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G.984.3

Amendment 1
(07/2005)

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

Digital sections and digital line system – Optical line systems for local and access networks

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Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification

Amendment 1

ITU-T Recommendation G.984.3 (2004) – Amendment 1

ITU-T

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ITU-T Recommendation G.984.3

Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification

Amendment 1

Summary

This amendment includes various improvements to the G-PON TC-layer specification, including editorial corrections that are aimed to improve readability and clarify points that were unclear or contradictory in the original text. Additional improvements are aimed at focusing the implementation of the GTC by reducing or eliminating some optional features that were included in the original ITU-T Rec. G.984.3 (02/04).

Source

Amendment 1 to ITU-T Recommendation G.984.3 (2004) was approved on 14 July 2005 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

Keywords

G-PON, optical.

FOREWORD

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Gigabit-capable Passive Optical Networks (G-PON): Transmission convergence layer specification

Amendment 1

1) Clause 2 References

Add the following new references:

[13] Federal Information Processing Standards 81, *DES Modes of Operation*, National Institute of Standards and Technology, U.S. Department of Commerce, December 1980.

[14] Federal Information Processing Standards 140-2, *Security Requirements for cryptographic modules*, National Institute of Standards and Technology, U.S. Department of Commerce, December 03, 2002.

2) Clause 3 Definitions

Add the following new definitions as follows:

3.14a Peak Information Rate (PIR): PIR is the rate of the maximum transmitting bytes of GEM packets. Its unit is "Bytes/s". This parameter is analogous to Peak Cell Rate in ATM.

3.18a Sustained Information Rate (SIR): SIR is the rate of committed transmitting bytes of GEM packets on the long-term range. Its unit is "Bytes/s". This parameter is analogous to Sustained Cell Rate in ATM.

3) Clause 4 Abbreviations

Add the following new abbreviations alphabetically:

PIR Peak Information Rate

SIR Sustained Information Rate

4) New clause 5.4 Traffic control facilities in ONU for upstream

Add the new clause 5.4 as follows:

5.4 Traffic control facilities in ONU for upstream

Traffic flows on a Port are controlled by facilities in the ONU as shown in Figure 5-6. The traffic flows can be optionally shaped by traffic descriptors for each Port. Subsequently, these shaped flows can be mapped into a T-CONT and transferred to OLT under allocation control.

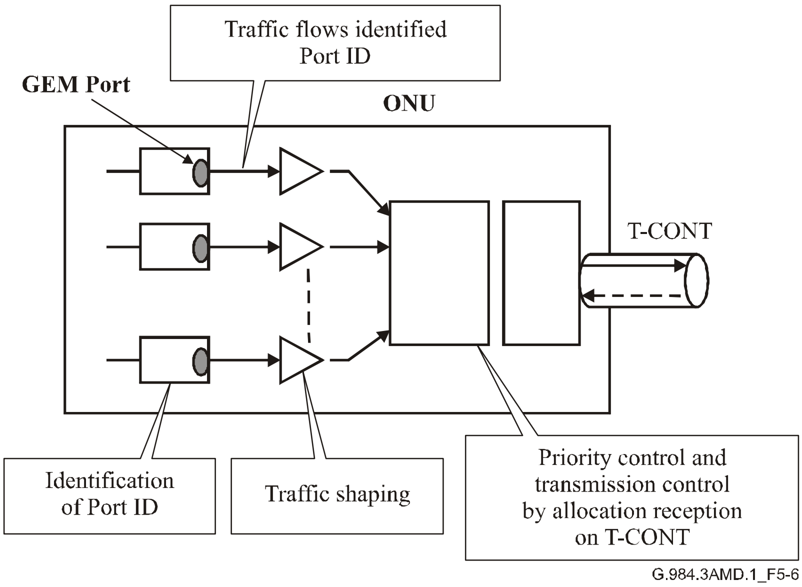


Figure 5-6/G.984.3 – Traffic control facilities in ONU

For GEM traffic, upstream traffic flow in each Port is controlled according to PIR, or PIR and SIR. PIR should be equal to SIR, or larger than SIR. For ATM traffic, upstream traffic flow in each connection is controlled according to the PCR, or PCR and SCR. These parameters are provisioned through OMCI specified in ITU-T Rec. G.984.4.

5) Clause 7.4.2 and elsewhere in the Recommendation

Replace "Method-A" *with* "Configured-S/N";

and "Method-B" *with* "Discovered-S/N".

6) Clause 8 GTC TC frame

Modify last sentence to read:

Figure 8-2 shows the case where the pointers are transmitted in ascending order. The OLT is required to transmit all pointers to any single ONU in ascending order of start time. It is recommended that all pointers are transmitted in ascending order of start time.

7) Clause 8.1.3.6 BWmap fields

Add the following sentences to the end of this clause:

The OLT is required to transmit all pointers to any single ONU in ascending order of start time. It is recommended that all pointers are transmitted in ascending order of start time. ONUs should be able to support up to eight allocation structures in any single BWmap, and optionally could support more. Further, the maximum BWmap size limitation of an ONU should be at least 256 allocation structures, with larger BWmaps optionally supported.

8) Clause 8.1.3.6.1 Allocation ID field

Insert the following new sentences after the fourth sentence:

The first Allocation-ID given to the ONU is referred to as the default allocation ID. This Allocation-ID number is the same as the ONU-ID number (used in the PLOAM messages). It is used to carry PLOAM and OMCI traffic, and optionally user traffic.

9) Clause 8.1.3.6.2 Flags field

a) Modify the first sentence to read:

The flags field is a 12-bit field that contains 4 separate indications that control certain functions of the associated upstream transmission.

b) Modify the second paragraph as follows:

– Bit 11 (MSB): Send PLSu (power levelling sequence): The PLSu feature is deprecated. Bit 11 should always be set to 0.

10) Clause 8.1.3.6.3 StartTime field

Add the following paragraph to the end of the clause:

Note that the StartTime must point to a time that occurs in the upstream frame. Hence, StartTime can have a minimum value of zero for all bit rates. The maximum value depends on bit rate as follows:

Upstream bit rate	Maximum StartTime value
155.52 Mbit/s	2429
622.08 Mbit/s	9719
1244.16 Mbit/s	19439
2488.32 Mbit/s	38879

11) Clause 8.1.3.6.4 StopTime field

Add the following to the end of the clause:

Note that the StopTime must indicate a time that is within the frame in which the allocation began.

12) Clause 8.1.4.1 ATM partition

a) Add the following sentence to the end of the first paragraph:

The ONU should implement the HEC error detection-correction state machine described in ITU-T Rec. I.432.1.

b) Add the following sentence to the end of the second paragraph:

Note that multicast can be supported by using VPIs that are configured to belong to multiple ONUs on the PON. The mandatory method of supporting multicast services over ATM uses a single VPI/VCI for all streams, while the optional method uses multiple VPI/VCIs.

13) Clause 8.1.4.2 GEM partition

Add the following sentence to the end of the second paragraph:

Note that multicast can be supported by using Port-IDs that are configured to belong to multiple ONUs on the PON. The mandatory method of supporting multicast services over GEM uses a single Port-ID for all streams, while the optional method uses multiple Port-IDs.

14) Clause 8.2 Upstream frame structure

a) Modify the second paragraph to read:

Figure 8-10 shows the contents of these overheads in detail. Note that the guard time is not shown in this figure, since the guard time does not contain any protocol elements. However, the OLT must create a BWmap that accounts for the guard time.

b) Add the following sentence at the end of the clause:

The StopTime pointer must always be larger than the associated StartTime pointer. In addition, contiguous pointers are not allowed to bridge over two BWmaps. In other words, every upstream frame must begin with an independent (non-contiguous) transmission.

15) Clause 8.2.2.1 BIP field

Change first sentence to read as follows:

The BIP field is an 8-bit field that contains the bit interleaved parity (exclusive OR) of all bytes transmitted since the last BIP (not including the last BIP) from this ONU, excluding the preamble and delimiter bytes.

16) Clause 8.3.2 Mapping of GEM frames into GTC payload

a) Modify the fourth paragraph to read:

The Port ID is used to provide 4096 unique traffic identifiers on the PON, to provide traffic multiplexing. Each Port-ID contains a user transport flow. There can be one or more Port-IDs transmitted within an Allocation-ID/T-CONT.

b) In the second to last paragraph of this clause, modify the 8th sentence to read as follows:

In the case where X bytes of time remaining in the partition or payload (0<X<5), the transmitting process shall send a pre-empted GEM header pattern, defined to be the first X bytes of the idle GEM header pattern.

c) Modify paragraphs 5 (and the accompanying table), 6 and 7 as follows:

The PTI field is used to indicate the content type of the fragment payload and its appropriate treatment. The coding is shown below.

PTI code	Meaning
000	User data fragment, Not the end of a frame
001	User data fragment, End of a frame
010	Reserved
011	Reserved
100	GEM OAM, Not the end of a frame
101	GEM OAM, End of a frame
110	Reserved
111	Reserved

For code point 4, GEM will reuse the OAM cell format specified in ITU-T Rec. I.610, that is, it will support the 48-byte fragment payload that is formatted in the same manner as described for ATM OAM functions.

d) Add the following to the end of the last paragraph:

Each ONU is required to have at least two GEM re-assembly buffers to support the usage of time-urgent fragmentation. Support for more re-assembly buffers is possible. The OLT should not interleave more than two user data frames to any single ONU unless it determines that the ONU has additional capability. The OLT is required to have at least two GEM re-assembly buffers per Alloc-ID for the same purpose. Support for more re-assembly buffers is possible. The ONU should not interleave more than two user data frames unless it determines that the OLT has additional capability.

17) Clause 8.4 Dynamic bandwidth allocation signalling and configuration

Add the following paragraph to the end of the clause:

Implementers are strongly encouraged to implement Piggy-back reporting method. The other DBA methods are deprecated.

18) Clause 8.4.2.1 Definitions of the message

Modify the bulleted items to read as follows:

- Mode 0: A single field contains the non-linear coding of the total amount of data in the T-CONT buffer.
- Mode 1: Two fields, the first contains the non-linear coding of the amount of data with "PR tokens" (1 byte), and the second contains the non-linear coding of the amount of data with "SR tokens" (1 byte) in the T-CONT buffer. This type of reporting is suitable for T-CONTs type 3 and 5.
- Mode 2: Four fields, the first contains the non-linear coding of total number of T-CONT#2 class cells that have "PR tokens" (assured BW) (1 byte). The second field contains the non-linear coding of the total number of T-CONT#3 class cells that have "SR tokens" (assured BW) (1 byte). The third field contains the non-linear coding of the total number of T-CONT#3 class cells that have "PR tokens" (non-assured BW) (1 byte). The fourth field contains the non-linear coding of the total number of T-CONT#4 class cells that have "PR tokens" (best effort BW) (1 byte). This type of reporting uses 4 bytes in total. This is suitable for T-CONT type 5 reporting, or for ONUs to provide summarized reporting of all its subtending T-CONTs in one single message.
- In modes 1 and 2, "PR" and "SR" represent peak rate and sustained rate of the underlying connections, respectively. These are specified in cells for ATM connections or fixed length reporting blocks in GEM connections. In the case of ATM connections, the peak rate corresponds to the peak cell rate, and the sustained rate corresponds to the sustained cell rate. In the case of GEM connections, the peak rate corresponds to the peak information rate, and the sustained rate corresponds to the sustained information rate.

19) Clause 9.2.1 Downstream message definition

a) In lines 10, 14, and 19 of the table, add the following text to the cells in column 6:

Send 1 acknowledge after each correctly received message.

b) Add the following line to the table:

	Message Name	Function	Trigger	Times sent	Effect of receipt
20	Extended_Burst_Length	To instruct the ONU the number of type 3 preamble bytes to use in the upstream direction.	Each time activation process is started. Following the Upstream Overhead message	3	The ONU sets the type 3 preamble length.

20) Clause 9.2.2 Upstream message definition

In line 9, column 4 of the table, revise the text to read as follows:

After receiving correct downstream messages that require acknowledge.

21) Clause 9.2.3.1 Upstream_Overhead message

In line 10 of the table, modify the first line of the "**Description**" *cell to read:*

xx = reserved

22) Clause 9.2.3.2 Serial_Number_Mask message

In line 3 of the table, modify the "**Description**" *cell to read:*

Number of valid bits, count started from LSB of byte 11 counting up to the MSB of byte 4.

23) Clause 9.2.3.10 Assign_Alloc-ID message

In line 5 of the table, modify the "**Description**" *cell to read:*

Indicates for what payload type this Alloc-ID will use:

0: ATM payload

1: GEM payload

2: DBA payload

3-254: Reserved

255: De-allocate this Alloc-ID

24) Clause 9.2.3.19 Key_Switching_Time message

In line 3 of the table, modify the "**Description**" *cell to read:*

Six MSBs of the 30-bit superframe counter of the first frame to use the new key.

In line 6 of the table, modify the "**Description**" *cell to read:*

Eight LSBs of the 30-bit superframe counter of the first frame to use the new key.

25) New clause 9.2.3.20 Extended_burst_length message

Add new clause 9.2.3.20, as follows:

9.2.3.20 Extended_burst_length message

Extended_Burst_Length message		
Octet	**Content**	**Description**
1	11111111	Broadcast message to all ONUs.
2	00010100	Message identification "Extended_Burst_Length" (Note 1)
3	pppppppp	pppppppp = Number of Type 3 preamble bytes used when the ONU is in the "pre-ranged" states: Serial_Number State (O3) and Ranging State (O4). Each byte of the Type 3 preamble contains the pattern specified in Octet 6 of the "Upstream_Overhead" message. (Note 2)
4	rrrrrrrr	rrrrrrrr = Number of Type 3 preamble bytes used when the ONU is in the "ranged" states: Operation State (O5) and POPUP State (O6). Each byte of the Type 3 preamble contains the pattern specified in Octet 6 of the "Upstream_Overhead" message. (Note 2)
5-12	Unspecified	Reserved for Future Study
NOTE 1 – This message is optional. NOTE 2 – Type 1, 2, and 3 preambles are defined in the message definition and notes of the "Upstream_Overhead" message (see 9.2.3.1). When this "Extended_Burst_Length" message is not used, the length of the Type 3 preamble is determined by subtracting the lengths of the Guard bits, Types 1 and 2 preambles, and Delimiter from the recommended burst overhead times specified in Appendix I/G.984.2. When this message is received by an ONU in Serial Number State (O3), the values specified in Octets 3 and 4 of this message supersedes the length of the Type 3 preamble implied by the "Upstream_Overhead" message. The maximum length of the entire physical layer overhead is 128 bytes. Note that the length of the Type 3 preamble is an integer number of bytes. It is the responsibility of the OLT to ensure that the total length of the burst overhead (Guard bits + Type 1 + Type 2 + Type 3 + Delimiter) is also an integer number of bytes.		

26) Clause 10 Activation method

Replace the entire clause with the following new text:

10 Activation method

10.1 Overview

This clause describes the normative process for activating ONUs in a G-PON system. The informative activation method for OLTs is described in Appendix IV. ONU activation is a multi-step process whereby the operating parameters are communicated by the OLT to the ONUs, the logical reach between the OLT and each ONU is measured and the downstream and upstream communication channels are established. Measuring the logical reach between the OLT and each ONU is called the Ranging Process. G-PON uses an in-band method whereby the transmission delay is measured for each ONU while the PON is in-service.

When ranging new ONUs, working ONUs must temporarily suspend transmissions, thereby opening a so-called ranging window. The size of this ranging window depends on the range of distances to the ONU. *A priori* information about the position of the new ONUs can minimize this duration, but typically the duration is determined by the maximum differential range of the PON – 20 km.

10.2 ONU activation summary

The activation process is performed under the control of the OLT. The outline of the activation procedure is:

- The ONU receives the PON operating parameters through the Upstream_Overhead message.
- The ONU adjusts its parameters accordingly (e.g., the transmission optical power level based on OLT requirement).
- The OLT discovers the Serial Number of a newly connected ONUs using a Serial_Number Acquisition procedure.
- The OLT assigns an ONU-ID to all newly discovered ONUs.
- The OLT measures the Equalization Delay of the new ONUs.
- The OLT communicates the Equalization Delay to the ONU.
- The ONU adjusts the start of its Upstream Frame clock based on its Equalization Delay.

This procedure is performed by the exchange of upstream and downstream flags and PLOAM messages.

In the normal operating state, all transmissions can be used for monitoring the phase of the arriving transmission. Based on monitoring transmission phase information, the Equalization Delay can be updated.

10.2.1 Serial_Number acquisition procedure summary

Figure 10-1 graphically shows the procedure for Serial_Number Acquisition. First the OLT creates a quiet zone by suspending all upstream bandwidth grants. After waiting the appropriate ranging delay, the OLT issues the Serial_Number Request. ONUs in Serial_Number state that receive this request wait for the SN-Response-Time, as defined in 10.7.1, and then respond to this request. Upon successful reception of this response, the OLT transmits an Assign ONU_ID message and the ONU moves to Ranging State (O4).

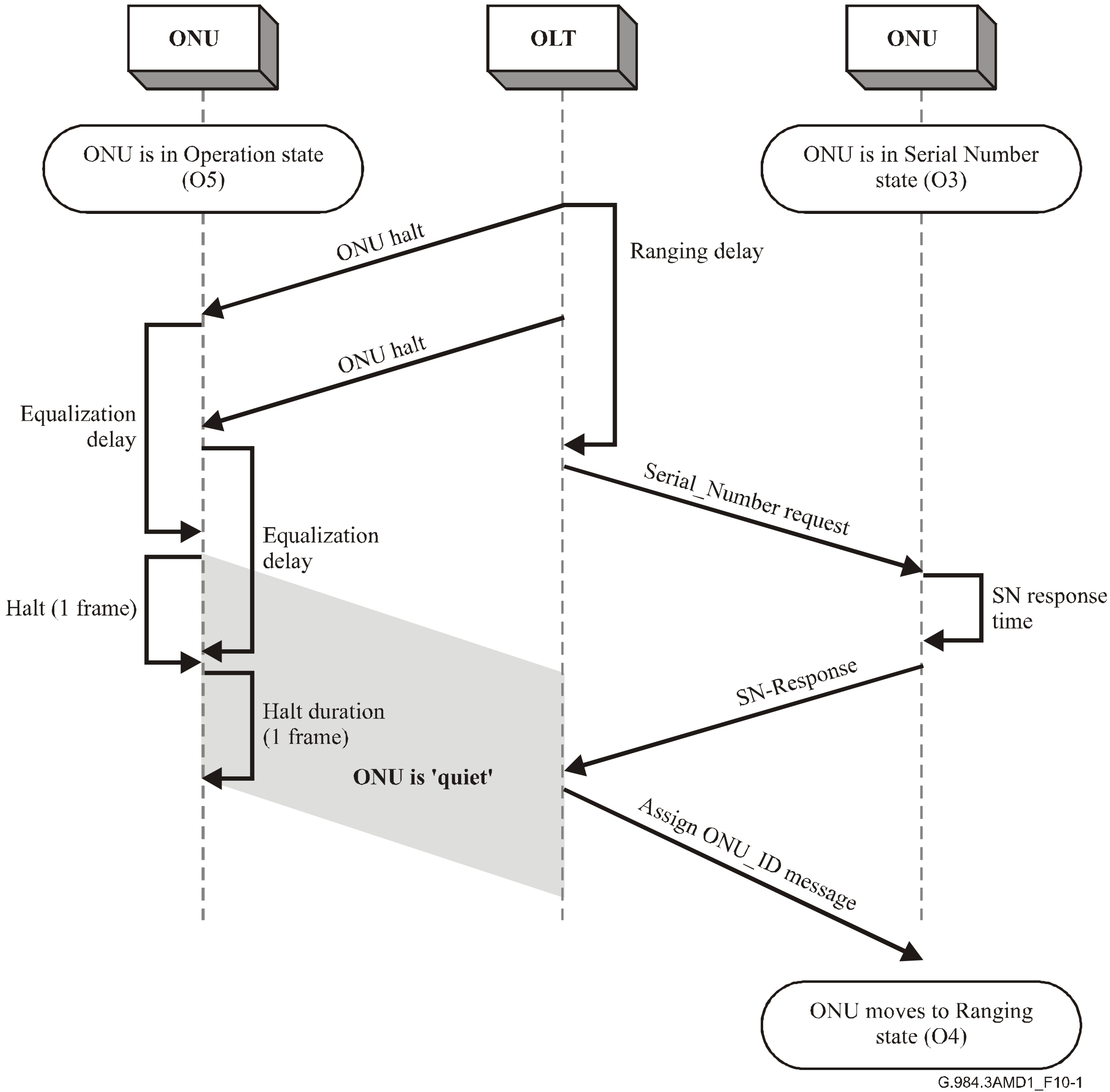
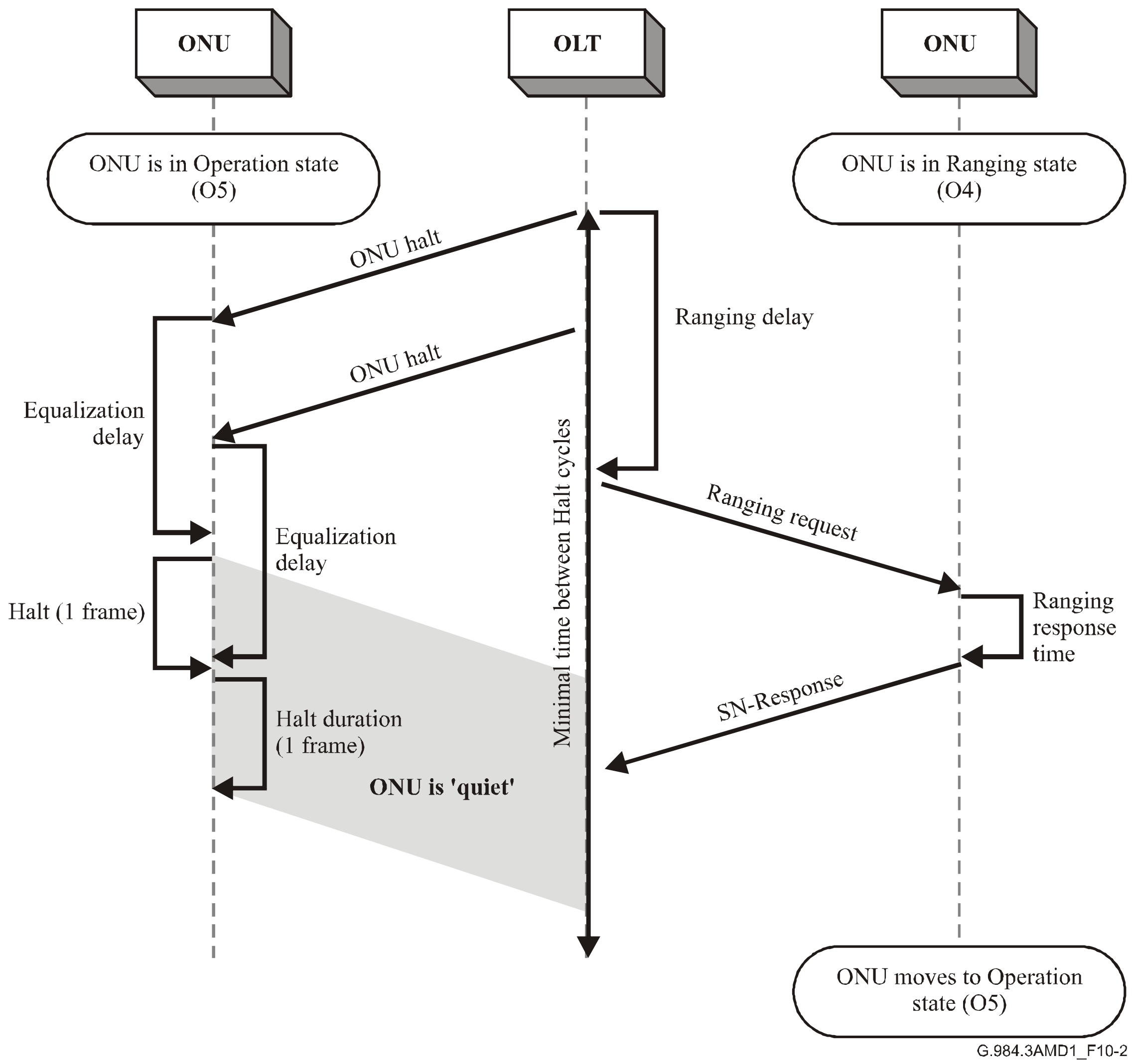


Figure 10-1/G.984.3 – Serial_number acquisition process

10.2.2 Ranging procedure

Figure 10-2 graphically shows the procedure for ranging ONUs. First the OLT creates a quiet zone. After waiting the appropriate ranging delay, the OLT issues Ranging Requests to individual ONUs. When an ONU receives this request it waits for the Ranging-Response-Time, as defined in 10.7.2, and then responds with a Serial-Number message. Upon successful reception of this response, the OLT transmits an Assign Ranging Time message and the ONU moves to Operation State (O5).



NOTE – Several Ranging requests may be sent during the ranging cycle.

Figure 10-2/G.984.3 – Ranging process – Warm network

10.3 States of the ONU

The activation procedure is specified by the functional behaviour of the states and the state transitions as shown below.

10.3.1 ONU states

The ONU has 7 states:

a) **Initial-state** (O1)

The ONU powers up in this state. LOS/LOF is asserted. Once downstream traffic is received, LOS and LOF are cleared, the ONU moves to the Standby-state (O2).

b) **Standby-state** (O2)

Downstream traffic is received by the ONU. The ONU waits for global network parameters. Once the Upstream_Overhead message is received, the ONU configures these parameters (e.g., delimiter value, power level mode, and pre-assigned equalization delay) and moves to Serial-Number-state (O3).

c) **Serial-Number-state** (O3)

By sending a Serial_Number request to all ONUs in Serial-Number state, the OLT discovers new ONUs and their Serial Numbers.

Once the ONU is discovered, it waits for the unique ONU-ID assignment from the OLT. The ONU-ID is assigned using the Assign_ONU-ID message. Once assigned, the ONU moves to Ranging-state (O4).

d) **Ranging-state** (O4)

The upstream transmission from the different ONUs must be synchronized with the upstream frame. In order to make the ONUs appear to be at an equal distance from the OLT, an Equalization-Delay per ONU is required. This Equalization-Delay is measured during this ranging state. Once the ONU receives the Ranging_Time message, it moves to Operation-state (O5).

e) **Operation-state** (O5)

Once in this state the ONU can send upstream data and PLOAM messages as directed by the OLT. Additional connections can be established with the ONU as required while in this state. Once the network is ranged, and all ONUs are working with their correct Equalization-Delay, all upstream frames will be synchronized together between all ONUs. The upstream transmissions will arrive separately, each one in its correct location within the frame.

Halting operating ONUs: At various times during normal operations, operating ONUs may be halted by the OLT due to serial number acquisition or ranging processes on other ONUs. This is accomplished by withholding all upstream bandwidth grants for a certain appropriate period of time. The ONUs will process this in the normal way, which will result in the desired upstream quiet zone.

f) **POPUP-state** (O6)

The ONU enters this state from the Operation state (O5) following the detection of LOS or LOF alarms. When entering the POPUP state (O6), the ONU immediately stops upstream transmission. As a result, the OLT will detect an LOS alarm for that ONU.

In the case of a break in the fibre ODN, there will be multiple ONUs that enter the POPUP State. Based on the network survivability scheme, one of the following options will be implemented:

– If protection switching has been implemented, OLT can switch all ONUs to the protection fibres. In this case all ONUs have to be re-ranged. To accomplish this, the OLT sends a Broadcast POPUP message to the ONUs instructing them to move to Ranging state (O4).

– If there is no protection switching, or in case the ONU has internal protection capabilities, the OLT can send a Directed POPUP message to the ONU instructing it to move to Operation state (O5). While the ONU is in Operation state (O5), the OLT can test the ONU before returning it to full service.

– If the ONU does not recover from the LOS or LOF alarms, it will not receive the POPUP message (Broadcast or Directed) and will move to Initial-state (O1), following time-out (TO2).

g) **Emergency-Stop-state** (O7)

An ONU that receives a Disable_Serial_Number message with the "Disable" option moves to the Emergency-Stop-state (O7) and shuts its laser off.

During Emergency-Stop, the ONU is prohibited from sending data in the upstream direction.

If the ONU fails to move to Emergency-Stop state, and the OLT continues to receive the ONU upstream transmission (LOS alarm is not asserted), a Dfi alarm is asserted in the OLT.

When the deactivated ONU's malfunction is fixed, the OLT may activate the ONU in order to bring it back to working condition. The activation is achieved by sending a Disable_Serial_Number message with the "Enable" option to the ONU. As a result, the ONU returns to Standby-state (O2). All parameters (including Serial Number and ONU-ID) are re-examined.

10.3.2 ONU states diagram

Figure 10-3 shows a graphic representation of the 7 states of the ONU. The arrows in this diagram show the state transitions described in the following clauses.

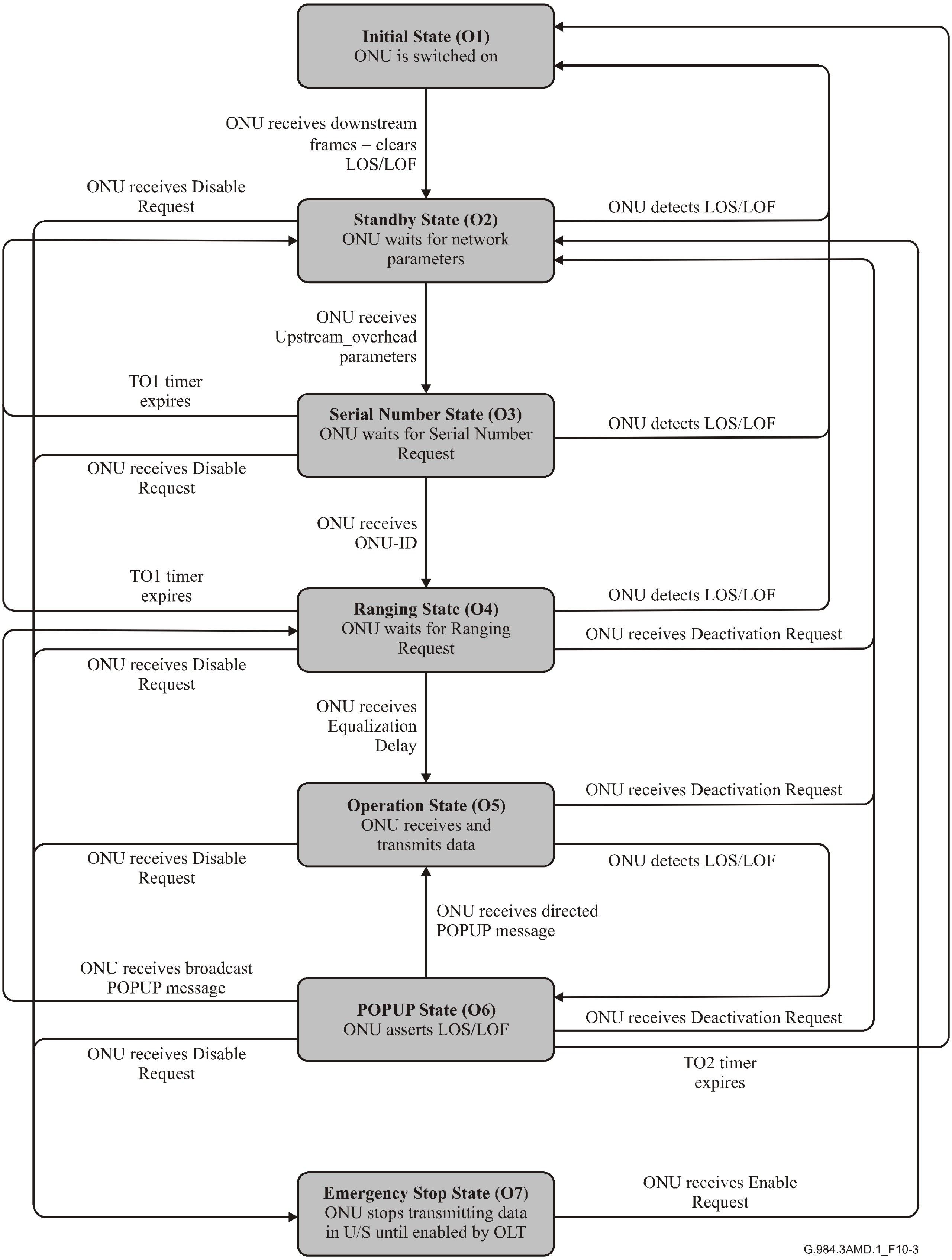


Figure 10-3/G.984.3 – The state diagram of the ONU

10.4 ONU functional transitions

The following table describes the functional behaviour of the ONU with respect to state transitions. The first column indicates the event that triggers a state change. The subsequent columns indicate the state the ONU transitions to as a function of the current state.

Event	States of the ONU						
	Init (O1)	**Standby (O2)**	**Serial number (O3)**	**Ranging (O4)**	**Operation (O5)**	**POPUP (O6)**	**Emergency-stop (O7)**
ONU Power up ⇒ O1	–	–	–	–	–	–	–
ONU receives downstream data and clears LOS & LOF	⇒ **O2**	–	–	–	–	–	–
The ONU receives the upstream overhead parameters (PLOAMd = Upstream_Overhead) and configures its transmitter w/ these values.	–	The ONU configures its transmit parameters w/ the received values; starts timer TO1 then: ⇒ **O3**	–	–	–	–	–
The ONU receives the extended burst parameters (PLOAMd = Extended_Burst_ Length) and configures its transmitter w/ these values.	–	–	The ONU configures its Type 3 Preamble length w/ the received value	–	–	–	–
The ONU receives a Serial_Number request (BW Grant w/ Alloc_ID = 254 PLOAMu = '1')	–	–	The ONU waits for Minimum response time, plus pre-assigned delay, plus Random delay before responding w/ a Serial Number response message.	–	–	–	–

Event	States of the ONU						
	Init (O1)	**Standby (O2)**	**Serial number (O3)**	**Ranging (O4)**	**Operation (O5)**	**POPUP (O6)**	**Emergency-stop (O7)**
The SN_Request_ Threshold is crossed	–	–	The ONU changes its power level (see 10.8.1)	–	–	–	–
The ONU receives its ONU ID (PLOAMd = Assign_ONU-ID)	–	–	The ONU configures its ONU-ID and then: ⇒ **O4**	–	–	–	–
The ONU receives Ranging request message (BW Grant w/ Alloc_ID = ID of ONU to be ranged, PLOAMu = '1')	–	–	–	The ONU waits for ONU Minimum response time plus pre-assigned delay and responds with a Serial_Number response message	In this state, ranging-request looks just like regular PLOAM request, so ONU should respond with a PLOAM.	–	–
The ONU receives a Change_Power_Level message	–	–	–	Match ONU-ID? – Change Power Level	Match ONU-ID? – Change Power Level	–	–
The ONU receives its Equalization Delay (PLOAMd = Ranging_Time)	–	–	–	ONU sets its Equalization delay; stops timer TO1 & then: ⇒ **O5**	ONU sets its Equalization Delay	–	–
Timer TO1 expires	–	–	⇒ **O2**	⇒ **O2**	–	–	–
Data request	–	–	–	–	Match Alloc ID? – Start Tx at specified time	–	–
Implied Halt as a result of receiving no BW Allocation	–	–	–	–	– Suspend Tx for one frame	–	–

Event	States of the ONU						
	Init (O1)	**Standby (O2)**	**Serial number (O3)**	**Ranging (O4)**	**Operation (O5)**	**POPUP (O6)**	**Emergency-stop (O7)**
The ONU receives Deactivation message (PLOAMd = Deactivate_ ONU-ID)	–	–	–	Match ONU-ID? The ONU stops timer TO1 then: ⇒ **O2**	Match ONU-ID? ⇒ **O2**	Match ONU-ID? Stop timer TO2, then: ⇒ **O2**	–
ONU detects LOS or LOF	–	⇒ **O1**	The ONU stops the TO1 timer then: ⇒ **O1**	The ONU stops the TO1 timer then: ⇒ **O1**	The ONU ceases upstream transmission; starts TO2 timer and then: ⇒ **O6**		–
Broadcast POPUP message (PLOAMd = POPUP; w/ ONU-ID = 0xFF) is received by ONU	–	–	–	–	–	The ONU stops timer TO2; starts timer TO1; & then: ⇒ **O4**	–
Directed POPUP message (PLOAMd = POPUP; w/ ONU-ID = ID of ONU) is received by ONU	–	–	–	–	–	The ONU stops timer TO2 and then: ⇒ **O5**	–
Timer TO2 expires	–	–	–	–	–	⇒ **O1**	–
The ONU receives disable request (PLOAMd = Disable_Serial_Number with Disable)	–	Match SN? ⇒ **O7**	Match SN? The ONU stops timer TO1 and then ⇒ **O7**	Match SN? The ONU stops timer TO1 and then: ⇒ **O7**	Match SN? ⇒ **O7**	Match SN? The ONU stops timer TO2 and then: ⇒ **O7**	–
The ONU receives enable request (PLOAMd = Disable_Serial_Number with Enable)	–	–	–	–	–	–	Match SN? ⇒ **O2**

Event	States of the ONU						
	Init (O1)	**Standby (O2)**	**Serial number (O3)**	**Ranging (O4)**	**Operation (O5)**	**POPUP (O6)**	**Emergency-stop (O7)**
ONU Power up Was last operational state (before power-down) O7? ⇒ **O7**	–	–	–	–	–	–	–

10.5 ONU events

10.5.1 D/S PLOAM message reception events

Downstream PLOAM messages are sent three times by the OLT. The ONU generates a message receive event after receiving one valid message. A valid message is one with a valid CRC. The following is a list of the message reception events that occur during ONU activation.

a) *The receive event of **Upstream-Overhead** message*

This event occurs only in the Standby state (O2). After successful reception of the Upstream-overhead message, the ONU learns the number of preamble bits, the value of the delimiter, and equalization and power level parameters.

b) *The receive event of **Assign ONU-ID** message*

This event occurs only in the Serial-Number state (O3). When the serial number in the Assign_ONU-ID message matches its own serial number, the ONU-ID is acquired and the ONU moves to Ranging state (O4).

c) *The receive event of **Ranging_Time** message*

This event occurs only in the Ranging state (O4) and Operation state (O5). When the ONU-ID number in the PLOAM field matches its own ONU-ID, the Equalization Delay is acquired. When the ONU is in the Ranging state (O4), timer TO1 is stopped and transition of the ONU state to Operation state (O5) occurs.

d) *The receive event of **Change_Power_Level** message with specific ONU-ID*

This event occurs only in the Ranging state (O4) and Operation state (O5). When the ONU-ID in the Change_Power_Level_message matches its own ONU-ID, the ONU adjusts (increase/reduce) its Power-level.

e) *The receive event of **Broadcast POPUP** message*

This event occurs only in the POPUP state (O6). The transition of the ONU state to Ranging state (O4) occurs. The timer TO2 is stopped and timer TO1 is started.

f) *The receive event of **Directed POPUP** message*

This event occurs only in the POPUP state (O6). When the ONU-ID number in the PLOAM field matches its own ONU-ID, the ONU stops timer TO2 and transitions to Operation state (O5).

g) *The receive event of **Deactivate_ONU-ID** message*

This event occurs only in the Ranging state (O4), Operation state (O5), and POPUP state (O6). When the ONU-ID number in the PLOAM field matches its own ONU-ID, the ONU stops transmitting in the upstream direction and transitions to Standby state (O2). If the ONU was in the Ranging-state (O4), the timer TO1 is stopped as well. If the ONU was in the POPUP-state (O6), the timer TO2 is stopped as well.

h) *The receive event of **Disable_Serial_Number** message with Disable parameter*

This event occurs only in the Standby state (O2), Serial-Number state (O3), Ranging state (O4), Operation state (O5) and POPUP state (O6). When the serial number in the Disable_Serial_Number message matches its own serial number, the ONU stops transmitting in the upstream direction and transitions to the Emergency-Stop state (O7). If ONU was in the Serial-Number state (O3) or Ranging state (O4), the timer TO1 is stopped as well. If the ONU was in POPUP state (O6), the timer TO2 is stopped as well.

i) *The receive event of **Disable_Serial_Number** message with Enable parameter*

This event occurs only in the Emergency-Stop state (O7). When the serial number in the Disable_Serial_Number message matches its own serial number, the ONU transitions to the Standby state (O2).

10.5.2 D/S bandwidth map reception events

Special requests by the OLT to the ONU are conveyed in the downstream overhead section, specifically in the Bandwidth Grants, Pointers, and Flag fields. These requests require a real-time reaction from the ONU. Unlike the PLOAM Messages above, these requests are sent only once to the ONU and a request receive-event is generated immediately.

j) *The **Serial_Number Request** receive event*

This event occurs only in the Serial-Number state (O3). The Serial-Number Request is generated by the OLT with the following asserted fields: Alloc-ID = 254, PLOAMu = "1", SStart = xx, & SStop = xx + 12, where xx is a starting time in bytes within the upstream frame. The ONU, at its discretion, can send a longer SN transmission than defined by the Sstop for the purposes of optical power calibration, as long as the size of this additional transmission is 500 ns or less.

Upon reception of the Serial_Number request, the ONU waits for an ONU Response Time, random delay time plus the Pre-assigned Equalization Delay as indicated in the Upstream_Overhead Message. Following this combined delay, it sends a SN response in the upstream direction at the xx bytes. The SN response is an upstream transmission containing the following fields: PLOu and PLOAMu with the Serial-Number-ONU message.

k) *The **Ranging Request** receive event*

This event occurs only in the Ranging state (O4). The Ranging request is generated by the OLT with the following asserted fields: Alloc-ID = ONU-ID of ONU to be ranged, PLOAMu = "1", SStart = xx, SStop = xx + 12, where xx is the starting time in bytes within the upstream frame that the Ranging Response is requested. The ONU, at its discretion, can send a longer Ranging transmission than defined by the Sstop for the purposes of optical power calibration, as long as the size of this additional transmission is 78 bytes or less.

Upon reception of the Ranging request, the ONU waits for an ONU Response Time plus the Pre-assigned Equalization Delay as indicated in the Upstream_Overhead Message. Following this combined delay, it sends a Ranging response in the upstream direction at the xx bytes. The Ranging transmission is an upstream transmission containing the following fields: PLOu and PLOAMu with the Serial-Number-ONU message.

l) *The "receive" event of the **Halt Request***

This event occurs only in the Operation state (O5). There is no "Halt" message that is actually received. Instead, the event is generated when there are no bandwidth allocations for a given ONU. This is an implicit indication from the OLT that a S/N or Ranging window is being opened.

m) *The receive event of **Data Request** via valid pointers*

This event occurs only in the Operation state (O5). The Data request is generated by the OLT with the following asserted fields: Alloc-ID = Alloc-ID of the T-CONT to be granted BW, SStart = xx, SStop = yy, where xx and yy are the appropriate start and stop time. The ONU transmits its U/S transmission during these allocated timeslots. The ONU starts transmitting valid data at precisely the xx byte and ceases transmission at the end of the yy byte.

10.5.2.1 Other events

n) *SN_Requests Threshold Crossed*

This event is generated when the ONU is in Serial Number state (O3) and its Serial Number Request Counter meets or exceeds the Serial Number Threshold. See 10.8.1 for an explanation of this counter and the resulting action taken by the ONU. The proposed value for the Serial Number Threshold is 10.

o) *Timer TO1 expire*

This event is generated when the activation procedure is not completed within a certain time period. This event generates a state transition to Standby state (O2). The proposed value of TO1 is 10 s.

p) *LOS or LOF detection*

Either of these events causes the ONU to move to the Initial state (O1) except when it is in Operating state (O5) or POPUP state (O6) or in the Emergency-Stop state (O7). In addition, in Serial-Number states (O3) and Ranging state (O4), it will stop the timer TO1.

In Operating state (O5), this event causes the ONU to move to the POPUP state (O6) after the timer TO2 is set to start.

q) *Clear of LOS or LOF*

This event causes the ONU to move from the Initial state (O1) to Standby state (O2).

r) *Timer TO2 expire*

This event is generated when the POPUP message is not received in the POPUP state within a certain time period. This event generates a state transition to Initial-state (O1). The proposed value of TO2 is 100 ms.

10.6 Quiet zones during Serial_Number acquisition and ranging

10.6.1 Opening a quiet zone by OLT

During the Serial Number Acquisition and Ranging states, new ONUs transmit S/N Responses at the request of the OLT. Because the OLT does not yet know the Equalization Delay (EqD) for these ONUs, it cannot prevent collisions between these transmissions and those from in-service ONUs. Therefore, the OLT temporarily halts all of the in-service ONUs in order to create a "quiet zone" or "ranging window" in the upstream frame.

This halting is accomplished by withholding all BW grants from in-service ONUs for the appropriate period of time. Note that even after the ONUs "receive" this halting indication, they continue to send data in the upstream direction for the Equalization-Delay time. Following this time, the ONUs in Operation state will stop sending data in the upstream direction for the duration of the quiet zone.

Since the operational ONUs typically halt their upstream transmission for several frames, the OLT must ensure that the period between these quiet zones is long enough for the working ONUs' queues to return to their normal operation status. The exact time depends upon implementation considerations.

10.6.1.1 Reduction of the quiet zone with knowledge of ONU distance

When some information about the ONU position is known, there is no need for the OLT to create the above "full quiet zone". Instead, the OLT may open a smaller quiet zone, whose duration depends on the precision of the known OLT-ONU distance. The exact implementation of this procedure is left to the individual vendor.

10.6.2 Duration of the quiet zone during Serial_Number acquisition

During S/N acquisition, the OLT must open a quiet zone that is the sum of the round trip propagation delay, the Random-delay, and the variation of the ONU response time. The propagation delay in the typical case of a 20-km reach is 200 µsec. The Random-delay value is limited to 48 µsec as described in the following clause. The variation in the ONU response time is ±1 µsec or 2 µsec. Adding these terms gives a suggested duration of the quiet zone during Serial_Number Acquisition of 250 µsec. This is shown in Figure 10-4.

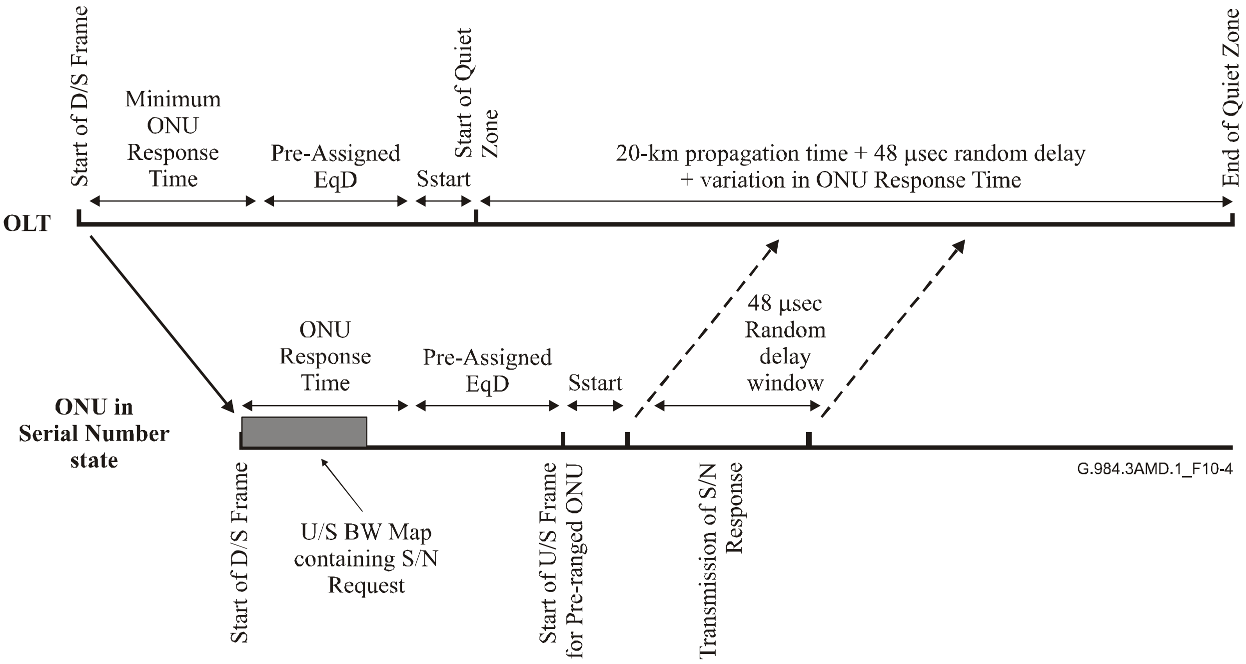


Figure 10-4/G.984.3 – Timing diagram for an ONU in the serial number acquisition state

10.6.3 Duration of the quiet zone during ranging

During Ranging, the OLT must open a quiet zone whose duration is the round trip propagation delay and the variation of the ONU response time. Just as is the case for S/N Acquisition, the propagation delay in the typical case of a 20-km reach is 200 µs and the variation in ONU response time is 2 µsec. Thus, the total duration of the quiet zone during ranging is 202 µsec.

10.7 ONU timing

At all times the ONU maintains a running Upstream Frame clock that is synchronized to the Downstream Frame clock and offset by a precise amount. The amount of offset is the sum of two values: the "ONU Minimum Response Time" and an equalization delay. The ONU Minimum Response time, hereafter referred to as simply the ONU response time, is a system-wide parameter that was chosen to give the ONU sufficient time to receive the downstream frame including upstream bandwidth map, perform D/S and U/S FEC as needed, and prepare an upstream response. The value of the ONU response time is 35 ±1 µsec.

The equalization delay is different for pre-ranged states (S/N Acquisition and Ranging) and ranged state (Operation). When the ONU is in the pre-ranged states it uses the pre-assigned equalization delay. When the ONU is in the ranged states, it uses the assigned equalization delay it received through the Ranging-Time message.

10.7.1 ONU timing during S/N acquisition

When the ONU receives a Serial_Number Request it transmits a Serial_Number Response after waiting for the SN-Response-Time. The SN-Response-Time is the sum of the ONU Response Time, the Pre-assigned Equalization Delay, the SStart time, and the Random Delay (see 10.7.1.1). This Serial_Number response consists of a PLOAMu containing the Serial-Number-ONU message. This is shown in Figure 10-4.

10.7.1.1 Random delay method

Since the Serial-Number request is broadcast to all ONUs in the Serial-Number state, a response from more than one ONU might be produced. A problem may occur when more than one Serial_Number transmission arrives at the same time at the OLT, thus causing a collision. The Random Delay Method is used to resolve this problem.

Based on the Random Delay Method, each Serial_Number transmission is delayed by a random number of delay units generated by each ONU. The delay units are 32 bytes long for all bit rates. The random delay must be an integral number of delay units. Following each response to a Serial_Number request, the ONU generates a new random number, thus collisions are reduced.

The Random-Delay range is 0-48 μs. This range is measured from the beginning of the earliest possible transmission (with zero processing delay) to the end of the latest possible transmission (the ONU internal processing delay and the duration of the upstream burst is included in the Random-Delay range and, therefore, should be taken into account when selecting a new random delay value).

10.7.2 ONU timing during ranging state

When the ONU receives a Ranging Request it transmits a Ranging Response message after waiting for the Ranging-Response-Time. The Ranging-Response-Time is the sum of the ONU Response Time, the Pre-assigned Equalization Delay, and the Sstart time. The Ranging response consists of a PLOAMu containing the Serial-Number-ONU message. This is shown in Figure 10-5.

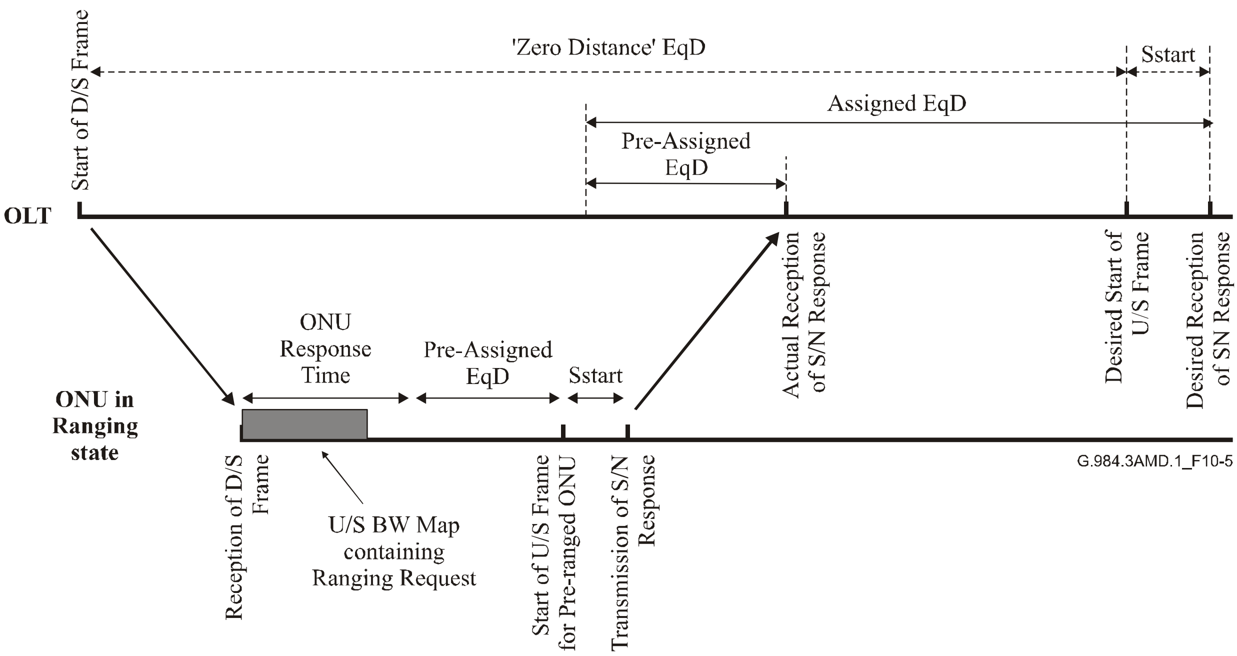


Figure 10-5/G.984.3 – Timing diagram for an ONU in the ranging state

10.7.2.1 Measuring the equalization delay

There are two different yet equally valid methods for measuring Equalization Delay by the OLT. In one case, the OLT measures the Equalization Delay directly by timing the duration between the actual and desired S/N response times, and adding the pre-assigned EqD. The alternate method is to measure RTD by timing the duration between the transmission of the start of the frame that contains the S/N Request and the reception of the S/N Response and subtracting SStart. The desired Equalization Delay is then obtained using EqD(n) = Teqd – RTD(n), where Teqd is the "zero-distance" EqD, which is the offset between the D/S frame and the desired reception of the U/S frame at the OLT.

Once the ONU is supplied with its Equalization-Delay factor, it is considered synchronized to the beginning of the upstream frame. The actual upstream data is transmitted in a specific transmission block of the upstream frame based on the pointers in the bandwidth grant.

10.7.2.2 Phase monitoring and updating EqD

The ONU's upstream transmission is expected to arrive in a fixed time during the upstream frame. The arrival phase of the ONU transmission may drift due to aging and temperature changes, etc. In those cases, the Equalization-Delay can be recalculated/updated from the drift of the upstream transmission. This allows small corrections to be made without having to re-range the ONU.

The change in the Equalization-Delay will be equal to the drift time with opposite sign. Therefore, if the frame is early, the drift time will be added to the Equalization-Delay. If the frame is late, the drift time will be subtracted from the Equalization-Delay.

The new Equalization-Delay value will be calculated by the OLT and will be transmitted to the ONU using the Ranging_Time PLOAM message.

10.7.3 PON distances greater than 20 km

The nominal reach of a PON is 0 to 20 km and, in fact, the PHYs described in ITU-T Rec. G.984.2 are only specified out to 20 km. Nevertheless, the G-PON protocol anticipates longer reach PONs. Table 2-a/G.984.2 specifies the maximum logical reach of a PON as 60 km and the maximum differential logical reach as 20 km. This means that the serving area of a PON with greater than 20-km reach is an annulus with an inner radius of X km and an outer radius of x+20 km, where $0 \leq X \leq 40$ km. In either the 20 km case or the longer reach "annulus" case situation, the maximum Equalization delay or Pre-equalization delay required is ~250 microseconds. However, implementers could optionally support equalization and pre-equalization delays up to ~625 microseconds such that unrestricted PON operation over the entire ultimate logical reach could be achieved.

The Ranging process for longer-distance PONs is identical to that described above except that the fibre propagation delay is adjusted accordingly.

10.7.4 ONU timing during operational state

In the Operational State, the ONU maintains its Upstream Frame clock synchronized with the downstream frame clock but offset by the sum of the ONU response time and its Equalization Delay. This is shown in Figure 10-6. When the ONU receives a Bandwidth grant it transmits data starting at the upstream byte indicated in the Sstart field.

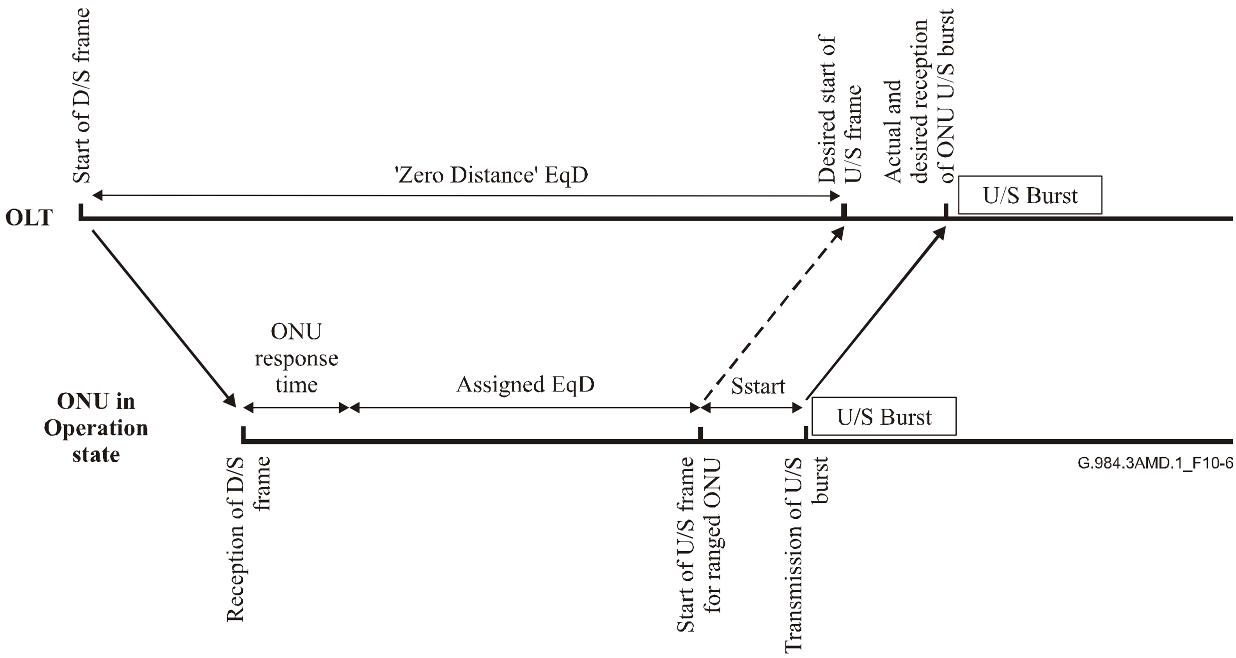


Figure 10-6/G.984.3 – Timing diagram for an ONU in the operation state

10.8 Power levelling

Due to the differences in the ODN losses for different ONUs, the OLT receiver must provide a high sensitivity and a large dynamic range for reception at high bit rates.

In order to relax the dynamic range of the OLT receiver, the transmitter power level of the ONUs experiencing a low ODN loss could be reduced in order to avoid overload of the OLT receiver. Similarly, in case of a high ODN loss, the transmitter power level of the ONUs could be increased.

Power Levelling is the process whereby the ONU changes (increases or decreases) its transmit power in order to improve the signal-to-noise ratio at the OLT. There are two methods for initiating this process: ONU-activated and OLT-activated.

10.8.1 ONU-activated power levelling

ONU-activated Power Levelling is initiated when the ONU responds to a specified number of S/N Requests without receiving an Assign_ONU-ID message from the OLT. This specified number of S/N Requests is called the S/N_Request_Threshold and the recommended value is 10.

Initially, the ONU uses the Power Level mode specified in the Upstream_Overhead message. When the S/N_Response_Threshold is crossed, the ONU increments its operating Power Level using modulo 3 (…,0,1,2,0,1,2,…) and resumes responding to S/N Requests. If the ONU again responds to a specified number of S/N Requests without response, it increments again its Power Level using modulo 3. This cycle is repeated until it receives either an Assign_ONU-ID message or a Disable ONU message.

10.8.2 OLT-activated power levelling

OLT-activated Power Levelling is initiated when the OLT determines the ONU needs to change its power level. This determination could occur when the ONU is in Ranging State or Operation State and is indicated by an unacceptable BER for a particular ONU. In this case, the OLT sends a directed Change Power Level message to the specific ONU to increase and/or decrease power level as needed.

27) Figure 11-1

In Figure 11-1, in the items detected at the OLT, change "RDI" *and* "REI" *to* "RDIi" *and* "REIi", *respectively*.

28) Clause 11.1.1 Items detected at OLT

In the "LOSi" *row of the table, change the* "**Detection conditions**" *cell to read as follows*:

No valid optical signal from ONU during 4 consecutive non-contiguous allocations to that ONU.

In the "LOSi" *row of the table, change the first* "**Actions**" *cell to read as follows*:

If the OLT supports POPUP, it sends the POPUP message 3 times. If POPUP is not supported, the OLT sends deactivate ONU-ID message 3 times.

Generate Loss_of_phy_layer_I notification.

In the "LOS" *row of the table, change the* "**Detection conditions**" *cell to read as follows*:

The OLT did not receive any expected transmissions in the upstream (complete PON failure) for 4 consecutive frames.

In the "LCDAi" *row of the table, change the* "**Detection conditions**" *cell to read as follows*:

When ATM cell delineation of ONUi is lost according to the H.432.1 state machine.

In the "LCDAi" *row of the table, change the first* "**Action**" *cell to read as follows*:

Generate Loss_of_phy_layer notification.

In the "LCDGi" *row of the table, change the* "**Detection conditions**" *cell to read as follows*:

When GEM fragment delineation of ONUi is lost according to clause 8.3.2 state machine.

In the "LCDGi" *row of the table*, *change the first* "**Actions**" *cell to read as follows*:

Generate Loss_of_phy_layer notification.

29) Clause 11.1.2 Items detected at ONU

In the "LOS" *row of the table*, *change the* "**Detection conditions**" *cell to read as follows*:

No valid signal is received in the downstream.

In the "LOS" *row of the table*, *change the first* "**Actions**" *cell to read as follows*:

Switch off laser. Generate Loss_of_phy_layer notification. Change state according to clause 10.

In the "LOF" *row of the table*, *change the first* "**Actions**" *cell to read as follows*:

Switch off laser. Generate Loss_of_phy_layer notification. Change state according to clause 10.

In the "LCDA" *row of the table*, *change the* "**Detection conditions**" *cell to read as follows*:

When ATM cell delineation is lost according to the H.432.1 state machine.

In the "LCDA" *row of the table*, *change the first* "**Actions**" *cell to read as follows*:

Generate Loss_of_phy_layer notification.

In the "LCDG" *row of the table*, *change the* "**Detection conditions**" *cell to read as follows*:

When GEM fragment delineation is lost according to clause 8.3.2 state machine.

In the "LCDG" *row of the table*, *change the first* "**Actions**" *cell to read as follows*:

Generate Loss_of_phy_layer notification.

30) Clause 12.2 Encryption systems

In the first paragraph, modify the third sentence to read:

It accepts 128, 192, and 256 bit keys.

In the second paragraph, first sentence, add the reference number [13] *before the semi-colon.*

31) Clause 12.3 Key exchange and switch-over

In the second paragraph, after the third sentence, insert the following sentence:

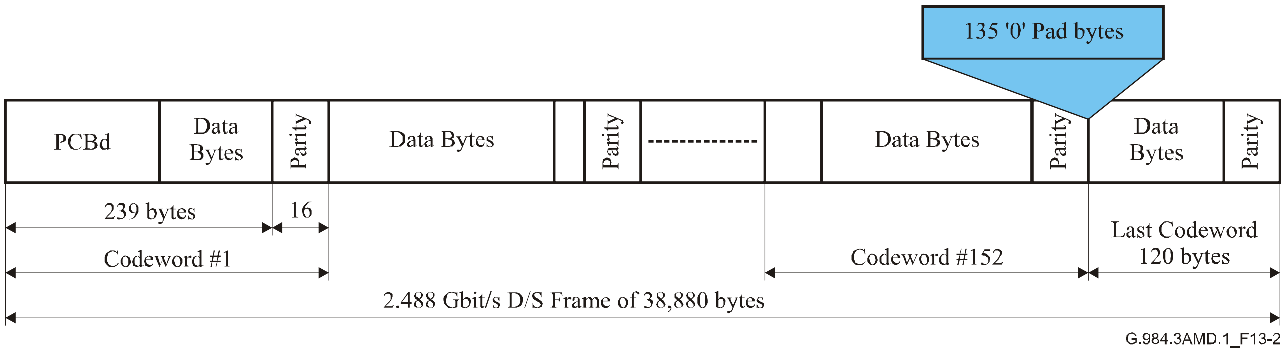
The ONU should generate a cryptographically unpredictable key. For guidance in achieving this, see [14].

32) Clause 13.2.1.2 Shorter last codeword

In the 4th bullet point, change "OLT" *to* "ONU".

In the 1st and 4th bullet points, change "end" *to* "beginning".

Modify Figure 13-2 as follows:



33) Clause 13.2.3.1 D/S FEC indication bit

Modify this clause as follows:

The downstream FEC function can be activated/deactivated at the OLT by the OpS system. An in-band indication bit is used for notifying the ONUs about a change in the FEC status.

The D/S frame contains a FEC indication bit located in the IDENT field.

The FEC indication bit acts as follows:

- "0" – FEC Off. No FEC in the downstream frame.
- "1" – FEC On. The downstream frame contains FEC parity bytes.

Note that the activation and deactivation of FEC is not meant to be an "in-service" operation. The behaviour during switch over is undefined, and likely to cause a momentary loss of data.

34) Clause 13.3.1.1 Parity bytes

Add the following new paragraph and figure at the end of the clause:

All allocations on a particular ONU will have the same FEC status. Contiguous allocations will be encoded as a single block of data, and have only one shortened last codeword. The start pointers cannot point to parity byte locations. As a consequence, the stop pointers cannot point to the first 15 parity byte locations, or the last data byte, before a parity byte location. These restrictions are illustrated in Figure 13-5a.

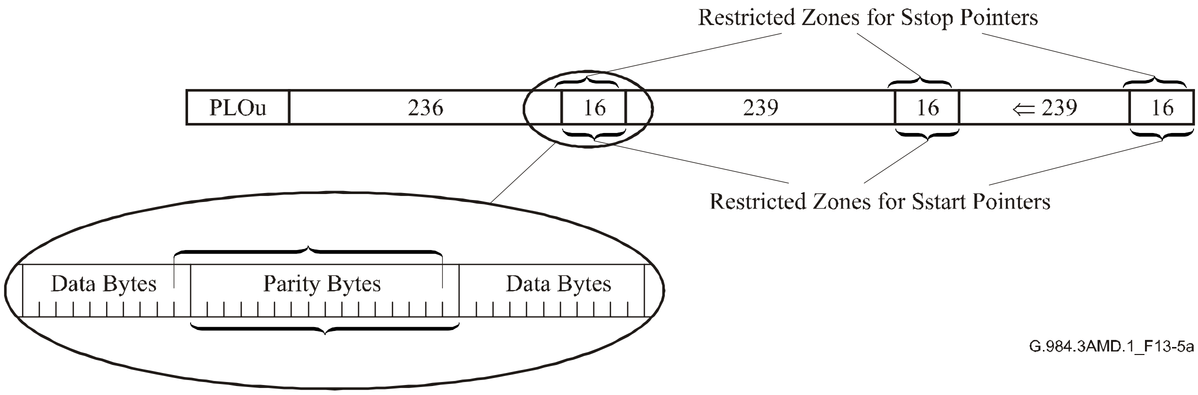
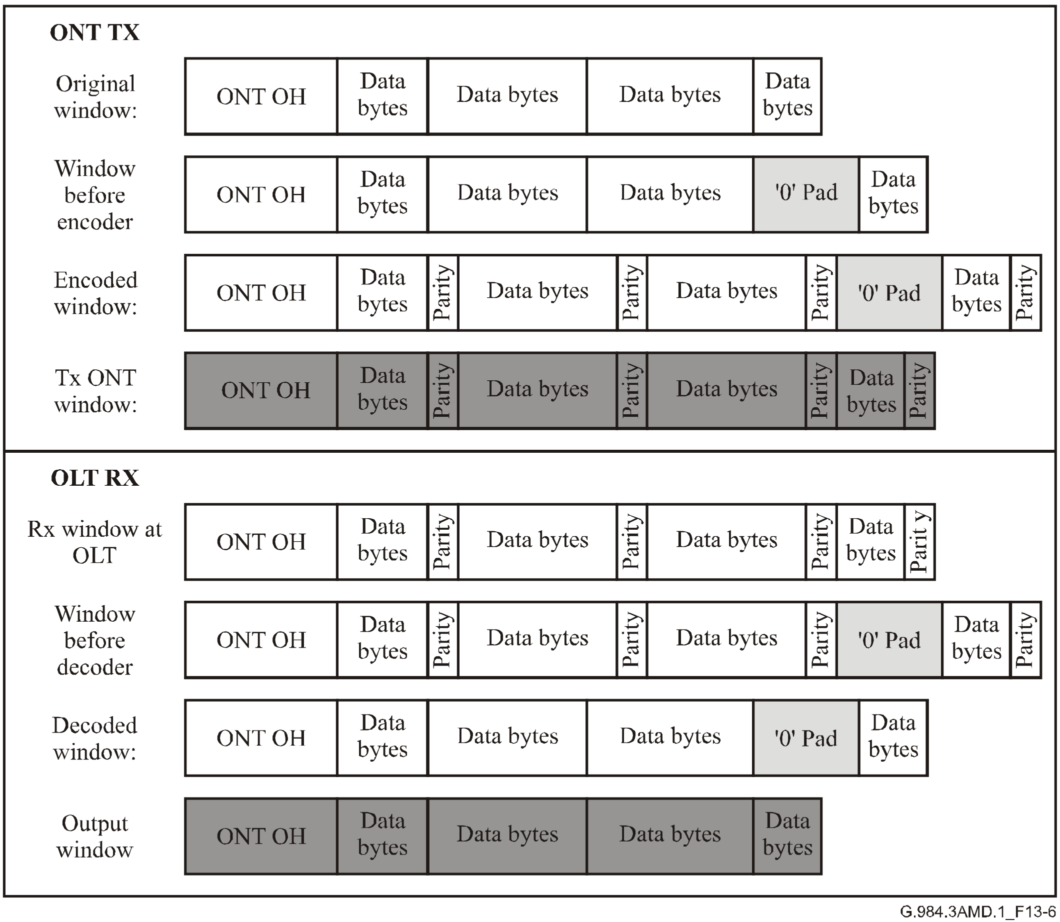


Figure 13-5a/G.984.3 – Pointer restrictions in the case of contiguous allocations with FEC

35) Clause 13.3.1.2 Shorter last codeword

In the 1st and 5th bullet points, change "end" *to* "beginning".

Modify Figure 13-6 as follows:



Add the following new paragraph to the end of the clause:

Note that if less than 17 bytes are available for the last codeword, then all zeroes should be sent.

36) Clause 13.3.1.3 ONU transmission size

Add the following new text to the clause:

The OLT should take the usage of FEC into account in the calculation of the bandwidth map, and strive to allocate an integral number of FEC blocks for those ONUs that are utilizing FEC.

37) Clause 13.3.3.1 U/S FEC indication bit

Modify clause 13.3.3.1 as follows:

The upstream FEC function of the ONU can be activated/de-activated by the OpS system via the OLT. An in-band indication bit is used by the ONU to notify the OLT of a change in the FEC status.

The OLT sets the ONU FEC encoding status (on/off) using the UseFEC bit in the Flags field. Note that all allocations in any ONU must use the same FEC status. The ONU should act immediately on the UseFEC bit.

The FEC indication bit acts as follows:

- "0" – Off. No FEC in U/S transmission.
- "1" – On. The U/S transmission contains parity bytes.

The indication bit serves as a confirmation that the ONU has complied with the UseFEC command.

38) Clause 13.3.3.2 U/S FEC on/off detection behaviour at OLT

Modify clause to read:

The OLT knows *a priori* the FEC status of the upstream burst, since it controls this via the flags field. Hence, if FEC is requested, the OLT should then expect FEC to be included in the upstream transmission. The content of the FEC indication bit is a piece of auxiliary information that can be used to confirm the FEC status of the ONU.

39) Clause 13.4 ONU activation transmissions

Replace this clause with the following:

No upstream FEC will be applied while the ONU is outside of the normal operating state. This is required due to the short length of the special transmissions that occur in the non-operating states, and to the rare occurrence of special transmissions.

40) Appendix IV

Replace Appendix IV as follows:

Appendix IV

OLT Activation Overview

This appendix describes how the Activation Process might be implemented in an OLT. This description is given for informative purposes in order to further clarify the interaction between the OLT and the ONU. The actual details of the OLT Activation is left to the vendor.

The activation procedure described below gives an example of how the state machines of the OLT might be implemented. The specific details of the OLT implementation are left to the individual vendors.

The functions of the OLT during the activation procedure can be divided into the Common-part and the ONU-specific-part(n). The Common part performs a common function in one line-interface and the ONU-specific-part(n) performs functions pertaining to an individual ONU on a line-interface. The states for both parts are described in detail below.

IV.1 Common part

The Common part deals with OLT functions that are common to one or more ONUs. Examples of this include acquisition of new ONU Serial numbers and the discovery of ONUs that return to service following LOS state.

IV.1.1 States of the OLT common-part

The states of the OLT common part are defined as:

a) **Serial Number Acquisition Standby State** (OLT-COM1)

OLT waits for a "new" or "missing" ONU indication, or for a periodic cycle time-out.

b) **Serial Number Acquisition State** (OLT-COM2)

When entering this state, the OLT starts the Serial number acquisition cycle by Halting the active ONUs and transmitting a Serial Number Request. The OLT checks for "new" or "missing" ONUs, and assigns an ONU-ID to each newly discovered ONU.

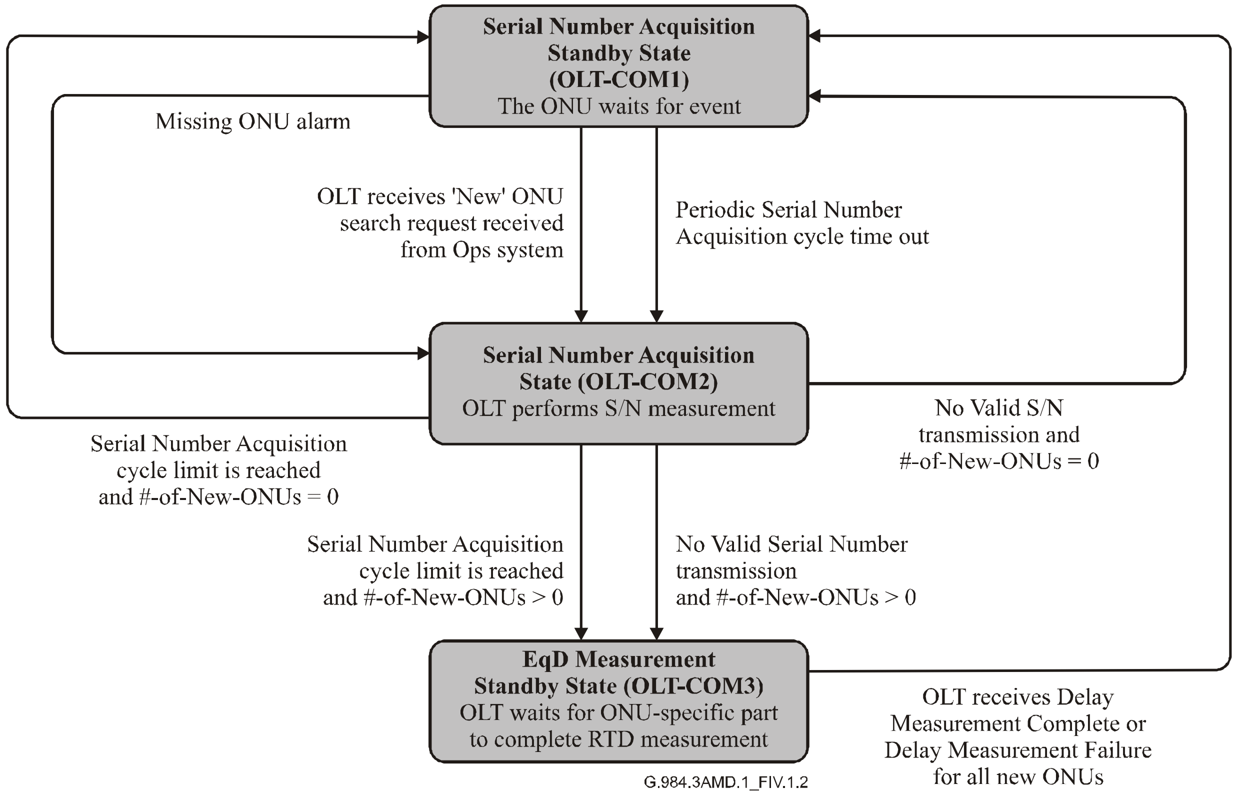
When there are one or more newly discovered ONUs, the OLT activates an Equalization Delay measurement cycle for each discovered ONU. The OLT transitions to the Equalization Delay Measurement Standby State (OLT-COM3)

c) **EQD Measurement Standby State** (OLT-COM3)

The OLT Common part waits in this state while the various ONU-specific-part(n)s start their Equalization Delay measurement cycles. As each Equalization Delay measurement cycle completes, it sends an indication to the OLT Common part. When all Equalization Delay measurements are complete, the OLT Common part transitions to the Serial Number Acquisition Standby State (OLT-COM1).

IV.1.2 Common-part state diagram

The OLT Common part state diagram is shown below.



IV.1.3 Functional transition table for the common-part

The following table describes the functional behaviour of the OLT Common part with respect to state transitions. The first column in the table indicates the events that trigger an OLT action. The subsequent columns indicate the OLT action as a function of the OLT state.

	Serial Number Acquisition Standby state (OLT-COM1)	**Serial Number Acquisition state (OLT-COM2)**	**EqD Measurement Standby State (OLT-COM3)**
"New" ONU from OpS system	⇒OLT-COM2	–	–
Periodic Serial number acquisition cycle time-out	⇒OLT-COM2	–	–
"Missing" ONUs (LOS state) alarm	⇒OLT-COM2	–	–
Received valid Serial_Number transmission for "new" ONU		Extract SN Allocate free ONU-ID	–
Received valid Serial_Number transmission for "missing" ONU		Extract SN; Re-assign the ONU-ID	–
Received Unexpected Serial_Number transmission		Deactivate ONU	
No valid Serial_Number transmission received and #-of-New-ONUs = 0		⇒OLT-COM1	
No valid Serial_Number transmission received and #-of-New-ONUs > 0		⇒OLT-COM3	

	Serial Number Acquisition Standby state (OLT-COM1)	Serial Number Acquisition state (OLT-COM2)	EqD Measurement Standby State (OLT-COM3)
Serial number acquisition cycle limit is reached and #-of-New-ONUs = 0		⇒OLT-COM1	
Serial number acquisition cycle limit is reached and #-of-New-ONUs > 0		⇒OLT-COM3	
OLT receives Delay measurement complete or Delay Measurement Failure responses for all new ONUs			⇒OLT-COM1

IV.1.4 Events of the OLT common-part

The events of the OLT common part are defined as follows.

a) *"New" ONU search request from Ops system*

This event is generated when a new ONU is defined by the OpS system.

b) *Periodic Serial number acquisition cycle time-out*

When using the auto-discovery process, the OLT will start a SN cycle even if no ONUs are missing. This event is generated when the time-out for this periodic operation has expired.

c) *"Missing" ONUs (Loss-of-Signal – LOS state) alarm*

This event is generated when the number of active ONUs (not in LOS) is less than the number of installed ONUs, as defined by the Ops system.

d) *Valid Serial_Number transmission for "new" ONU*

This event is generated when a valid Serial Number Response is received for a new ONU during the SN acquisition cycle. A valid response is one with a valid CRC. The OLT responds by allocating a free ONU-ID and incrementing the #-of-new-ONUs parameter.

e) *Valid Serial_Number transmission for "missing" ONU*

This event is generated when a valid Serial Number Response with correct ONU-ID is received for a "missing" ONU during the SN acquisition cycle. The OLT increments the #-of-new-ONUs parameter by one. While technically the missing ONU is not "new" it is necessary to increment this parameter in order to initiate the ranging process.

f) *Received Unexpected Serial_Number transmission*

This event is generated when an unexpected Serial Number is received during the SN acquisition cycle.

g) *No Valid Serial_Number transmission is received*

This event is generated when no Serial_Number transmission is received for 2 Serial_Number cycles.

h) *Serial number acquisition cycle limit is reached*

This event is generated after the 10th Serial number acquisition cycle.

i) *Delay measurement complete*

This event is generated by the Common-part when it has received the Delay Measurement Complete(n) notification from all the ONU-specific-part(n) that were discovered during the above Serial number acquisition state. That is, the Equalization Delay measurements over all the ONUs have ended.

IV.2 ONU-specific part

As its name implies, the ONU-specific-part(n) deals specifically with the nth ONU. The OLT will maintain up to 64 separate state machines, one for each ONU.

IV.2.1 States of the ONU-specific-part

The states of the ONU-specific-part(n) are defined as:

a) **Initial State** (OLT-IDV1)

The OLT is waiting for the Ranging Measurement start order, i.e., ONU(n) is in Initial state, Standby state or Serial Number state.

b) **Ranging Measurement State** (OLT-IDV2).

When entering this state, the OLT starts the Equalization Delay measurement cycle.

c) **Operating State** (OLT-IDV3).

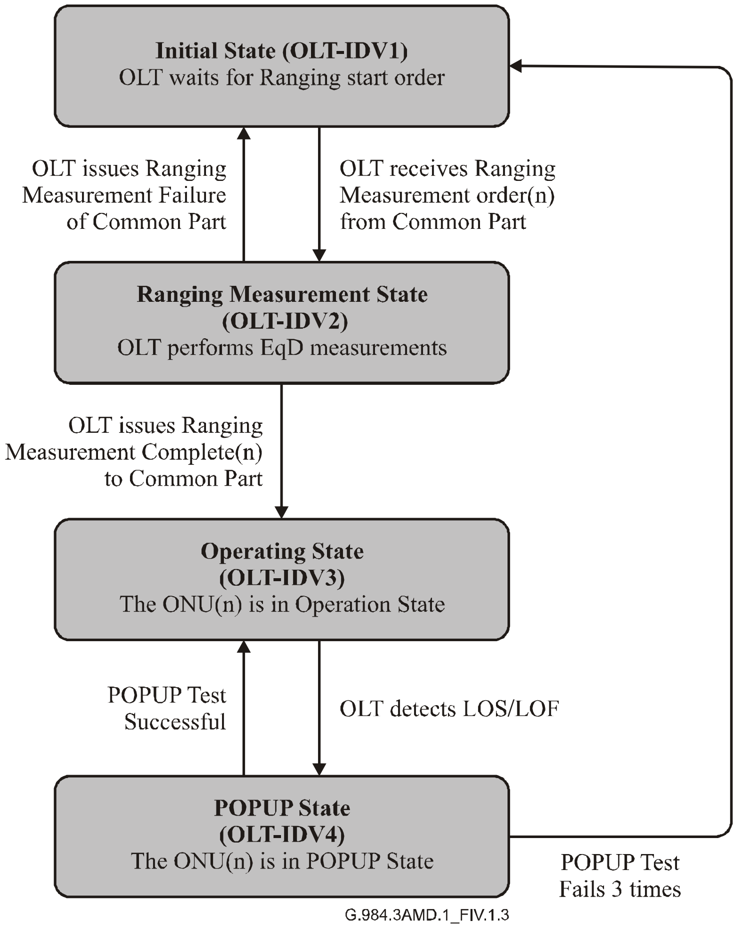
The ONU(n) is in Operation state.

d) **POPUP State** (OLT-IDV4).

The ONU(n) is in POPUP state.

IV.2.2 State diagram of the ONU-specific-part

The ONU-Specific-Part(n) State Diagram is shown below:



IV.2.3 Functional behaviour table for the ONU-specific-part

The following table describes the functional behaviour in the ONU-specific-part(n). The first column in the table indicates the event that generates an OLT response. The remaining columns indicate the resulting OLT actions as a function of OLT state.

	Initial state (OLT-IDV1)	**Ranging measurement state (OLT-IDV2)**	**Operating state (OLT-IDV3)**	**POPUP state (OLT-IDV4)**
Ranging measurement start order(n)	Notification of Ranging measurement start(n). ⇒ OLT-IDV2	–	–	–
Ranging measurement complete(n)	–	Send Ranging_time message 3 times. Notification of Ranging measurement end(n). ⇒OLT-IDV3	–	–

	Initial state (OLT-IDV1)	Ranging measurement state (OLT-IDV2)	Operating state (OLT-IDV3)	POPUP state (OLT-IDV4)
Ranging measurement abnormal stop(n)	–	Send Deactivate_ONU-ID message 3 times. Notification of Ranging measurement end(n). ⇒ OLT-IDV1	–	–
Detect of LOS(n), LOF(n)	–	–	Notification of LOS(n). ⇒ OLT-IDV4	

IV.2.4 Events of the ONU-specific-part

The events are defined as follows:

a) *Ranging measurement start order(n)*

This event is generated when instruction is received from the Common-part.

b) *Ranging measurement complete(n)*

This event is issued by the ONU-specific-part to the Common-part when the nth Equalization Delay measurement has been performed successfully.

The nth Ranging measurement has been performed successfully when the Equalization Delay measurement has completed and the Ranging_time message containing the Equalization_Delay has been sent to ONU(n) 3 times. After issuing the Ranging measurement complete(n), the OLT ONU-specific-part transitions to the Operating-State (OLT-IDV3).

The criteria for the completion of all ONUs is given in IV.5.3.

c) *Ranging measurement abnormal stop(n)*

This event is generated when the Ranging measurement has failed.

The ONU-specific-part(n) sends a Deactivate_ONU-ID message to ONU(n) 3 times, sends a Notification of Ranging measurement complete(n) to the OLT Common part and the OLT transitions to the Initial state (OLT-IDV1).

d) *Detect of LOS(n), LOF(n)*

This event causes the state to move to the POPUP state (OLT-IDV4).

IV.3 Automatic ONU discovery method

The activation procedure described above is applicable for several types of installation methods of ONUs.

The G-PON protocol relies on the unique serial number of the ONU for identification and provisioning purposes. Some operators will use an OpS system that pre-provisions ONUs based on serial number. In this case, a directed activation method is used. In all other situations, the serial numbers of the ONTs are unknown initially and, therefore, must be discovered. G-PON allows for an automatic discovery method to accommodate this situation.

There are three triggers for initiating the activation of an ONU:

– The network operator enables the activation process to start when it is known that a new ONU has been connected.

– The OLT automatically initiates the activation process, when one or more of the previously working ONUs are "missing", to see if those ONUs can return to service. The frequency of polling is programmable under instruction of the OpS system.

– The OLT periodically initiates the activation process, testing to see if any new ONUs have been connected. The frequency of polling is programmable under instruction of the OpS system.

IV.3.1 Type of activation process

Different situations, as described below, are possible where the activation process may occur. There are three categories under which the activation process would occur.

IV.3.1.1 Cold PON, cold ONU

This situation is characterized when no upstream traffic is running on the PON, and the ONUs have not yet received ONU-IDs from the OLT.

IV.3.1.2 Warm PON, cold ONU

This situation is characterized by the addition of new ONU(s) that have not been previously ranged, or by the addition of previously active ONU(s) having power restored and coming back to the PON while traffic is running on the PON.

IV.3.1.3 Warm PON, warm ONU

This situation is characterized by a previously active ONU which remains powered-on and connected to an active PON but, due to long alarm status, returned to the Initial state (O1).

IV.4 POPUP process

The purpose of the POPUP state is to give ONUs, that detected LOS or LOF alarms, a certain period of time to recover and return to the Operation state without moving to the Initial state.

Since the ONU might be using a wrong EqD value (due to network protection operation or internal ONU error), the POPUP function will test the ONU before returning it to the Operation state.

Regarding the POPUP functioning, there are two pathways:

- Transmission-Test: OLT checks that ONU transmission is received at the expected location.
- Ranging-Test: OLT re-ranges the ONU.

Method 1 – Transmission-Test (using a directed POPUP message):

1) Following LOS/LOF, ONU enters the POPUP state. As long as the ONU is in POPUP state, no U/S transmission is allowed. All BW allocations are ignored by ONU.

1.1) When entering the POPUP state, ONU activates the TO2 timer.

1.2) Following time-out (TO2), ONU transits to Initial state.

2) OLT discovers that ONU is in POPUP state: it stops normal allocations to that ONU, and sends the ONU a **directed** POPUP message.

3) When the ONU receives the POPUP message, the ONU transitions into the Operation state (this confirms that both sides know that the ONU has experienced an outage).

3.1) When entering the Operation state, ONU stops the TO2 timer.

4) Before returning the ONU to full operation (regular allocations), the OLT **can** test the ONU by halting the working ONUs and sending a short PLOAMu allocation (PLOAMu = '1', SStart = xx, & SStop = xx + 12) to the ONU.

4.1) ONU waits for its **assigned** EqD and responds to it with a PLOAMu transmission based on the Start value (any PLOAMu is fine, and can be an empty PLOAM as well).

4.2) If the ONU responds back in the correct time, or the ONUs equalization delay can be adjusted based on the test transmission, OLT considers the ONU recovered and start sending regular data allocations. Else, the OLT can deactivate the ONU.

Method 2 – Ranging-Test (using a broadcast POPUP message):

1) Following LOS/LOF, ONU enters the POPUP state. As long as the ONU is in POPUP state, no U/S transmission is allowed. All BW allocations are ignored by ONU.

1.1) When entering the POPUP state, ONU activates the TO2 timer.

1.2) Following time-out (TO2), ONU transits to Initial state.

2) OLT discovers that ONU is in POPUP state: it stops normal allocations to that ONU, and sends the ONU a **broadcast** POPUP message.

3) When the ONU receives the POPUP message, the ONU transitions into the Ranging state (this confirms that both sides know that the ONU has experienced an outage).

3.1) When entering the Ranging state, ONU stops the TO2 timer and activates the TO1 timer.

4) The OLT sends a Ranging-request (PLOAMu = "1", Sstart = xx, & Sstop = xx + 12).

5) ONU waits for the **pre-assigned** EqD and responds to the Ranging-request.

6) If the ONU responds back, OLT considers the ONU recovered and sends a Ranging-time message. Else, the OLT can deactivate the ONU, or wait till the ONU reaches TO1 and moves back to the Standby state.

7) When the ONU gets the Ranging-time message, it transits to Operating state. Else, following time-out (TO1), it transits to Initial state.

IV.5 Equalization delay measurement theory

IV.5.1 Phase relation specification between D/S and U/S

The Phase relation between the transmission of a D/S frame and the reception of the corresponding U/S frame at the OLT is called the Zero-distance Equalization Delay. As its name implies, this is the Equalization Delay that an ONU would receive if it were at zero distance from the OLT. It is recommended that the Zero-distance Equalization Delay be set to 250 µsec.

IV.5.2 Definitions of phase relation delay

The configuration of the phase delay points described below is shown in Figure IV.1.

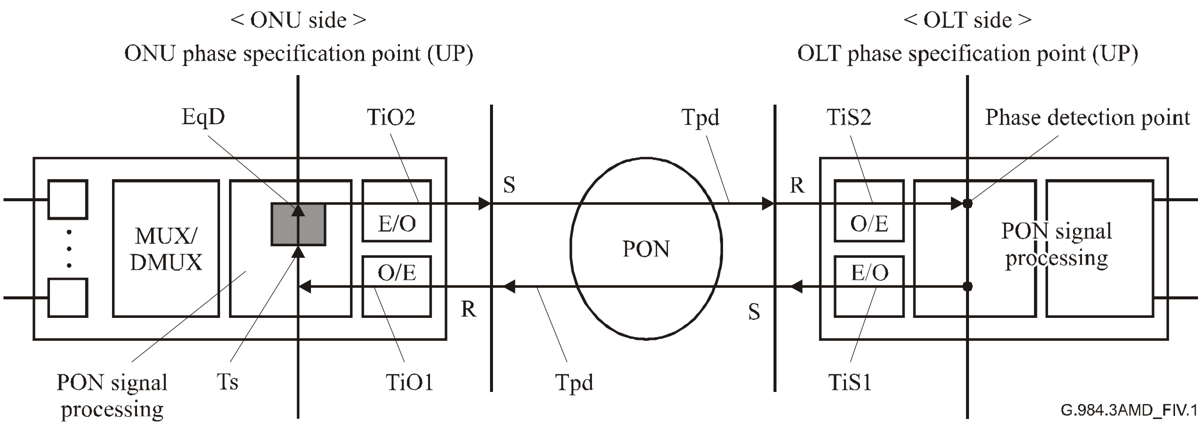


Figure IV.1/G.984.3 – Configuration of the phase delay points

IV.5.2.1 Optical fibre propagation delay (Tpd)

The Optical fibre propagation delay (Tpd) is the time of signal propagation along the length of optical fibre between the OLT and ONU.

IV.5.2.2 Basic transmission delay (Ts)

The Basic transmission delay (Ts) is the time the ONU takes to process an immediate range request.

IV.5.2.3 Optical delay

The optical delays TiO1, TiO2 are the times of the opto-electrical and electro-optical conversions in the ONU, respectively. The optical delays TiS1 and TiS2 are the times of opto-electrical and electro-optical conversions in the OLT, respectively.

IV.5.2.4 Equalization-Delay (EqD)

The Equalization delay is an internal delay in the ONU, set and controlled by the OLT. The purpose of this parameter is to delay the upstream transmission so it arrives at the OLT at the correct phase.

IV.5.2.5 *A priori* round trip delay

Using Figure IV.1 as a guide, the *a priori* round trip delay from the OLT phase specification point out to the ONU and back to the OLT phase specification point with zero equalization delay is given by:

$$\mathrm{RTD}(n) = \mathrm{TiS1} + \mathrm{Tpd}(n) + \mathrm{TiO1} + \mathrm{Ts} + \mathrm{TiO2} + \mathrm{Tpd}(n) + \mathrm{TiS2}$$

Rearranging terms we find:

$$\mathrm{RTD}(n) = 2 * \mathrm{Tpd}(n) + (\mathrm{TiS1} + \mathrm{TiO1} + \mathrm{Ts} + \mathrm{TiO2} + \mathrm{TiS2})$$

The last term in parenthesis is the equipment response time, Ter, and it is recommended that this be fixed for all ONUs at a value less than 50 µs.

In addition, 2*Tpd can be expressed as:

$$2 * \mathrm{Tpd} = \frac{\text{Distance to ONU [km]}}{0.1\left[\frac{\mathrm{km}}{\mu\mathrm{s}}\right]}$$

IV.5.3 Criteria for successful or failed EqD measurement

An EqD measurement is considered successful if all of the following conditions are satisfied. If one of the conditions is not satisfied, the EqD measurement is considered **failed**.

– A valid Ranging response with a matching ONU ID and Serial Number is received by the OLT.

– The Ranging response is received within the expected time limits based on the maximum length of the PON.

– The measured EqD is within a time range, which is based on an estimated distance value between the ONU and the OLT. The OpS System supplies the estimated distance value to the OLT. If no distance value was supplied, this condition is ignored.

– The EqD is within Allowed-Ranging-Variance, which is N bits according to the upstream bit rate, compared with the last successful EqD measurement. This condition is ignored until the first successful EqD.
  - 1.244 Gbit/s – 8 bits
  - 622 Mbit/s – 4 bits
  - 155 Mbit/s – 1 bit

Some inaccuracies might occur during the ranging procedure. In order to reduce these inaccuracies, several EqD measurements may be performed before calculating the Equalization-delay factor.

The EqD measurement procedure is considered completed following one or more successful or two failed measurements.

– When two EqD measurements are used during a successful EqD measurement procedure, the resulting EqD will be the average of the two.
– For failed EqD measurement procedure, a **SUFi** alarm will be asserted and the ONU will be deactivated, using the Deactivate_ONU-ID message (thus moving to Standby-state (O2)).

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