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Access networks – Optical line systems for local and access networks

Higher speed bidirectional, single fibre, point-to-point optical access system (HS-PtP)

Recommendation ITU-T G.9806

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Recommendation ITU-T G.9806

Higher speed bidirectional, single fibre, point-to-point optical access system (HS-PtP)

Summary

Recommendation ITU-T G.9806 describes a higher speed bidirectional single fibre point-to-point optical access system than the data rate in existing ITU-T point-to-point access systems. It supports 10 Gbit/s and above for the optical access services including the optical distribution network (ODN) specification, the physical layer specification, services requirements and the operation, administration and maintenance (OAM) specification.

History

Edition	Recommendation	Approval	Study Group	Unique ID[*]
1.0	ITU-T G.9806	2020-06-06	15	11.1002/1000/14196

Keywords

Optical access network, point to point optical transmission, single fibre (aka BiDi), 10 Gbit/s, single fibre bidirectional transmission.

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

FOREWORD

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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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Recommendation ITU-T G.9806

Higher speed bidirectional, single fibre, point-to-point optical access system (HS-PtP)

1 Scope

This Recommendation describes a higher speed bidirectional point-to-point (HS-PtP) Ethernet-based optical access system for the optical access services including the optical distribution network (ODN) specification, the physical layer specification, services requirements and the operation, administration and maintenance (OAM) specification.

For an effective use of optical fibres cited in [ITU-T G.986], this Recommendation specifies only a single fibre bidirectional transmission system, also known as diplex working as defined in [ITU-T G.982]. Dual-fibre systems are out of the scope of this Recommendation. This Recommendation also specifies systems with line rate at 10 Gbit/s. Line rates higher than 25 Gbit/s are for future study.

In addition, this Recommendation describes the case of a single domain managed optical network unit (ONU) and related optical line termination (OLT) requirements. The case of a dual domain managed ONU and related OLT requirements are for future study.

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.982]	Recommendation ITU-T G.982 (1996), *Optical access networks to support services up to the ISDN primary rate or equivalent bit rates.*
[ITU-T G.985]	Recommendation ITU-T G.985 (2003), *100 Mbit/s point-to-point Ethernet based optical access system.*
[ITU-T G.986]	Recommendation ITU-T G.986 (2010), *1 Gbit/s point-to-point Ethernet-based optical access system.*
[ITU-T G.988]	Recommendation ITU-T G.988 (2017), *ONU management and control interface (OMCI) specification.*
[ITU-T G.9807.1]	Recommendation ITU-T G.9807.1 (2016), *10-Gigabit-capable symmetric passive optical network (XGS-PON).*
[IEEE 802]	IEEE Standard 802 (2014), *IEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.*
[IEEE 802.3]	IEEE Standard 802.3 (2015), IEEE Standard for *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.*
[BBF TR-156]	Broadband Forum Technical Report 156 (2017), *Using GPONN Access in the context of TR-101.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 optical access network (OAN) [ITU-T G.985]: The set of access links sharing the same network-side interfaces and supported by optical access transmission systems.

3.1.2 optical distribution network (ODN) [ITU-T G.985]: An ODN provides the optical transmission means from the OLT towards the users, and vice versa. It utilizes passive optical components.

3.1.3 optical line termination (OLT) [ITU-T G.985]: An OLT provides the network-side interface of the OAN, and is connected to the ODN.

3.1.4 optical network unit (ONU) [ITU-T G.982]: An ONU provides (directly or remotely) the user-side interface of the OAN, and is connected to the ODN.

3.1.5 diplex working [ITU-T G.982]: Bidirectional communication using a different wavelength for each direction of transmission over a single fibre.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ANI	Access Node Interface
BER	Bit Error Ratio
Bm	Class B- stands for B minus
CPRI	Common Public Radio Interface
CRC	Cyclic Redundancy Check
DWLCH	Downstream Wavelength Channel
EMS	Element Management System
FEC	Forward Error Correction
FER	Frame Error Rate
FCS	Frame Check Sequence
GEM	GPON Encapsulation Method
HS-PtP	Higher Speed Point to Point
ID	Identifier
LPT	Link Pass Through
LRS	Line Rate Switching
MAC	Media Access Control
MC	Media Converter
MIB	Management Information Base
OAM	Operation, Administration and Maintenance

OAN   Optical Access Network

OC   Operation Control

ODN   Optical Distribution Network

OLT   Optical Line Termination

OMCC   ONU Management and Control Channel

OMCI   ONU Management and Control Interface

OPL   Optical Path Loss

ONU   Optical Network Unit

OSS   Out Of Sync

OUI   Organizationally Unique Identifier

PLOAM   Physical Layer Operations, Administration and Maintenance

PON   Passive Optical Network

QoS   Quality of Service

RE   Reach Extender

R/S   Receive/Send reference point at the interface of the ONU to the ODN

SNI   Service Node Interface

S/R   Send/Receive reference point at the OLT side

TOL   Transmit Optical Level

UNI   User Network Interface

5   Conventions

None.

6   Configuration of an OAN

6.1   System configuration

See clause 5.1 of [ITU-T G.985].

6.2   Fibre type

See clause 5.2 of [ITU-T G.985].

6.3   Transmission methodology

Bidirectional transmission is accomplished by the diplex technique using two wavelength bands in each transmission direction over a single fibre.

Former point to point diplex systems defined in ITU-T make use of the 1310 nm and 1550 nm windows operating at line rates of 1 Gbit/s and below.

For diplex mode to accommodate line rates higher than 1 Gbit/s over longer distances, HS-PtP would benefit from the progress of the optical filtering and active devices technology developed for the bulk market.

Going fully O band can minimize chromatic dispersion effects and offer the capacity to benefit from the building blocks designed for larger markets. Having both upstream and downstream

channels in the same wavelength window in the low dispersion area also enables the use of the lowest cost coding.

To enable energy efficiency in low payload or idle periods, it is required that the system be line rate versatile with agility between the line rates of interest and sub-rates (e.g.,: 50 G / 40 G / 25 G / 10 G / 1 G / 100 Mbit/s) with a dynamic auto-negotiation capability.

6.4 Transmission distances

Transmission distances of 10 km, 20 km, and 40 km are within the scope of this Recommendation.

Transmission distances longer than 40 km are for further study.

6.5 Wavelength allocation

To match the full range of distance and line rates, the following wavelength plan is specified.

Table 6-1 – Wavelength plan

Wavelength pair against nominal line rate	10 Gbit/s	25 Gbit/s	50 Gbit/s
Downstream direction	1330 ± 10 nm	For further study	For further study
Upstream direction	1270 ± 10 nm	For further study	For further study

Clear visual recognition of the pluggable optical modules at both the transmit and receive sides, shall be provided. Colour coding must enable quick identification of which side of the point-to-point link the optical module is intended. If different modules are necessary to cover the full extent of line rates and distances, the colour code must also enable easy identification to avoid errors in complex inventory situations.

6.6 ODN model

See clause 5.5 of [ITU-T G.985].

6.7 Line rates

Line rate at 10 Gbit/s is within the scope of this Recommendation.

Higher line rates, such as 25 Gbit/s and 50 Gbit/s, are for further study.

6.8 Classes for optical path loss

Recommended classes for optical path loss are shown in Table 6-2.

Table 6-2 – Classes for optical path loss

	Class S	Class A	Class B-	Class B
Minimum loss	0 dB	5 dB	10 dB	10 dB
Maximum loss	15 dB	20 dB	23 dB	25 dB

6.9 Reflectance in ODN

See clause 5.7 of [ITU-T G.985].

6.10 Module naming convention

The structure of an optical module naming convention is given in Table 6-3.

The names are composed of 3 letters appended to the "line rate GBase" main body. They represent:

- First letter "B" stands for single fibre bi-directional as in IEEE naming
- Second field stands for the optical budget class (S, A or Bm)
- Third letter stands for the direction (Downstream or Upstream)

Table 6-3 – Optical module naming convention

Optical budget class	Nominal line rate	Downstream	Upstream
S	10 G	10GBase-B-S-D	10GBase-B-S-U
	25 G	25GBase-B-S-D	25GBase-B-S-U
	50 G	50GBase-B-S-D	50GBase-B-S-U
A	10 G	10GBase-B-A-D	10GBase-B-A-U
	25 G	25GBase-B-A-D	25GBase-B-A-U
	50 G	50GBase-B-A-D	50GBase-B-A-U
B- (Bm)	10 G	10GBase-B-Bm-D	10GBase-B-Bm-U
	25 G	25GBase-B-Bm-D	25GBase-B-Bm-U
	50 G	50GBase-B-Bm-D	50GBase-B-Bm-U

7 Physical layer specification

The operation of the optical interface shall be full-duplex. Physical layer parameters are specified for each of the following applicable areas:

– Class S: Optical path loss 0-15 dB is intended to cover distances from 0 to 20 km.

– Class A: Optical path loss 5-20 dB.

– Class B: 10-23 dB: Introduced to relax the transceiver performances to cover distance up to 40 km.

– Class B: Optical path loss 10-25 dB is intended to cover distances from 20 to 40 km.

NOTE – The 5 dB overlap between class S and class B enables to avoid gaps due to ODN designs and wavelength choices.

All parameters are specified as follows and should be in accordance with Tables 7-1 and 7-2 for ONU and OLT for different wavelength and line rate options.

Commonalities across the OLT and ONU physical layer specifications should be maximized: transmit wavelength, receive wavelength, line code, maximum laser width, pulse mask and bit error ratio.

Specifications for 10 Gbit/s developed in Table 7-1 and 7-2 should be replicated as necessary for other line rates under consideration.

As a comparison, the methodologies in ITU-T and [IEEE 802.3] are compared in Appendix II.

Table 7-1– Physical layer specification for 10 Gbit/s ONU

Items	Unit	Specification	
ODN class		Class S	Class B-
Nominal bit rate	Gbit/s	10.3125	
Transmit wavelength	nm	1260-1280	

Table 7-1– Physical layer specification for 10 Gbit/s ONU

Items	Unit	Specification	
ODN class		**Class S**	**Class B-**
Receive wavelength	nm	1320-1340	
Line code	–	64B66B	
Spectral characteristic Maximum –20 dB width	nm	Less than 1	
Spectral characteristic Minimum side mode suppression ratio	dB	More than 30	
Mean launch power MAX	dBm	–5.6	+4.0
Mean launch power MIN	dBm	–9.0	–0.4
Minimum overload	dBm	–5.6	–6.0
Minimum sensitivity	dBm	–25	–25.0
Damage threshold MAX	dBm	–4.6	–5.0
Optical path penalty MAX	dB	1	1.6
Transmitter Penalty MAX	dB	1	1
Extinction ratio Nominal	dB	6.5	6.5
Extinction ratio MIN	dB	5	5
Pulse mask {X1,X2,Y1,Y2,Y3}	UI	For further study	
S/X			
Optical return loss condition	dB	More than 14	
Bit error ratio	–	Less than 5^{-5}	
Optical return loss of the interface	dB	More than 14	

Table 7-2– Physical layer specification for 10 Gbit/s OLT

Items	Unit	Specification	
ODN class		**Class S**	**Class B-**
Nominal bit rate	Gbit/s	10.3125	
Transmit wavelength	nm	1320-1340	
Receive wavelength	nm	1260-1280	
Line code	–	64B66B	
Spectral characteristic Maximum –20 dB width	nm	Less than 1	
Spectral characteristic Minimum side mode suppression ratio	dB	More than 30	
Mean launch power MAX	dBm	+5.6	+4.0
Mean launch power MIN	dBm	–9.0	–0.4
Minimum overload	dBm	–5.6	–6.0
Minimum sensitivity	dBm	–25	–25.0

Table 7-2– Physical layer specification for 10 Gbit/s OLT

Items	Unit	Specification	
ODN class		Class S	Class B-
Damage threshold MAX	dBm	–4.6	–5.0
Optical path penalty MAX	dB	1	1.6
Transmitter Penalty MAX	dB	1	1
Extinction ratio nominal	dB	6.5	6.5
Extinction ratio MIN	dB	5	5
Pulse mask {X1,X2,Y1,Y2,Y3}	UI	For further study	
S/X			
Optical return loss condition	dB	More than 14	
Bit error ratio	–	Less than 5^{-5}	
Optical return loss of the interface	dB	More than 14	

7.1 Transmit wavelength/Receive wavelength

The transmit and receive wavelengths are described in clause 6.5.

7.2 Bit rate and line coding

HS-PtP systems must provide a suite of line rates, preferably integer multiples of line rates in legacy systems, adjusting to the actual traffic load to be conveyed.

Bit rate of both upstream and downstream must be versatile to enable energy efficiency with dynamic line rate switching, without causing any downstream clock disruption.

The optical interface of the ONU and the OLT uses the transmission and 64B66B coding specification in conformance with the 10GBASE-R PCS and PMA sublayers to support a nominal line rate of 10 Gbit/s as defined in clause 158 of [IEEE 802.3] .

To meet the bit error ratio requirements, the use of frame error rate: RS(528, 514) as specified in clause 91.5.2.7 of [IEEE 802.3] is required.

The line coding for 50 Gbit/s is for further study.

7.3 Spectral characteristics

The maximum spectral width is specified by the maximum full width measured at the point of 20 dB lower than the maximum amplitude of the central wavelength under standard operating conditions. Additionally, for control of mode partition noise in single longitudinal mode systems, a minimum value for the laser side-mode suppression ratio is specified.

7.4 Mean launched power

See clause 6.4 of [ITU-T G.985].

7.5 Receiver characteristics

See clause 6.5 of [ITU-T G.985].

7.6 Extinction ratio

See clause 6.6 of [ITU-T G.985].

7.7 Pulse mask

Pulse mask at reference points is in conformance with the mask of the transmitter eye diagram for 1000BASE-BX10 specified in clause 52.9.7 of [IEEE 802.3].

7.8 S/X

See clause 6.8 of [ITU-T G.985].

7.9 Optical return loss of the interface

The optical return loss of the interface means the ODN reflection of its received light. Therefore, the optical return loss of the interface is defined by the wavelength allocation in Table 6-1.

7.10 Test pattern

The data pattern to be used in measuring wavelength or spectral characteristics is not specified in this Recommendation, but the test patterns defined in clause 52.9.1 of [IEEE 802.3] may be used as a reference.

7.11 Signal detect

See clause 6.12 of [ITU-T G.985].

8 Transmission convergence layer and ONU management

8.1 OAM structure

The following combined OAM structure is applied to HS-PtP transmission. ONU management and control interface (OMCI) specifications are optimized for single domain ONU management, of which the managed entities are specified in [ITU-T G.988].

– OAM for link operation: The OAM functions specified in clause 57 of [IEEE 802.3] are applied.

– OAM for ONU equipment and service management: The OMCI specifications optimized for this section are applied.

Table 8-1 summarizes the OAM functions and indicates whether the OAM specifications from clause 57 of [IEEE 802.3], or the OMCI specifications optimized for this section, are applicable to each of them.

Table 8-1 – OAM functions and applicable specifications

OAM functions		Applicable specifications
ONU status notification	ANI status	Clause 57 (OAM)of [IEEE 802.3]
	ONU vendor code and ONU model number	OMCI for this section ONU-E defined in clause 9.1.13 of [ITU-T G.988]
	UNI status	OMCI for this section Physical path termination point of Ethernet UNI defined in clause 9.5.1 of [ITU-T G.988]

Table 8-1 – OAM functions and applicable specifications

OAM functions		Applicable specifications
ONU remote setting	UNI status	OMCI for this section Physical path termination point of Ethernet UNI defined in clause 9.5.1 of [ITU-T G.988]
Fault management	Power supply	Clause 57 (OAM) of [IEEE 802.3]
	ONU failure	Clause 57 (OAM) of [IEEE 802.3] and/or OMCI for this section ONU-E defined in clause 9.1.13 [ITU-T G.988]
	Received signal	Clause 57 (OAM) of [IEEE 802.3]
	UNI status	OMCI for this section Physical path termination point of Ethernet UNI defined in clause 9.5.1 of [ITU-T G.988]
Loop-back test	ONU loop-back status	OMCI for this section Physical path termination point of Ethernet UNI defined in clause 9.5.1 of [ITU-T G.988]

8.2 OMCI Ethernet frame

8.2.1 Frame structure

For OAM used for ONU equipment and service management, each ONU management and control protocol packet is encapsulated into the protocol data field as the OMCI message field in a media access control (MAC) frame with the organizationally unique identifier (OUI) extended Ethertype in the Length/Type field defined in clause 2.3 of [IEEE 802]. The frame is called the OMCI Ethernet frame in this Recommendation. Figure 8-1 shows the OMCI Ethernet frame structure where the ONU management and control protocol packet is assumed to be taken from a G-PON encapsulation method (GEM) packet.

The OMCI Ethernet frame contains a single 40-byte long OMCI message field.

Methods for extended OMCI messages are in conformance with clause 11 of [ITU-T G.988].

ONT management and control protocol packet in a GEM packet

Figure 8-1 – OMCI Ethernet frame structure

8.2.2　Frame format and messages

The OMCI Ethernet frame format and messages are defined in Table 8-2.

Table 8-2 – OMCI Ethernet frame format and messages

Field	Length		Definition		Value
Destination MAC address	6 bytes		Destination MAC address		See clause 7.2.2.1
Source MAC address	6 bytes		Source MAC address		See clause 7.2.2.1
OUI extended Ethertype	2 bytes		OUI extended Ethertype defined in [IEEE 802]		0x88-B7
Protocol identifier	5 bytes		Protocol ID defined in [IEEE 802]		
OUI		3 bytes		ITU-T OUI	0x00-19-A7
ITU-T Subtype		2 bytes		ITU-T Subtype reserved by Q.2/15 for OMCI	0x00-02
Length of next OMCI message	2 bytes		Indication of the length of a following OMCI message field		0x00-28
OMCI message	40 bytes				For further study, to accept flexible length messages.
Transaction correlation identifier		2 bytes		Defined in [ITU-T G.988]	
Message type		1 byte		Defined in [ITU-T G.988]	
Device identifier		1 byte		Defined in [ITU-T G.988]	0x0A
Message identifier		4 bytes		Defined in [ITU-T G.988]	
Message contents		32 bytes		Defined in [ITU-T G.988]	
End of OMCI	2 bytes		Indication of no OMCI message following		0x00-00
Frame check sequence	4 bytes		FCS defined in [IEEE 802.3]		

8.2.2.1　Destination MAC address and source MAC address

In the OMCI Ethernet frame format shown in Table 8-2, the destination MAC address shall be the broadcast address or the unicast MAC address of the far end equipment, which is not defined in this Recommendation. Source MAC address shall be the source equipment MAC address.

8.2.3　Frame termination rule

The following frame termination rule shall be applied to the OMCI Ethernet frame.

1)　Frame termination rule at access node interface (ANI):

When a frame with destination MAC address, OUI extended Ethertype and protocol identifier, all of which satisfy the values defined in Table 8-2, is received,

- the received frame shall not be transferred to UNI nor to service node interface (SNI).

2)　Frame termination rule at UNI or SNI:

When a frame with OUI extended Ethertype and protocol identifier, both of which satisfy the values defined in Table 8-2, is received,

- the received frame shall not be transferred to ANI;
- messages contained in the received frame shall be ignored.

8.3 Activation process

Figure 8-2 shows the activation process. As described in clause 10.1, the ONU shall follow the silent start function first.

After recognizing the OLT initial operation control (OC) message, the ONU answers through its OC message answer.

This message exchange also allows distance estimation with the procedure outlined below. It is optional to implement the distance estimation function in OLT/ONU.

The OLT then transmits the estimation of the OLT to ONU distance in its OC message. After the ONU acknowledges receiving the distance estimation OC message, both the OLT and ONU will enter full speed mode, with the necessary digital compensation processing as appropriate. Clause 8.3.1 describes the message format.

The full content of the OC adapted from the one defined for PON in clause 10.1.1 of [ITU-T G.9807.1] and the ONU answer details are described in clauses 8.3.2 and 8.3.3, respectively.

Upon the start of link up, the ONU reflects in the upstream OAM the OLT identifier and transmits information enabling the round trip delay estimation to recover the delay for phase knowledge necessary for some mobile applications.

Then, the ONU management and control channel (OMCC) handshaking process begins.

During the process, the OLT shall check if the OMCI and which managed entities are supported by the ONU: The OLT performs a Get action on the ONU data managed entity. When the OLT receives a proper Get response from the ONU, the OLT recognizes that the ONU supports a proper OMCI. It is outside the scope of this Recommendation if the OLT should perform Get actions on other entities.

When the OMCC handshaking is done, the OMCC is established. Before, during, or after the OMCC handshaking process, the OAM discovery process for link operation begins. The OAM discovery process is specified in clause 57 of [IEEE 802.3].
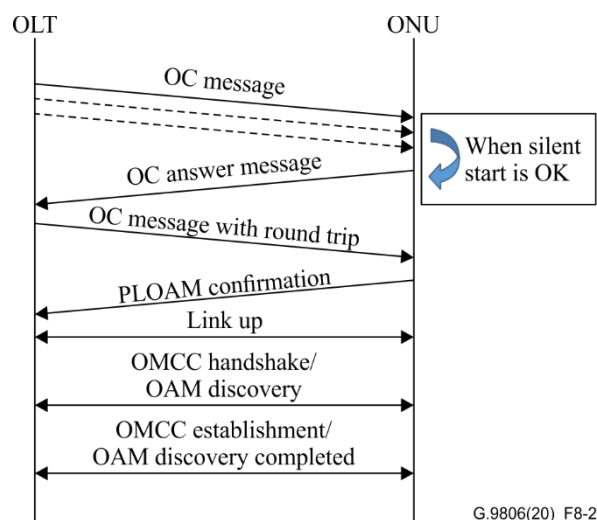

Figure 8-2 – Activation process

8.3.1 Activation initial messaging

The initial activation will be based on generic PtP OC messages. These messages are to be used by the OLT CT and ONU as long as ONU valid answer has not been received and estimation of the round trip delay has not been completed.

This messaging will also be resumed upon loss of connectivity between OLT and ONU, corresponding then to a possible trouble shooting situation.

The message structure consists of a preamble, a PtP OC body and a CRC protection enabling its quick recovery as shown in Figure 8-3.

– The preamble is 4 byte long (suggested pattern 0x AA AA AA AF)

– The PtP OC body is 8 byte long

– The CRC is 1 byte long

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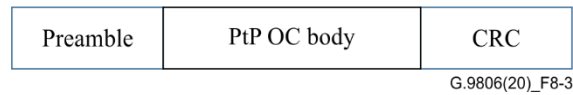
Figure 8-3 – OC message structure

For the sake of low power consumption and low cost, the OLT CT and ONU adopt an NRZ modulation at 10 Mbit/s.

The OLT cyclically transmits this PtP OC message once in a second.

The ONU transmits its answer upon OLT implicit prompting.

Upon detection of a valid ONU OC answer message, the OLT performs an estimation of the round-trip delay and transmits it to the ONU that will acknowledge it.

Upon reception of the ONU acknowledgment of the round-trip delay, both ends enter the "link up" state of the activation process.

8.3.2 OC message

The PtP OC body content is meant to report to field engineers and ONUs, the nature and the capabilities of the OLT, in order for the engineers to check the status of the ODN. It also enables a generic answer to start the "link up" stage of the activation process across future options of this Recommendation.

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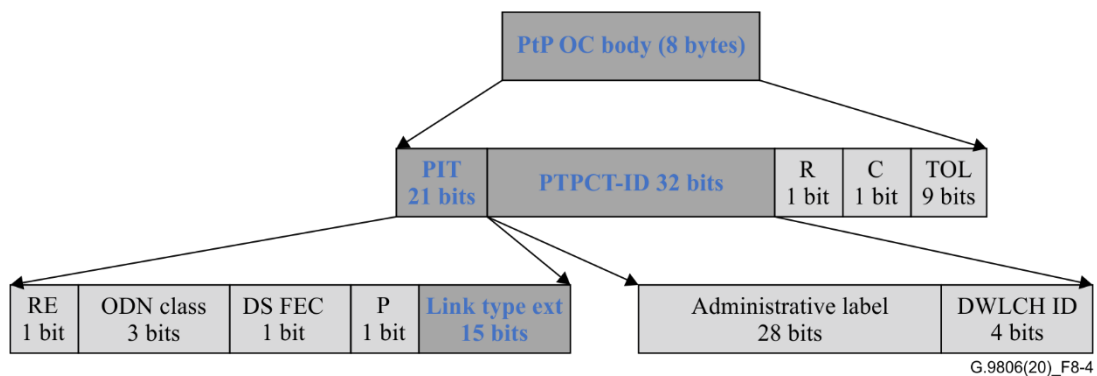
Figure 8-4 – Operation control structure

The OC structure is shown in Figure 8-4 and the content of the PtP OC body as follows:

PIT, or **PTPCT-ID type** (8 bits, static, provisioned by the operator): an indication of the ODN architecture, the source of the reported launch power and the ODN class. The PTPCT-ID type (PIT) field is further partitioned as follows:

•   **RE flag** (1 bit): indicates whether the transmit optical level (TOL) field contains the launch power of the OLT (RE = 0) or of a reach extender (RE = 1).

- **ODN class** (3 bits): identifies the nominal optical parameters of the transceiver according to ODN optical path loss (OPL) class as defined in Table 8-3, reusing [ITU-T G.985] and [ITU-T G.989] code values.

Table 8-3 – ODN optical path loss (OPL) class encoding

Code value	ODN OPL class
000	S
001	A
010	B
011	L1
100	L2
101	B-
110	Reserved
111	Reserved

- **DS FEC flag** (1 bit): Indicates whether FEC is enabled in the downstream direction. When this bit is set to 1, the FEC of the carried downstream channel is enabled. When this bit is set to 0, the FEC of the carried downstream channel is disabled.

- **P flag** (1 bit): Initially set to zero, the P flag is set when an ONU has been detected and round-trip delay confirmation is expected from the ONU.

- **Link type ext** (15 bits): The link type "extended" is segmented in two sections.

    – **Distance estimation** (13 bits): Set to zero by default, it contains upon reception of a valid answer from an ONU the estimated distance between the OLT and ONU in multiple of 10 m. 13 bits enable to cover up to 80 km.

    – **Link type legacy** (2 bits): reserved

    NOTE – This two-bit field inherited from PON OC could be used to indicate the ITU-T G.9806 mode (transparent or transcoded, or data rate or else …) and the type of application/terminal supported by the OLT. This application remains FFS.

PTPCT-ID (32 bits, static, provisioned by the operator): Identifies the OLT CT within a certain domain. PTPCT-ID consists of two fields:

- **Administrative label**: 28-bit field, supplied by an element management system/Out Of Sync to the OLT in accordance with certain physical or logical numbering plan. The administrative label is treated transparently by the OLT.

- **DWLCH ID**: 4-bit field, can take on any value for future wavelength division multiplexing context. It also enables to cover the case of several wavelength options for a single channel co-existing on the market. This application remains for further study.

    – **R** (1 bit): Reserved.

    – **C** (1 bit): Transmit optical level reference point indicator. This must be set to 0 for single channel systems.

    – **C = 0**: The TOL value below refers to the S/R reference point.

TOL (9 bits, dynamic, maintained by the system): Transmit optical level. An indication of the current OLT transceiver channel launch power into the ODN (at the S/R reference point), if RE = 0, or reach extender transceiver launch power, if RE = 1. Its value is an integer representing a logarithmic power measure having 0.1 dB granularity with respect to –30 dBm (i.e., the value zero represents −30 dBm, 0x12C represents 0 dBm, and 0x1FE represents 21 dBm). The 0x1FF default value indicates that TOL is not supported on the given PtP interface.

8.3.3 OC answer message

In order to simplify the messaging mechanism, symmetrical OC message structure is used. Hence the OC answer body is 8 byte long. The OC answer message structure is shown in Figure 8-5.

The OC answer message shall be used twice in the activation process.
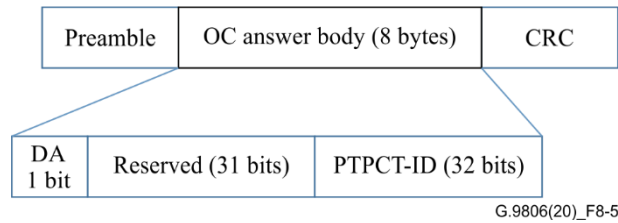
**Figure 8-5 – OC answer message structure**

Detail of the OC answer body is given below:

- Byte 0:
  - Bit 7 DA (Distance Acknowledge): set to zero by default, will carry the acknowledgement of the distance information, when the P flag of the OC downstream message has been found set to "1".
  - Bit 0-6 are reserved.
- Bytes 1 to 3 are reserved.
- Bytes 4 to 7 carry the downstream PTPCT-ID.

8.4 ONU with multiple UNI ports

The specification of the ONU having multiple user network interface (UNI) ports shall be specified in this Recommendation as optional. Figure 8-6 shows an image of the ONU having multiple UNI ports. The physical path termination point Ethernet UNI managed entity defined in clause 8.7.3 is specified to support multiple UNI ports also.

NOTE – Data forwarding permission rule between UNI ports is for further study.
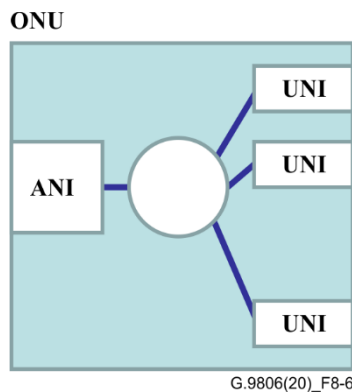
Figure 8-6 – ONU with multiple UNI ports

8.5 Managed entities

The possible managed entities are listed in Table 8-4.

Table 8-4 – Managed entities of the OMCI for this Recommendation

Managed entity	Required/ Optional	Description
ONU-E	R	Used for ONU point to point equipment management
ONU data	R	Used for OMCI MIB management
Physical path termination point Ethernet UNI	R	Used for physical path termination point at the Ethernet UNI

8.6 Managed entity relation diagram

See clause 8.2 [ITU-T G.988].

8.7 MIB description

8.7.1 ONU-E

See clause 9.1.13 in [ITU-T G.988].

8.7.2 ONU data

See clause 9.1.3 in [ITU-T G.988].

8.7.3 Physical path termination point Ethernet UNI

See clause 9.5.1 in [ITU-T G.988].

8.8 Dual managed ONU

The OAM structure for dual domain managed HS-PtP ONU elaborates on [ITU-T G.988] Appendix II.2 mechanisms.

8.9 Encapsulation method for transparent payload

Within this described transmission system's capabilities, it is of major interest to encode transparently some legacy tributary units, with smallest possible delay. It will be enforced by the OLT depending on the ONU capabilities, for operators/use cases requiring it so as not to induce extra costs for regular ONU.

Such a feature will in any case remain optional to use.

Possibly a switch over after the regular activation process, at the initiative of the OLT, can switch to such an encapsulation method over a general purpose Ethernet point to point link, while maintaining the necessary performances.

Details of such an XBytes, (X+N)Bytes encoding methods are for further study.

8.10 Link pass through capability

The option to implement link pass through is described in Appendix I.

9 Service requirements and service enabling features

9.1 Service requirements

Service requirements will be fully in line with those described in clause A.7 of [ITU-T G.9807.1].

9.2 Hitless line rate switching

In order to provide the most efficient transmission for variable traffic loads, HS-PtP must have the ability to adapt to it. This is especially required for 5G because of its ambitious power consumption objectives.

HS-PtP must provide a dynamic auto-neg of the line rate between OLT and ONU, which should be provided among the plurality of line rates supported according to the actual payload.

Because of the high clock quality requirements, and long recovery time of clock recovery circuitry, no phase drift will be permitted in the downstream direction when switching. Also, such switching will have to be without any loss.

9.2.1 Hitless line rate switching principles

Among the current requirements, disturbance to the end users should be kept minimal and preferably remain fully unnoticed. The delay to resume full speed operation must not become incompatible with the applications running.

Line rate switching conditions must therefore maintain quality of service (QoS) of connections running by monitoring of the queuing at both sides of the link. Unlike the DBA, the local (OLT) and remote (ONU) memory queues status may initiate line rates switching, with regard to the gross link rate, while maintaining the required delay performances attached to the QoS level.

In order not to cause any glitch in clock phase recovery of the ONT upon line rates switching, for timing sensitive applications, it is required that clock alignment is provided across the line rates, so that phase stability is secured for clock recovery circuits at the remote end.

9.2.2 Switching messaging sequence
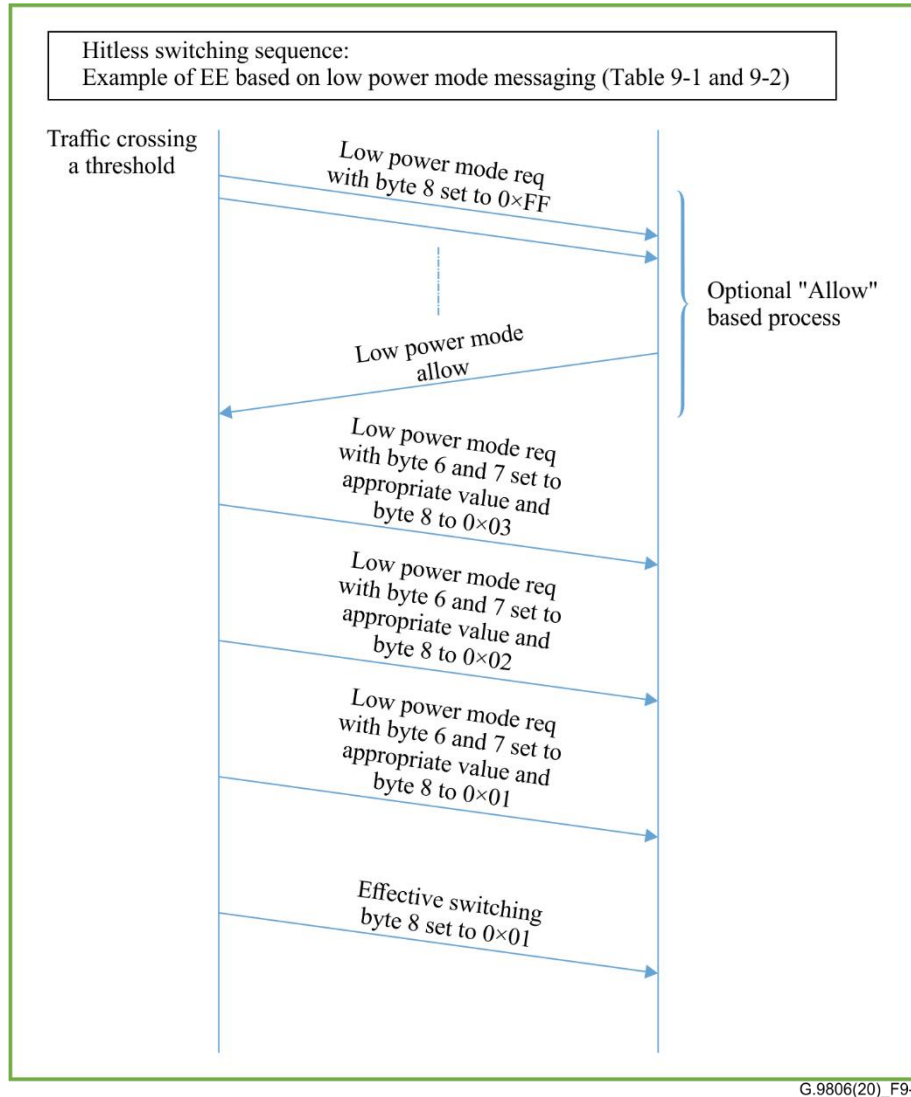
Figure 9-1 – Hitless switching protocol

Although the link is likely to be symmetrical in line rates, the clock quality maintaining and the watchful sleep protocol enabling will remain under control of the OLT.

9.2.3 Switching messages for line rate switching addition to the legacy "watchful sleep"

Ideally the switching does not require any bi-directional messaging exchange; on point to point switching can rely on simple preliminary redundant and protected announcements by the transmitter. Nevertheless, to secure switching, it is preferred to get acknowledgement of the process from the remote end.

In specific case of low power modes in passive optical networks (PONs), operations are handled in a single PLOAM message per direction. For point to point and here the addition of line rate switching (LSR) to the existing sleep mode (watchful sleep), this messaging needs to extend the [ITU-T G.9807.1] PLOAM legacy (dedicated to watchful sleep) and has been therefore re-branded as "Low power mode" with two messages, one for upstream and the other one for downstream.

In order to avoid multiple mapping of messages, it is proposed to shorten the related PLOAM messages to 40 bytes for point to point to adopt the mapping used for OMCI described in clause 8.2.1.

Table 9-1 – Low_power_mode_Allow message

Octet	Content	Description
1-2	0x03FF	As a broadcast message, ONU-ID = 0x03FF
3	Message type ID	0x12, "Low power mode allow"
4	SeqNo	Eight-bit unicast or broadcast PLOAM sequence number, as appropriate

5	Control flag	0000 000A, where:
		    A = 0: Sleep allowed OFF
		    A = 1: Sleep allowed ON
		Other values reserved

6	Current line rate	0xLR where LR represents an integer in the variety of possible values in Gbit/s (e.g., 0x01 for 1G 0x0A for 10G 0x32 for 50G …)

7	Line rate switching status	0000 000S, where:
		    S = 0: Line rate switching not ready
		    S = 1: Line rate switching authorized
		Other values reserved

8	Nature of transition	0000 00CD, where C stands for the direction, D for a single or the max step
		    CD = 00: Transition to next lower speed
		    CD = 01: Transition to lowest speed
		    CD = 10: Transition to next higher speed
		    CD = 11: Transition to highest speed
		Other values reserved

9-32	Padding	Set to 0x00 by the transmitter; treated as "don't care" by the receiver
33-40	MIC	Message integrity check, computed using the default PLOAM_IK in case of broadcast message, and using the ONU-specific derived shared PLOAM_IK in case of directed message

Table 9-2 – Low_power_mode_Request message

Octet	Content	Description
1-2	ONU-ID	ONU-ID of the message sender if such an ID remains used for PLOAM, else set to 0x0000 and ignored by the receiver
3	Message type ID	0x10, "Low power mode_Request"
4	SeqNo	Always 0x00
5	Activity _level	Activity Level: 0x00: Sleep_Request (Awake) 0x03: Sleep_Request (WSleep) Watchful sleep mode request: when in a LowPower state, the ONU periodically checks the downstream traffic for wake-up indications from the OLT Other values are reserved
6	Current line rate	0xLR where LR represents an integer in the variety of possible values in Gbit/s (e.g., 0x01 for 1G 0x0A for 10G 0x32 for 50G …)

7	Nature of transition	0000 00CD, where C stands for the direction, D for a single or the max step
		    CD = 00: Transition to next lower speed
		    CD = 01: Transition to lowest speed
		    CD = 10: Transition to next higher speed
		    CD = 11: Transition to highest speed
		Other values reserved

8	Switching count down	Set to 0x00 by default Set to 0xFF to request the other end to send a "low power mode allow" message Counter is set to 0x03 and decremented upon each "Low power mode_Request" PLOAM message transmission, either upon reception of an allow message or freely if no acknowledgement is needed Switching effective with 0x00
9-32	Padding	Set to 0x00 by the transmitter and treated as "don't care" by the receiver
33-40	MIC	Message integrity check, computed using the ONU-specific derived shared PLOAM integrity key

9.3 Round trip delay knowledge

So far in ITU-T the optical access point to point recommendations did not focus so much on the system aspects. Nevertheless, when used for mobile and wireless applications, phase compensation requires some knowledge of the OLT to ONU distance which is a new feature long known in PONs.

9.4 Port identification

For field operation purposes, the inheritance of capabilities of the OC structure, previously named PON-ID will have to be translated into the HS-PtP world.

9.5 Synchronization features and quality

Synchronizing features and performance requirements will be fully in line with those described in clause A.7 of [ITU-T G.9807.1]

10 Other requirements

10.1 Silent start function of ONU

The transmitter in the ONU must be initially disabled in order to avoid disturbing other access systems in case of misconnection. The ONU shall enable the transmitter to enter a handshaking process with OLT only after confirming that the frame structure and/or the line coding of the received downstream signal match those the ONU complies with. This confirmation shall be done with both OLT and ONU being set to the auto-negotiation function defined in clause 37 of [IEEE 802.3] disabled.

When the connection between ONU and OLT is disabled, the ONU shall return to the initial state in which the transmitter is disabled, after waiting for at least 20 ms from the moment the disconnection is detected, so that the ONU can send notification signals to the OLT.

This is a unique function for the single fibre optical-access systems hence working in diplex mode, such as in [IEEE 802.3] the 10GBASE-LR (clause 52 of [IEEE 802.3]).

10.2 Provisioning/authentication method

Provisioning and authentication methods will be replicated from [BBF TR-156].

10.3 Power saving and energy efficiency

HS-PtP will provide the best user and network energy efficiency experience combining sleep periods behaviours when the link is idle (derived from the ITU-T PON watchful sleep and [b-IEEE 802.3az]), plus line rates switching during low duty periods according to the actual payload to be conveyed, enabling the logic at its ends to adapt the clock rate to the necessary throughput.

10.3.1 Sleep mode

During sleep modes bi-directional connectivity between both ends of the link will be temporarily lost.

This clause is FFS.

10.3.2 Line rate switching

LRS is optional, since not all of the payload to be conveyed can support LRS when no similar hierarchy of line rates are applicable (e.g., lowest rate only ONUs) or when the interfaces cannot support any variation in payload (e.g., incompatibility with CPRI based fronthaul).

Only a hierarchy with integer multiplication factors will be considered. Ideally factors in the form of 2^n are preferred by electronic industry engineers, but because of the IEEE suite of legacy, 1 Gbit/s, 10 Gbit/s and 50 Gbit/s are suggested as primary line rates for this energy saving scheme. Integration of 25 Gbit/s in the hierarchy is for further study because of the fractional ratio with 10 Gbit/s.

LRS protocol is required to support unidirectional switching, to also provide the best efficiency for asymmetric traffic.

A classical figure of merit widely used in network planning to start upgrading any link was 85% of the capacity. Therefore, the following thresholds over an observing period (OP) are considered:

• Switching from low speed to its next step will occur when the effective payload crosses the threshold of 85% of its capacity.

- Reversely the switching down will occur when the effective payload is lower than 85% of this lower speed link capacity.

The LRS state machine is shown in Figure 10-1 using the 85% capacity threshold as an example.

NOTE – The term "effective capacity" is used to avoid confusing idle patterns with actual payload.
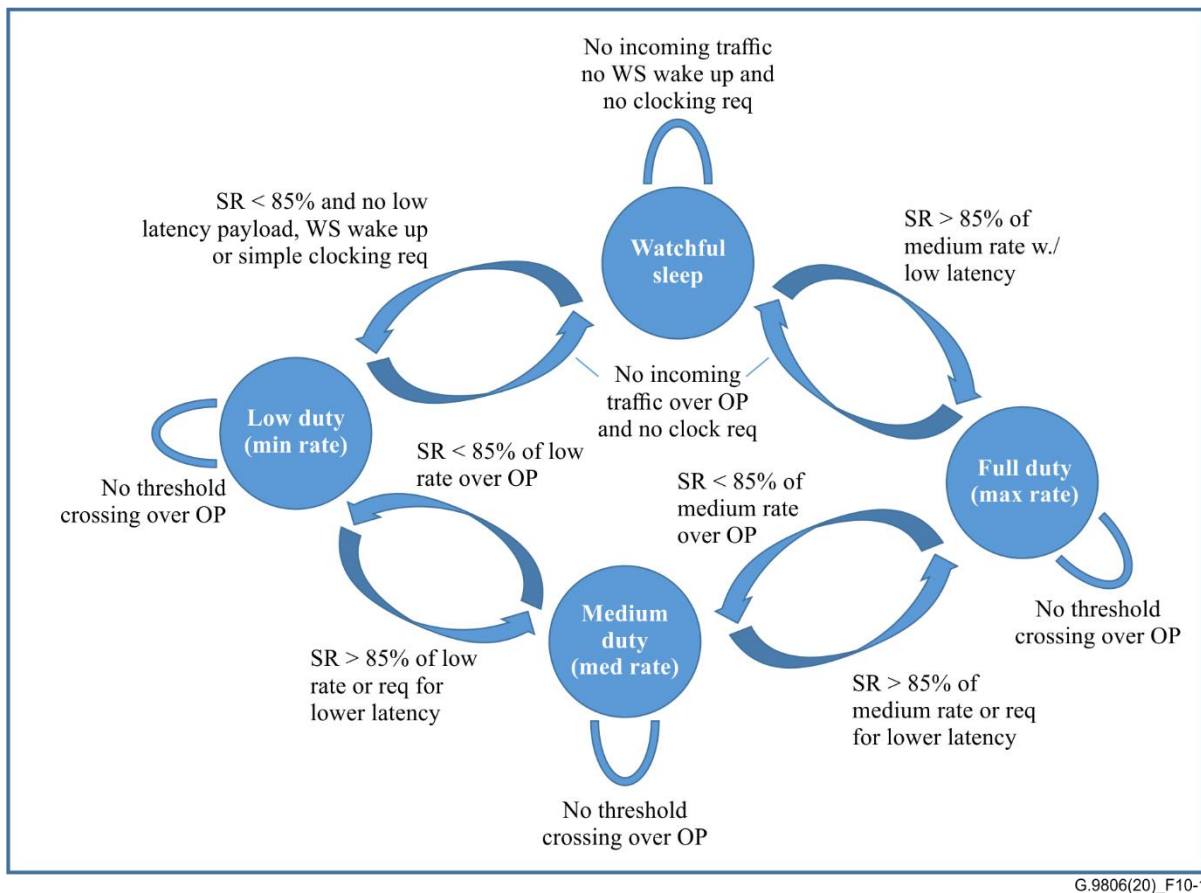
Figure 10-1 – LRS state machine

10.4 Environmental requirements

Outdoor operation may be needed in many of the envisaged applications for HS-PtP systems; thus, ONUs shall operate over outdoor temperature ranges. The following are informative examples of environmental requirements:

– ATIS-0600010.01.2008: (Class 4 unprotected environment) –40°C to either +46°C ambient plus solar loading, or +70°C ambient.

– Telcordia GR-487: –40°C to either +46°C ambient plus solar loading, or +70°C ambient.

– ETSI ETS 300 019-1-4: (Class 4.1E: Non-weather protected locations – extended) –45°C to +45°C ambient plus solar loading.

– IEC 61753-1 cat OP^{HD}: –25°C to +85°C for Outdoor Protected (OD) environment with additional Heat Dissipation (HD).

Optionally, the OLT should also be able to operate over the extended outside temperature range.

10.5 E-OTDR support

For further study.

10.6   Encryption/Data privacy

For further study.

10.7   Eye safety concerns

For further study.

Appendix I

Link pass through

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

Link pass through (LPT) is an optional function in media converters (MCs) to be inherited in the context of this Recommendation in which MC takes the name of optical line termination (OLT) or optical network unit (ONU). To obtain interoperability, the function will be fully described in this clause.

The purpose of LPT is quick detection of link-down on an end-to-end link between two devices connected to OLT or ONU.

The LPT is restricted to the OLT that does not perform any concentration or multiplexing. Each optical interface (ANI or S/R) of the OLT corresponds to one service node interface (SNI). LPT is not applicable for multi-port ONUs.

Layer 2 switches connected to an OLT or ONU generally have difficulties to rapidly detect the link-down, which results in problems for services with stringent requirements. Therefore, LPT is a useful function to mitigate these problems.

The expected LPT behaviours of OLT and ONU are as follows:

1)   if the ONU detects the link-down on the user network interface UNI, the OLT reflects the link-down on the related service node interface (SNI) port;

2)   if an OLT detects the link-down on the SNI, the ONU reflects the link-down on the related UNI port;

3)   if the OLT detects link-down on the transmission link (ANI or at S/R), the OLT reflects the link-down on the related SNI;

4)   if an ONU detects link-down on the transmission link (ANI or at R/S), the ONU reflects the link-down on its UNI.

Figure I.1 a) to d) show several failure cases supported by LPT. First, if link-down on the SNI side of an OLT occurs, the LPT function in the ONU will set the UNI to link-down as described in Figure I.1 a) and vice versa as in Figure I.1 b). Next, if the link-down on the ODN between an OLT and an ONU happens, the link-down both on the SNI and the UNI sides will be forced by LPT as shown in Figure I.1 c). Finally, if the electrical power failure to an ONU occurs, the link-down both on the SNI is forced by LPT as depicted in Figure I.1 d). Regarding the setting of "enabled" or "disabled" for LPT, the OLT and the ONU should be independently controlled according to the operator's choice.
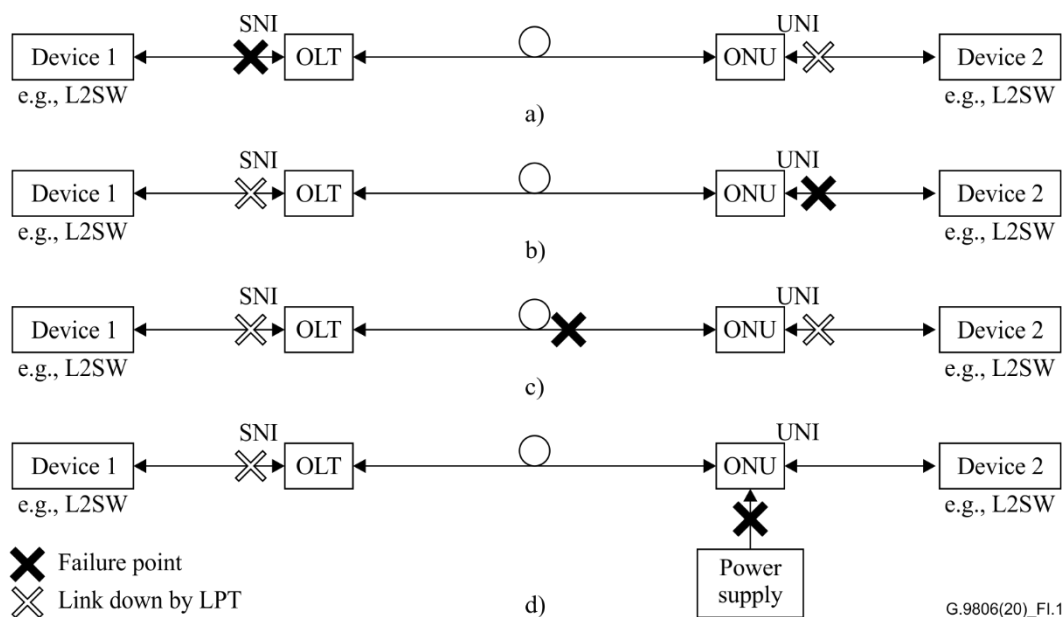
Figure I.1 – Failure cases supported by LPT: a) link-down on SNI side, b) link-down on UNI side, c) link-down between OLT and ONU, and d) power supply failure at ONU

Table I.1 shows various kinds of failure events and examples of the corresponding operations at OLT and ONU for both "enabled" and "disabled" modes of the LPT function. The operations in this table are based on the existing OAM functions in [ITU-T G.986].

Table I.1 – Failure events and the corresponding operations at OLT and ONU

<table>
<tr><td colspan="2" rowspan="2" style="text-align:center">Events</td><td colspan="2" style="text-align:center">Operations</td></tr>
<tr><td style="text-align:center">LPT enabled</td><td style="text-align:center">LPT disabled</td></tr>
<tr><td rowspan="4">OLT</td><td>ANI gets down</td><td>SNI gets administrative down</td><td>Do nothing</td></tr>
<tr><td>SNI gets down</td><td>OLT sends administrative UNI down OMCI</td><td>Do nothing</td></tr>
<tr><td>OLT receives UNI down notification</td><td>SNI gets administrative down</td><td>Do nothing</td></tr>
<tr><td>OLT receives dying gasp</td><td>OLT changes ANI status to down, and SNI gets administrative down</td><td>OLT changes ANI status to down</td></tr>
<tr><td rowspan="4">ONU</td><td>ANI gets down</td><td>UNI gets administrative down</td><td>Do nothing</td></tr>
<tr><td>UNI gets down</td><td>ONU sends UNI link down notification</td><td>ONU sends UNI link down notification</td></tr>
<tr><td>ONU receives administrative UNI link down OMCI</td><td>UNI gets administrative UNI down</td><td>UNI gets administrative UNI down</td></tr>
<tr><td>ONU detects power down</td><td>ONU sends dying gasp</td><td>ONU sends dying gasp</td></tr>
</table>

Table I.2 shows various kinds of recovery events after failure and examples of the corresponding operations at OLT and ONU for both "enabled" and "disabled" mode of the LPT function. The operations in this table are based on the existing OAM functions in [ITU-T G.986].

Table I.2 – Recovery events and the corresponding operations at OLT and ONU

Events		Operations	
		LPT enabled	**LPT disabled**
OLT	ANI gets up	SNI gets administrative up	Do nothing
	SNI gets up	OLT sends administrative UNI up OMCI	Do nothing
	OLT receives UNI up notification	SNI gets administrative up	Do nothing
	ONU is activated	OLT changes ANI status to up, and SNI gets administrative up	OLT changes ANI status to up
ONU	ANI gets up	UNI gets administrative up	Do nothing
	UNI gets up	ONU sends UNI link up notification	ONU sends UNI link up notification
	ONU receives administrative UNI link up OMCI	UNI gets administrative UNI up	UNI gets administrative UNI up
	ONU gets power up	ONU starts activation process	ONU starts activation process

In addition, 1:1 link protection for external devices can be performed as an application of the LPT function. Figure I.2 shows an example of 1:1 link protection. If link-down occurs on the active line between two devices, the path of the data transmission will be switched to the protection line.
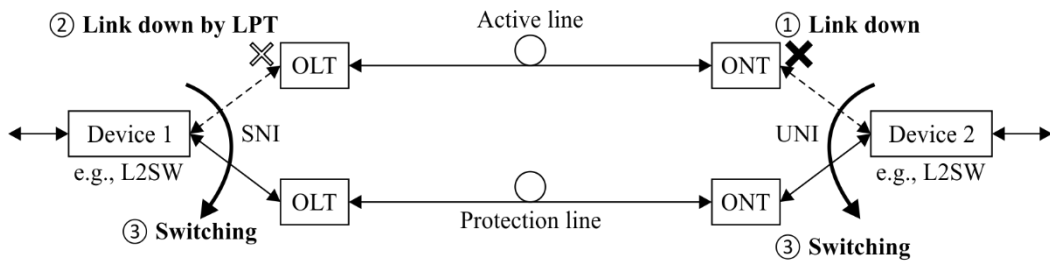
G.9806(20)_FI.2

Figure I.2 − An example of 1+1 link protection by LPT

Appendix II

Comparison of ITU-T and IEEE 802.3 transceiver specification methodologies

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

The ITU and IEEE 802.3 (10G) specification schemes are described in the two equations below.

In the ITU specification scheme:

$$\text{TxPower} - \text{PathLoss} - \text{PathPenalty} = (\text{Rxsensitivity} + \text{TxPenalty}) = \text{ITUrxSensitivity} \quad \text{(II.1)}$$

In the IEEE (10G) specification scheme:

$$(\text{TxPower} - \text{TxPenalty} - \text{PathPenalty}) - \text{PathLoss} = \text{RxSensitivity} \quad \text{(II.2)}$$

Note that TxPower in two equations are not measured the same way and cannot be directly substitute with each other.

Bibliography

[b-IEEE 802.3az]   IEEE Standard 802.3az (2010), IEEE Standard for *Information technology –*
Telecommunications and information exchange between systems – Local and
metropolitan area networks – Specific requirements Part 3: Carrier Sense
Multiple Access with Collision Detection (CSMA/CD) Access Method and
Physical Layer Specifications Amendment 5: Media Access Control
Parameters, Physical Layers, and Management Parameters for Energy-
Efficient Ethernet.

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