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Digital terminal equipments – Other terminal equipment

Types and characteristics of optical transport network equipment

Recommendation ITU-T G.798.1

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
General	G.700–G.709
Coding of voice and audio signals	G.710–G.729
Principal characteristics of primary multiplex equipment	G.730–G.739
Principal characteristics of second order multiplex equipment	G.740–G.749
Principal characteristics of higher order multiplex equipment	G.750–G.759
Principal characteristics of transcoder and digital multiplication equipment	G.760–G.769
Operations, administration and maintenance features of transmission equipment	G.770–G.779
Principal characteristics of multiplexing equipment for the synchronous digital hierarchy	G.780–G.789
Other terminal equipment	**G.790–G.799**
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

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

Keywords

Optical transport network.

FOREWORD

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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.

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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.

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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/.

Table of Contents

Recommendation ITU-T G.798.1

Types and characteristics of optical transport network equipment

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.709] Recommendation ITU-T G.709/Y.1331 (2009), *Interfaces for the Optical Transport Network (OTN).*

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

[ITU-T G.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.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.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
LF	Local Fault
LO	Low Order
LOA	Loss Of Alignment
LOF	Loss Of Frame
LOFLOM	Loss Of Frame and Loss Of Multiframe
LOFLANE	Loss of Frame of logical Lane
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

OPS	Optical Physical Section
ONTU	OTN Network Termination Unit
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 ADMs/Cross Connects, Sub-Wavelength Cross Connects, and Optical Line Amplifiers.

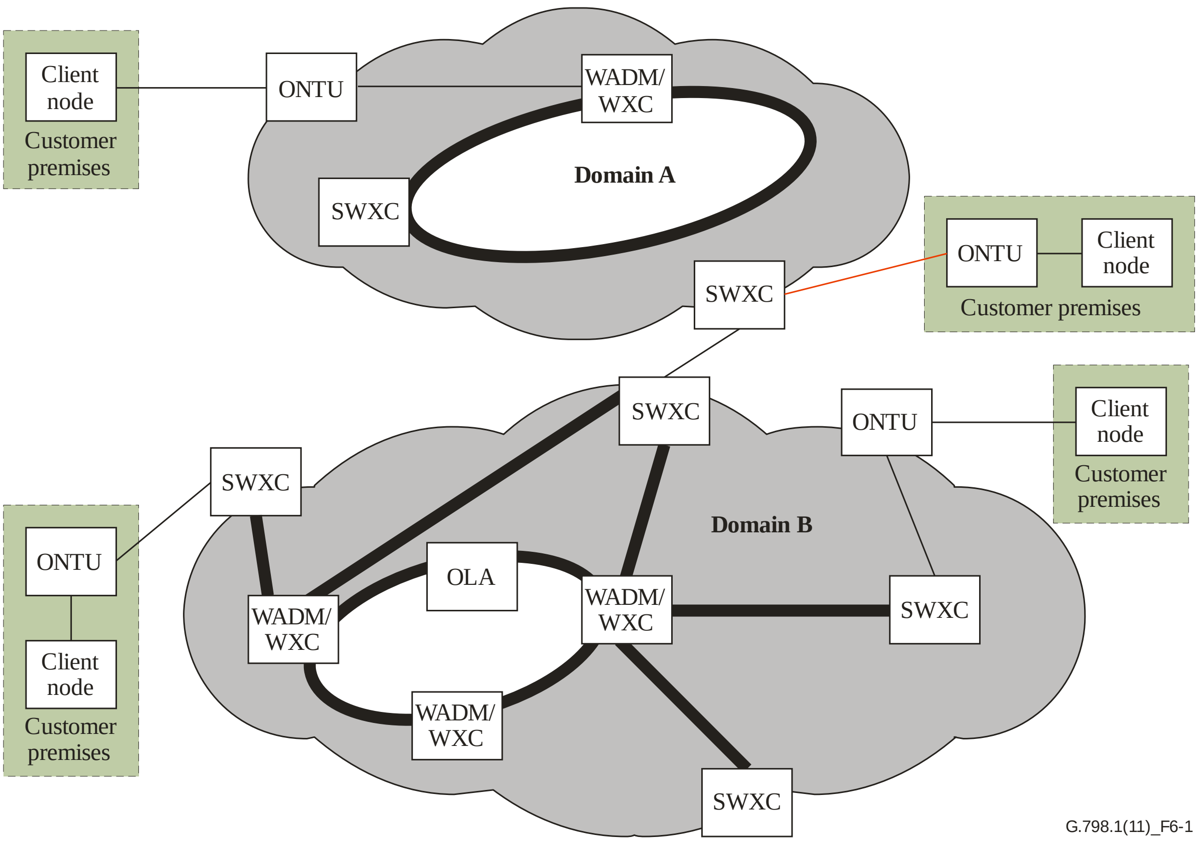

Figure 6-1 – OTN network example

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 TDM multiplexing 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 multiplexing 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.

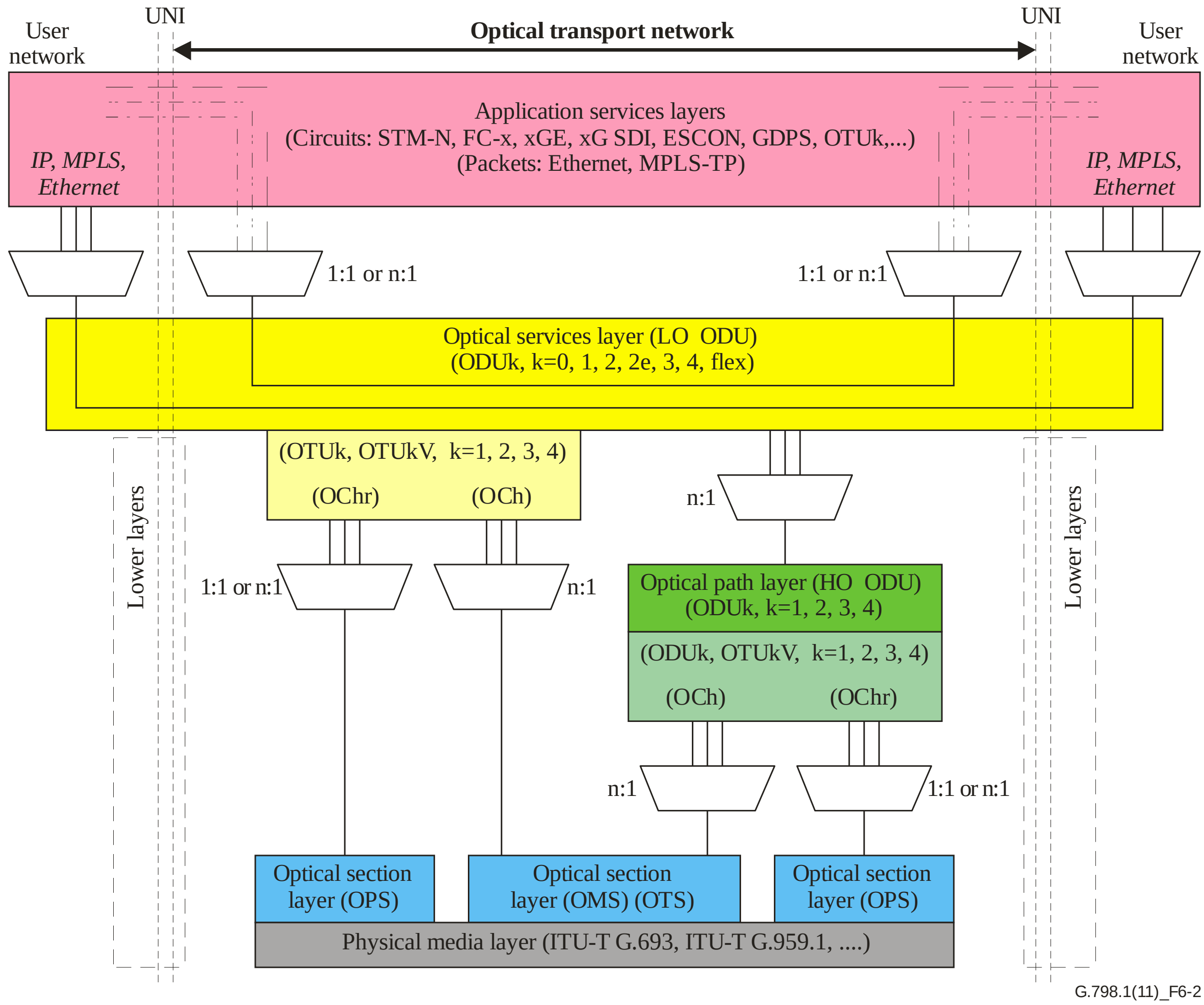

Figure 6-2 – OTN network layer stack example

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.

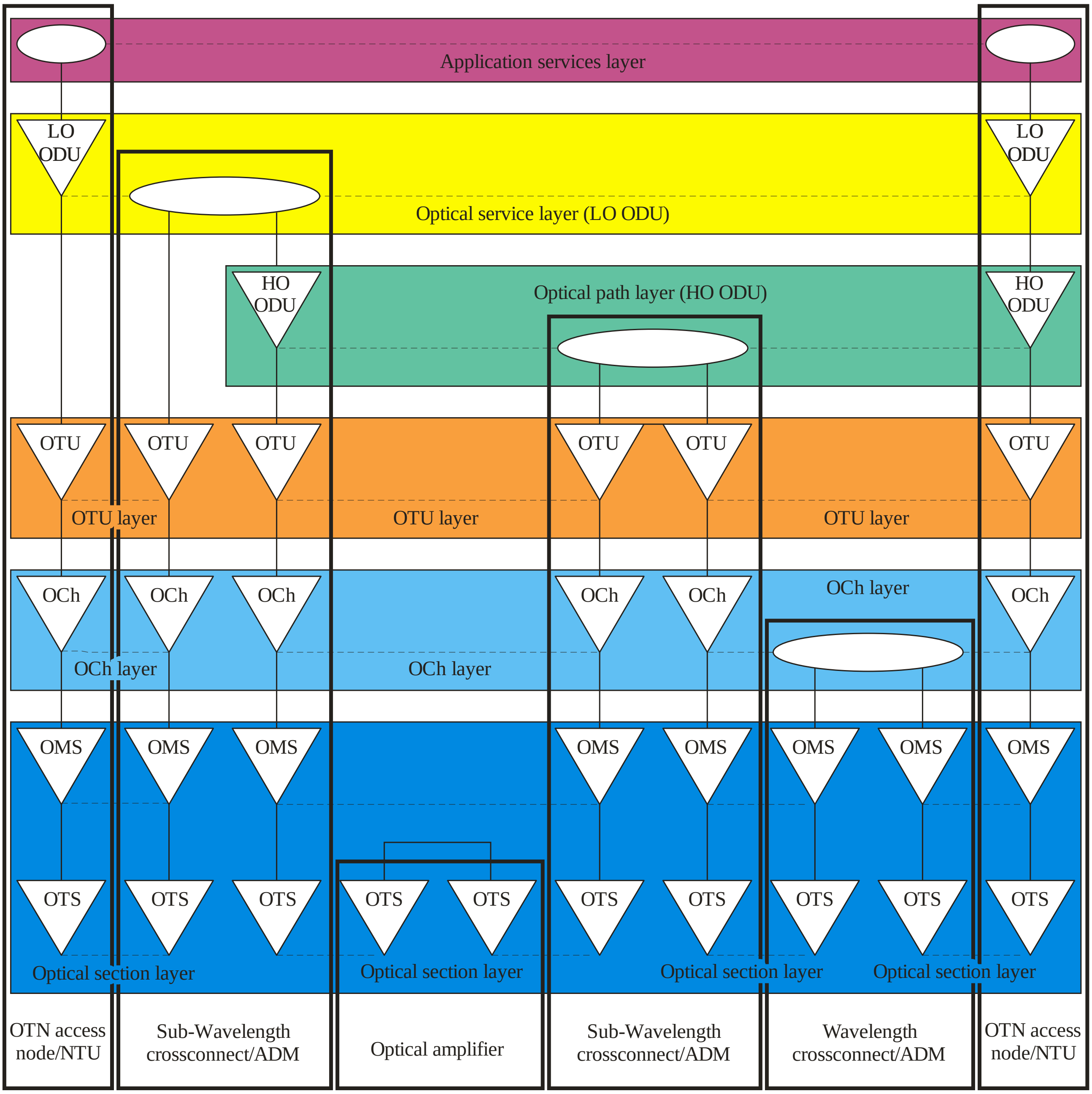

Figure 6-3 – Example of an OTN layer stack showing OAM entities

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 (FDI, AIS). Figures 7-1 and 7-2 illustrate the layer-to-layer and peer-to-peer maintenance interaction provided by OTN OAM.

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.

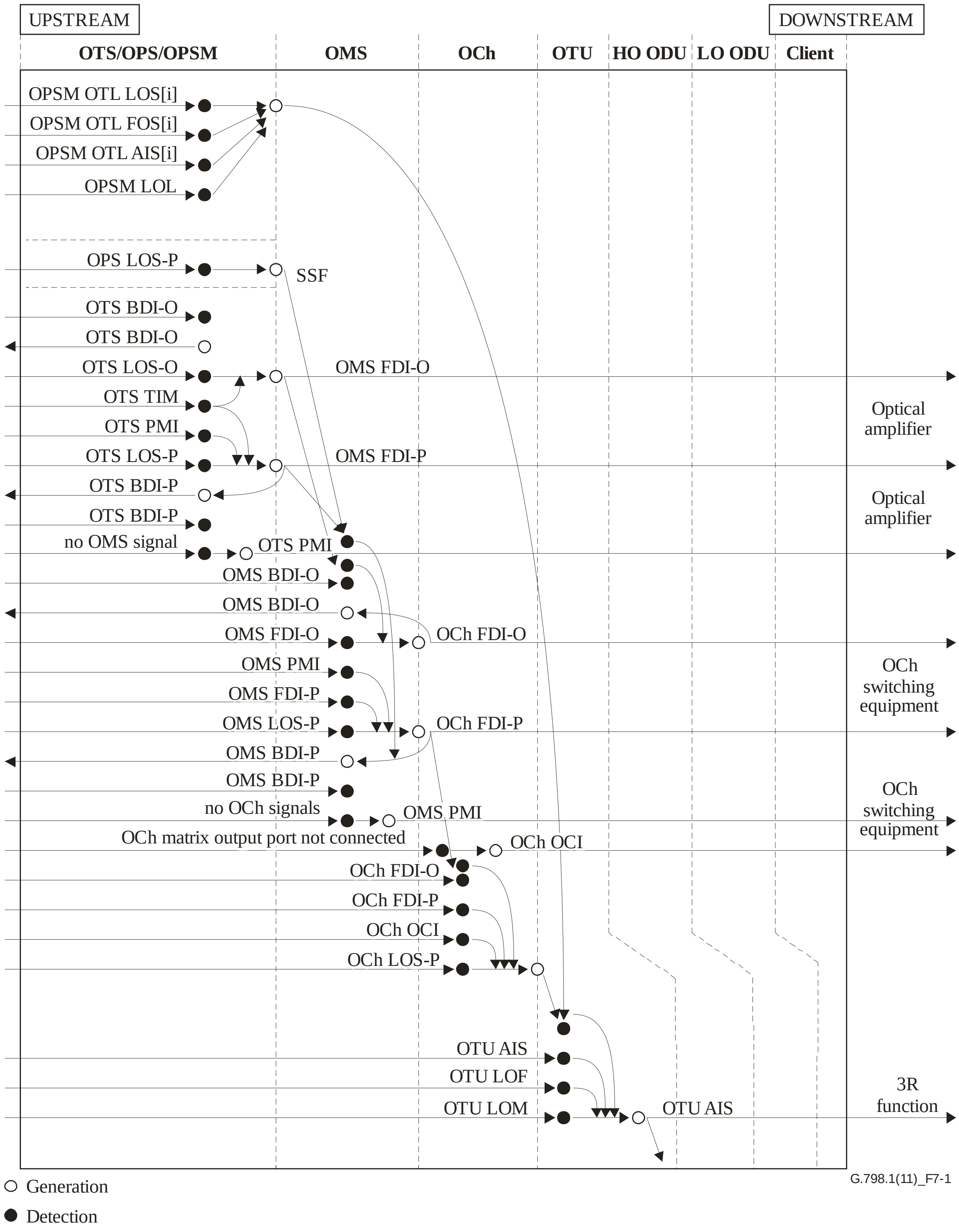

Figure 7-1 – OTN maintenance signal interaction (part I)

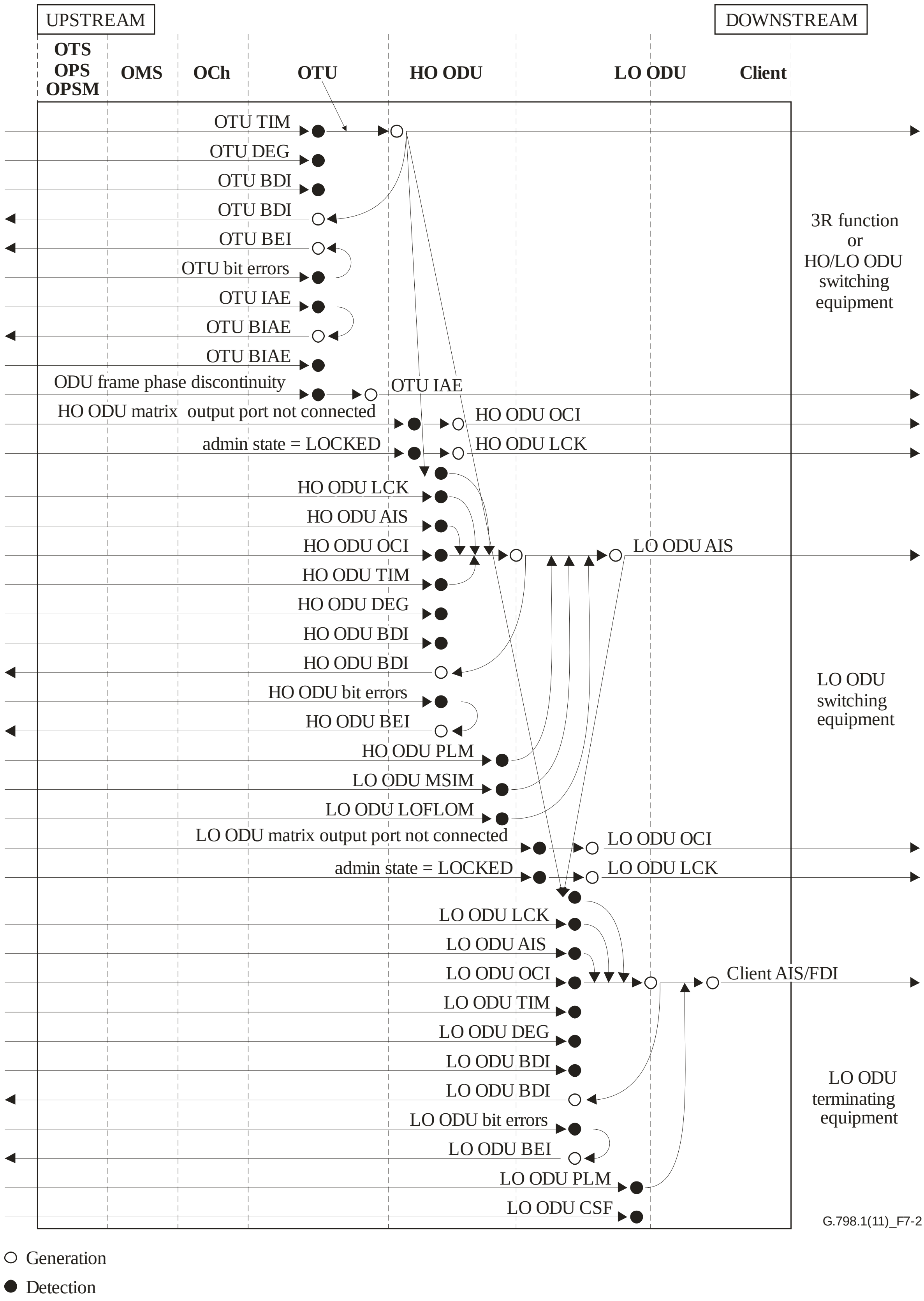

Figure 7-2 – OTN maintenance signal interaction (part II)

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 individual service basis. For the OTN this is on 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 those 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.

(a) shows an I-NNI port with multiplexing of low order ODUj into ODUk and tandem connection monitoring on the low order ODUs to support SNC/S protection.

(b) shows an I-NNI port where the low order ODU is mapped directly onto the wavelength.

(c) shows an I-NNI port with two levels of multiplexing.

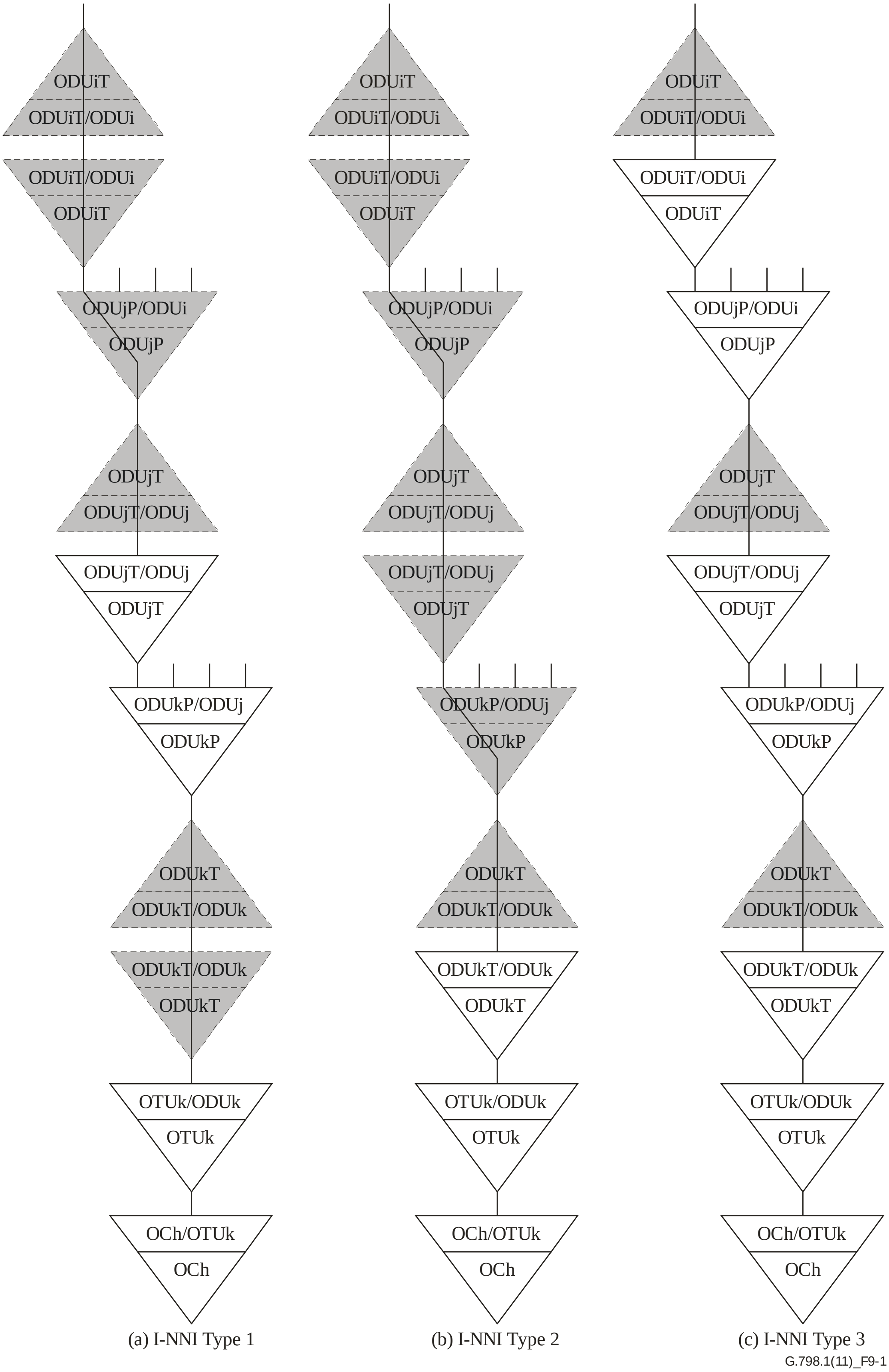

Figure 9-1 – I-NNI port compound function

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.

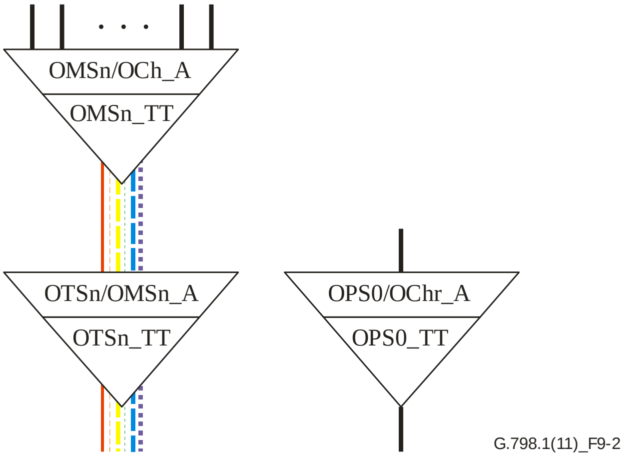

Figure 9-2 – WDM and single-channel physical layer compound functions

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.

(a) shows an E-NNI port with multiplexing of low order ODUj into ODUk and tandem connection monitoring onthe low order ODUs to support SNC/S protection.

(b) shows an E-NNI port where the low order ODU is mapped directly onto the wavelength.

(c) shows an E-NNI port with two levels of multiplexing.

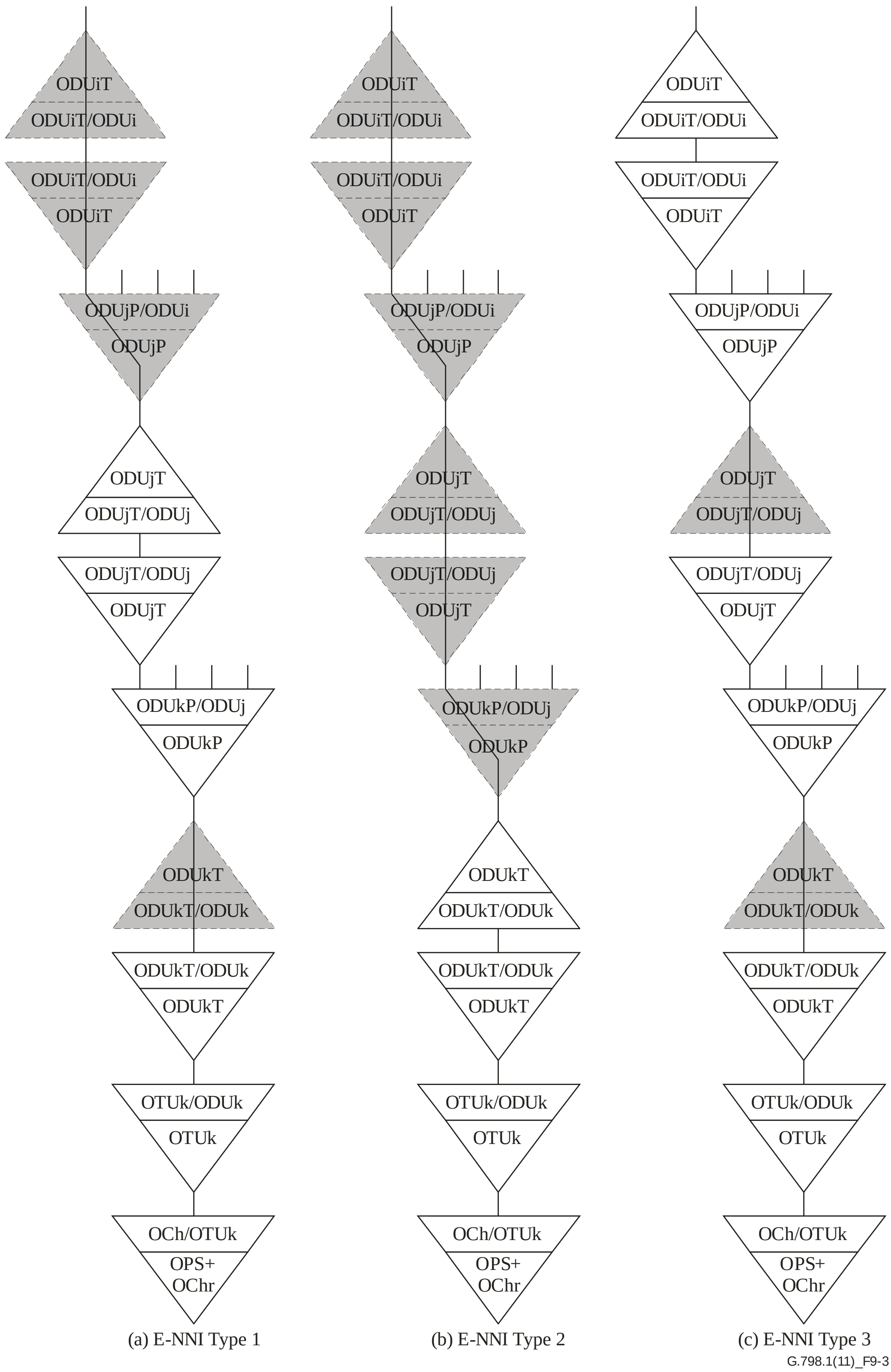

Figure 9-3 – E-NNI port compound functions

9.3 UNI

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

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

(c) 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.

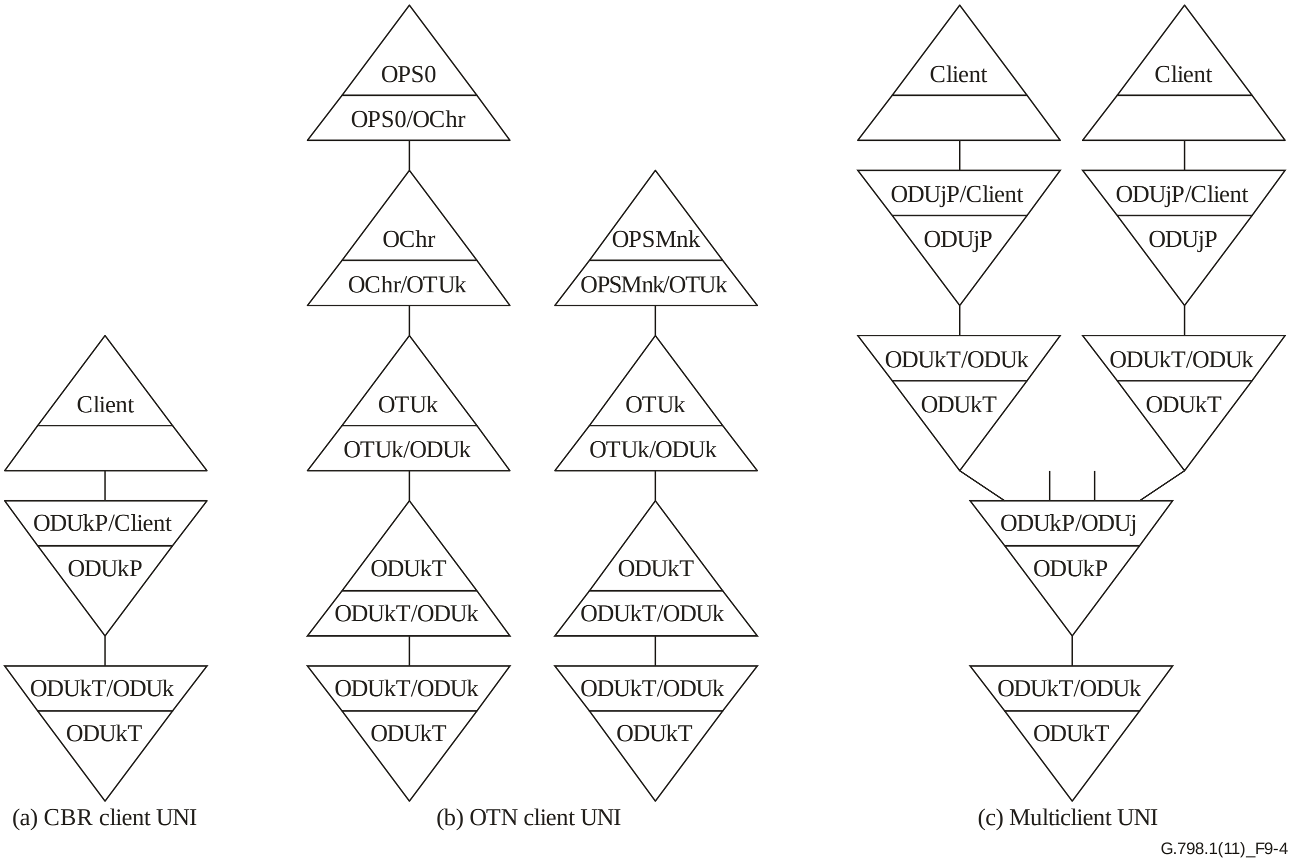

Figure 9-4 – UNI port compound functions

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 diagrammes 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.

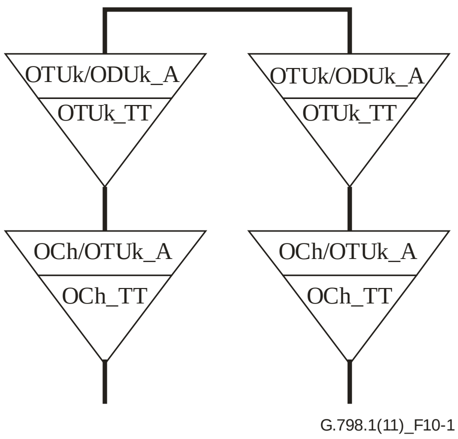

Figure 10-1 – 3R regenerator compound function

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.

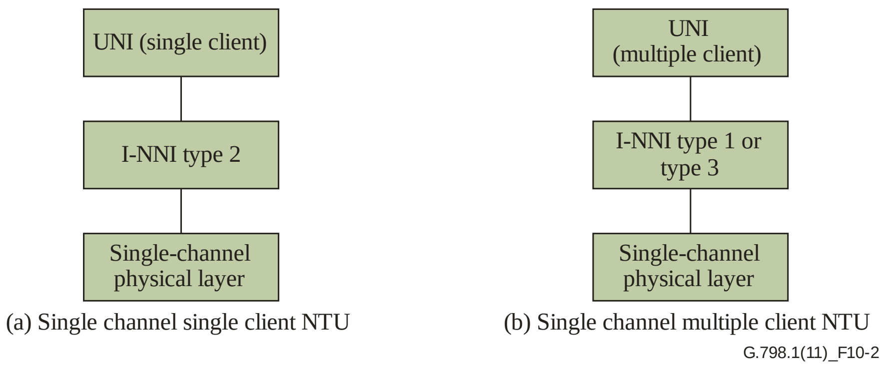

Figure 10-2 – Examples of single channel OTN NTU equipment

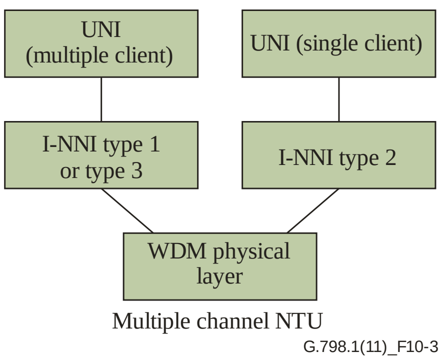

Figure 10-3 – Example of multiple channel OTN NTU equipment

10.3 Wavelength Add/Drop Multiplexer (WADM)

A wavelength ADM consists of two WDM ports 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).

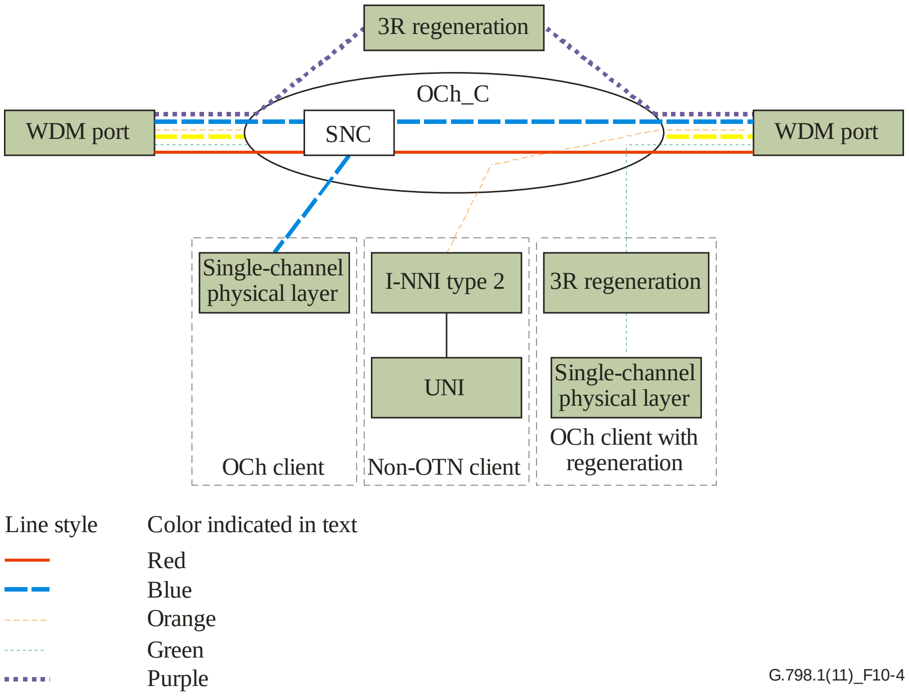

Figure 10-4 – Example of wavelength ADM showing various connections

10.4 Wavelength cross connect (WXC)

A wavelength cross connect is similar to a WADM, except that it supports more than two WDM ports. 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).

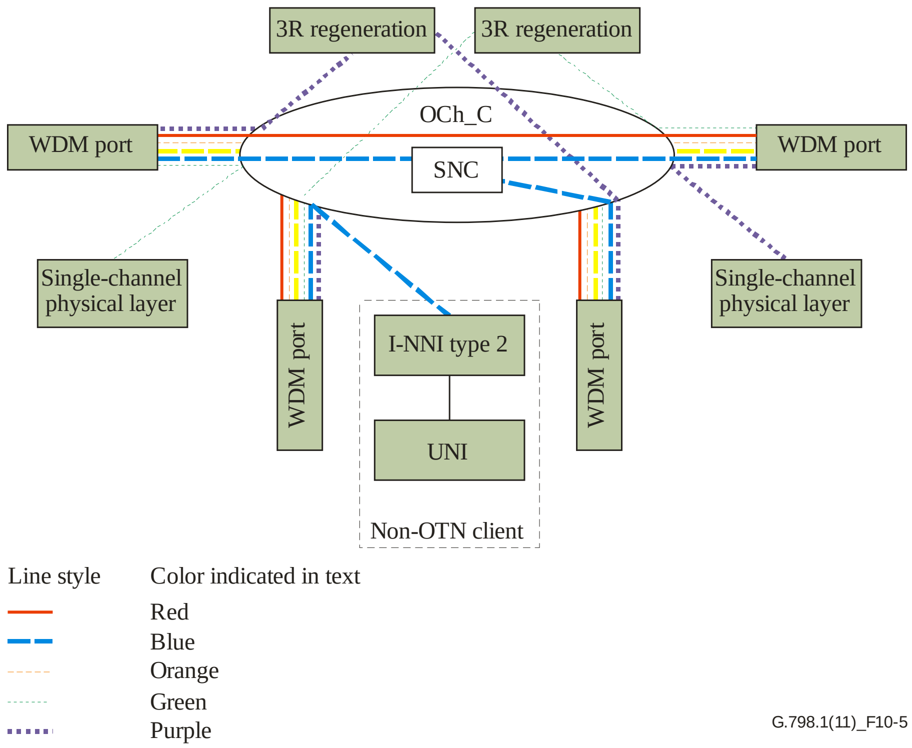

Figure 10-5 – Example of wavelength cross connect

10.5 Sub-wavelength cross connect (SWXC)

A sub-wavelength cross connect 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.

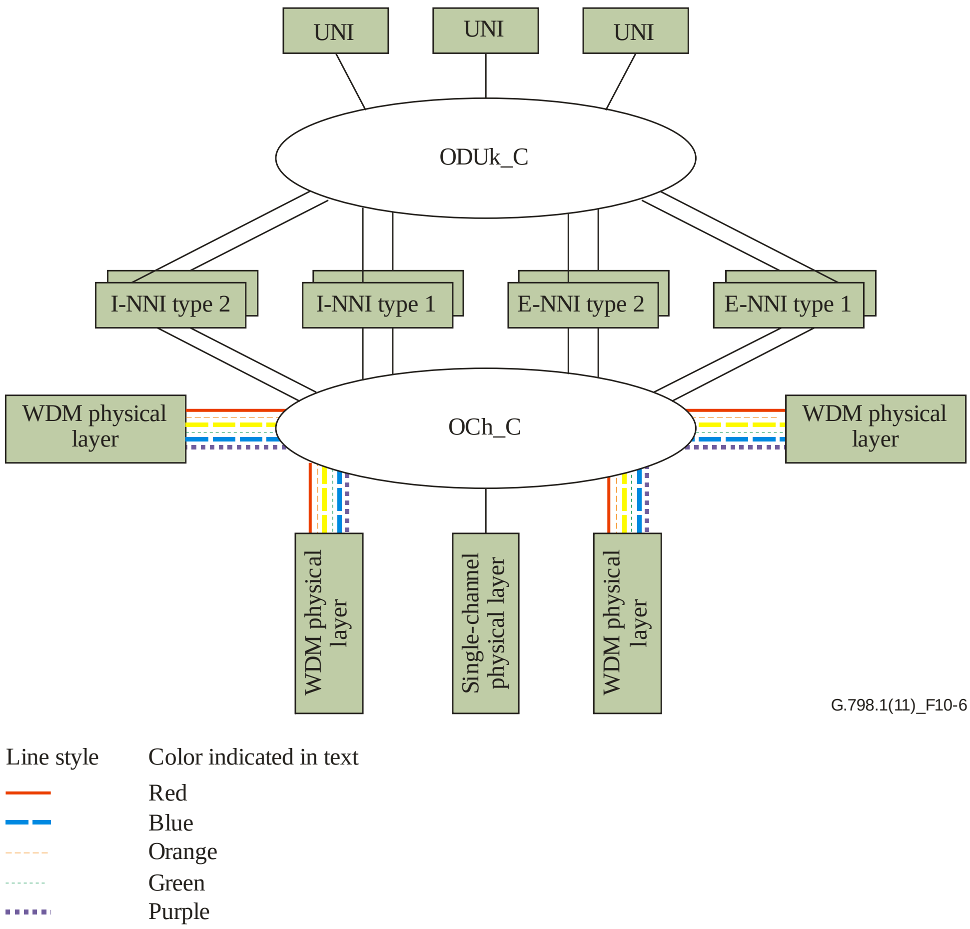

Figure 10-6 – Example of sub-wavelength cross connect

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.

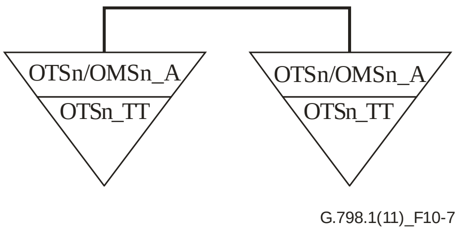

Figure 10-7 – Example of optical amplifier

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.

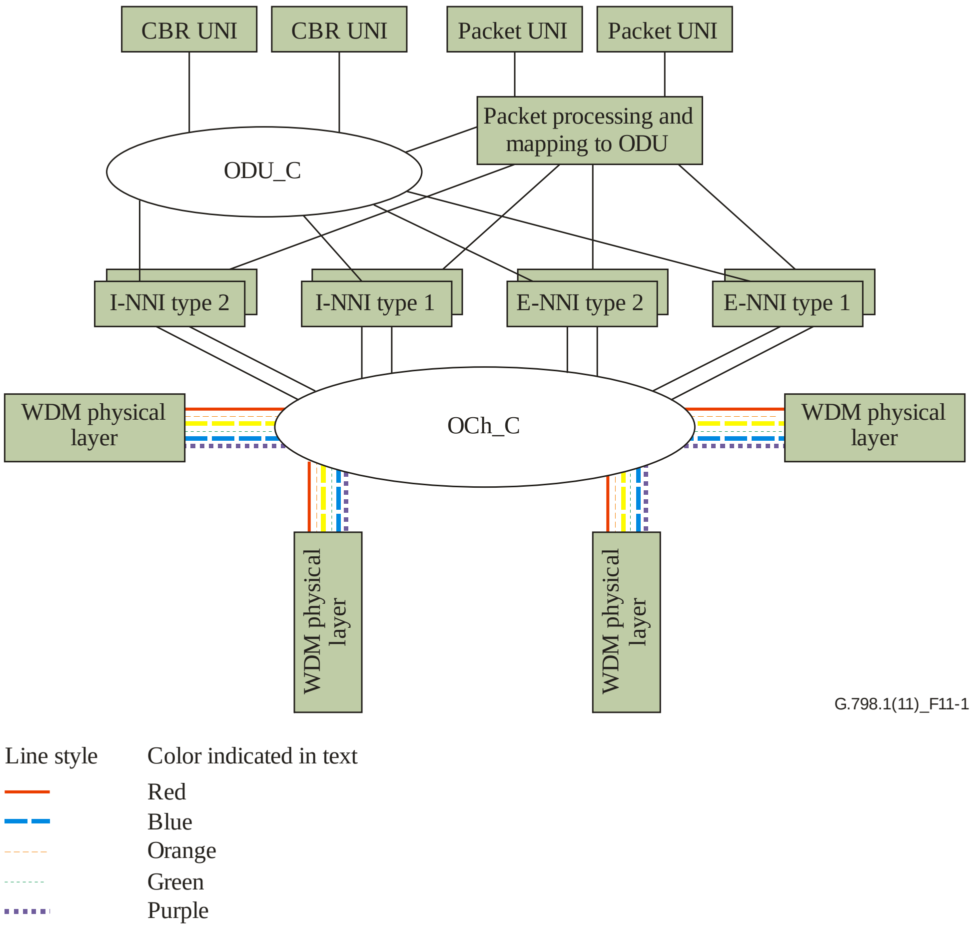

Figure 11-1 – OTN/PTN hybrid equipment

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 center. In this case, there would be two stages of multiplexing built up in multiple network elements until the switching center 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.

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