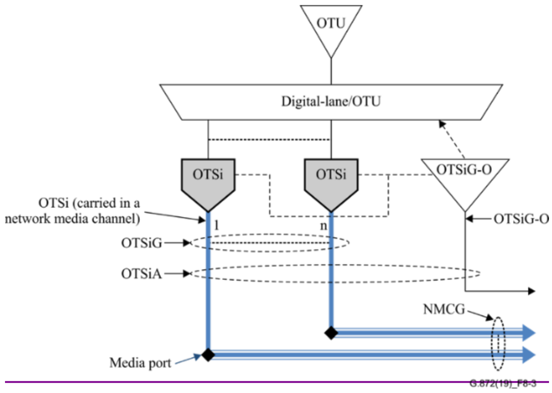


Figure 8-2 – Mapping an OTU to an OTSiG that contains more than one OTSi

The OTSiG may have non-associated overhead (OTSiG-O). The combination of the OTSiG and OTSiG-O is represented by the OTSiA management/control abstraction (which is not present in the media network). This is illustrated in Figure 8-3.



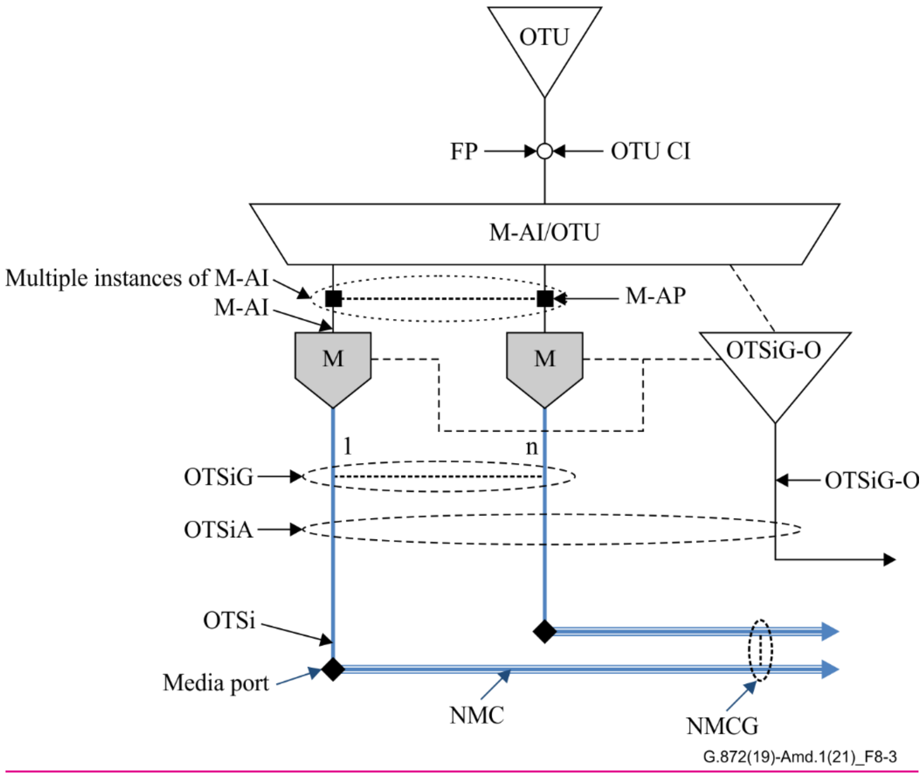


Figure 8-3 – Mapping an OTU to an OTSiA with non-associated overhead (OTSiG-O)

The digital payload processing functions related to the OTU termination, ~~digital lane~~ media layer adapted information (M-AI)/OTU adaptation and OTSiG-O termination use the processes defined in [ITU-T G.798] and the frame formats defined in [ITU-T G.709]. The frame format and forward error correction (FEC) are defined in the ITU-T G.709.x series of Recommendations.

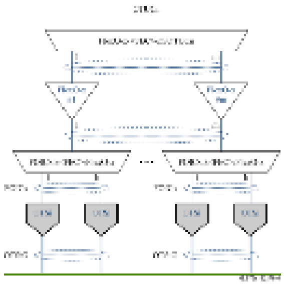
NOTE – As described in clause 10.~~1~~2.1 of [ITU-T G.807], the OTSi may support two independent digital clients, one of which is the ~~OTU~~out, and the other may be the~~also support digital~~ OTSiG-O~~ information~~.

Figures 8-1, 8-2 and 8-3 give an overview of the payload processing functions that provide the interface to the media. The client of the OTSiA (the OTU) is presented to the ~~digital lane~~M-AI/OTU adaptation function. The OTSi is generated from ~~a digital stream~~the M-AI by a modulator and converted back to the M-AI ~~a digital stream~~ by a demodulator. The OTSi is carried in a network media channel.

The OTN uses the frequency grids defined in [ITU-T G.694.1] and the wavelength grids defined in [ITU-T G.694.2] for media channels.

8.3.1 Flexible OTN interfaces

The frame format for the ~~F~~flexible optical transport network~~OTN~~ (FlexO) interface~~ frame format~~, as defined in [ITU-T G.709.1] ~~or~~ and [ITU-T G.709.3], may be used to implement the ~~digital lane~~M-AI/OTUCn adaptation~~ and OTSi modulator or demodulator~~ function as shown in Figure 8-4~~s~~. The FlexO frame format~~,~~ supports multiplexing of one or more OTUCn over a group of FlexO instances which are transported by one FlexO-**x**-<FEC>-m interface group, where **x** is a positive integer equal to the interface bit rate divided by 100G and m is the number of interfaces. The FlexO-**x**-<FEC>-m interface group bonds (i.e., combines) m~~n~~ standard-rate interfaces ~~(e.g. 100G interfaces)~~ to provide a contiguous capacity of ~~n~~m×**x**×100G~~, over which the OTUCn is carried~~. ~~An overview of the FlexO payload processing functions is provided in Figure 8-4 below.~~



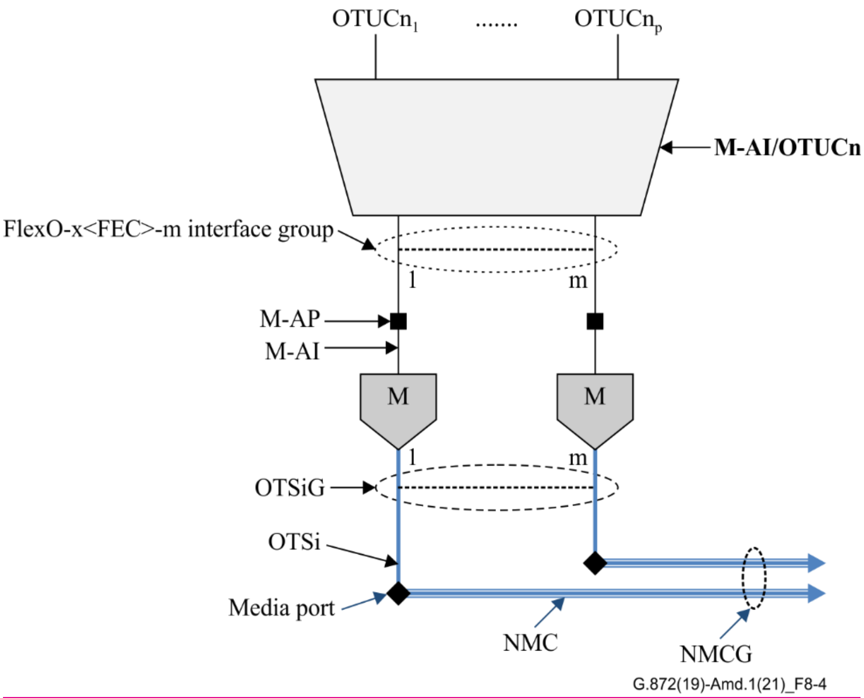


Figure 8-4 – Mapping an OTUCn to FlexO group where each FlexO-x-<FEC> interface is carried by one OTSi

Figure 8-4 shows the case where each FlexO-**x**-<FEC> interface is carried by a single OTSi, for example by using the optical tributary signal class DP-DQPSK 100G as defined in [ITU-T G.698.2]. Alternatively, each FlexO-**x**-<FEC> interface may be inversely multiplexed over y OTSi. For example, the 4-channel NRZ OTL4.4 short-haul interface defined in [ITU-T G.695] may be used. In this case the FlexO-**x**-<FEC>-m interface group is carried by m × y OTSi.

To align the aggregate rate of the OTUCn clients to the payload capacity of the FlexO-**x**-<FEC>-m interface group, each FlexO instance (transported by a FlexO-**x**-<FEC>-m interface group) may carry one OTUC from the OTUCn clients or it may be unequipped. Details of the processes used to implement FlexO interfaces are provided in clause 15 of [ITU-T G.798].

The use of the FlexO-**x**-<FEC> frame format in conjunction with one of the interfaces defined in, for example, [ITU-T G.695] or [ITU-T G.698.2], provides a fully standardized optical interface.

8.4 Management of optical signals

8.4.1 OMS and OTS media channel group

The OTS media channel group (MCG) and OMS MCG are described in clause ~~11~~ 7.3.3 of [ITU-T G.807] as topological constructs that are used for management control purposes. The management and monitoring of these entities is also described in clause ~~11~~ 8.2 of [ITU-T G.807].

NOTE – The terms OMS media link and OTS media link used in the previous version of this Recommendation have been replaced with the terms OMS media channel group (MCG) and OTS MCG in [ITU-T G.807].

8.4.2 OSC

The OSC is described in clause 12 of [ITU-T G.807].

8.4.3 Optical signal maintenance entities (OSMEs)

The optical system maintenance entities (OSMEs) are described in clause 8.2 of [ITU-T G.807].

8.4.4 Media channels and OSMEs

The relationship between media channels and OSMEs is described in clause ~~11~~8.2 of [ITU-T G.807].

8.5 Management of media and signals

8.5.1 Management of media channels

The management of media channels is described in clause 7.4 of [ITU-T G.807].

8.5.2 Assignment of signals to media channels

The assignment of signals to media channels is described in clause 10.1.~~2~~ 1 of [ITU-T G.807].

8.5.3 Management of OTSiA connections

The management of OTSiA connections is described in clause 10.3.1 of [ITU-T G.807].

8.6 Modulator/demodulator and termination functions

The modulator/demodulator and the termination functions in the media network are described in clause 13 of [ITU-T G.807].

8.7 Client/server associations

8.7.1 ~~Digital lane~~M-AI/OTU adaptation function

The bidirectional ~~digital lane~~M-AI/OTU adaptation function is performed by a collocated pair of source and sink ~~digital lane~~M-AI/OTU adaptation functions.

The ~~digital lane~~M-AI/OTU adaptation source performs the following processes between its input and its output:

– accepts the output of the OTU trail termination and performs the processing required to generate one or more instances of M-AI.~~a continuous data stream that can be modulated onto an OTSi or multiple OTSi.~~ The actual processes required are dependent upon the particular implementation of the client/server. Forward error correction is an optional feature, which may be required in cases where impairments (e.g., bit errors) are expected to be present in the M-AI at the output of the demodulator.

– generate any OTSiG-O that is required.

The ~~digital lane~~M-AI/OTU adaptation sink performs the following processes between its input and its output:

– accepts the M-AI from one or more demodulators and recover~~sy~~ ~~of~~ the OTU ~~data stream~~CI. The actual processes are dependent upon the particular implementation of the client/server relationship. Forward error correction is an optional feature[7].

– accept and process any OTSi overhead from the OTSiG-O trail termination function.

8.7.2 OMS-O/OTSiG-O adaptation function

The OMS-O/OTSiG-O adaptation function is described in clause 14.2 of [ITU-T G.807].

8.7.3 OTS-O/OMS-O adaptation function

The OTS-O/OMS-O adaptation function is described in clause 14.3 of [ITU-T G.807].

8.7.4 ~~Digital lane~~M-AI/OTS-O adaptation

The ~~digital lane~~M-AI/OTS-O adaptation function is described in clause 14.4 of [ITU-T G.807].

9 Media network topology

The OTN digital layers can support unidirectional and bidirectional point-to-point connections, and unidirectional point-to-multipoint connections as described in [ITU-T G.805].

The media can be configured to provide point-to-point and point-to-multipoint media channels. ~~Note that a~~A media channel may support the propagation of a signal in one direction or both directions. A bidirectional OTSi is supported by two network media channels (one for each direction of propagation). Media topology is described in clause 7.3 of [ITU-T G.807].

10 Management

This clause provides an overview of the fault, performance and configuration management capabilities provided by the OTN. The full set of capabilities are described in [ITU-T G.709] and [ITU-T G.798].

The OTN digital layers (ODU, OTU) use digital overhead to provide OAM, which can report on the status of the layer and may be used to infer the status of the server layer.

A media network, that is deployed as a part of an OTN network, uses the management capabilities (including media monitoring and non-associated overhead) described in clause 15 of [ITU-T G.807] and the OSC described in clause 12 of [ITU-T G.807].

10.1 Capabilities

10.1.1 Fault, configuration and performance management

The OTN provides support for fault, configuration and performance management end to end, within an administrative domain and between the boundaries of administrative domains.

The OTN shall provide the capability to:

– interconnect reference points e.g., FP (with compatible CI) and media ports that will support compatible OTSi;

– detect and isolate faults and initiate recovery actions where applicable;

– support single-ended maintenance;

---

[7] Some of these processes may rely on information extracted from the ~~modulated optical signal~~OTSi by the ~~OTSi~~ demodulator.

– detect and report misconnections;
– report any interruptions within a layer to the upstream and downstream entities in that layer;
– detect performance degradation and verify quality of service.

10.1.2 Client/server interaction

The server detects and indicates to the client layer when the M-AIa digital stream or optical signal is not present.

To avoid unnecessary, inefficient or conflicting survivability actions, escalation strategies (e.g., introduction of hold-off times and alarm suppression methods) may be required:

– within a layer;
– between a server and client layer.

10.1.3 Adaptation management

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

10.1.4 Connection and MCG supervision

10.1.4.1 Continuity supervision

Continuity supervision refers to the set of processes for monitoring the continuity of an entity (e.g., connection, trail, MCG).

In general, a continuity fault in a server is indicated to a client through server signal fail ~~(SSF)~~ indication.

Continuity supervision of media

This is described in clause 15 of [ITU-T G.807].

10.1.4.2 Connectivity supervision

Connectivity supervision refers to the set of processes for monitoring the integrity of the routing of a MCG or a 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.

Connectivity supervision of MCGs is described in clause 15 of [ITU-T G.807].

Trail trace identifier (TTI) is necessary to ensure that the signal received by a trail termination sink originates from the intended trail termination source:

– TTI is provided at the OTU layer to ensure proper OTU layer connections.
– TTI is provided at the ODU layer to ensure proper ODU layer connections.
– TTI is provided at the OTS-O layer to ensure proper connectivity of the OTS MCG.
– TTI is provided at the OTSiG-O layer to ensure proper connectivity of the NMCG.

NOTE – OTSiG-O TTI is not supported in equipment that complies with Edition 5 (or earlier editions) of [ITU-T G.709].

10.1.4.3 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.

An overview of the maintenance information for the media network is described in clause 15 of [ITU-T G.807], detailed information is provided in [ITU-T G.709] and [ITU-T G.798].

Four maintenance information processes are identified for the digital layers:

– forward defect indication ~~(FDI)~~;
– backward defect indication ~~(BDI)~~;
– payload missing indication (PMI);
– open connection indication (OCI).

These processes enable defect localization and single-ended maintenance.

10.1.4.4 Subnetwork/tandem/unused connection supervision

Supervision for subnetwork connections, tandem connections and unused connections is required for the ODU layer. Connection supervision techniques and applications are listed in clauses 10.2 and 10.3.

10.1.5 Connection quality supervision

Connection quality supervision refers to the set of processes for monitoring the performance of a connection. Generic processes include parameter measurement, collection, filtering and processing. Connection quality supervision, by means of BIP-8, is only supported for the ODU and OTU layer networks. Delay measurement is also supported by the ODU layer.

10.1.6 Management communications

Management communications are transported via an embedded communication channel (ECC) as specified in [ITU-T G.7712]. The embedded communication channel may be supported by one of the ODU or OTU general communications channels (GCC) or by the OSC (see clause 12 of [ITU-T G.807]).

10.1.7 Frequency and time synchronization

The communication of time and frequency information between adjacent network elements is supported by the OTUk, FlexO and OSC.

10.2 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.

10.3 Connection supervision applications

10.3.1 Unused connections

In order to detect the inadvertent opening of a subnetwork connection in a subnetwork, ODU overhead includes an indication of whether an ODU TS is occupied or not (OPU MSI). See [ITU-T G.798] for further details.

10.3.2 Connection monitoring

ODU connection monitoring may be applied to:

– a network connection;

– a subnetwork connection, establishing a serving operator administrative domain tandem connection;
– a link connection, establishing a service requesting administrative domain tandem connection or a protected domain tandem connection;
– a 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 [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

It is expected that survivability techniques will only be used in the OTN for the ODUk layer network and the media.

For ODU transport entities digital overhead is used to detect faults or performance degradations (see clause 10) these events may be used to trigger the replacement of the failed transport entity with a protection transport entity.

Survivability techniques for the media network are described in clause 16 of [ITU-T G.807]

Specific survivability techniques include protection (defined in the ITU-T G.873.x series Recommendations) and restoration such as being controlled by an automatically switched optical network (ASON) or a software defined network (SDN). ~~d~~Details of these techniques are out of the scope of this Recommendation.

Appendix I

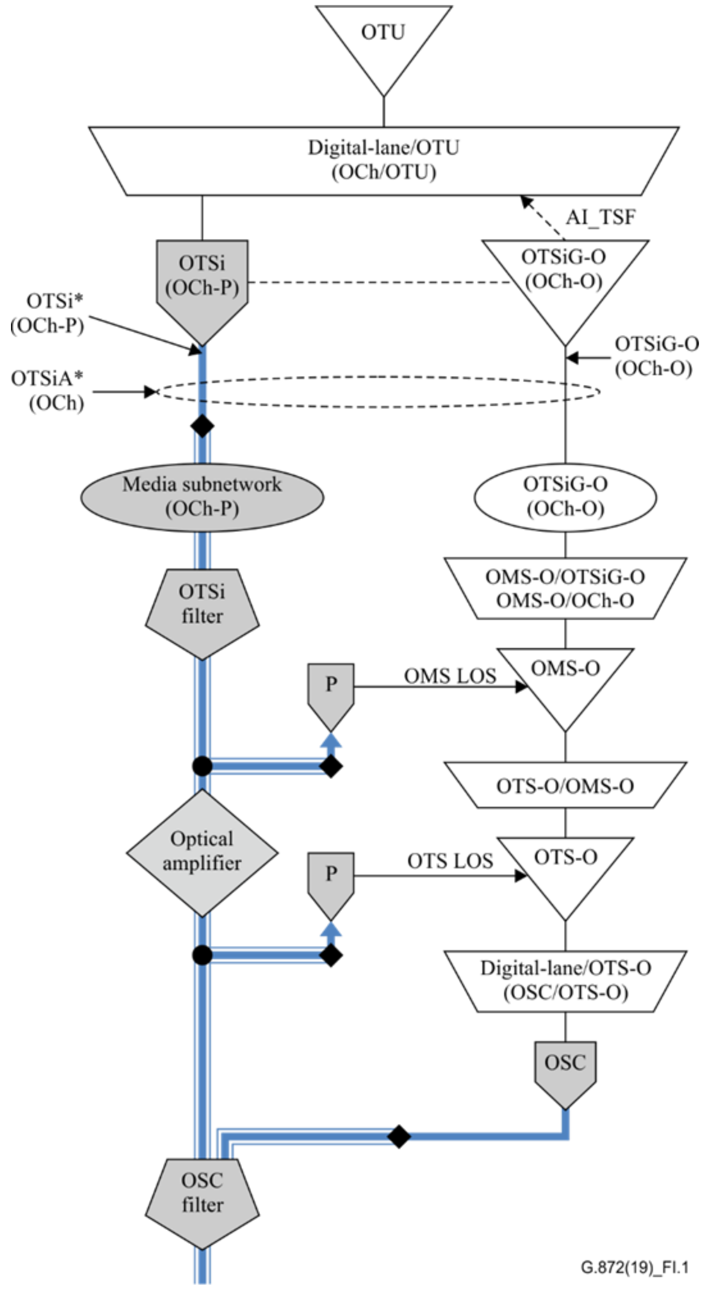
Relationship between OCh and OTSi terminology

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

The mapping from the OCh terminology to the OTSi terminology is provided in Table I.1 and Figure I.1.

Table I.1 – Mapping between OCh and OTSi terminology

OCh term	OTSi term	Number of OTSi in the OTSiG
OCh-P	OTSi	1
none	OTSi	>1
OCh-P	OTSiG	1
none	OTSiG	>1
OCh-O	OTSiG-O	*
OCh	OTSiA	1
none	OTSiA	>1
OCh-P connection function	Media subnetwork	not applicable
NOTE – The OCh-O supports a subset of the capabilities provided by the OTSiG-O. These differences are described in detail in [ITU-T G.709].		



* NOTE – This figure only applies when the OTSiG contains a single OTSi

Figure I.1 – Relationship between OCh and OTSi terminology

Appendix II

Use of the OTN to carry Flex Ethernet

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

II.1 Overview of Flex Ethernet

Flex Ethernet (FlexE) provides two, essentially independent, capabilities:

– Bonding:

  The ability to bond existing Ethernet physical interfaces (PHYs) allows, for example a 400G MAC to be supported over four bonded 100GBASE-R PHYs. The set of PHYs that are bonded are referred to as a FlexE group.

– Support of sub-rate clients:

  FlexE allows a PHY to support MAC clients at rates of 10, 40 or m×25Gbit/s, the bitrate of these MAC clients is not constrained to correspond to an existing Ethernet PHY rate. The allocation of the capacity of the PHY is managed by a calendar. The calendar can allocate the PHY capacity to a combination of MAC clients, up to the capacity of the PHY, for example:

  – A 100GBASE-R PHY could support two 25Gbit/s and five 10Gbit/s MAC clients; or
  – Two bonded 100GBASE-R PHYs could be used to support one 150Gbit/s MAC client (with the remainder of the PHY calendar slots marked as unused).

The capabilities of FlexE are defined in [b-OIF FlexE IA], the mapping of FlexE into an ODUk (via OPUflex) is defined in [ITU-T G.709].

Ethernet PHY interfaces to the OTN, which are being used for FlexE, may operate in one of the three modes described below.

II.2 FlexE unaware

In this case the OTN is unaware of FlexE. This case allows, for example, an OTN network that only supports OTU4s to be used to carry FlexE clients with a bitrate in excess of 100 Gbit/s.

The payload from each Ethernet PHY is independently mapped (using a PCS codeword transparent mapping) into the appropriate ODUk, which is carried by an OTU (see clause 7).

If the FlexE group is carried over more than one OTU then, to control the differential delay between the members of the FlexE group, all of the OTUs must be co-routed through the media network e.g. carried over the same OMS MCG~~link~~.

II.3 FlexE aware

In this case, the OTN is aware of FlexE but the FlexE group is not terminated. This case supports, for example, applications where the bitrate carried by an OTU does not match the bitrate of the Ethernet PHY or is not an exact multiple of the Ethernet PHY rate.

The equipped FlexE instances~~clients~~ from one or more of the Ethernet PHYs, in the same FlexE group, are mapped into an ODUflex, the contents of the "UNAVAILABLE" calendar slots are discarded as described below ~~which is carried by an OTU (see clause 7)~~.

If the FlexE group is mapped into more than one ODUflex (each~~is~~ carried over ~~more than one~~an OTU) then, to control the differential delay between the members of the FlexE group, all of the OTUs must be co-routed through the media network e.g., carried over the same OMS MCG~~link~~.

~~In cases where the bitrate of the Ethernet PHY is greater than the OTU bitrate or is not an integral multiple of the OTU bitrate, t~~The transport network ~~may~~ discards unequipped FlexE instances and bits ~~or bytes~~ from the unavailable calendar slots at the ingress to the OTN network~~ ingress~~. The unequipped FlexE instances and~~se~~ bits ~~or bytes~~from unavailable calendar slots, (that were discarded at the ingress) are re-inserted with fixed values at the egress of the OTN network (to restore the original Ethernet PHY bitrate).

II.4 FlexE terminating

In this case the FlexE is fully terminated, the members of the FlexE group are aligned (i.e., the differential delay is compensated) and the FlexE clients are extracted. Each FlexE client is then mapped into an ODUflex. Each of the FlexE clients (carried in an ODUflex) may be routed to a different destination.

Appendix III

Examples of views of an ODU layer network

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

This appendix provides examples of how the topology of an ODU layer network may be viewed either independent of k or to provide a view for a specific value of k.

Figure III.1 shows the topology of a simple ODU network, this view is independent of the value of k.

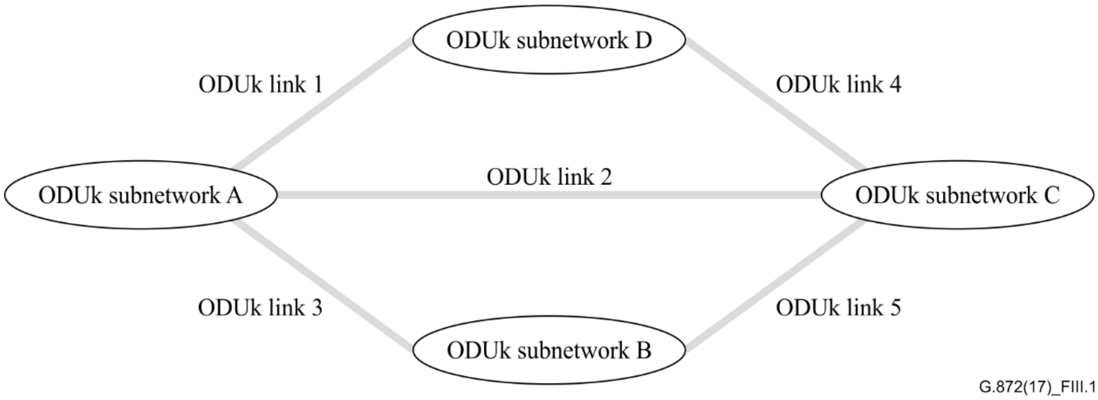


Figure III.1 – Example ODU network

A link or subnetwork may not be able to support all values of k because of limitations in the resources that support it, or because of a decision by the network operator. Because of these limitations for a specific value of k, some links and subnetworks may be removed from the topology. Considering the example in Figure III.1, if links 1 and 5 cannot support an ODU4 but all other links and subnetworks can support an ODU4, then the topology for an ODU4 would be reduced as shown in Figure III.2.

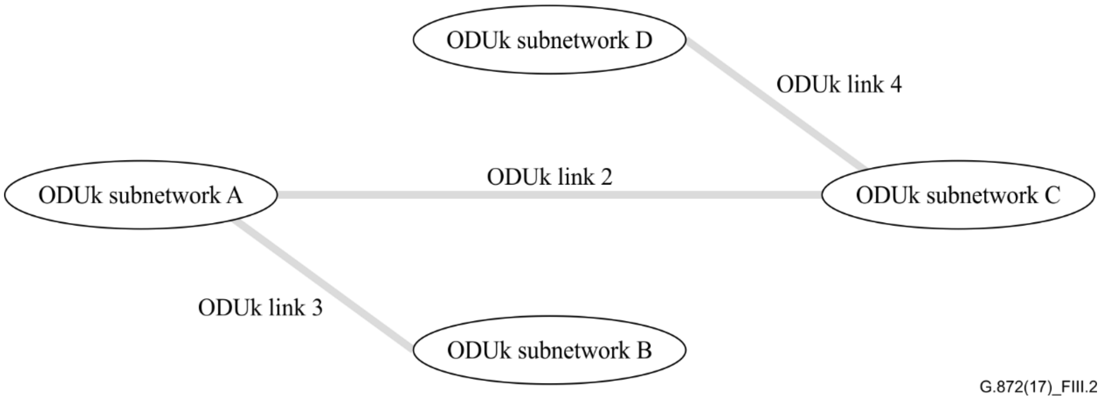


Figure III.2 – Example for ODU4 network

In the case where some regions of a network cannot support particular ODUj connections, for example as shown in Figure III.3, subnetwork B cannot support ODU0 connections. With this topology it is not possible to support an ODU0 connection between ODUk subnetworks A and C.

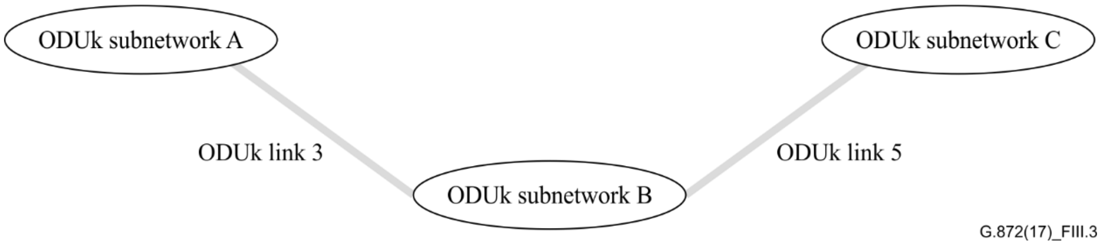


Figure III.3 – Limited capability ODUk subnetwork

To allow ODU0 to be carried between ODUk subnetwork A and C, an ODUk connection can be established, as shown in Figure III.4.

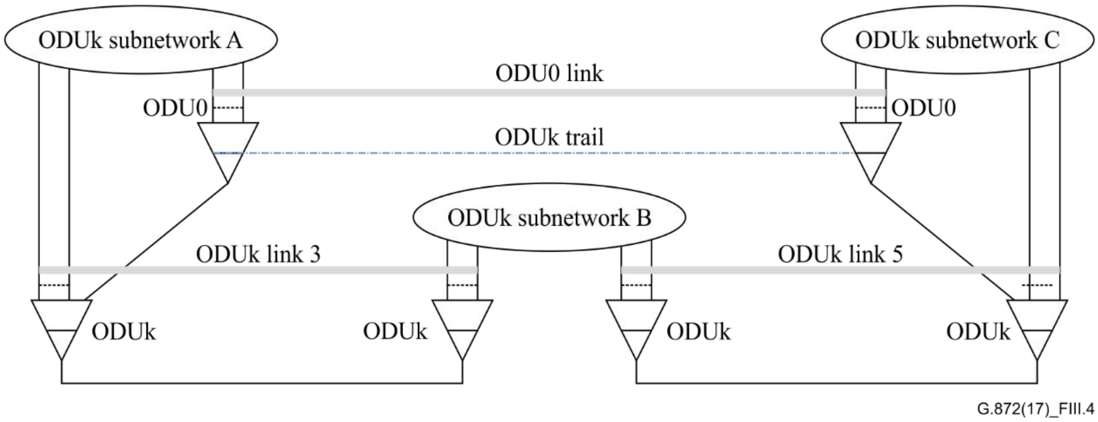


Figure III.4 – ODUj link construction

The ODUk trail supports an ODU0 link, which then appears in an ODUk topology, as shown in Figure III.5.

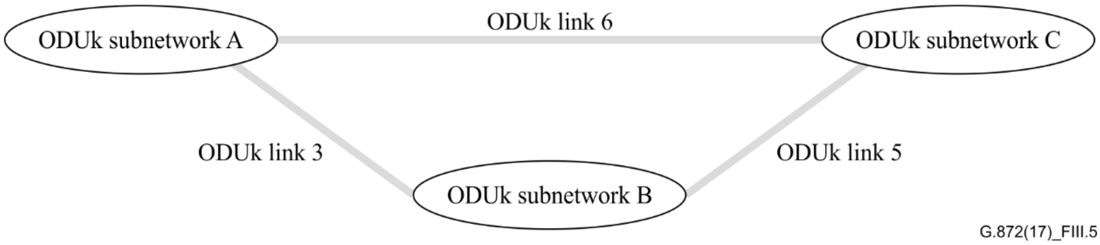


Figure III.5 – Modified ODUk topology

For the ODU0 topology, ODUk subnetwork B and ODUk links 3 and 5 are removed resulting in the ODU0 topology shown in Figure III.6.

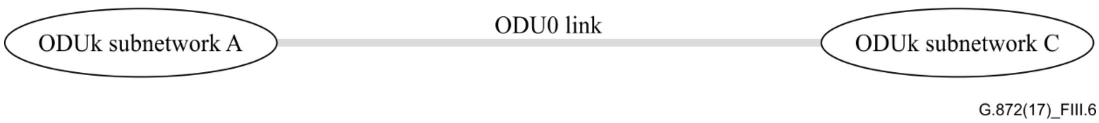


Figure III.6 – ODU0 topology

The topology for other values of k would be as shown in Figure III.7. The capacity of ODUk links 3 and 5 are reduced by the capacity used by the ODU0 link.

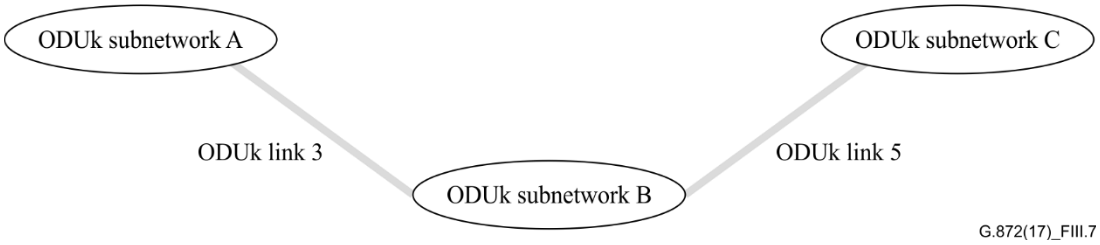


Figure III.7 – ODUk topology

Appendix IV

Examples of multi-domain OTN applications

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

This appendix provides an example of the use of OTN in multi-domains where two disjoint domains in the network of carrier A (domain A1 and domain A2) are interconnected through the network of another carrier (domain B). The interconnection is supported by an ODUk. Carrier A multiplexes several (lower rate) ODUj services into this ODUk. This ODUk may be carried across domain B in several different ways, the following three scenarios illustrate these options.

In scenario 1 shown in Figure IV.1 the ODUk is carried directly by an OTUk in domain B.

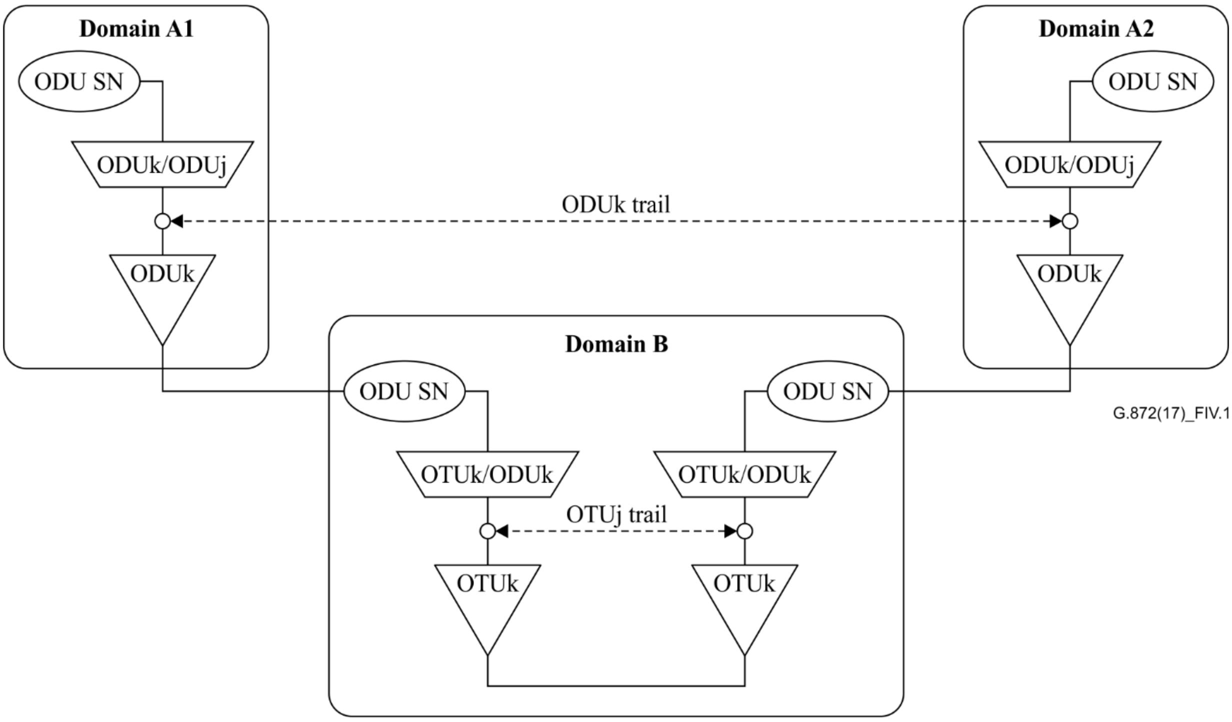


Figure IV.1 – Multi-domain OTN scenario 1

In scenario 2 shown in Figure IV.2 ODUk is carried by a higher rate ODU in domain B.

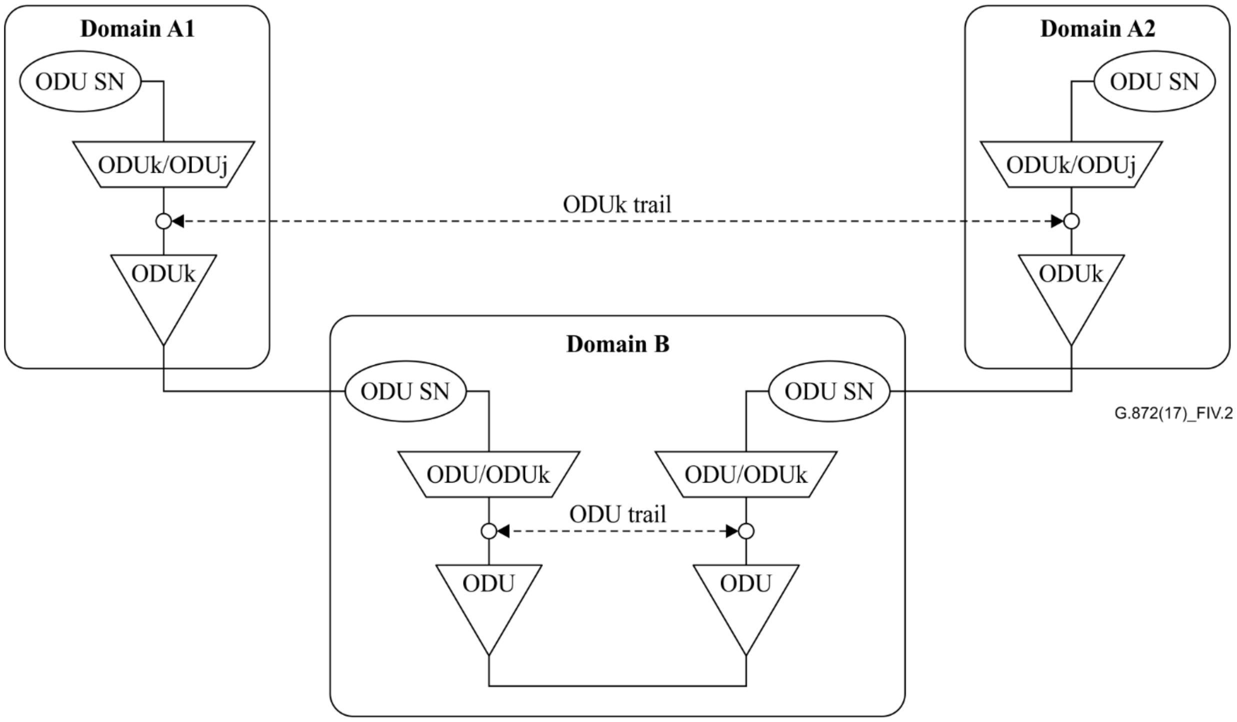


Figure IV.2 – Multi-domain OTN scenario 2

Figure IV.3 illustrates scenario 2 with the addition of TCM in domain B. This allows carrier B to directly monitor the service being provided to carrier A.

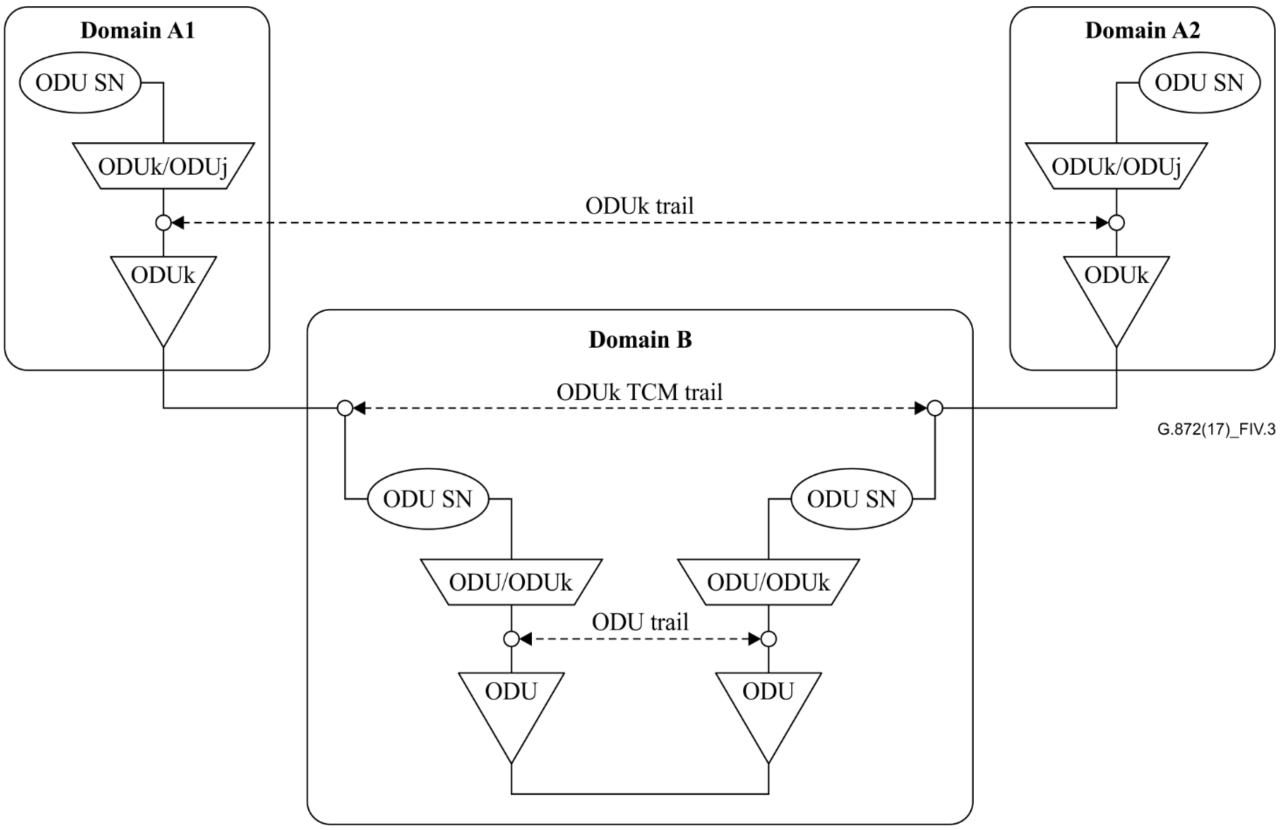


Figure IV.3 – Multi-domain OTN scenario 3

Bibliography

[b-OIF FlexE IA] OIF-FLEXE-2.1 (2019), *Flex Ethernet 2.1 Implementation Agreement*.

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Printed in Switzerland
Geneva, 2021