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

Digital terminal equipments – Other terminal equipment

Types and characteristics of optical transport network equipment

Recommendation ITU-T G.798.1

ITU-T

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Recommendation ITU-T G.798.1

Types and characteristics of optical transport network equipment

Summary

Recommendation ITU-T G.798.1 provides an overview of the functions of optical transport network (OTN) equipment and examples of possible OTN equipment types based on the atomic functions specified in Recommendation ITU-T G.798.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.798.1	2011-04-13	15
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Keywords

Optical transport network.

FOREWORD

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

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

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

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

NOTE

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

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As of the date of approval of this Recommendation, ITU had not 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 provides an overview of the functions of optical transport network (OTN) equipment and examples of possible OTN equipment types. It does not define required OTN equipment types. The Recommendation is based on the OTN atomic functions specified in [ITU-T G.798].

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.703] Recommendation ITU-T G.703 (2001), *Physical/electrical characteristics of hierarchical digital interfaces.*

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

[ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2009), *Interfaces for the optical transport network (OTN).*

[ITU-T G.783] Recommendation ITU-T G.783 (2006), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks.*

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

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

[ITU-T G.806] Recommendation ITU-T G.806 (2009), *Characteristics of transport equipment – Description methodology and generic functionality.*

[ITU-T G.808.1] Recommendation ITU-T G.808.1 (2010), *Generic protection switching – Linear trail and subnetwork protection*.

[ITU-T G.870] Recommendation ITU-T G.870/Y.1352 (2008), *Terms and definitions for optical transport networks (OTN).*

[ITU-T G.872] Recommendation ITU-T G.872 (2001), *Architecture of optical transport networks*.

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

[ITU-T G.874] Recommendation ITU-T G.874 (2010), *Management aspects of optical transport network elements*.

[ITU-T G.7710] Recommendation ITU-T G.7710/Y.1701 (2007), *Common equipment management function requirements*.

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

[ITU-T G.8012.1] Recommendation ITU-T G.8012.1/Y.1308.1 (2012), *Interfaces for the Ethernet transport network.*

[ITU-T G.8021] Recommendation ITU-T G.8021/Y.1341.1 (2012), *Types and characteristics of Ethernet transport network equipment.*

[ITU-T G.8112] Recommendation ITU-T G.8112/Y.1371 (2012), *Interfaces for the MPLS Transport Profile layer network*.

[ITU-T G.8121] Recommendation ITU-T G.8121/Y.1381 (2012), *Characteristics of MPLS-TP equipment functional blocks.*

[ITU-T G.8080] Recommendation ITU-T G.8080/Y.1304 (2006), *Architecture for the automatically switched optical network (ASON)*.

[ITU-T I.112] Recommendation ITU-T I.112 (1984), *Vocabulary of terms for ISDNs*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 adaptation function (A): [ITU-T G.806].

3.1.2 compound function: [ITU-T G.806].

3.1.3 connection function (C): [ITU-T G.806].

3.1.4 defect: [ITU-T G.806].

3.1.5 fault cause: [ITU-T G.806].

3.1.6 function: [ITU-T G.806].

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

3.1.8 ODUk path (ODUkP): [ITU-T G.870].

3.1.9 ODUk TCM (ODUkT): [ITU-T G.870].

3.1.10 optical channel (OCh[r]): [ITU-T G.870].

3.1.11 optical channel data unit (ODUk): [ITU-T G.870].

3.1.12 optical channel payload unit (OPUk): [ITU-T G.870].

3.1.13 optical channel transport unit (OTUk[V]): [ITU-T G.870].

3.1.14 optical channel with full functionality (OCh): [ITU-T G.870].

3.1.15 optical channel with reduced functionality (OChr): [ITU-T G.870].

3.1.16 optical multiplex section (OMS): [ITU-T G.872].

3.1.17 optical physical section of order n (OPSn): [ITU-T G.870].

3.1.18 optical supervisory channel (OSC): [ITU-T G.870].

3.1.19 optical transmission section (OTS): [ITU-T G.872].

3.1.20 optical transport hierarchy (OTH): [ITU-T G.870].

3.1.21 optical transport module (OTM-n[r].m): [ITU-T G.870].

3.1.22 optical transport network (OTN): [ITU-T G.870].

3.1.23 subnetwork connection (SNC): [ITU-T G.805].

3.1.24 switching: [ITU-T I.112].

3.1.25 trail termination function (TT): [ITU-T G.806].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADM	Add-Drop Multiplexer
AIS	Alarm Indication Signal
AMP	Asynchronous Mapping Procedure
BDI	Backward Defect Indication
BDI-O	Backward Defect Indication Overhead
BDI-P	Backward Defect Indication Payload
BEI	Backward Error Indicator
BIAE	Backward Incoming Alignment Error
BMP	Bit-synchronous Mapping Procedure
CBR	Constant Bit Rate signal
COMMS	Communications channel
EEC	Ethernet Equipment Clock
E-NNI	External Network Node Interface
FDI	Forward Defect Indication
FDI-O	Forward Defect Indicator Overhead
FDI-P	Forward Defect Indicator Payload
GMP	Generic Mapping Procedure
HO	High Order
IAE	Incoming Alignment Error
I-NNI	Internal Network Node Interface
IP	Internet Protocol
LCK	Locked indication
LF	Local Fault
LO	Low Order
LOA	Loss Of Alignment
LOF	Loss Of Frame
LOFLANE	Loss of Frame of logical Lane
LOFLOM	Loss Of Frame and Loss Of Multiframe
LOL	Loss of Lane Alignment
LOM	Loss of Multiframe

LOR	Loss of Recovery
LOS	Loss Of Signal
LOS-O	Loss Of Signal Overhead
LOS-P	Loss Of Signal Payload
LSP	Label Switched Path
MPLS-TP	Multiprotocol Label Switching – Transport Profile
MSIM	Multiplex Structure Identifier Mismatch
OAM	Operations, Administration and Maintenance
OCh	Optical Channel
OCI	Open Connection Indication
ODU	Optical Data Unit
OH	Overhead
OLA	Optical Line Amplifier
OMS	Optical Multiplex Section
ONTU	OTN Network Termination Unit
OPS	Optical Physical Section
OTM	Optical Transport Module
OTN	Optical Transport Network
OTS	Optical Transport Section
OTU	Optical Transport Unit
PMI	Payload Missing Indication
PRC	Primary Reference Clock
PTN	Packet Transport Network
SEC	SDH Equipment Clock
SNC	Subnetwork Connection
SNC/S	Subnetwork Connection protection with Sublayer monitoring
SSU	Synchronization Supply Unit
STM-N	Synchronous Transport Module, level N
SWXC	Sub-Wavelength Cross Connect
TDM	Time Division Multiplexing
TIM	Trail trace Identifier Mismatch
UNI	User Network Interface
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
WADM	Wavelength Add-Drop Multiplexer
WDM	Wavelength Division Multiplexing
WXC	Wavelength Cross Connect

5 Conventions

None.

6 OTN layer hierarchy, domains, topology and connections

6.1 Network overview

Figure 6-1 shows a simplified view of an OTN network that consists of two optical domains (identified by the clouds) and showing different types of OTN equipment within those clouds. At the customer premises there may be client nodes, or there may be a client node and an OTN network termination unit (ONTU). Within the service provider domains there are ONTUs, wavelength add-drop multiplexers (WADMs)/cross connects, sub-wavelength cross connects (SWXC), and optical line amplifiers (OLAs).

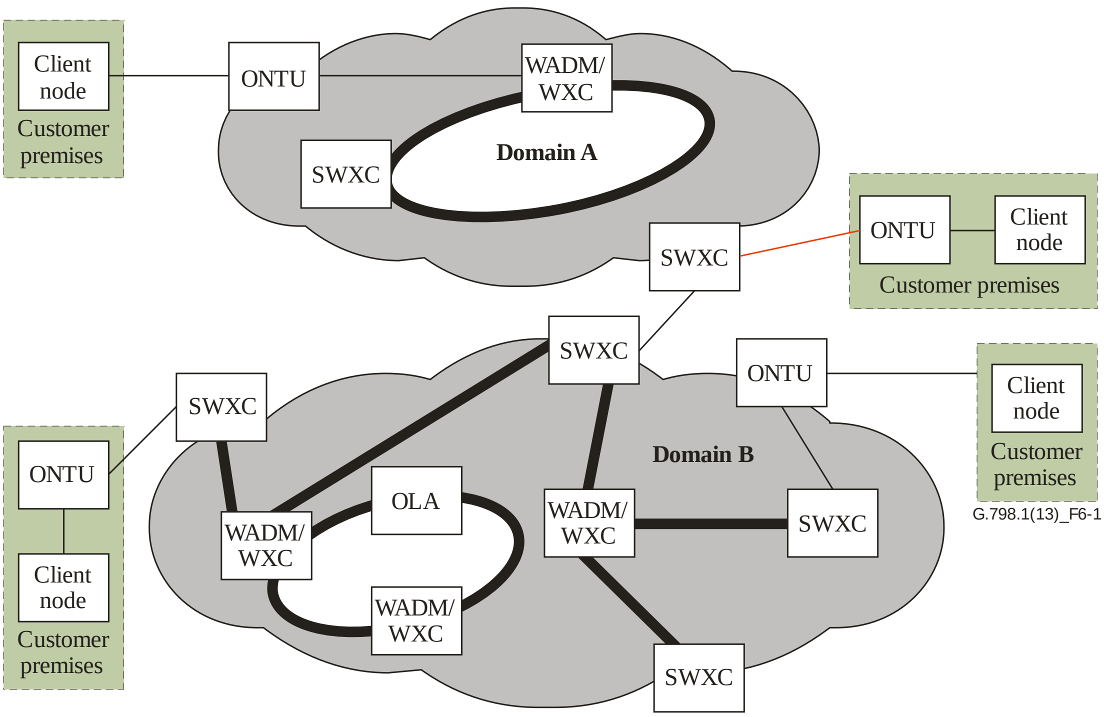


Figure 6-1 – OTN network example

6.2 Layer networks

[ITU-T G.872] decomposes an OTN into four layers: optical channel (OCh), optical multiplex section (OMS), optical transport section (OTS), and physical media. In cases where there is a single wavelength, the OMS and OTS layers are collapsed into a single optical physical section (OPS). The OCh layer is further decomposed into digital section (optical transport unit (OTU)) and digital path (optical data unit (ODU)) sublayers. The ODU layer further supports time division multiplexing (TDM) of lower-speed ODU clients into a server ODU.

For the purposes of this Recommendation, it is convenient to introduce some additional terminology to differentiate the ODU layers when TDM is used: the optical services layer (low order ODU, service ODU, or sub-wavelength), which represents an ODU into which a service is mapped, and the optical path layer (high order ODU, wavelength), which represents an ODU into which low order ODUs are multiplexed. The use of the optical path layer is optional. Further, within this Recommendation, the term optical section is used to refer to either the OMS and OTS layers or the OPS layer.

Figure 6-2 shows how these layers are related to one another. The dashed boxes labelled "Lower layers" indicate that the detail of the layers below the application services layer or the optical services layer are not included in the figure; the lower layers that are present will depend on whether the service ODU begins on the customer or network side of the UNI.

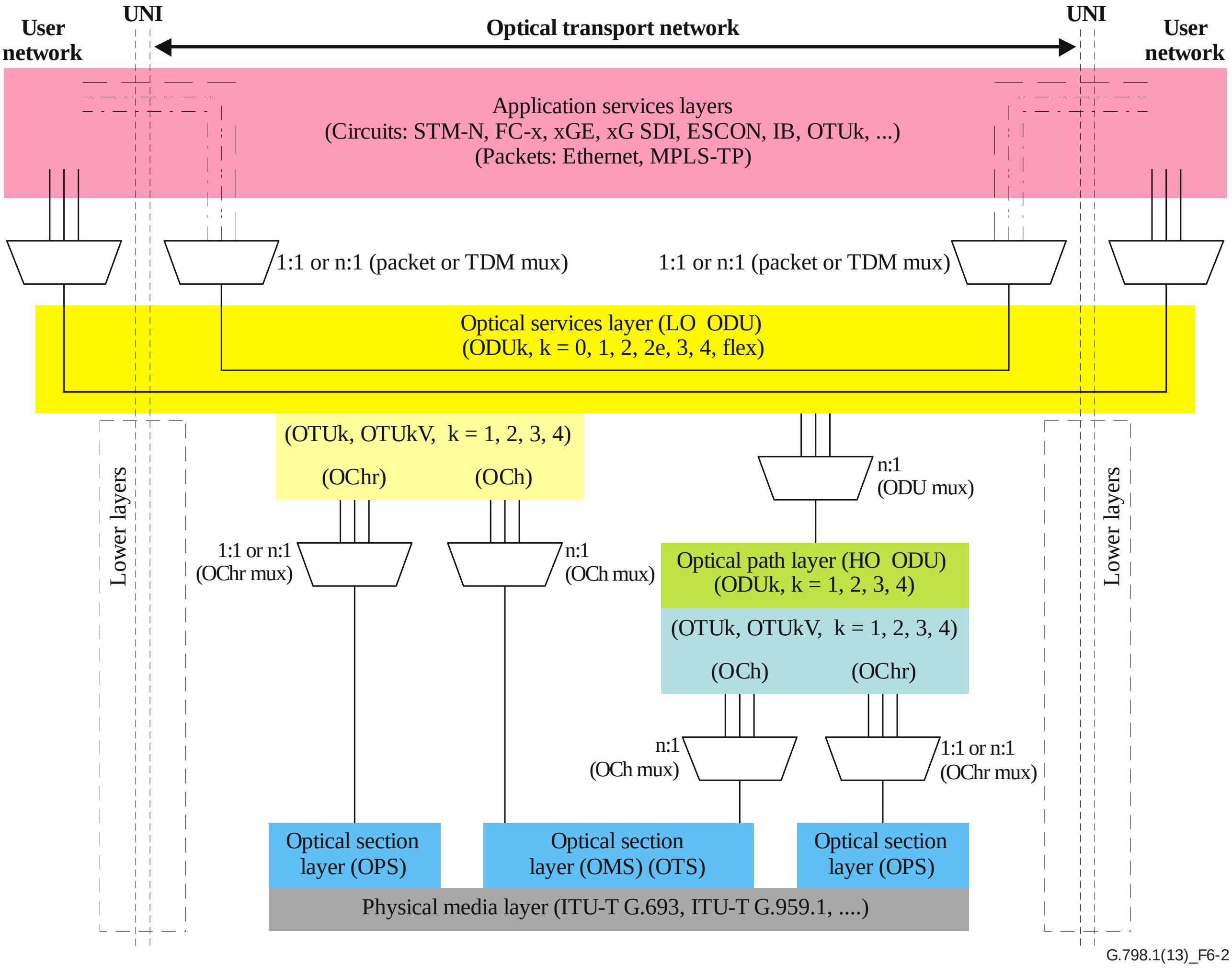


Figure 6-2 – OTN network layer stack example

These layer networks are depicted from the viewpoint of network management, however other perspectives are possible. OTN network management manages the OTM-n physical media connections, optical section connections, optical path connections and optical services connections. An OTU or OCh connection is always 1-to-1 related to an ODU network connection (in the case of no 3R regeneration or optical cross-connection) or link connection (in the case where 3R regeneration or optical cross-connection occurs between ODU endpoints).

6.2.1 Application services layer

The application services layer network instance is the client of the OTN. Details of this layer are outside the scope of this Recommendation. Client signals may be constant bit rate circuit signals like STM-N, 802.3 Ethernet, fibre channel, and high definition SDI, or packet signals like Ethernet VLANs, MPLS-TP LSPs and IP VPN or Internet.

6.2.2 Optical services layer

The optical services layer network instance provides point-to-point and point-to-multipoint transport network services. Those services are supported by means of an ODU connection, which carries a single instance of the client service. From the perspective of this network, the ODU in the optical services layer is referred to as a low order ODU (LO ODU). The optical services layer network provides OAM for inherent monitoring of the client service. The structure of the client service may comprise a single client signal, a bundle of such client signals or a port-based client signal.

Client signals may be mapped into ODU signals within the bounds of the optical transport network, or outside those bounds and inside the user network.

In situations where a service transits multiple domains (or operators), the optical services layer of Domain A may also be the optical services layer of Domain B as well (peering relationship). Alternatively, the optical services layer of Domain A may be multiplexed to an optical path layer in Domain B (client/server relationship). The optical services layer in Domain A may also be multiplexed to an optical path layer within Domain A.

6.2.3 Optical path layer

The use of an optical path layer is optional. It is only present when time-division multiplexing of ODUs from the optical services layer into a wavelength is required. The optical path layer is supported by an ODU connection (at a higher rate than that of the ODUs supporting the optical services layer). From the perspective of the network in which is exists, the ODU supporting the optical path is referred to as a high order ODU (HO ODU).

The optical path layer network establishes the point-to-point optical service layer links (i.e., LO ODU layer topology) in metro and core subnetwork domains. Those links are supported by means of a point-to-point ODU connection, which starts/ends at the edges of metro domains. The optical path layer network instance provides OAM for monitoring, which may also be used to trigger protection within the optical path layer or optical service layer compound link SNC group protection switching, as specified in [ITU-T G.808.1].

In situations where a service transits multiple domains (or operators), the optical path layer of Domain A is the optical services layer for Domain B. Within Domain B, the operator may perform further time-division multiplexing of the Domain B optical services layer into an optical path layer within Domain B.

6.2.4 OTU and OCh layers

The OTU layer provides the digital section layer that allows monitoring of the OCh. The OCh is the individual optical channel. There is always a 1:1 association between an OTU and OCh, and these two layers always terminate at the same location. From the perspective of the OTU layer, there is no difference between HO and LO ODUs; the mapping of either type of ODU onto an OTU/OCh is identical. The OTU layer establishes the point-to-point ODU layer links.

6.2.5 Optical section layers

The optical section layer network consists of either the OPS layer network, or the OMS/OTS layer networks.

The OPS layer network provides the capability to monitor the physical media layer point-to-point connections for a loss of signal condition and establish point-to-point OCh layer links. Those links carry one or more ODU signals between OTN network nodes.

The OMS/OTS layer network provides the capability to monitor the physical media layer point-to-point connections and establishes the point-to-point OCh layer links (OCh layer topology). Those links carry one or more ODU signals between OTN network nodes. Those links and their monitoring are supported by means of a point-to-point OMS connection, which starts/ends typically at wavelength or sub-wavelength cross-connects. An OMS connection is supported by means of one or more OTS connections that start/end at the same points where the physical media layer connection starts/ends.

6.2.6 Physical media layers

The Physical media layer network provides the fibre interconnection between OTN systems. Details of this layer are outside the scope of this Recommendation.

6.3 OTN OAM functions

The optical transport network supports ITU-T G.709-based OTN OAM in each of the OTN layer networks. In the optical path and optical services layers, ODU trail termination functions are present; optionally, ODU tandem connection monitors and/or end-to-end non-intrusive monitor functions may be present. For ODUs that are mapped onto wavelengths, OTU and OCh trail termination functions are also present. Trail termination functions are also present in the optical section layer (either OMS and OTS, or OPS).

Figure 6-3 shows an example with several different types of network elements and the OAM functions that are present in each. In this figure, there are no tandem connection functions present, but such functions could be added to the ODU layers.

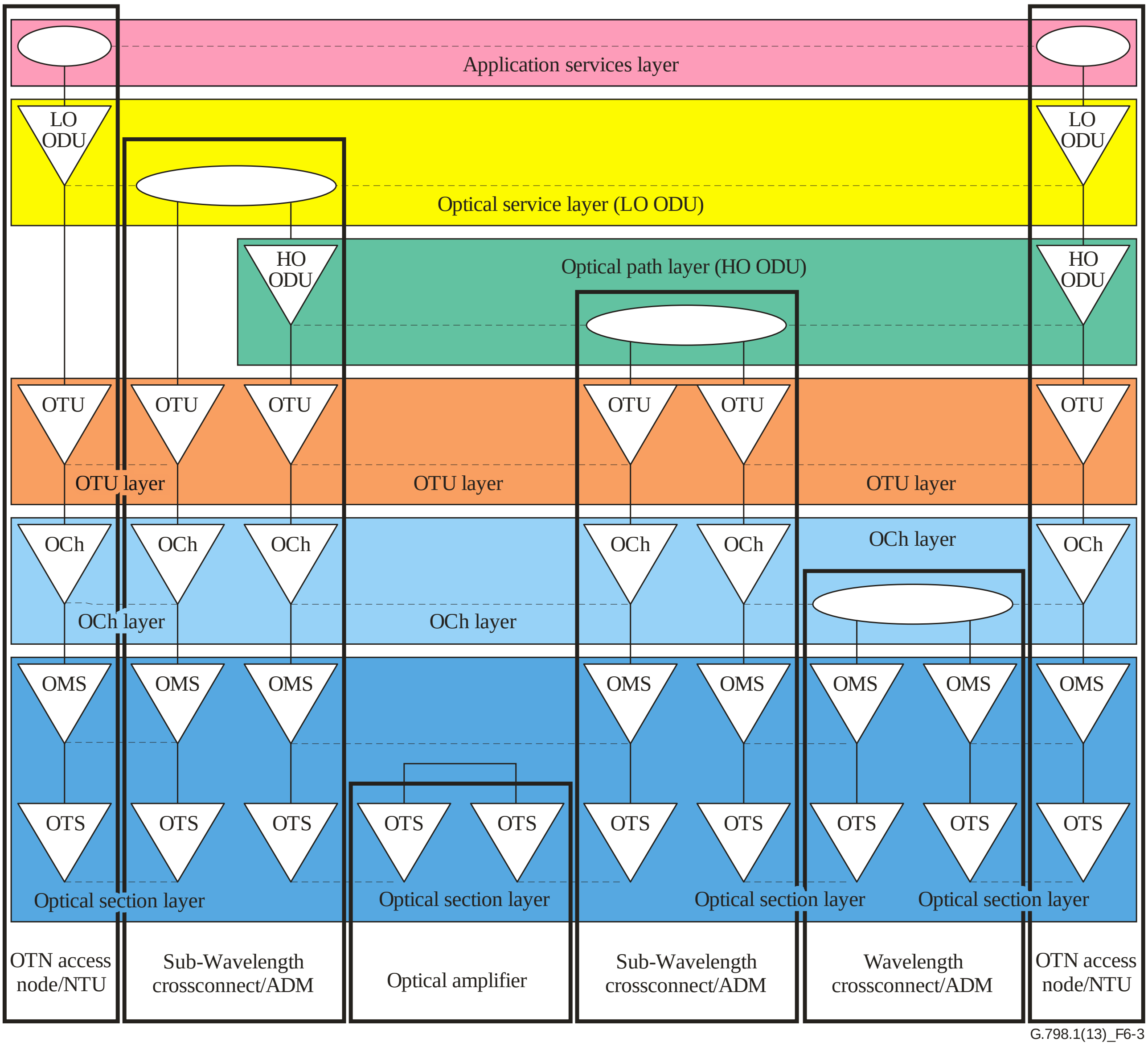


Figure 6-3 – Example of an OTN layer stack showing OAM entities

7 Operations, administration, maintenance and provisioning

7.1 OAM applications

[ITU-T G.709] specifies bandwidth allocated within the OPUk, ODUk, OTUk, OCh, OMSn and OTSn characteristic and adapted information for various control and maintenance functions. Seven types of overhead for OAM are identified: OPUk overhead, ODUk overhead, OTUk overhead, OCh overhead, OMS overhead, OTS overhead and COMMS overhead. [ITU-T G.798] specifies the processing of this overhead.

7.1.1 OPU, ODU, OTU and OCh OAM application

The functions of the OPU, ODU, OTU and OCh overhead include pro-active and on-demand fault management, performance monitoring, protection switching, embedded communications channels, and ODU maintenance and operation functions.

The OPU and ODU overhead is generated and terminated at the point where the payload is assembled or disassembled. It is used for end-to-end monitoring of the payload and may transit several switching systems. Some of the OPU and the ODU overhead is completely payload independent, while other parts of the OPU overhead are used in specific ways according to the type of payload. The ODU overhead may be monitored at any point within an ODU network to confirm network operation.

NOTE – ODU AIS/OCI/LCK and OCh FDI maintenance signals are generated at intermediate points along the ODU connection.

Additional levels of ODU overhead may also be generated and terminated at administrative domain boundaries and at protected domain boundaries to provide those domains with dedicated ODU monitoring capabilities. These are referred to as tandem connections. Six layers of tandem connections are possible per [ITU-T G.709].

If the ODU is carried over a wavelength or over an OTM-0, OTU overhead will be deployed to monitor the ODU link connection supported by the OCh trail. The OCh trail supports maintenance signals for alarm suppression and open connection indications, but no further overhead to support fault management, performance monitoring or protection switching.

7.1.2 OMS, OTS, OPS, OPSM and COMMS OAM application

The functions of the OMS, OTS, and COMMS overhead include pro-active fault management and optical section maintenance and operation functions for a single owner of an optical section.

The OPS and OPSM do not support any overhead; monitoring of the OPS and OPSM is delegated to monitoring of the individual OTU or OTUs carried by it.

The optical section overhead is subdivided into optical amplifier section overhead (OTS OH) and optical multiplex section overhead (OMS OH). The OMS OH is accessible only at terminal equipment, whereas the OTS OH is accessible at both terminal equipment and optical amplifiers.

The OMS overhead is generated and terminated at the point where the OCh signals are multiplexed or demultiplexed. It is used for end-to-end monitoring of the OCh/ODU aggregate.

NOTE – OMS FDI maintenance signals are generated at intermediate points along the OMS connection.

The OTS, OMS, and COMMS overhead is carried out of band in the optical supervisory channel (OSC).

7.1.3 Maintenance signals

The maintenance signals defined in [ITU-T G.709] provide network connection status information in the form of payload missing indication (PMI), backward error and defect indication (BEI, BDI), open connection indication (OCI), and link and tandem connection status information in the form of locked indication (LCK) and alarm indication signal (forward defect indication (FDI) and alarm indication signal (AIS)). Figures 7-1 and 7-2 illustrate the layer-to-layer and peer-to-peer maintenance interaction provided by OTN OAM. At the generation points where multiple arcs are shown, the arcs pointing to the right indicate signals that are transmitted out of the type of equipment listed to the right of the diagram; the arcs that point in a downward direction to other generators show the propagation of signals between layers (e.g., at the open circle where OMS FDI-P originates, there are two arcs, one that goes to the right, indicating that this signal is transmitted out of an optical amplifier, and one that goes downward, indicating the propagation to the next layer for other equipment types).

NOTE – These figures provide a consolidated view of the maintenance signalling behaviours that are specified by the atomic functions in [ITU-T G.798]. In the event of a conflict between these figures and the atomic functions in [ITU-T G.798], the description in the atomic functions takes precedence.

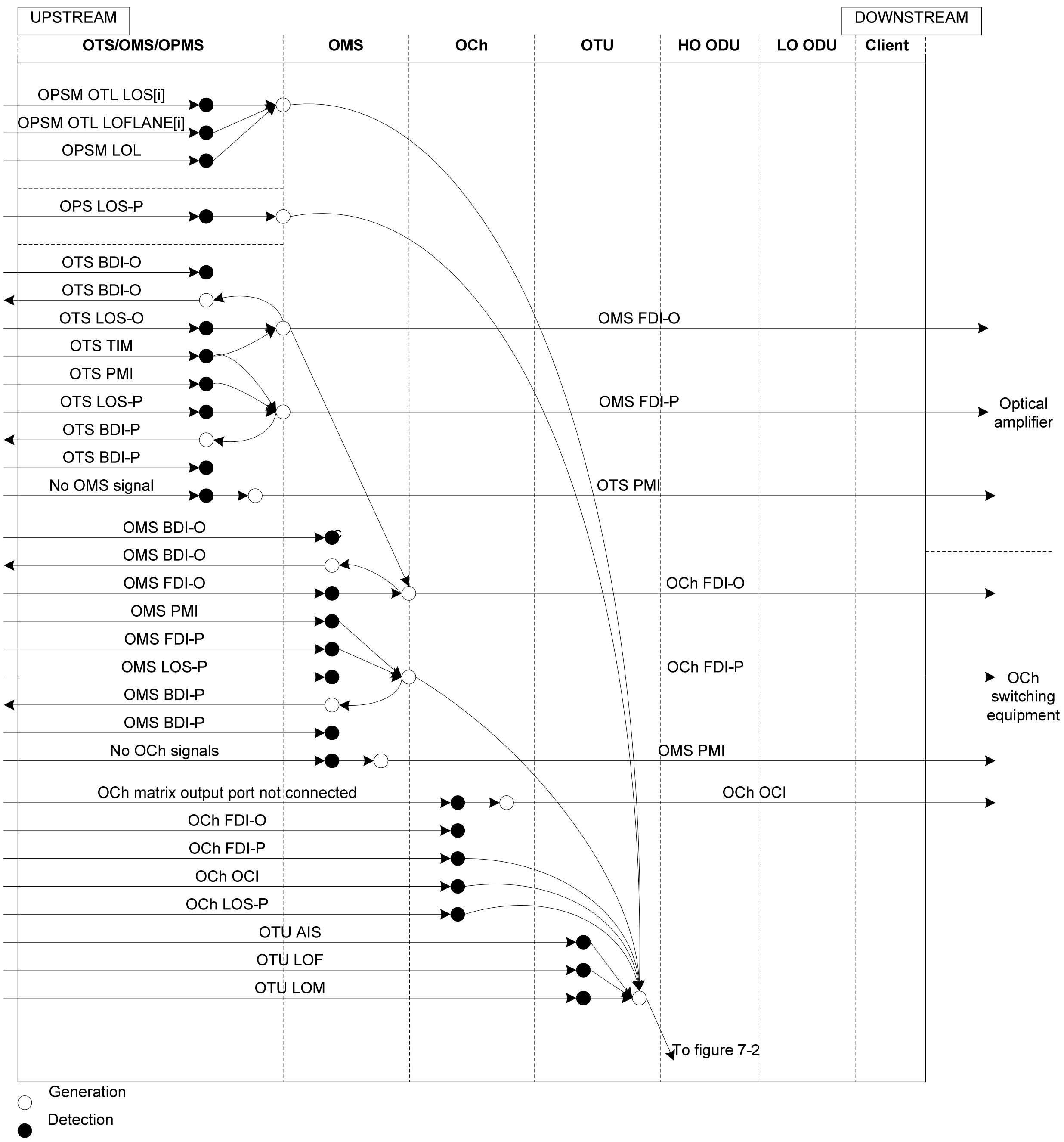


Figure 7-1 – OTN maintenance signal interaction (Part I)

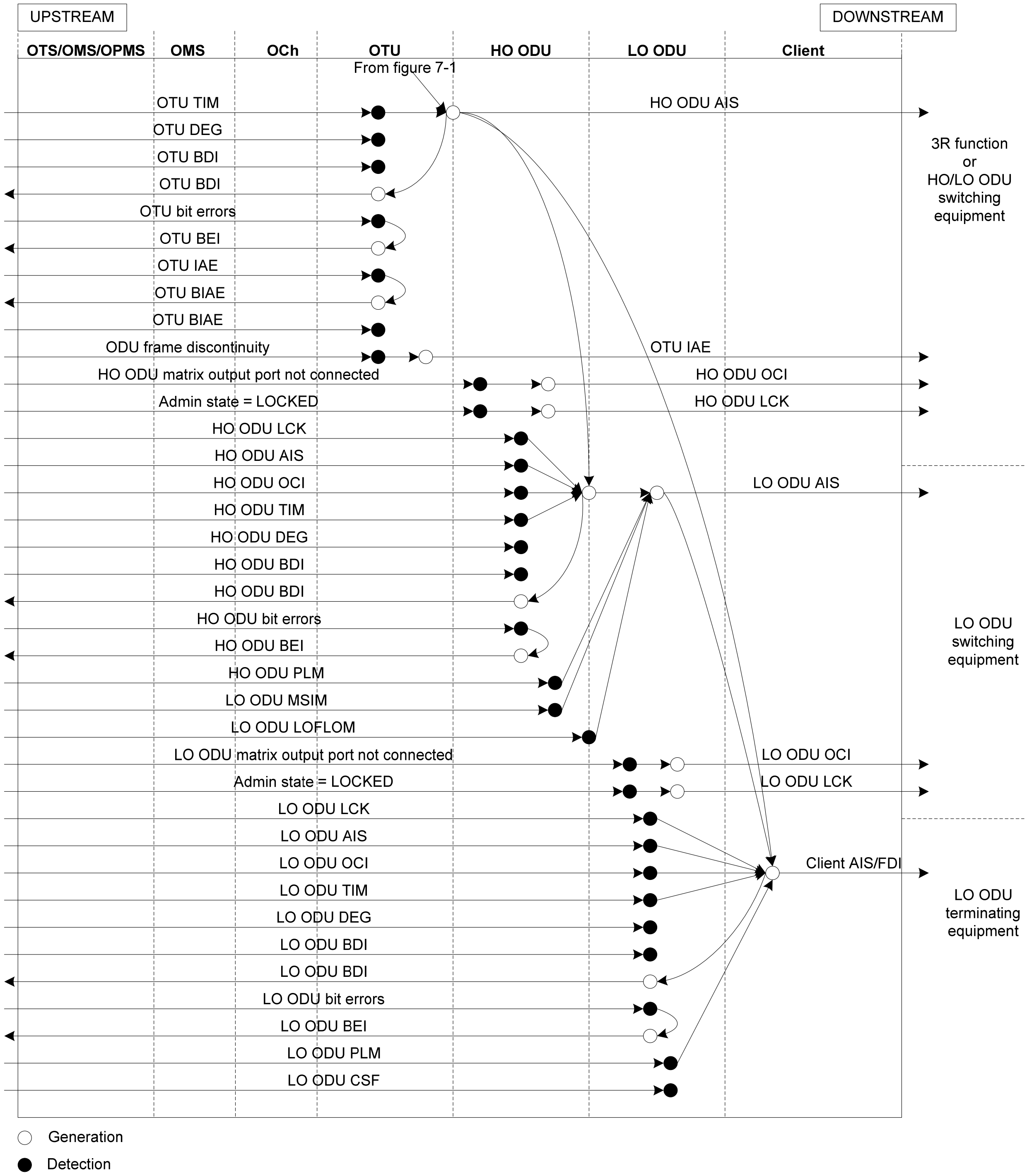
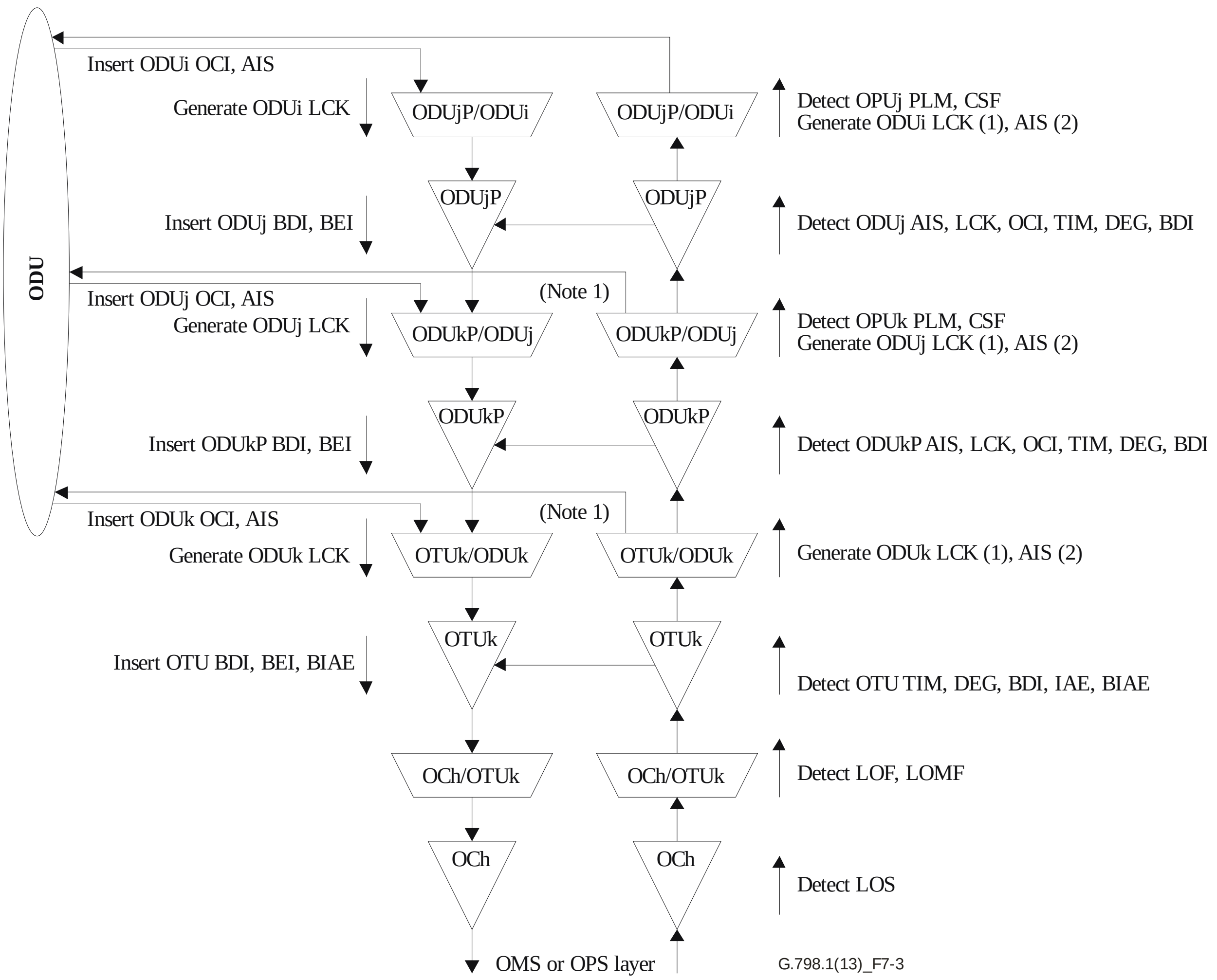


Figure 7-2 – OTN maintenance signal interaction (Part II)

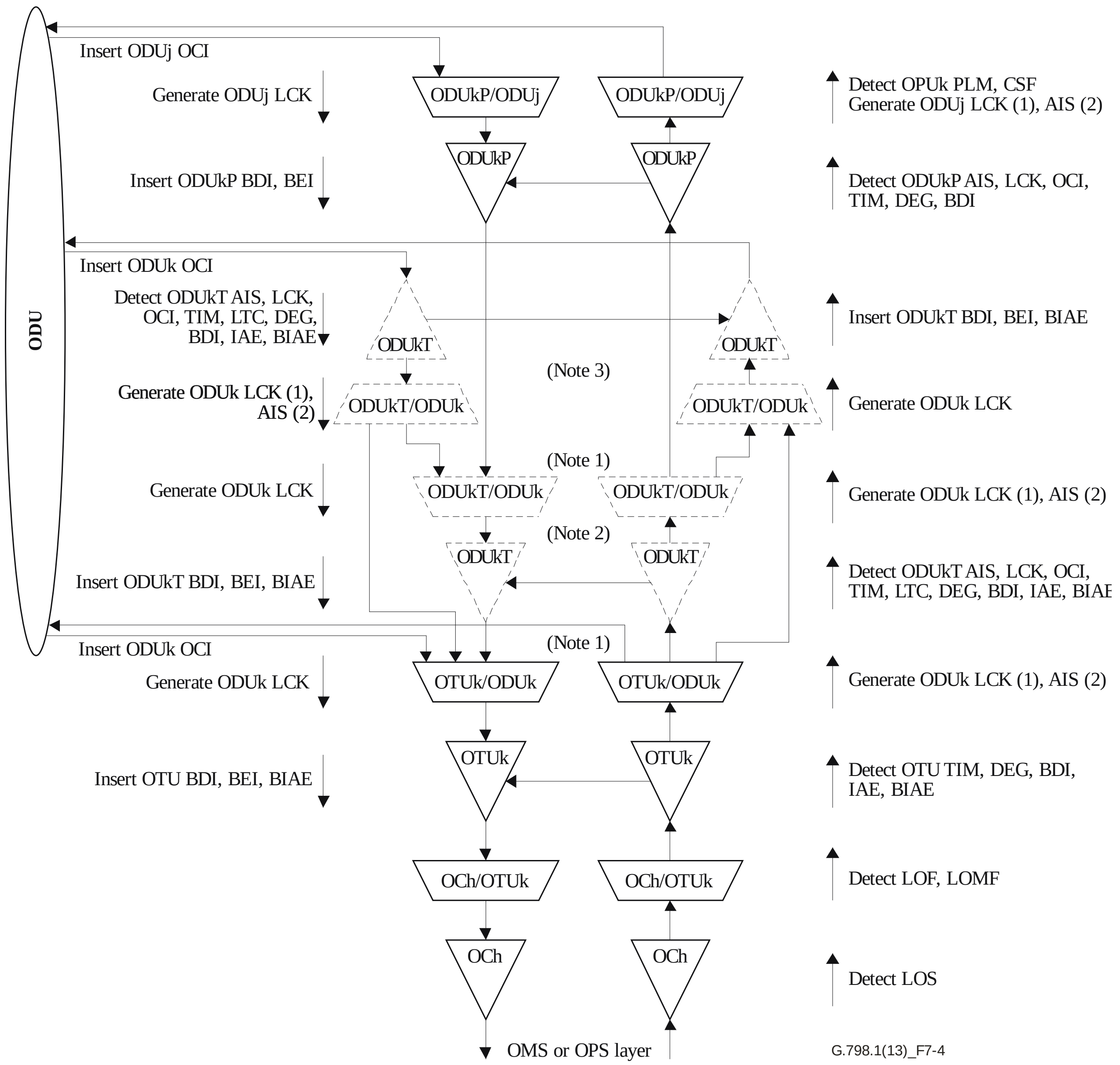
Figure 7-3 below provides an example of the ITU-T G.798 atomic functions in an OTN NE two stages of ODU multiplexing, followed by the OTUk and OCh adaptation/termination functions. Figure 7-4 provides an example with one stage of ODU multiplexing that includes tandem connection monitoring functions.

Identified beside each of the atomic functions are the maintenance signals detected and generated at those points. Where the generation of more than one maintenance signal is possible, numbers indicate their relative priority (e.g., Generate ODUk LCK (1), AIS (2) means that ODUk LCK generation overrides ODUk AIS generation).



NOTE 1 – From the OTUk/ODUk_A or ODUkP/ODUj_A functions the signal may either be connected to the ODU_C function or to the ODUkP_TT or ODUjP_TT function, respectively. In the case that the signal connects to the ODU_C function, it is also possible to have an ODUkP_TT_Sk or ODUjP_TT_Sk, respectively, for the purpose of non-intrusive monitoring.

Figure 7-3 – Example of maintenance signal detection/generation points with two stages of ODU multiplexing



NOTE 1 – From the OTUk/ODUk_A or ODUkT/ODUk_A functions only one of the paths shown is followed, based on network element configuration.

NOTE 2 – The tandem connection (ODUkT) sublayer that is monitoring the incoming signal is optional. It may be present zero to six times.

NOTE 3 – The tandem connection (ODUkT) sublayer that is monitoring the signal from the ODU_C function is optional. It may be present zero to six times.

Figure 7-4 – Example of maintenance signal detection/generation points with tandem connection monitoring

Within the ODU layer, there are interactions between the AIS, OCI, and LCK maintenance signals that occur across multiple atomic functions. The figures below illustrate several examples of these interactions.

Figure 7-5 shows an ODU that is not cross-connected and is also administratively locked. In this case the OCI signal that is generated by the ODU_C function for the unconnected ODU is overwritten by the LCK signal generated in the srv/ODUk_A_So function.

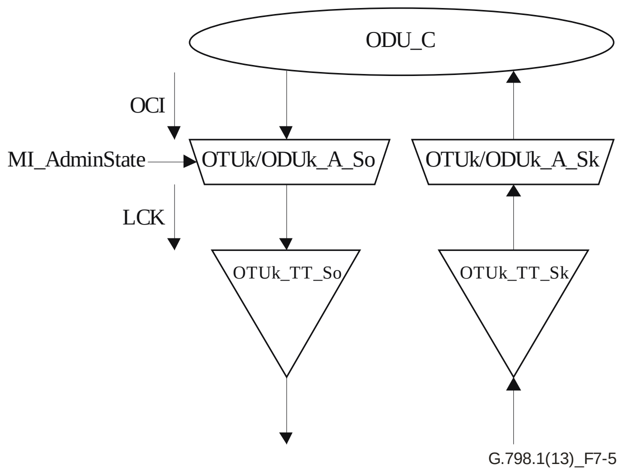


Figure 7-5 – ODU layer interaction between OCI and LCK maintenance signals

Figure 7-6 shows a cross-connection between two ODUs. One port has a failure, and as a result the srv/ODUk_A_Sk function is inserting AIS. The other port is administratively locked. In this case the AIS signal is overwritten by the LCK signal generated in the srv/ODUk_A_So function.

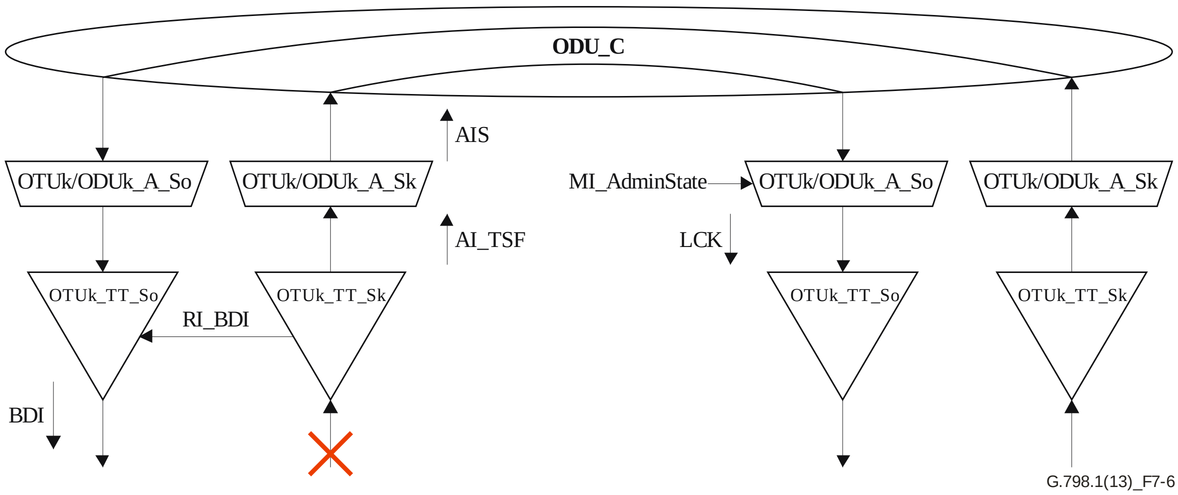


Figure 7-6 – ODU layer interaction between AIS and LCK maintenance signals

Figures 7-7 and 7-8 show examples that include the termination of a tandem connection. In this example, the incoming signal has either the OCI or LCK maintenance signal. This is detected by the ODUkT_TT_Sk function, and the AI_TSF signal is asserted as a result. The ODUkT/ODUk_A_Sk function inserts AIS in response to AI_TSF, so the incoming OCI/LCK is replaced with AIS. At a network level, this means that the OCI/LCK is confined to the tandem connection in which it occurs; any tandem connections that have larger scope, and the end-to-end ODUkP, will see AIS (i.e., a server layer failure).

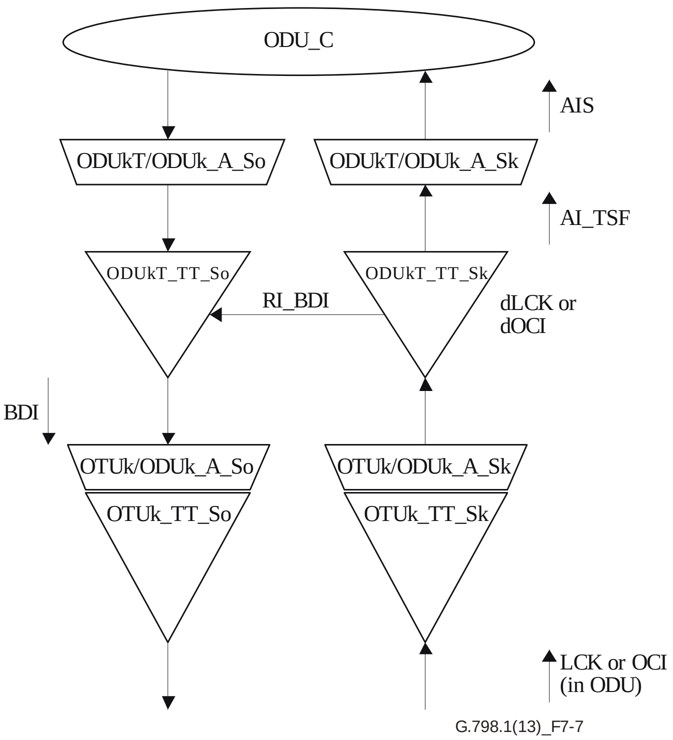


Figure 7-7 – OCI/LCK/AIS interaction with tandem connection endpoints (1)

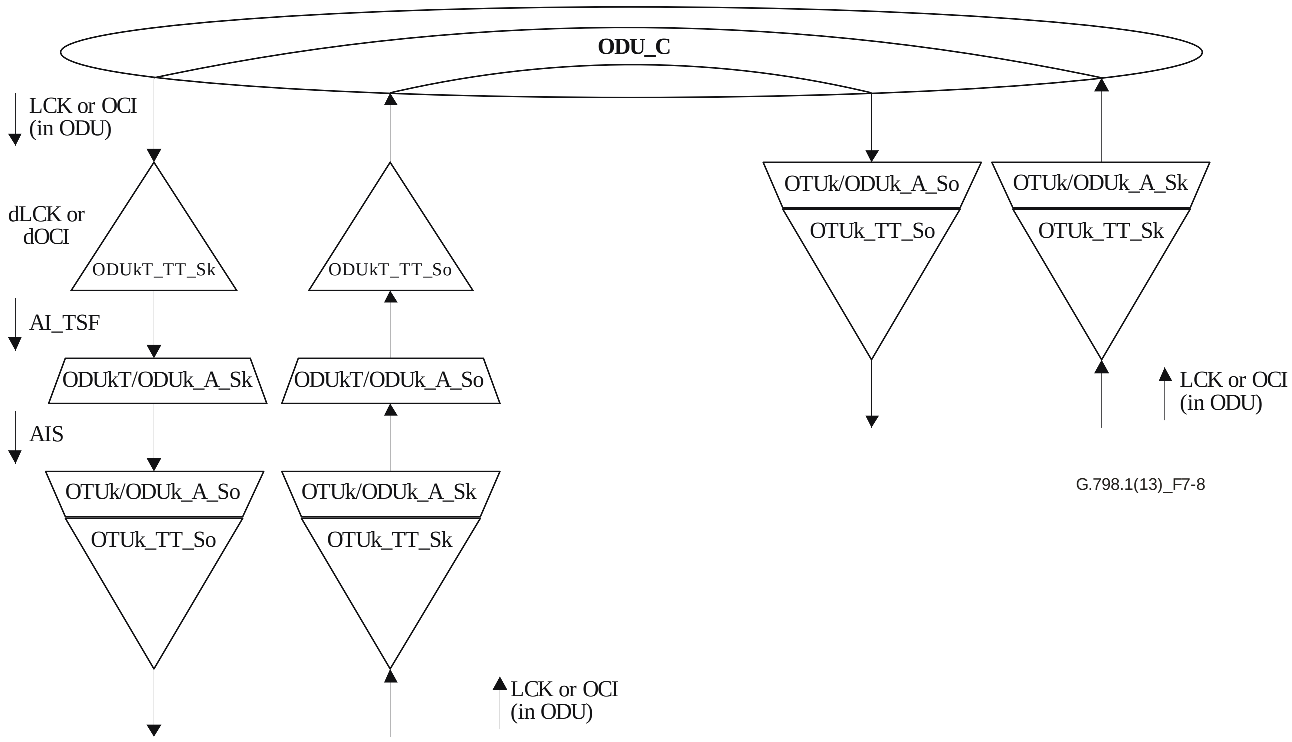


Figure 7-8 – OCI/LCK/AIS interaction with tandem connection endpoints (2)

When multiple tandem connection sublayers are in use, there are maintenance signal interactions between tandem connections that are concatenated in the same sublayer and between tandem connections that are in different sublayers. The next several figures illustrate two examples of these interactions. Figure 7-9 shows an example network with two layers of tandem connections, and indicates the status information for the PM, TCM1, and TCM2 overhead that is seen on each link.

The interpretation of the status values is defined by Tables 15-3 and 15-5 of [ITU-T G.709]; the values used in these examples are summarized in Table 7-1 for convenience.

Table 7-1 – ODUk PM and TCM status interpretation

PM or TCM bits 6 7 8	PM Status	TCM Status
0 0 0	(value reserved for future standardization)	TCM level not in use
0 0 1	Normal path signal	TCM level in use, no IAE
1 0 1	LCK	LCK
1 1 0	OCI	OCI
1 1 1	AIS	AIS

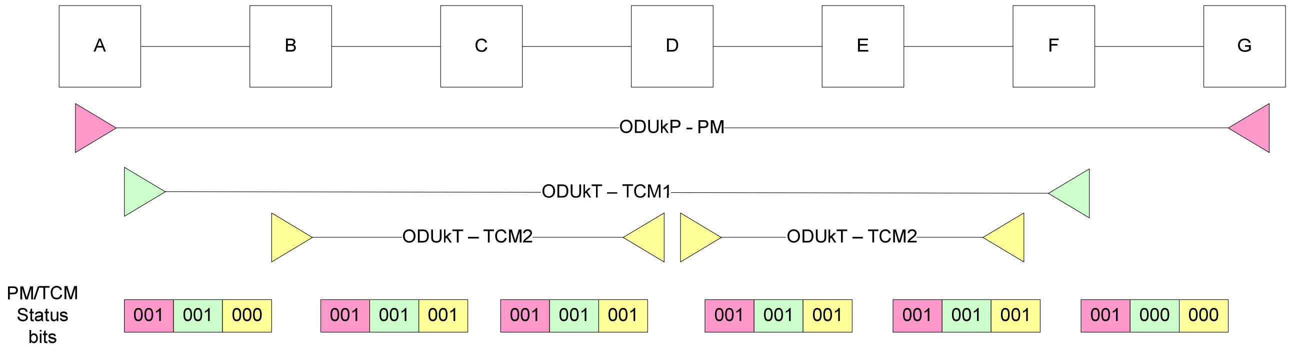


Figure 7-9 – Example network with two tandem connections sublayers in use

Figure 7-10 considers the case where there is a link failure within one of the level 2 tandem connections, and shows how the overhead for the concatenated connection at level 2 replaces the AIS maintenance signal with a 'normal' status. In this scenario, Node C detects the failure and inserts AIS in the PM and all TCM overheads. At Node D, the tandem connection at level 2 is terminated and new level 2 tandem connection is started. As such, Node D extracts the TCM2 overhead it receives from Node C, and initiates new TCM2 overhead toward Node E. Figure 7-11 shows the atomic functions for Node D.

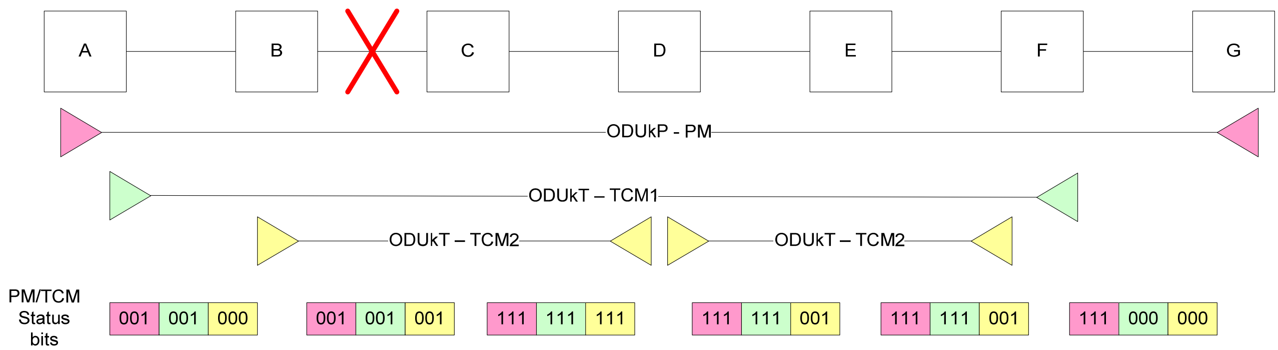


Figure 7-10 – Maintenance signalling due to link failure with two tandem connections

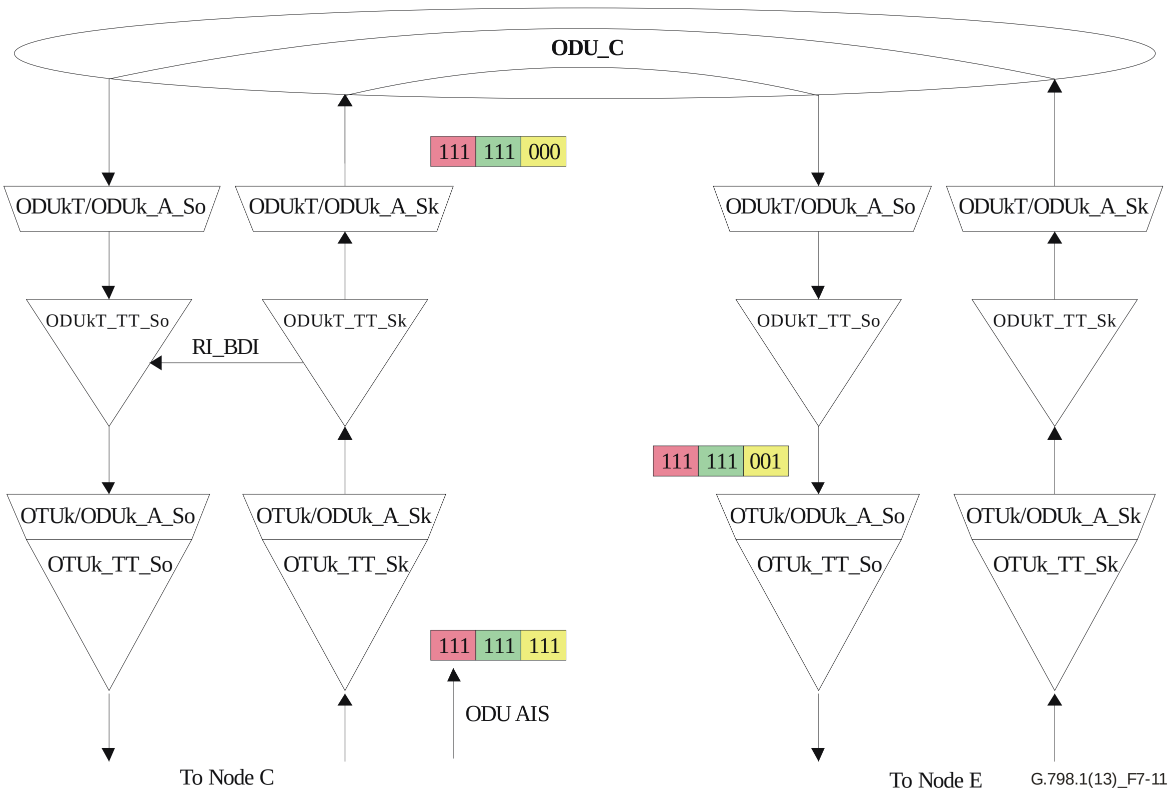


Figure 7-11 – Atomic function view of Node D in Figure 7-10

Figure 7-12 shows a network level example related to the behaviour described in Figures 7-7 and 7-8. In this example the cross-connection in Node B has been disconnected, causing Node B to insert the OCI maintenance signal in the PM and all TCM overheads. As there are no tandem connections that terminate in Node C, the OCI signal passes through unmodified. At Node D, the TCM2 overhead is extracted and processed, and as a result AIS is inserted in the PM and TCM1 overheads. The TCM2 overhead is then overwritten when the concatenated tandem connections starts, as in the previous example.

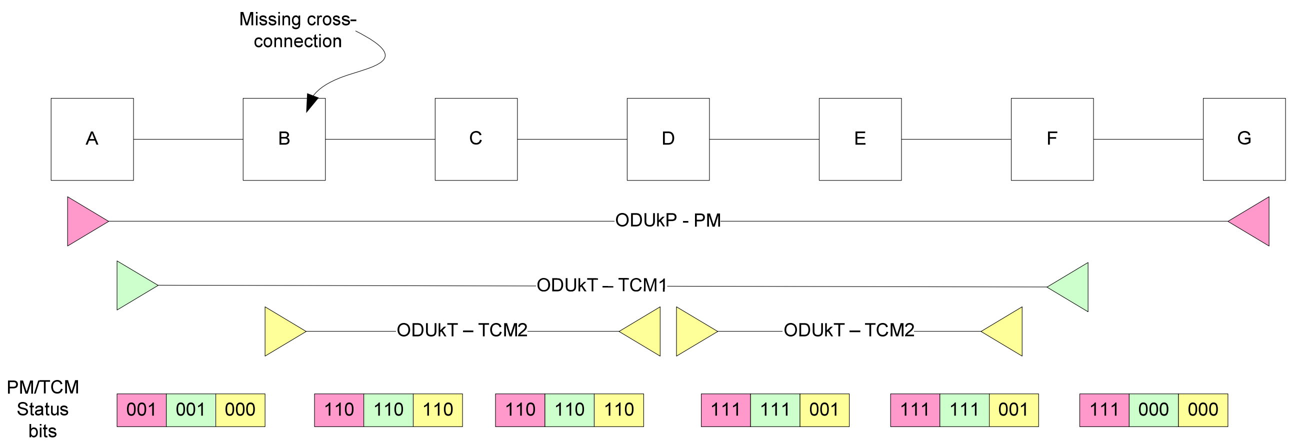


Figure 7-12 – Maintenance signalling due to open connection with two tandem connections

7.1.4 Fault and performance reports

Details of the fault and performance reporting functions are provided in [ITU-T G.798], [ITU-T G.874], and [ITU-T G.7710].

The fault management functions include fault and degradation detection, correlation, persistency filtering and reporting. Only the fault report representing the root cause is presented to network management. Fault reporting at client layers or sublayers above the (sub)layer with the fault is suppressed by forwarding detected signal fail conditions. Within one network element this is provided via the chain of trail signal fail (TSF) and server signal fail (SSF) signals. Between network elements, this is provided via the transmission of Forward Defect Indicator (FDI) and alarm indication signal (AIS) maintenance signals (see Figures 7-1 and 7-2).

Service management requires status information on an individual service basis. For the OTN, this is on an individual LO ODU basis. Suppression – for fault management – of fault reporting at client layers or sublayers due to a fault on a server layer, prevents by default the pro-active reporting of the interruption of the service to the service manager. To support service management, an additional pro-active SSF report is provided. This is configurable per service instance. Service management may instead have the ability to reactively request the status of the service connection at its endpoints when the customer makes inquiries.

A fault in a connection itself (e.g., a configuration fault) may occur. Reporting of such faults is not suppressed. In addition, degradation (e.g., bit errors) in a connection itself may occur. Such degradation can be detected; its sensitivity and detection period is configurable with default values, causing detection before entering unavailable time. This allows protection switching to switch to the standby subnetwork connection and thus prevent the service from becoming unavailable.

The performance monitoring functions include errored second, severely errored second, unavailable time and background block error reporting. There are maintenance and service performance monitoring functions, which are configurable per connection. Each second with an interruption or bit errors is counted in 15-minute and 24-hour intervals. For details refer to [ITU-T G.7710]. Counts of errored seconds represent the number of seconds in the interval in which there were bit errors detected, while there was no unavailable time and no signal fail condition. Counts of severely errored seconds represent the number of seconds in the interval in which there was a signal failure condition or there were more than a configured number of bit errors detected, while there was no unavailable time. Unavailable time starts at the first second of ten successive severely errored seconds, and ends at the first second of ten successive not severely errored seconds. Counts of background block errors represent the number of errored blocks detected outside severely errored seconds and unavailable seconds.

The ES, SES, BBE counters are equipped with configurable threshold crossing report capability, which pro-actively reports the presence of an excessive condition.

Performance reporting is independent of fault reporting, i.e., not impacted by fault report suppression.

7.2 TMN access

OTN equipment should provide interfaces for messages to or from the TMN via the COMMS, GCC, or a Q interface. Messages arriving at the interface not addressed to the local equipment should be relayed to the appropriate Q, GCC, or COMMS interface. The TMN can thus be provided with a direct logical link to any OTN equipment via a single Q interface and the interconnecting GCC or COMMS interfaces. OTN equipment may be located behind a third party network; for such cases the OTN equipment should provide interfaces for messages to or from the TMN via either a GCC or a Q interface or both.

7.2.1 Q interface

When access to the TMN is provided by a COMMS, GCC or Q-interface, the interface will conform to [ITU-T G.874].

7.2.2 Embedded communications channels (ECC)

Embedded communications channels may be used in support of management communications (MCC) and/or signalling communications (SCC). The use of the ECCs is dependent on the network operator's maintenance strategy and the specific situation. It may not always be required as it is possible to carry out the required functions by other means.

There are two types of ECCs:

i) the COMMS located in the OTN non-associated overhead accessible at NEs within the network operator's domain, but not accessible at remote NEs;

ii) the GCC located in the OTU overhead (GCC0) and/or the GCCs located in the ODU overhead (GCC1, GCC2), which are accessible within the network operator's domain and also may be accessible at remote NEs.

These channels are message based and provide communications between network elements. They can be used to support communications between sites and the TMN. Further information is given in [ITU-T G.874] and [ITU-T G.7712].

7.2.3 Equipment management function (EMF)

This converts performance data and implementation-specific hardware alarms into object-oriented messages for transmission on the MCC(s) and/or a Q-interface. It also converts object-oriented messages related to other management functions for passing across the MP reference points.

7.2.4 Message communication function (MCF)

This function receives and buffers messages from the MCC(s), Q- and F-interfaces and EMF. Messages not addressed to the local site are relayed to one or more outgoing MCC(s) and Q-interfaces in accordance with local routing procedures and/or Q-interface(s). The function provides layer 1 (and layer 2 in some cases) translation between a MCC and a Q-interface or another MCC interface.

7.3 Timing function

The OTN does not require any synchronization functionality. The OTN – specifically the mapping/demapping/desynchronizing and multiplexing/demultiplexing processes and justification granularity information – is designed to transport synchronous client signals, like synchronous STM-N and synchronous Ethernet signals. When these signals are bit synchronously mapped into the ODUk (using BMP), this ODUk will be traceable to the same clock to which the synchronous client signal is traceable (i.e., PRC, SSU, SEC/EEC and under a signal fail condition of the synchronous client the AIS/LF clock). When those signals are asynchronously mapped into the ODUk (using AMP or GMP), this ODUk will be plesiochronous with a frequency/bit rate tolerance of ±20 ppm.

Non-synchronous constant bit rate client signals can be mapped bit synchronous (using BMP) or asynchronous (using AMP, GMP) into the ODUk. In the former case, the frequency/bit rate tolerance of the ODUk will be the frequency/bit rate tolerance of the client signal, with a maximum of ±45 ppm for k=0, 1, 2, 3, 4 and ±100 ppm for k=2e, flex. In the latter case, the frequency/bit rate tolerance of the ODUk will be ±20 ppm.

Multiplexing of low order ODUs into a high order ODUk uses an asynchronous mapping (either AMP or GMP). The frequency/bit rate tolerance of the high order ODUk signal is ±20 ppm.

Variable rate packet client signals are mapped into the ODUk using the generic framing procedure (GFP-F). The frequency/bit rate tolerance of the ODUk is ±20 ppm for k=0, 1, 2, 3, 4 and ±100 ppm for k=flex.

NOTE – It is possible to use the clock from an EEC or SEC function to generate the ODUk carrying clients mapped with AMP, GMP, or GFP-F or a multiplex of low order ODUs. Such ODUk is then traceable to an EEC, SSU or PRC. At this point in time, such ODUk does not provide support for a Synchronization Status Message (ODUk SSM), and consequently cannot be used as a synchronous-ODUk, i.e., as a synchronous STM-N or synchronous Ethernet replacement signal.

ODUk signals are mapped frame-synchronously into OTUk, thus the frequency/bit rate tolerance of the OTUk signals depends on the frequency/bit rate tolerance of the ODUk signal being carried.

7.4 Control plane access

Control plane support for OTN is described in [ITU-T G.8080].

7.5 Connection management

OTN connection management is described in [ITU-T G.874].

8 Protection switching

8.1 Linear protection

ODU subnetwork connection protection is described in clause 14.1.1.1 of [ITU-T G.798] and [ITU-T G.873.1].

OCh subnetwork connection protection is described in clause 12.1.1.1 of [ITU-T G.798].

OMS trail protection is described in clause 10.4.1 of [ITU-T G.798].

8.2 Shared ring protection

ODU shared ring protection is under development.

8.3 Shared mesh protection

ODU shared mesh protection is under development.

9 Interface ports on optical transport network equipment

The figures in this section illustrate examples of different types of ports that could be used in OTN equipment. The term 'port' is used here in a logical context and does not imply any partitioning of functions to hardware modules. A hardware module may implement one port, many ports, or a portion of the functions for one or more ports.

9.1 I-NNI

Figure 9-1 shows several different examples compound functions for individual NNI wavelengths. In the examples, the functions drawn with dashed lines are not active.

The Type 1 I-NNI port supports multiplexing of low order ODUj into ODUk and tandem connection monitoring on the low order ODUs to support SNC/S protection.

The Type 2 I-NNI port is used when the low order ODU is mapped directly onto the wavelength.

The Type 3 I-NNI port supports two levels of multiplexing.

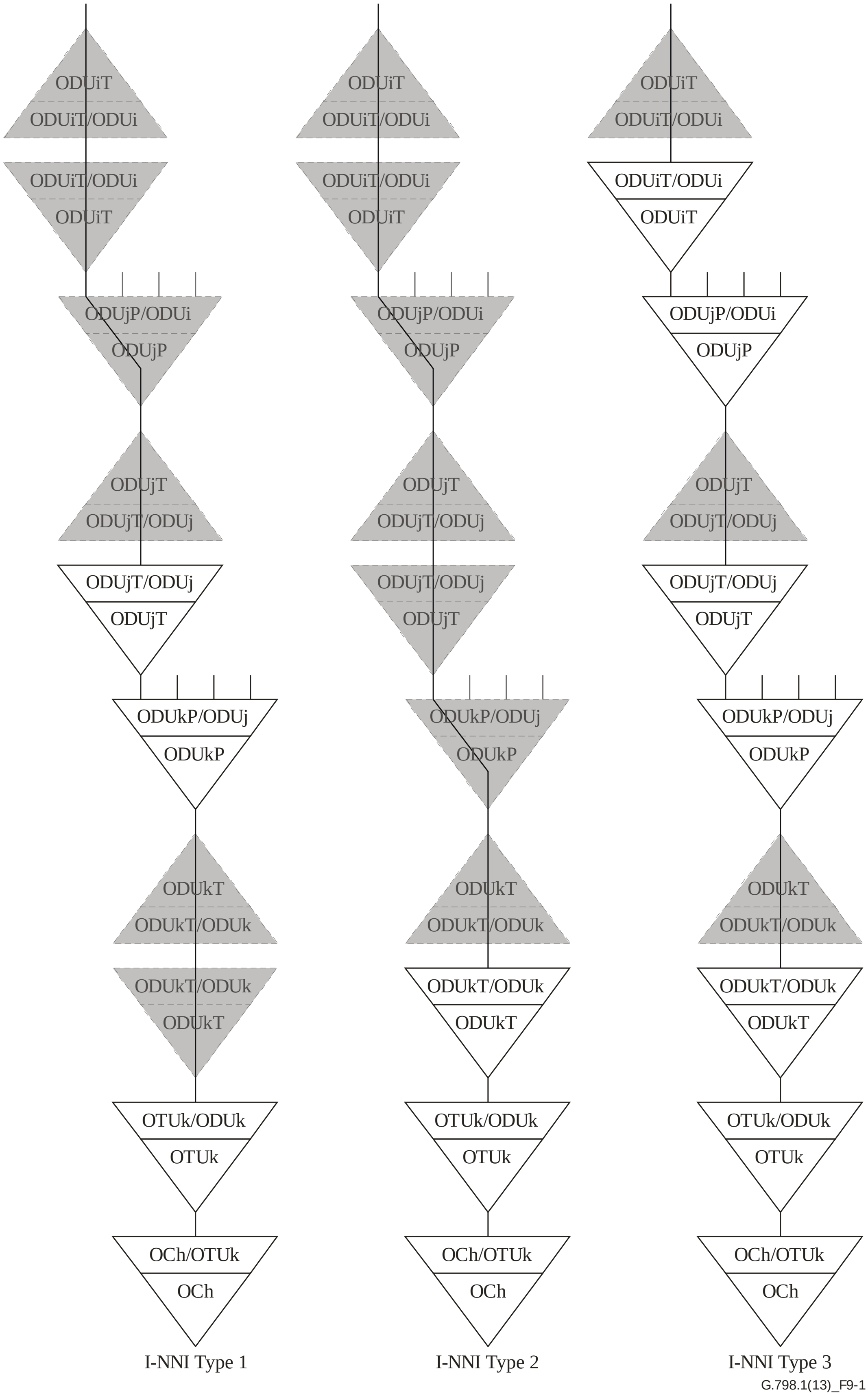


Figure 9-1 – I-NNI port compound function

An I-NNI can be single channel or multi-channel. Multi-channel I-NNI ports contain a WDM interface and individual NNI functions for each wavelength. Compound functions for these ports are shown in Figure 9-2.

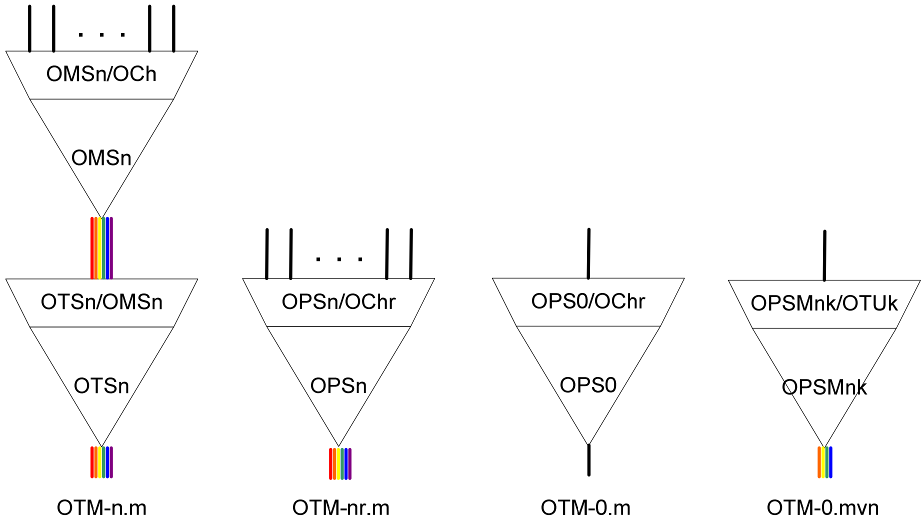


Figure 9-2 – WDM and single-channel physical layer compound functions

9.2 E-NNI

E-NNI ports are similar to I-NNI ports, but use only the OPS physical layers rather than OTS and OMS layers. Figure 9-3 shows several examples of E-NNI ports. In the examples, the functions shown in grey are not active.

The Type 1 E-NNI port supports multiplexing of low order ODUj into ODUk and tandem connection monitoring on the low order ODUs to support SNC/S protection.

The Type 2 E-NNI port is used when the low order ODU is mapped directly onto the wavelength.

The Type 3 E-NNI port supports two levels of multiplexing.

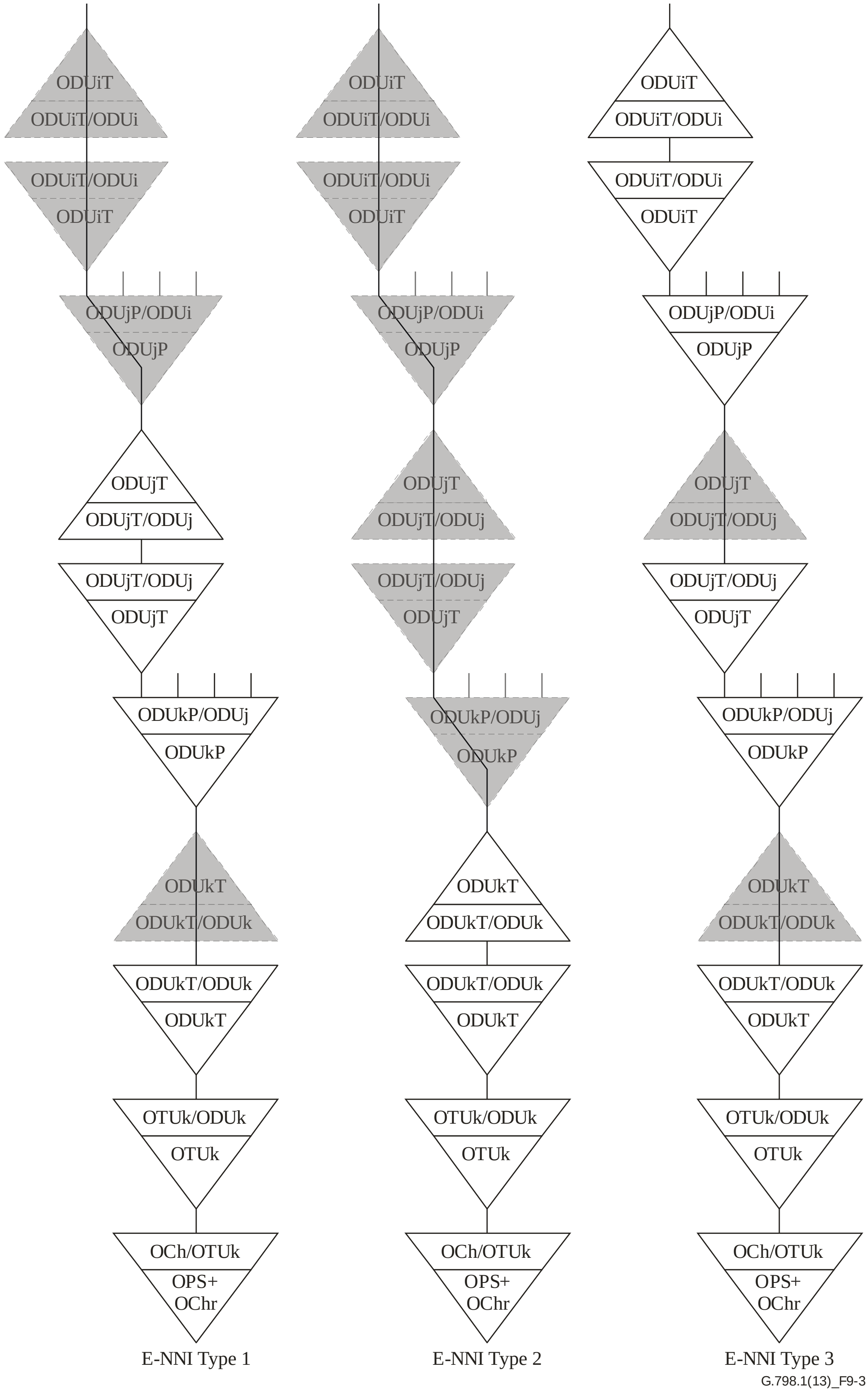


Figure 9-3 – E-NNI port compound functions

9.3 UNI

Figure 9-4 shows several examples of UNI-N ports.

(a) This shows a non-OTN client signal adapted to an ODUk. Path monitoring is used to verify the SLA between the UNI-N ports. The mapping to the ODUk is client-specific. Additional client-specific functions such as non-intrusive monitoring or protection may also be performed.

(b) This shows the two versions of OTN client UNIs, one for serial interfaces and one for multilane interfaces.

(c) This shows a UNI-N supporting multiple non-OTN clients that are multiplexed to a high order ODU directly at the UNI. Such a port might be used for the introduction of ODU0 or ODUflex services at the edge of a legacy network, without the need for upgrading all NEs in the network to be ODU0 or ODUflex capable.

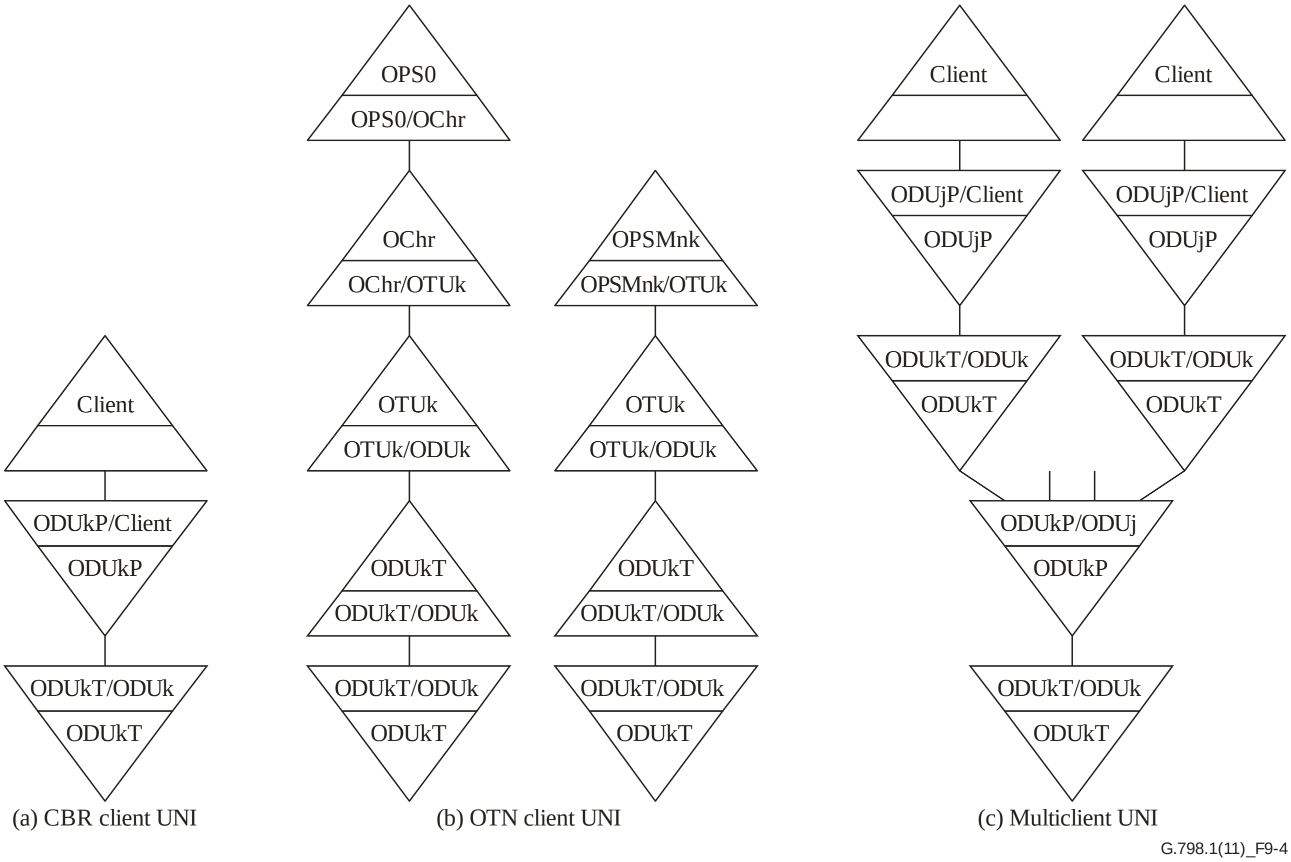


Figure 9-4 – UNI port compound functions

10 Basic OTN equipment types

Several examples of OTN equipment are described in this section, illustrating different ways to combine the atomic functions defined in [ITU-T G.798]. To keep diagrams simple, the NNI and UNI port compound functions from the previous section are used.

10.1 3R regeneration compound function

Figure 10-1 shows the model of 3R regeneration. This function is used in some of the equipment examples that follow.

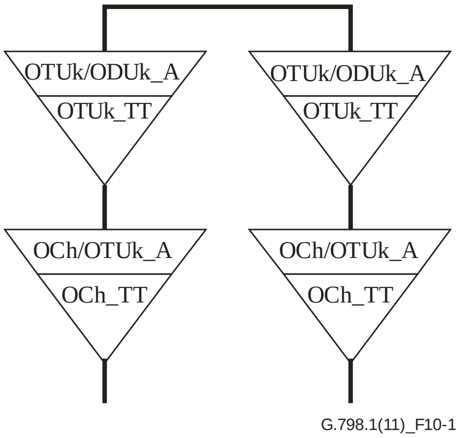


Figure 10-1 – 3R regenerator compound function

10.2 OTN network termination unit (NTU)

An OTN network termination unit adapts one or more client signals (CBR, packet, or single-channel OTN) into either a WDM port or a single-channel OTN port. Three examples of NTU are shown below: single channel single client, single channel multiple client, and multiple channel.

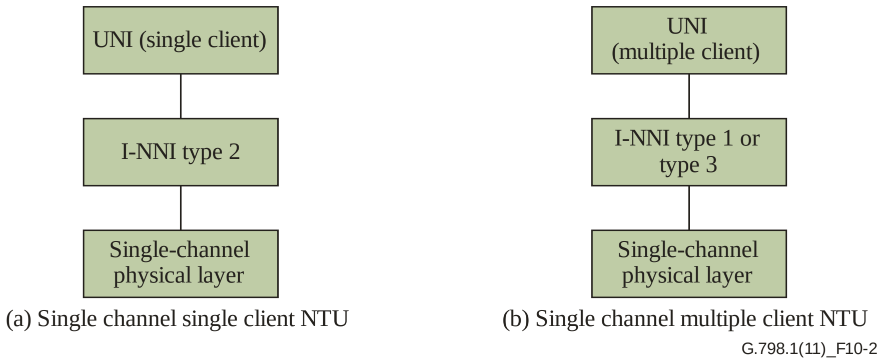


Figure 10-2 – Examples of single channel OTN NTU equipment

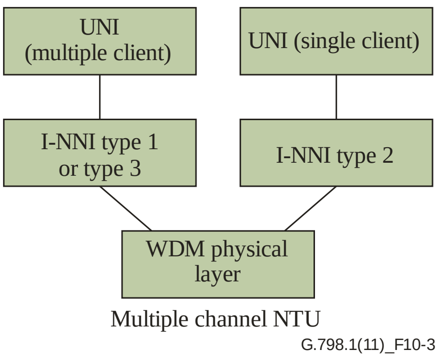


Figure 10-3 – Example of multiple channel OTN NTU equipment

10.3 Wavelength add/drop multiplexer (WADM)

A wavelength ADM consists of two WDM ports (OTM-n.m interfaces) with add-drop or pass-through capability for the individual optical channels within the WDM signals. Add-drop and pass-through may be performed in the optical domain or the electrical domain if 3R regeneration is necessary. The figure below illustrates several possible connections that can be made in a WADM. Note that the coloured lines are used only to make it easier to distinguish the different channels within the diagram, and are not meant to indicate that the signal at that point is a WDM-compliant wavelength.

The red channel illustrates optical pass-through.

The orange channel on the right illustrates unprotected optical add-drop to a non-OTN client port. In this case, the functions of a UNI and an I-NNI type 2 are present, but there is no ODUk matrix between them since a wavelength ADM does not support ODU layer switching.

The green channel on the right illustrates unprotected add-drop with 3R regeneration.

The orange and green channels on the left are not in use.

The blue channel illustrates protected optical add-drop.

The purple channel illustrates electrical pass-through (3R regeneration).

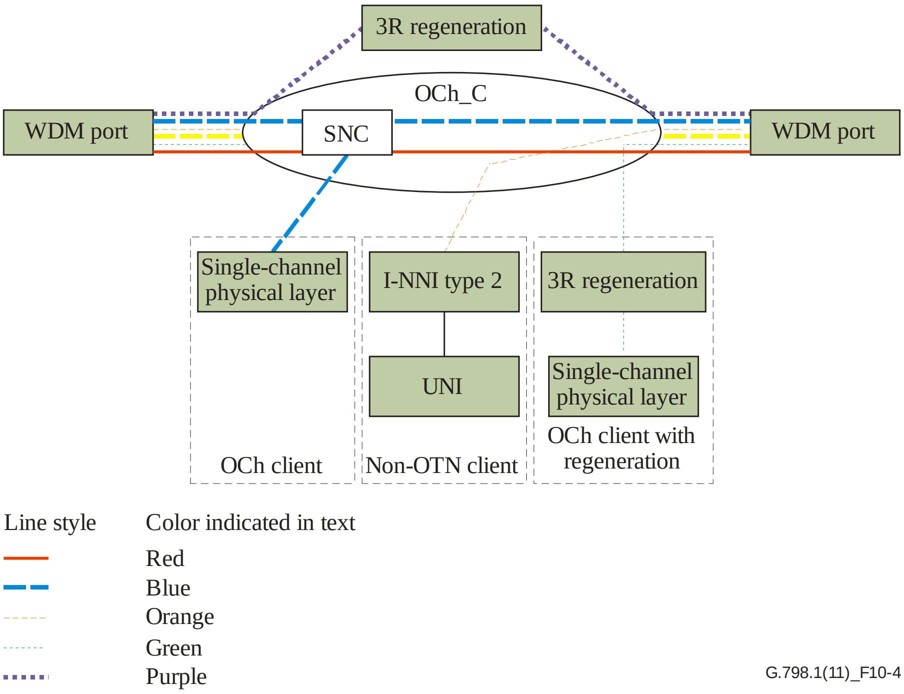


Figure 10-4 – Example of wavelength ADM showing various connections

10.4 Wavelength cross connect (WXC)

A wavelength cross connect is similar to a WADM, except that it supports more than two WDM ports (OTM-n.m interfaces). One consequence of this difference is that protected connections can be supported with all three connection points supported by WDM ports (whereas in the WADM, protected connections always have a client port as the reliable resource).

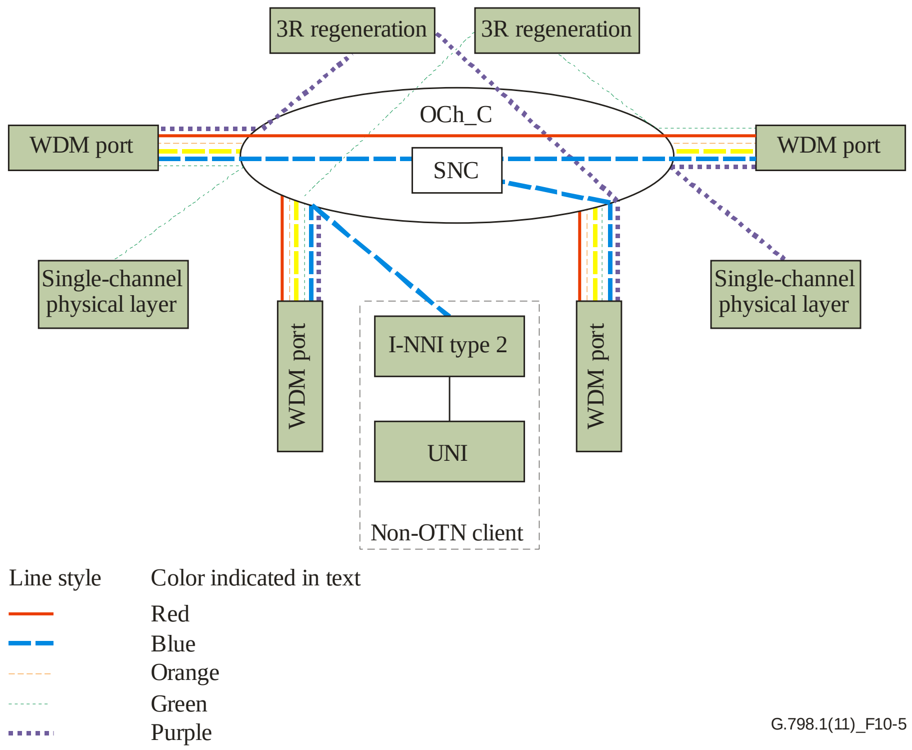


Figure 10-5 – Example of wavelength cross connect

10.5 Sub-wavelength cross connect (SWXC)

10.5.1 Sub-wavelength cross connect (SWXC) Type I

A sub-wavelength cross connect Type I adds an ODU matrix to a WXC. This allows flexibility in the assignment of clients to wavelengths and also supports multiplexing of multiple clients into a single wavelength. The I-NNI ports may or may not support an optical supervisory channel. Management and signalling communications channels may be supported via OSC or via GCC.

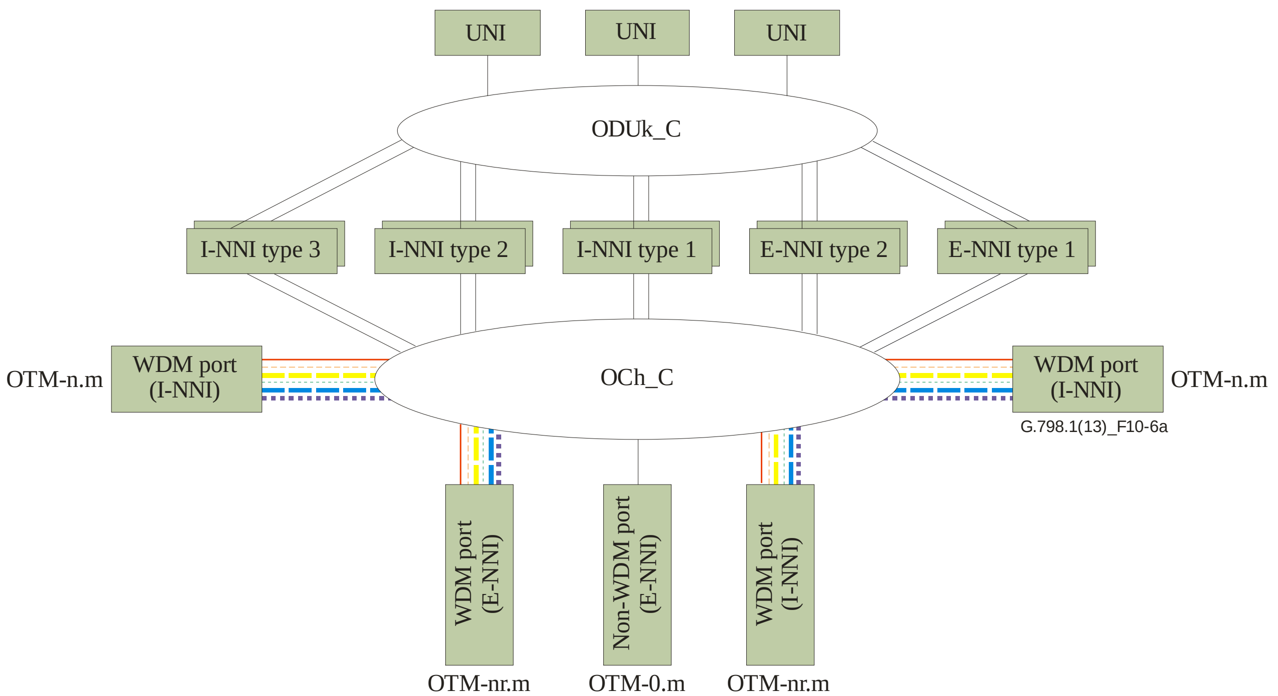


Figure 10-6a – Example of sub-wavelength cross connect

10.5.2 Sub-wavelength cross connect (SWXC) Type II

A sub-wavelength cross-connect Type II includes an ODU matrix, zero or more UNI-N ports and a number of OTM-n I-NNI ports directly connected to WDM ports. This allows flexibility in the assignment of clients to wavelengths and also supports multiplexing of multiple clients into a single wavelength. The SWXC Type II does not include an OCh matrix and all wavelengths are terminated on the NNI port cards. Optical supervisory channel wavelengths are not supported on the WDM ports and management and signalling communication channels (MCC, SCC) are supported via OTUk GCC0. Values for n are, e.g., 8, 12, 16 and 20 with 10G wavelengths. Values for n are, e.g., 4, 5 with 100G wavelengths.

The OTM-n NNI ports may support multiple I-NNI port types; e.g., I-NNI port types 1 and 2, or I-NNI port types 1, 2 and 3.

NOTE 1 – [ITU-T G.709] specifies that OTM-n interfaces which do not support an OSC are reduced functionality OTM-nr.m interfaces. These interfaces are stated to be ITU-T G.959.1 compliant inter-domain interfaces with 16 or 32 wavelengths. The OTM-n NNI ports described here are reduced functionality intra-domain interfaces with vendor specific numbers of wavelengths and optical parameters.

NOTE 2 – It is possible to deploy a set of four 10G wavelengths to transport an OTU3 over an n*10G OTM-n NNI; e.g., an OTM-12 NNI can support a mix of OTU2, OTU2e, OTU3 and OTU3e signals. It is possible to deploy a set of ten 10G wavelengths to transport an OTU4 over an n*10G OTM-n NNI; e.g., an OTM-20 NNI can then support a mix of OTU2, OTU2e, OTU3, OTU3e, OTU4 signals. The OTU3/3e and OTU4 signals are in those cases transported as groups of OTL-3.4/OTL3e.4 and OTL-4.10 signals. Care is to be taken not to exceed the differential delay compensation capabilities of the multi-lane receivers. The specific atomic functions to support such mixed OTUk/OTLk.n support are for further study.

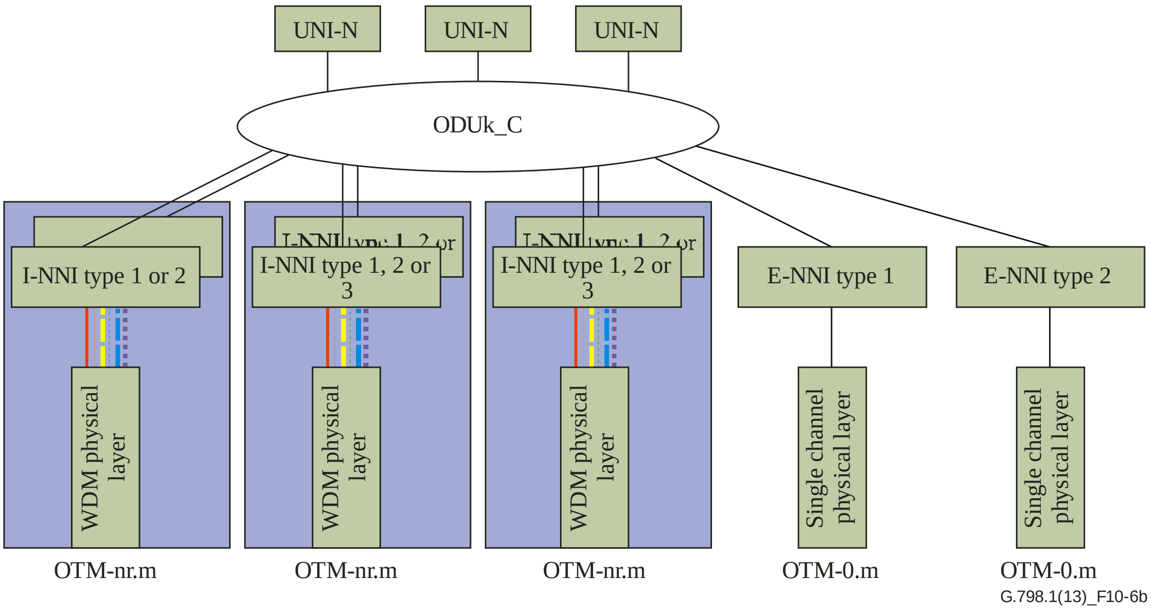


Figure 10-6b – Example of sub-wavelength cross-connect Type II

10.5.3 Sub-wavelength cross connect (SWXC) Type III

A sub-wavelength cross-connect Type III combines the functionalities of sub-wavelength cross connect Type I and Type II.

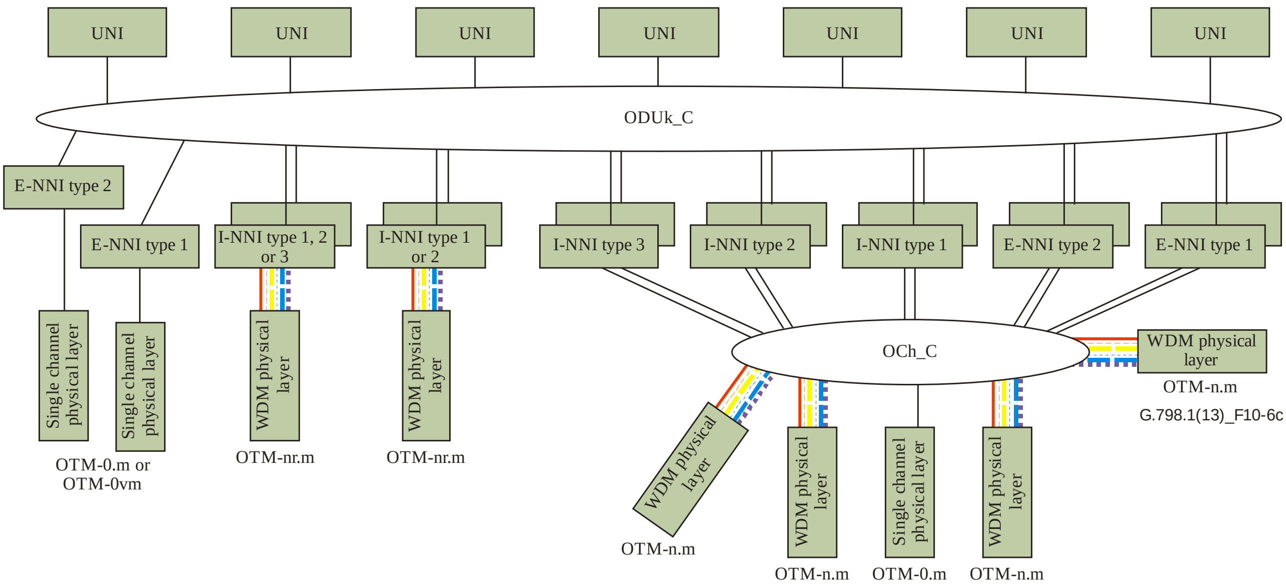


Figure 10-6c – Example of sub-wavelength cross-connect Type III

10.6 Optical amplifier

An optical amplifier is used to amplify a WDM signal. It terminates the OTS layer but passes the OMS layer through intact. The OSC is accessible at an optical amplifier, allowing management access via the OTS COMMS channel.

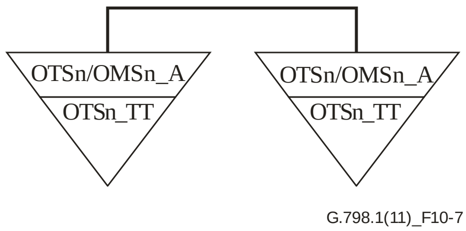


Figure 10-7 – Example of optical amplifier

10.7 Sub-wavelength add/drop multiplexer (SWADM)

10.7.1 Sub-wavelength add/drop multiplexer (SWADM) Type I

A SWADM Type I is a SWXC Type I with two WDM ports.

10.7.2 Sub-wavelength add/drop multiplexer (SWADM) Type II

A SWADM Type II is a SWXC Type II with two OTM-n ports.

11 OTN and packet transport network (PTN) hybrid equipment

Many OTN systems are also capable of supporting packet transport applications. A high-level description of OTN/PTN hybrid equipment is shown in Figure 11-1. The details of PTN functions are outside the scope of this Recommendation.

At the UNI, packet services may be treated as any other CBR flow and mapped into ODUk without packet awareness, or they may be treated as packet flows and processed as described in other Recommendations. The latter option allows for aggregation of packets from multiple UNIs and/or splitting the flow at one UNI to multiple NNIs. After packet processing, the resulting stream is mapped to an ODU.

At the NNI, ODUs carrying PTN traffic may pass through the ODU switch fabric prior to reaching the packet-processing function. This path is necessary if ODU SNC protection is required. This path provides greater flexibility in multiplexing ODUs because it allows the packet UNI, packet processing, and mapping to low order ODU functions, to be on a separate circuit pack from the NNI function.

ODUs carrying PTN traffic may also bypass the ODU switch fabric. This architecture might be used for ODU2 or higher rate ODUs that carry PTN traffic directly and do not require ODU connection functions. Note that ODU multiplexing is still possible in this architecture but it may be constrained if the packet UNI, packet processing, ODU mapping, and NNI functions, are all located on the same circuit pack.

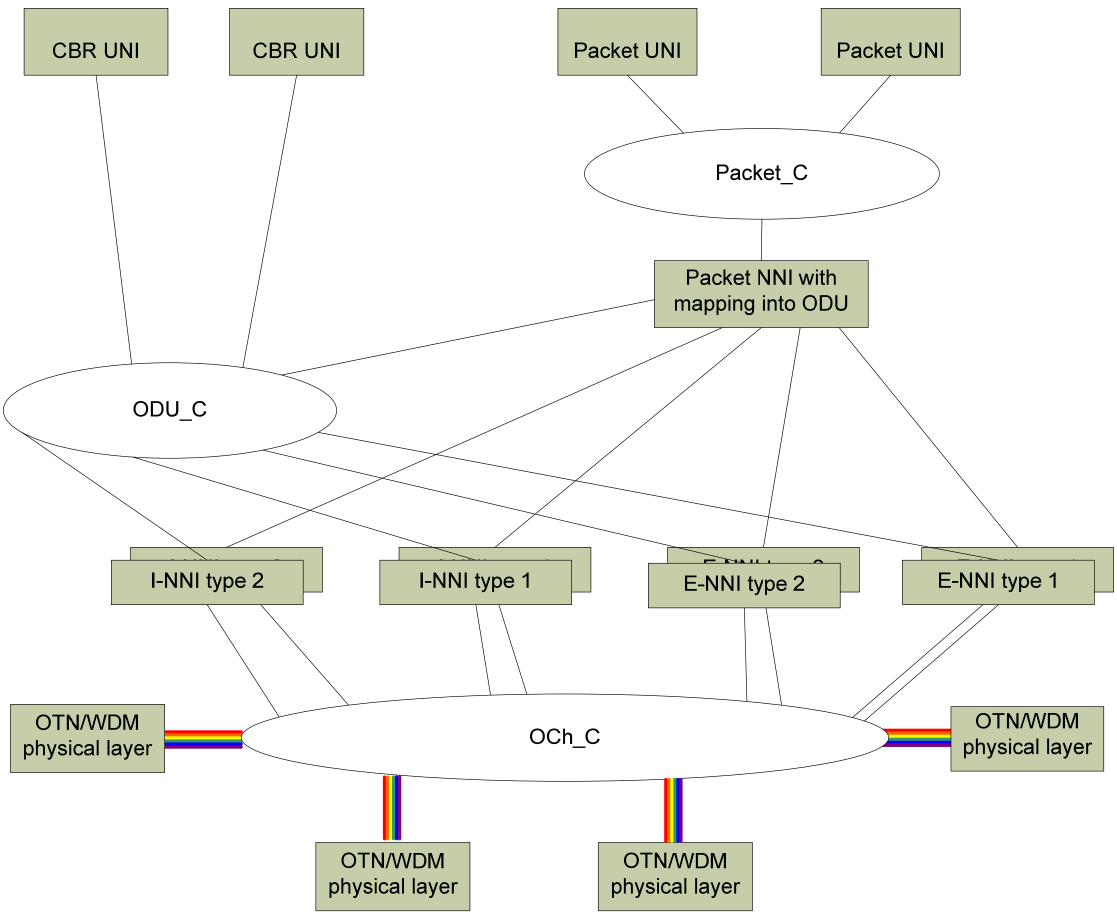


Figure 11-1 – OTN/PTN hybrid equipment

The Packet_C could be Ethernet connection function ETH_C as described in [ITU-T G.8021] or MPLS-TP connection function MT_C as described in [ITU-T G.8121].

The Packet UNI/NNI could be Ethernet UNI/NNI as described in [ITU-T G.8012.1] or MPLS-TP NNI as described in [ITU-T G.8112].

Appendix I

ODU multiplexing considerations

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

The ODU multiplexing mechanism is designed to allow ODUj of different rates to be multiplexed directly into an ODUk (e.g., an ODU3 may have ODU0, ODU1, ODU2, ODU2e, and/or ODUflex multiplexed directly into it). In many applications, a single stage of multiplexing is sufficient.

In other applications, more than one stage of multiplexing within a domain may be desirable or necessary. Examples of such applications include:

– Adding ODU0 or ODUflex clients to an existing OTN network based on equipment that does not support ODU0 or ODUflex. In this case, it will be necessary to first multiplex those signals into an ODU that the existing network can support. (e.g., 2 x ODU0 into an ODU1, or a mix of ODU0 and ODUflex into an ODU2). If the existing network uses ODU3 links, it will then be necessary to multiplex that ODU into an ODU3. The two stages of multiplexing could be done in one network element (on either the same card or different cards) or in separate network elements.
– Carrier-carrier applications, where the HO ODU of one carrier is treated as a LO ODU of the second carrier, may thus be multiplexed into a higher rate ODU in the second carrier's network. For example, carrier A may multiplex ODU0, ODU1, and ODUflex into an ODU2. When that ODU2 is handed off to carrier B, carrier B may then multiplex the ODU2 into an ODU4. In this case, the two stages of multiplexing are always in separate network elements.
– Within a carrier's network, aggregation of traffic may occur at multiple points along the backhaul to a switching centre. In this case, there would be two stages of multiplexing built up in multiple network elements until the switching centre is reached. In the switching centre, all the multiplexing would be undone so that the individual client signals can be switched.
– Bundling of services may require two stages of multiplexing. For example, suppose that five gigabit Ethernet services are to be bundled together, each service would be mapped into an ODU0, and the five ODU0s would be multiplexed into an ODU2. If the transport links in the service provider's network are ODU3, a second stage of multiplexing would be used.

Appendix II

Examples of SNC protection implementation

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

In a network element supporting ODU cross-connect functions, switching can be performed at multiple ODU layers (e.g., ODUk or ODUj). Because SNC protection (as specified in [ITU-T G.873.1]) is a process within the ODU_C function, SNC protection can also occur at multiple ODU layers. When the ODUk layer is protected, it can either be switched intact, or the reliable ODUk can be terminated with switching at the ODUj layer.

In a technology, commonly available and in use today, OTN NEs consist of "port units" (PU) and "switch units". The switch units perform the cross-connection/switching, the port units perform all necessary OTN overhead processing.

The typical implementation uses a single switch unit for both the ODUk and ODUj layers. A port unit will perform OTUk trail termination in all cases and ODUkP trail termination when the switching is being done at the ODUj layer (see Figure II.1 for HO ODUk SNC/S; Figure II.2 for HO ODUk SNC/I).

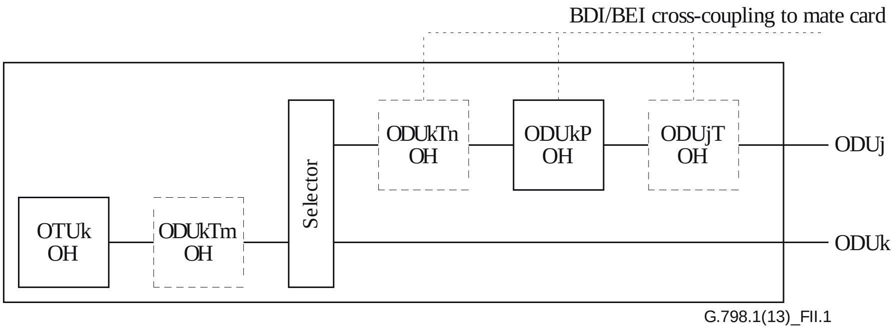


Figure II.1 – Port unit functions (simplified model) (HO ODUk SNC/S)

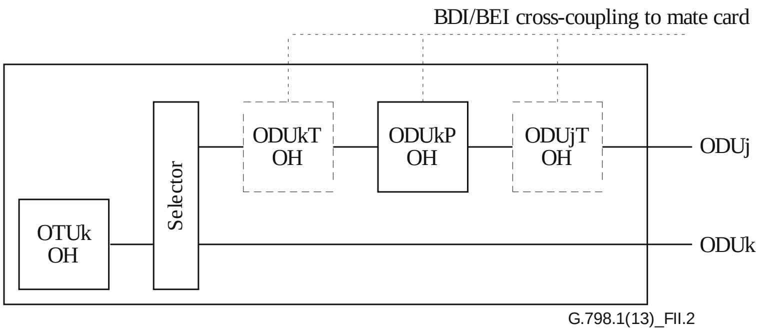


Figure II.2 – Port unit functions (simplified model) (HO ODUk SNC/I)

II.1 Analysis

In the case of ODUk switching (with or without ODUk SNC protection) or ODUkP termination and ODUj switching (with or without ODUj SNC protection), the implementation and functional models are fully aligned.

In the case of ODUk SNC protection but ODUj switching, the implementation does not strictly match the functional model (Figure II.3 for HO ODUk SNC/S; Figure II.4 for HO ODUk SNC/I). Two ports units are used (one for each ODUk), and each unit performs OTUk termination and ODUkP termination, while the ODUj protection switch is implemented at the switch unit by switching the total group of ODUj signals.

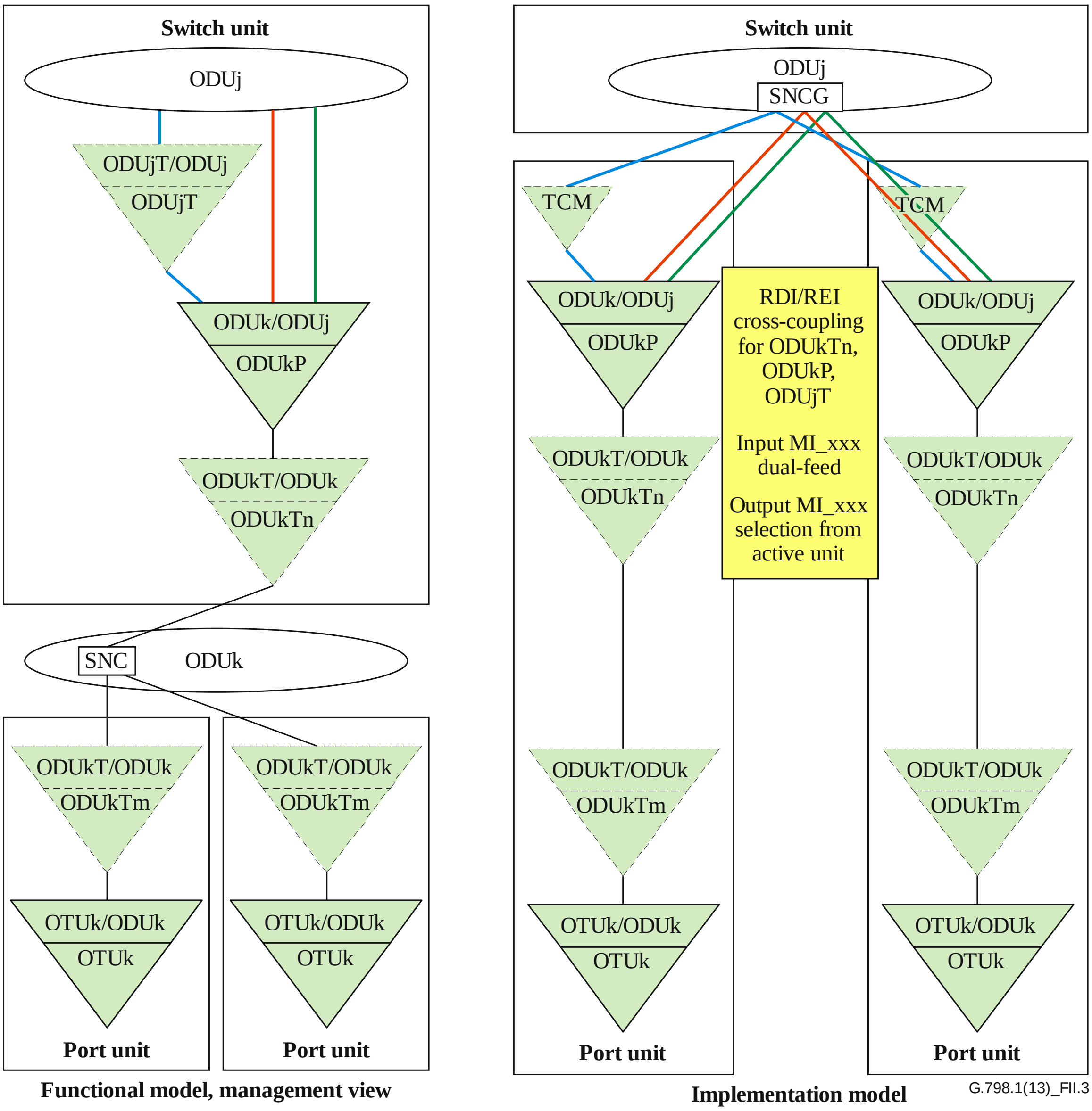


Figure II.3 – Mapping of functional view into implementation (HO ODUk SNC/S)

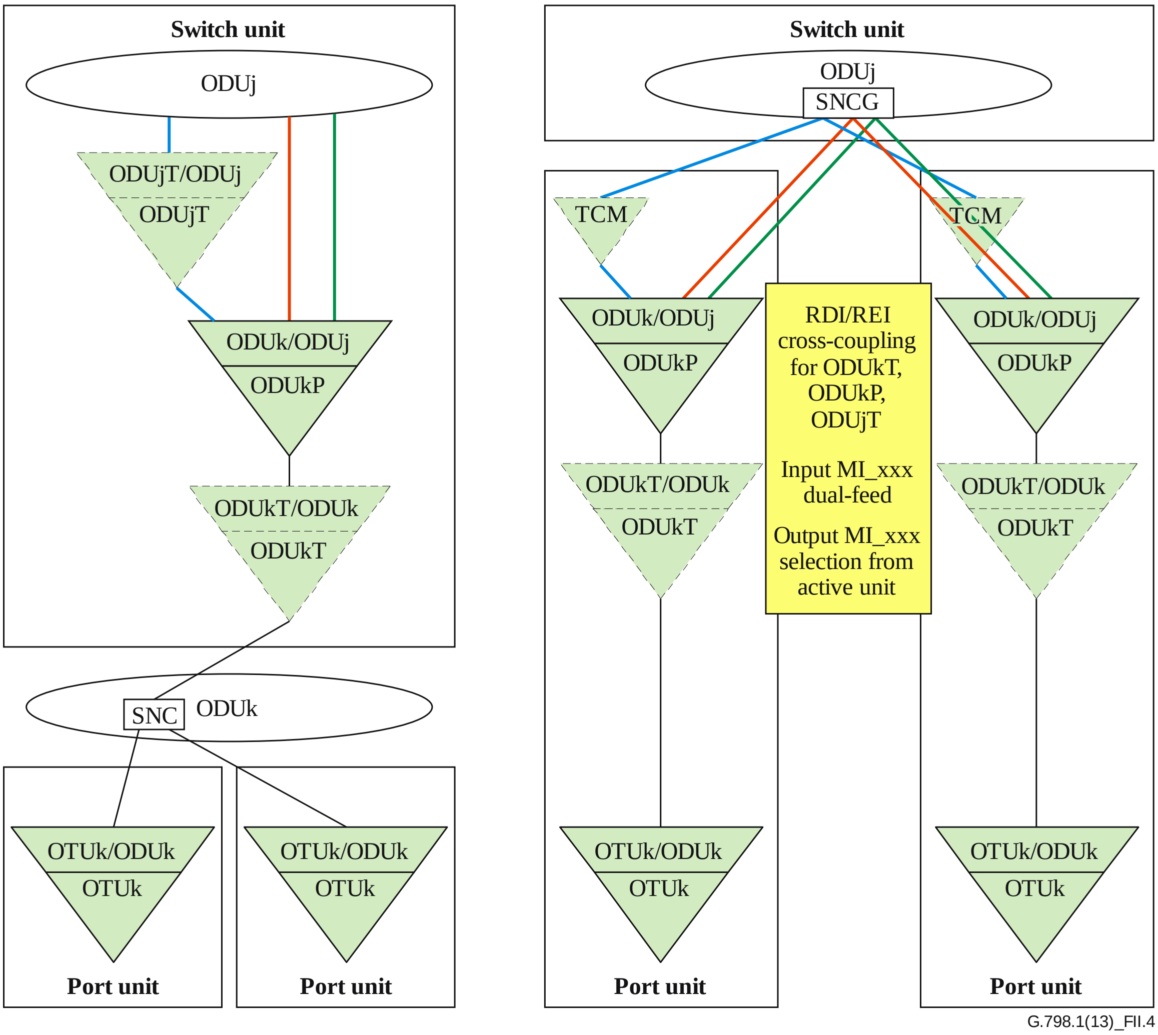


Figure II.4 – Mapping of functional view into implementation (HO ODUk SNC/I)

According to the functional model, too much functionality is present on each port unit in the implementation; i.e., OTUk processing and optional ODUkT processing is expected to be present twice, while ODUkP and optional ODUjT processing should be present only once. It is expected that SNC/I or SNC/S protection at the ODUk layer is present; instead. SNC group protection at the ODUj layer is performed.

With software, an NE can present the expected functionality via BDI/BEI cross-coupling:

- For SNC/S, it hides the standby ODUkT_TT (applicable to the TCM layer n which is outside of or the same scope as the specified TCM layer m for SNC/S protection), ODUkP_TT and ODUjT_TT processes for the manager, and presents the ODUj group switching as ODUk switching. This is accomplished by ensuring that all MI_xxx input signals are configured the same on both port units, selecting MI_xxx ouput signals from the active port unit, and ensuring that the same BDI and BEI signals are output from both ODUkT_TT, ODUkP_TT, and ODUjT_TT functions.
- For HO ODUk SNC/I, it hides the standby ODUkT_TT, ODUkP_TT and ODUjT_TT processes for the manager, and presents the ODUj group switching as ODUk switching. This is accomplished by ensuring that all MI_xxx input signals are configured the same on both port units, selecting MI_xxx ouput signals from the active port unit, and ensuring that the same BDI/BEI signals are output from ODUkT_TT (applicable to any terminated TCM layer), ODUkP_TT, and ODUjT_TT functions.

In the case where BDI/BEI cross-coupling is not implemented, it will not be possible to add ITU-T G.826 performance monitoring to networks in which the above protection implementations are operational. [ITU-T G.826] requires bidirectional (services based) performance monitoring to be supported. This requires that the far-end information be used. This far-end information must represent the error/defects detected in the signal path that is actually transporting the client information.

Unidirectional switching causes each end of the protection span to independently select between working and protection trail/SNC. If, in the direction A → Z, the working ODU SNC is selected and protection ODU SNC, in the direction Z → A the far-end information extracted at each end is inserted by the ODUkP_TT or ODUjT_TT on the standby port unit; i.e., the one that is not selected at this end. If it (now) uses its local RI_BDI/RI_BEI signals (instead of its companion RI_BDI/RI_BEI signals), the far-end would receive far-end information that is not related to the actually selected ODU.

The bidirectional performance monitoring registers would (in this case) represent the wrong information; i.e., it cannot be used.

The same problem exists for the unidirectional (maintenance based) far-end registers.

Appendix III

OTN link and connection examples

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

This appendix illustrates multiple types of OTN connections and links and the relationships between these OTN connections and links. These links and connections are illustrated within the context of an OTN subnetwork example illustrated in Figure III.1. This subnetwork contains a number of SWXC Type I and Type III, WXC and OA network elements (A to K). These network elements are connected via fibres over which OTM-n.m or OTN-nr.m interface signals are transported. This subnetwork provides an ODU0 or ODUflex subnetwork connection between port X on Node A and port Y on Node H. The subnetwork connection passes through intermediate Nodes B, C, D, E, F and G. Node G is not capable of supporting an ODU0 or ODUflex. Nodes E and H will therefore deploy I-NNI Type 3 (I3) ports supporting 2-stage ODU multiplexing. These I3 ports will cause nesting of ODU links. ODU link nesting implies that an outer ODU link contains or supports a smaller, inner ODU link. Such smaller, inner ODU link may have zero, one or both end points co-located with the larger, outer ODU link. In the first two cases, the smaller, inner ODU link is supported by two or more, larger, outer ODU links.

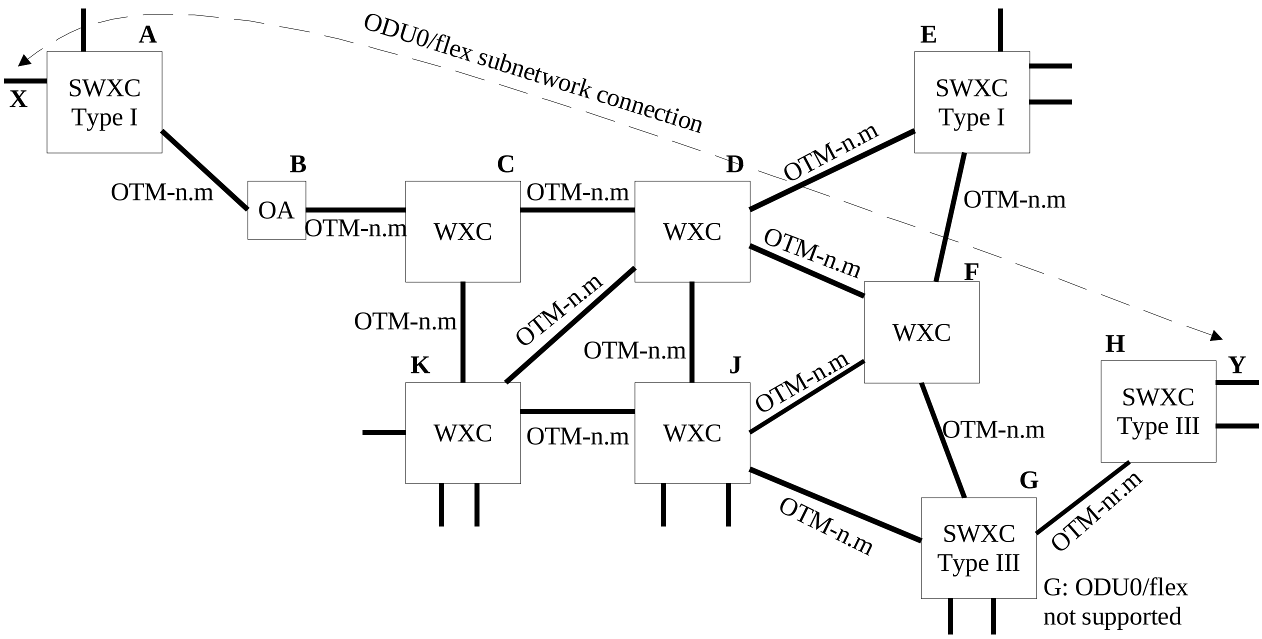


Figure III.1 – OTN subnetwork example

Figures III.2 to III.7 illustrate the set-up of OTS, OMS, OCh and ODU connections and OCh and ODU links in a step-by-step manner. The configurations of the atomic functions described hereafter are accomplished using the MI signals as specified in [ITU-T G.798].

Figure III.2 illustrates the main network elements and their functionality of interest in this example prior to interconnecting OTM-n ports on those network elements together. **NE A** is a SWXC Type I network element containing ODU (green ellipses) and OCh (red ellipses) connection functions, an I-NNI Type 1/2 port (I) interconnecting the ODU and OCh connection functions and an OTM-n.m port (n.m) connecting the OCh connection function with the physical interface port. **NE B** is an OA network element containing two back to back OTM-n interface ports. **NE C, NE D and NE F** are WXC network elements containing an OCh connection function and at either side an OTM-n.m port connecting the OCh connection function with the physical interface ports at the left and right sides. **NE E** is a SWXC Type I network element containing ODU and OCh connection functions, an I-NNI Type 1/2 port and an I-NNI Type 1/2/3 port interconnecting the ODU and OCh connection functions and at each side an OTM-n.m port connecting the OCh connection function with the physical interface ports. **NE G** is a SWXC Type III network element containing ODU and OCh connection functions, I-NNI Type 1/2 ports at each side of the ODU connection function, an OTM-n.m port connecting the OCh connection functions with the left physical interface port and an OTM-nr.m port connecting one of the I-NNI type 1/2 ports with the right physical interface port. **NE H** is a SWXC Type III network element with one I-NNI type 1/2 port and one I-NNI Type 1/2/3 port.

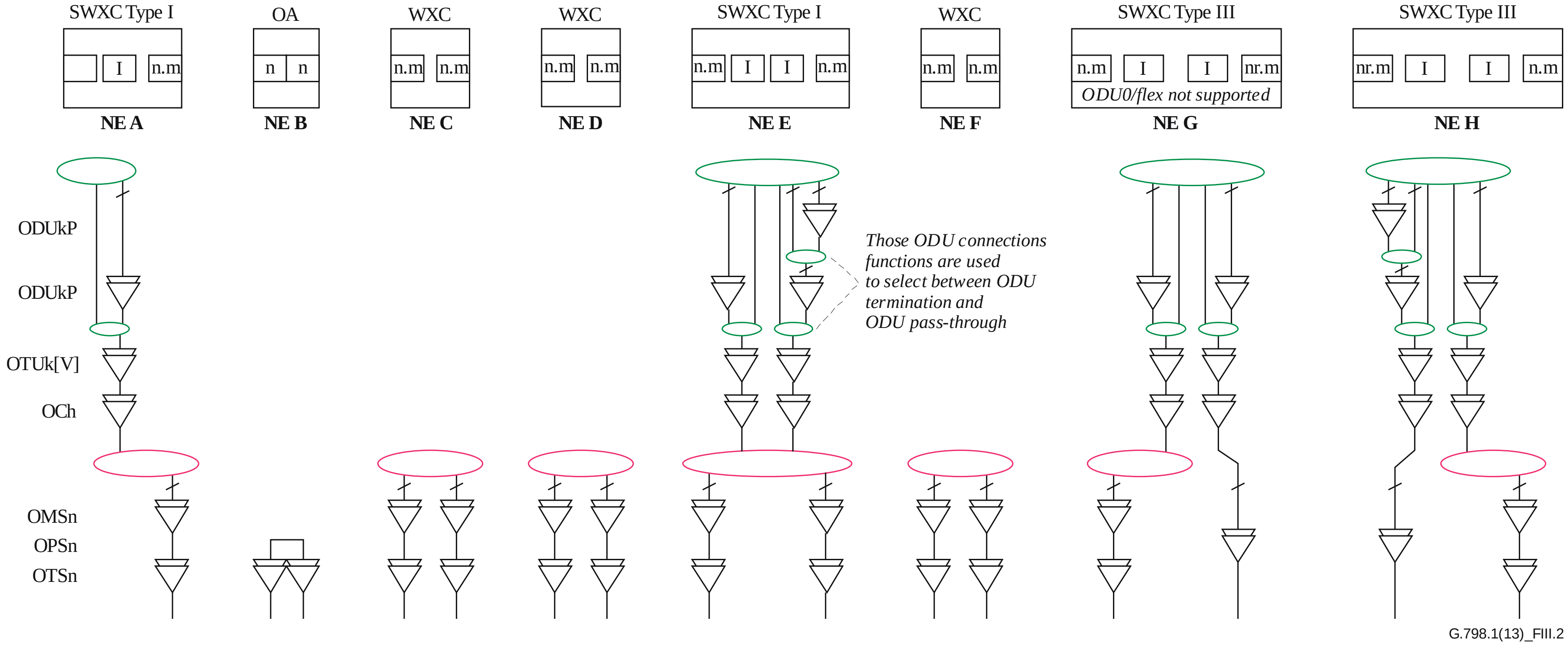


Figure III.2 – Some OTN network elements without fibre interconnections and their basic port and switching functionalities

Figure III.3 illustrates the interconnection of OTM-n and OTM-nr ports on NE A to NE H by means of fibres. After connection of a fibre between NE A and NE B, a physical link and an OTS network connection is created. After connection of a fibre between NE B and NE C a second physical link and second OTS network connection is created; also an OMS network connection between NE A and NE C appears. This latter network connection and its bounding OMS trail termination and adaptation functions establish an OCh link between NE A and NE C. Similarly, physical links and OCh links are established after connecting a fibre between NEs C and D, NEs D and E, NEs E and F and NEs F and G. After connection of a fibre between NE G and NE H a physical link, an OChr link and also an ODUk link are established.

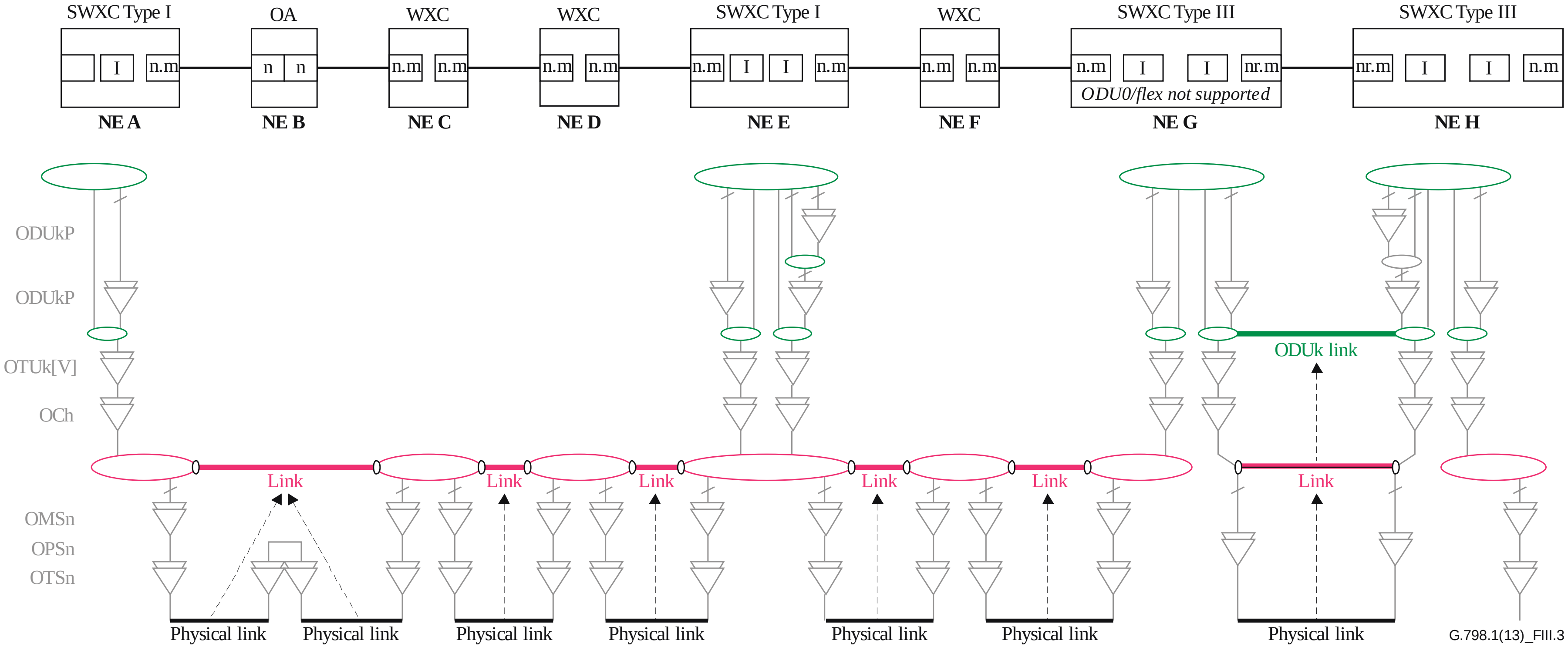


Figure III.3 – Interconnecting OTM-n interface ports via fibres to establish (i) OCh links between NEs A and C, C and D, D and E, E and F, and F and G; (ii) OChr link between NEs G and H; (iii) ODU link between NEs G and H

Figure III.4 illustrates the establishment of two ODUk links, one between NE A and NE E and the other one between NE E and NE G. The **ODUk link A-E** is established by creating an OCh network connection between NE A and NE E via the creation of OCh connection points in NEs A, C, D and E (which establishes OCh link connections between NEs A and C, NEs C and D, and NEs D and E), the set-up of four OCh matrix connections in NEs A, C, D, and E between those connection points, and the configuration of the OCh and OTUk[V] trail termination and adaptation functions at each end point. Similarly, the **ODUk link E-G** is established by creating an OCh network connection between NE E and NE G via the creation of OCh connection points in NEs E, F and G (which establishes OCh link connections between NEs E and F and NEs F and G), the set up of three OCh matrix connections in NEs E, F and G between those connection points, and the configuration of the OCh and OTUk[V] trail termination and adaptation functions at each end point.

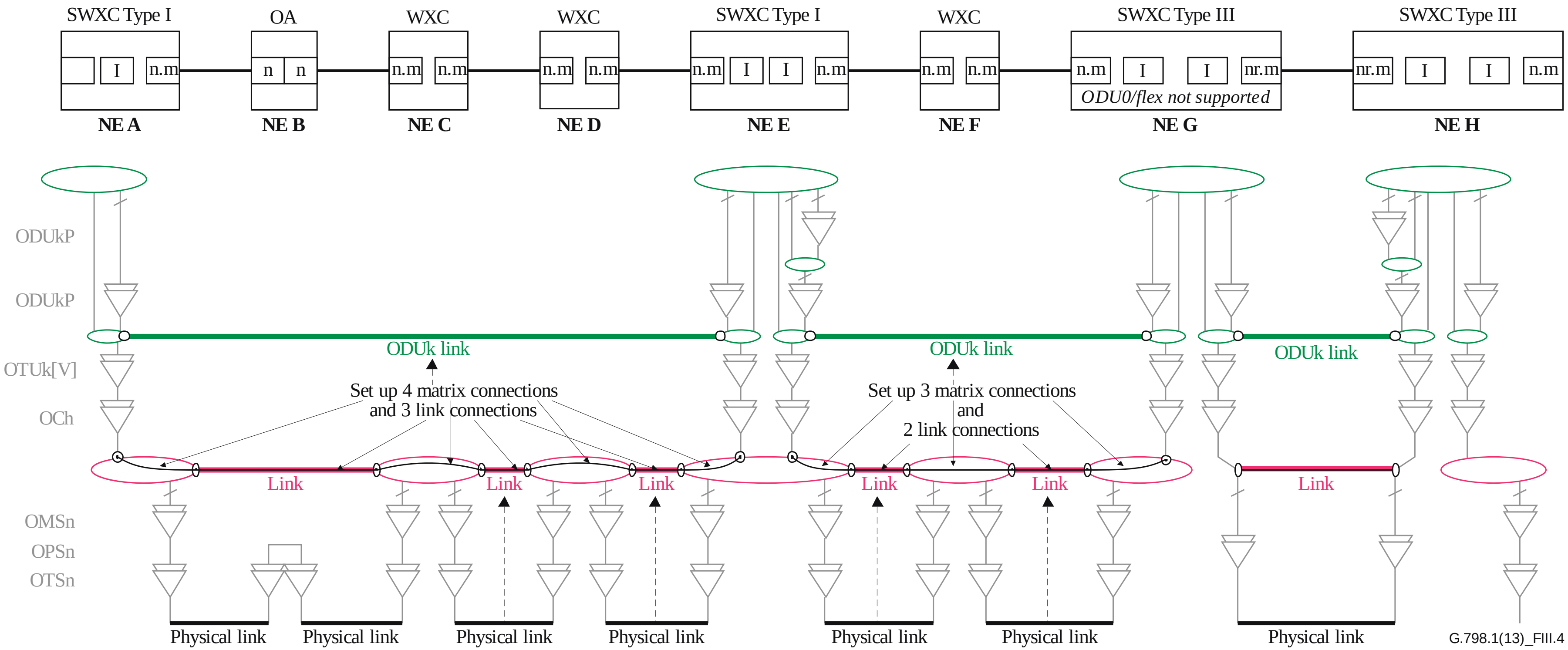


Figure III.4 – Setting up OCh network connections between NEs A and E, and E and G to establish ODU links between NEs A and E, and E and G

Figure III.5 illustrates the establishment of three ODUj links (j<k) between NEs A and E, NEs E and G and NEs G and H. The **ODUj link A-E** is established by creating an ODUk network connection between NE A and NE E via the configuration of the I-NNI type 1/2 ports in NEs A and E as a Type 1 ports (I1), the creation of ODU connection points in NEs A and E, the set up of two ODUk matrix connections in NEs A and E between those connection points, the set-up of an ODUk link connection in the ODUk link A-E between two of those connection points, and the configuration of the ODUkP trail termination and adaptation functions at each end point. The **ODUj link E-G** is established by creating an ODUk network connection between NE E and NE G via the creation of ODU connection points in NEs E and G, the configuration of the I-NNI type 1/2/3 port in NE E as a Type 3 port (I3), the configuration of the I-NNI type 1/2 port in NE G as a Type 1 port (I1), the set up of two ODUk matrix connections in NEs E and G between those connection points, the set-up of one ODUk link connection in the ODUk link E-G between two of those connection points, and the configuration of the ODUkP trail termination and adaptation functions at each end point. The **ODUj link G-H** is established by creating an ODUk network connection between NE G and NE H via the creation of ODU connection points in NEs G and H, the configuration of the I-NNI type 1/2 port in NE G as a Type 1 port (I1), the configuration of the I-NNI type 1/2/3 port in NE H as a Type 3 port (I3), the set up of two ODUk matrix connections in NEs G and H between those connection points, the set-up of one ODUk link connection in the ODUk link G-H between two of those connection points, and the configuration of the ODUkP trail termination and adaptation functions at each end point.

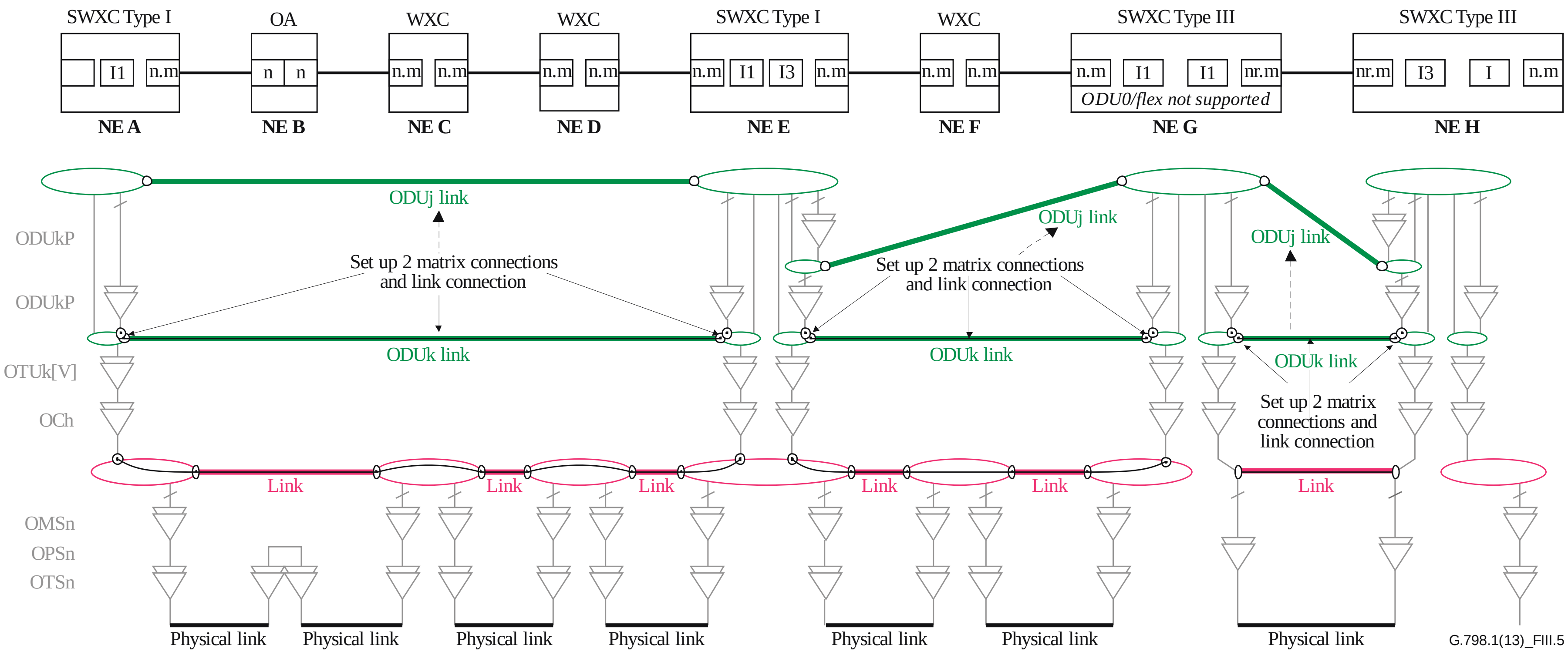


Figure III.5 – Setting up three ODUk network connections between NEs A and E, E and G, and G and H to establish three ODUj links between the same NE pairs

Figure III.6 illustrates the establishment of an ODUi link (i<j<k) between NEs E and H. The **ODUi link E-H** is established by creating an ODUj network connection between NE E and NE H via the creation of ODU connection points in NEs E, G and H, the set up of three ODUj matrix connections in NEs E, G and H between those connection points, the set up of two ODUj link connections in the ODUj links E-G and G-H between these connection points, and the configuration of the ODUkP trail termination and adaptation functions at each end point. There are no intermediate ODU link points present in NE G in this ODUi link. When setting up a connection in such ODUi link, it will only be required to configure ODU connection points in the ODUi link end points in NE E and NE H, see Figure III.7.

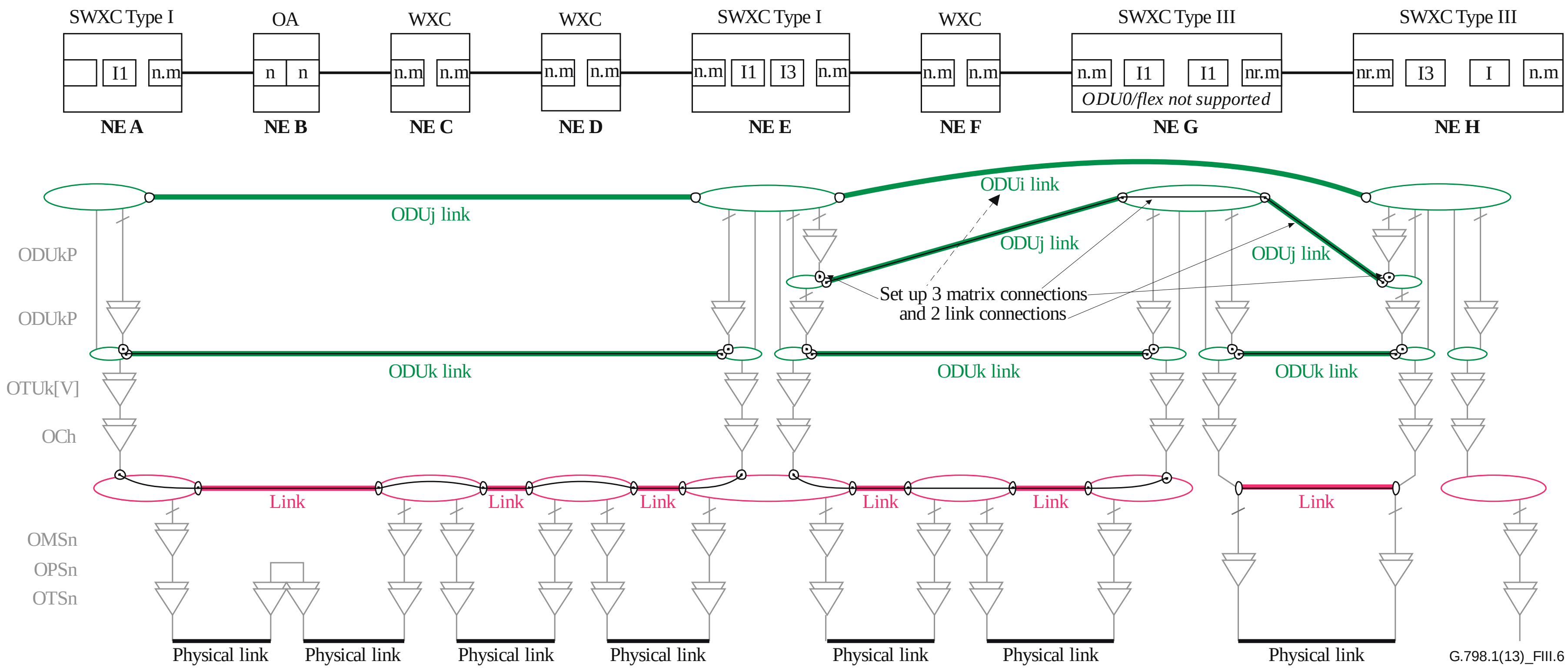


Figure III.6 – Setting up ODUj network connection between NEs E and H to establish an ODUi link between the same NEs

Figure III.7 illustrates the set-up of an ODU0 or ODUflex subnetwork connection between port X on NE A and port Y on NE H using the topology created in the previous steps illustrated above. This ODU0/flex subnetwork connection is created after creating ODU connection points in NEs A, E and H, setting up an ODU0/flex matrix connection in NEs A, E and H between those connection points and setting up an ODU0/flex link connection in ODUj link A-E and ODUi link E-H between those connection points.

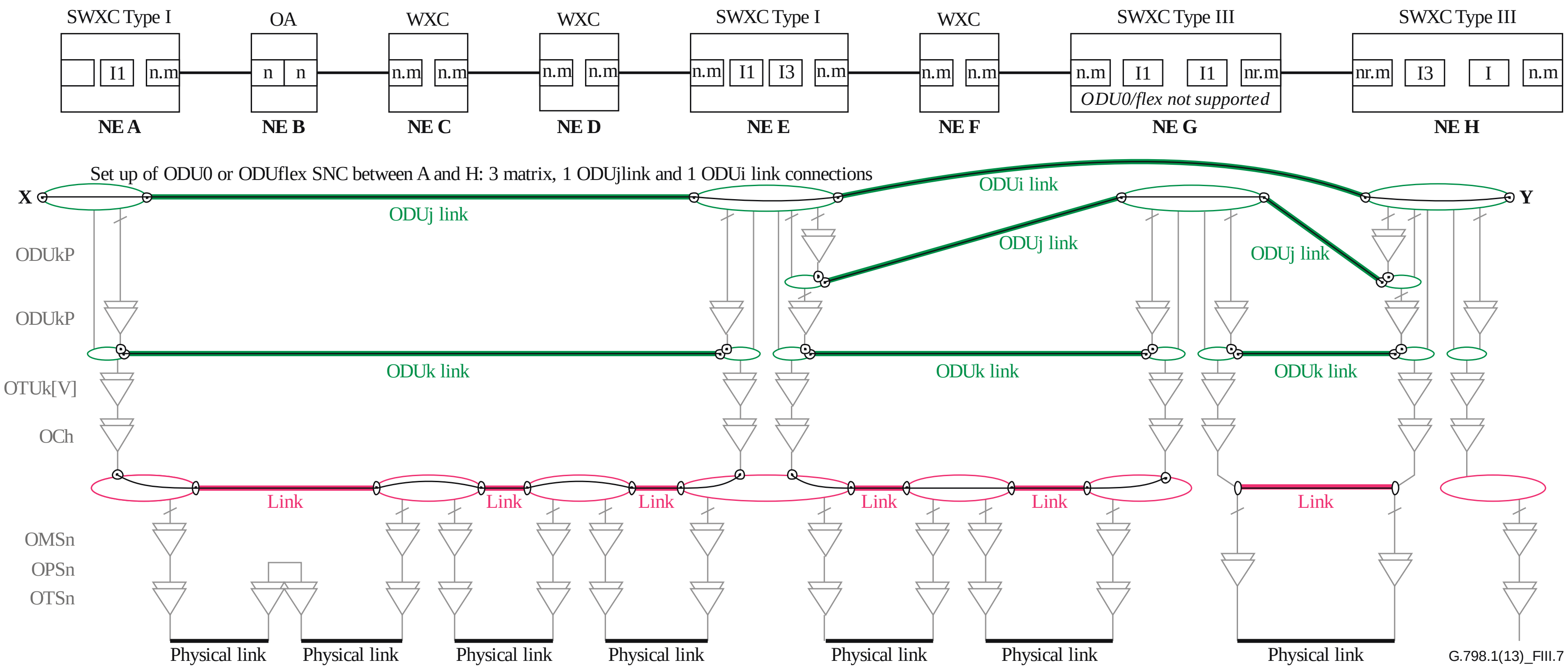


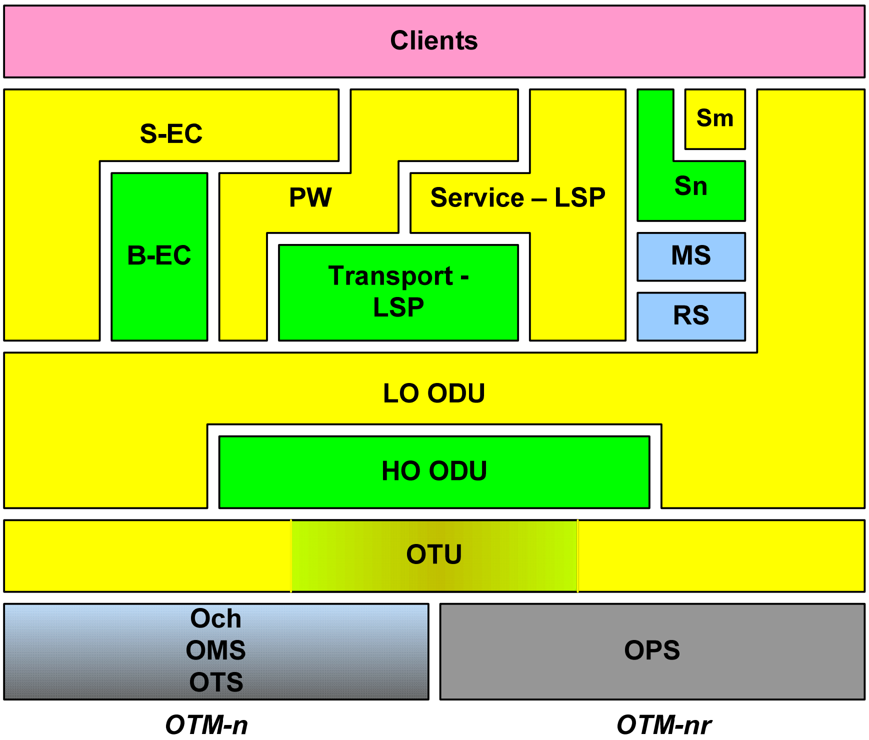
Figure III.7 – Setting up an ODU0 or ODUflex subnetwork connection between NEs A and H

Appendix IV

Multi-layer OTM-n network node interface

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

Figure IV.1 illustrates a layer stack supported by a multi-layer OTM-n network node interface. It represents a subset of the options supported by [ITU-T G.709], [ITU-T G.707], [ITU-T G.8012.1] and [ITU-T G.8112]. The options listed here are preferable to enhance interworking capabilities; for other options, future study is required.



S-EC: Service Ethernet Connection; B-EC: Backbone Ethernet Connection;
Sm: lower order VC-m layer; Sn: higher order VC-n layer;
MS: Multiplex Section; RS: Regenerator Section

Figure IV.1 – Multi-layer OTM-n network node interface

Appendix V

Converged packet and optical transport equipment type

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

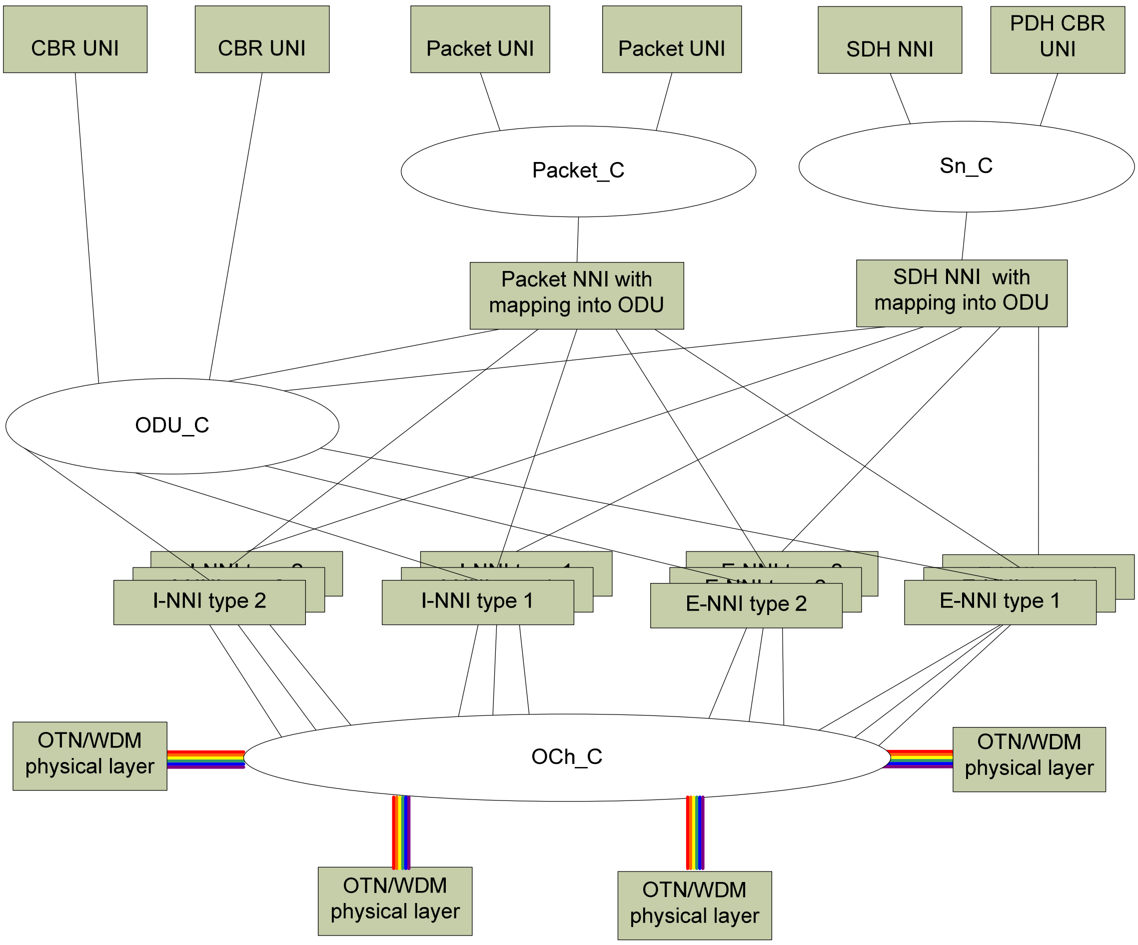


Figure V.1 – Converged packet and optical transport equipment type

The Packet_C could be Ethernet connection function ETH_C as described in [ITU-T G.8021] or MPLS-TP connection function MT_C as described in [ITU-T G.8121]. The Sn_C is SDH cross-connection function as described in [ITU-T G.783].

The Packet UNI/NNI could be Ethernet UNI/NNI as described in [ITU-T G.8012.1] or MPLS-TP UNI/NNI as described in [ITU-T G.8112]. The SDH NNI is defined in [ITU-T G.707], and the PDH CBR interface is defined in [ITU-T G.703]; PDH client support is a requirement of SDH functionality in such a converged packet and optical transport equipment.

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