LOS failure is present (see LOS failure definition above). An LOF failure is cleared when LOS failure is declared, or after 10 ± 0.5 s of no *sef*.

The high_BER-hs event in $RIpolicy_n$=0 shall be declared whenever any of the parameters listed in Table 12-3 exceeds the listed threshold. Other conditions are vendor-specific and are (but are not required to be) related to near-end and/or far-end performance primitives. As an example, the VTU may also declare a high_BER event after 30 s of persistent near-end or far-end *lom* defect. The VTU should trade-off the persistency in the high_BER events to, on the one hand, quickly recover data integrity, but on the other hand, not to unnecessarily interrupt data transmission. This trade-off may be enhanced if the VTU is able to detect and quantify instantaneous changes in line conditions.

Table 12-3 – Conditions for declaring a high_BER-hs event in $RIpolicy_n$=0

Parameter	Threshold
Number of successful SOS procedures performed within a 120-second interval	MAX-SOS threshold configured in CO-MIB
Number of seconds the actual net data rate (net_act_n) is below the minimum net data rate (net_min_n) for any bearer channel after a successful SOS procedure	20 seconds
Duration of time interval with consecutive eoc message time-outs without a single successful eoc command/response exchange	Vendor discretionary
NOTE – Other conditions declaring a high_BER event are vendor specific.	

In determining the number of successful SOS procedures performed within a 120-second interval, the 120-second measurement interval shall be started at the first successful SOS procedure after getting into Showtime and re-started at the first successful SOS procedure occurring after a previous 120-second period interval has expired with the number of successful SOS procedures being less than MAX-SOS. The 120 second measurement intervals shall be sequential periods, not a sliding window.

The SOS procedure shall be considered as successful when the VTU initiating the SOS receives the SyncFlag in response (regardless whether the SyncFlag was received after a single or multiple SOS requests).

In the second policy ($RIpolicy_n$=1) (optional), a VTU shall transition from the SHOWTIME state to the SILENT state in the case of:

1) loss of receive power (power loss); or
2) persistent link failure; or
3) persistent near-end loss of margin failure; or
4) persistent TPS-TC out-of-sync failure; or
5) upon a high_BER-hs event as defined below for $RIpolicy_n$=1.

The VTU shall declare a power loss identical to Re-Initialization Policy 0.

The VTU shall declare a persistent link failure identical to Re-Initialization Policy 0.

The VTU shall declare a persistent loss of margin failure after 60 ± 1 s of contiguous near-end loss of margin defect (*lom*).

The VTU shall declare a persistent TPS-TC out-of-sync failure after 15 ± 1 s of contiguous near-end TPS-TC out-of-sync condition.

In the case that the TPS-TC is ATM, the TPS-TC out-of-sync condition corresponds with near-end loss of cell delineation defect (*lcd-n*). (See clause L.2).

In the case that the TPS-TC is PTM, the TPS-TC out-of-sync condition corresponds with near-end

TC_out_of_sync (*oos-n*) anomaly. (See clause N.4 of [ITU-T G.992.3]).

The high_BER-hs event in $RIpolicy_n$=1 shall be declared whenever any of the parameters listed in Table 12-4 exceeds the listed threshold.

Table 12-4 – Conditions for declaring a high_BER-hs event in $RIpolicy_n$=1

Parameter	Threshold
Number of contiguous near-end SES	REINIT_TIME_THRESHOLD configured in CO-MIB
Number of successful SOS procedures performed within a 120-second interval	MAX-SOS threshold configured in CO-MIB
Number of seconds the actual net data rate (net_act_n) is below the minimum net data rate (net_min_n) for any bearer channel after a successful SOS procedure	20 seconds
Duration of time interval with consecutive eoc message time-outs without a single successful eoc command/response exchange	REINIT_TIME_THRESHOLD configured in CO-MIB
NOTE – At the VTU-R, no other conditions shall declare a high_BER-hs event. At the VTU-O, no other near-end conditions shall declare a high_BER-hs event. Declaration of a high_BER-hs event based on far-end conditions are vendor specific.	

12.1.5 Loop diagnostic procedure

Loop diagnostic mode is intended to identify channel conditions at both ends of the loop without transitioning to the SHOWTIME state. The VTUs will return to the SILENT state after completion of the loop diagnostic mode. Loop diagnostic mode is described in clause 12.4.

12.2 Special operations channel (SOC)

The SOC provides a bidirectional communication of messages between the VTU-O and the VTU-R to support initialization, fast start-up, and loop diagnostic procedures.

The SOC has 2 states; active and inactive. Its state is determined by the stages of initialization and is indicated in the timing diagrams in Figures 12-6, 12-9 and 12-11 and described in the signal and message summary tables in clauses 12.3.3, 12.3.4, and 12.3.5.

12.2.1 Message format

The SOC shall use an HDLC-like format with byte stuffing (octet transparency) and an FCS to monitor errors as specified in [ITU-T G.997.1].

The structure of an HDLC frame shall be as illustrated in Figure 12-4.

Size in octets	Meaning	Value
1	Flag	$7E_{16}$
1	Address field	Message index
1	Control field	Segmentation index
Up to 1024	Information payload	Payload bytes
1	Frame check sequence	FCS
1	Frame check sequence	FCS
1	Flag	$7E_{16}$

Figure 12-4 – Structure of HDLC frames used in the SOC protocol

The message index is dependent on the acknowledgment mode (i.e., AR or RQ) and whether a message is being repeated. It is defined in clause 12.2.2.

The segmentation index facilitates the message segmentation as described in clause 12.2.6. If no segmentation is used, the segmentation index shall be set to 11_{16}. The number of SOC bytes (before byte stuffing) transmitted in a single HDLC frame shall not exceed 1024.

12.2.2 Communication protocol

The SOC shall use either an automatic repeat (AR) mode or a repeat request (RQ) mode.

12.2.2.1 Automatic repeat (AR) mode

In AR mode, messages encapsulated in HDLC frames shall be automatically repeated. At least four idle flags ($7E_{16}$) shall be inserted between successive frames.

The message index shall always be set to 01_{16} in AR mode. The segmentation index shall be set to 11_{16} if the message is not segmented, and as specified in clause 12.2.6 if the message is segmented.

Table 12-5 shows the structure of each HDLC frame in AR mode.

Table 12-5 – HDLC frames in AR mode

Field	Content
Flag	$7E_{16}$
Message index	01_{16}
Segmentation index	11_{16} if not segmented; as in clause 12.2.6 if segmented
Information payload	Variable, up to 1024 bytes
FCS	Variable
FCS	Variable
Flag	$7E_{16}$

The sending of a message in AR mode shall be terminated by receipt of an acknowledgment of the message. The acknowledgment may be sent at any time.

12.2.2.2 Repeat request (RQ) mode

In RQ mode, each message encapsulated in an HDLC frame shall be sent only once. However, the VTU expecting the message shall have the opportunity to request the remote side to repeat the message by sending an O/R-REPEAT_REQUEST message when the expected message has a wrong FCS or when a time-out has expired. After two unsuccessful O/R-REPEAT_REQUEST attempts, the activation shall be aborted (i.e., considered an unsuccessful activation). The value of the time-out shall be 2 s. The VTU shall start the time-out counter as it transmits the last byte of the message (segment) and stop the counter as it receives the Control field of the expected incoming message (segment). For the first message (segment) following activation/re-activation of the SOC, the VTU shall count the time-out from this activation time to the reception of the Control field of the message (segment) in accordance with the specific message exchange protocol defined in clauses 12.3.3, 12.3.4, and 12.3.5.

In RQ mode, a VTU shall never send a message (segment) prior to receiving an acknowledgement of the previously sent message (segment). This acknowledgement could be either a message in accordance with the message exchange protocol of the specific initialization phase, or a special signal (O-P-SYNCHRO or R-P-SYNCHRO), as described in clauses 12.3.3, 12.3.4, and 12.3.5. Once acknowledged, messages (segments) shall not be re-sent.

Upon entering the RQ mode, the message index shall initially be set to 01_{16} and shall be incremented by 1 as the acknowledgement of a message is received. The index shall wrap around in case of overflow. The value 00_{16} has a special meaning, as described below, and shall be skipped. This means that index value FF_{16} shall be followed by 01_{16}. The index shall not be incremented if an O/R-REPEAT_REQUEST message is received. The segmentation index shall be set to 11_{16} if the message is not segmented, and as specified in clause 12.2.6 if the message is segmented. The message index and segmentation index of the message (segment) shall not be changed if the message (segment) is re-sent.

The message index and segmentation index of the O/R-REPEAT_REQUEST message shall be set to 00_{16}. These fields shall be ignored by the receiver (because there can be only one unacknowledged message or segment at a time).

12.2.3 Mapping of SOC data

An SOC message shall contain an integer number of octets. All octets shall be sent LSB first. An SOC message may be subdivided into fields. A field can contain parameter values expressed in more than one byte. In this case, the field shall be split into bytes with the byte containing the MSBs of the parameter value sent first. For example, a field carrying a 16-bit value $m_{15}, \ldots, m_0$ shall be split into a first byte $B_0=m_{15}\ldots m_8$ and a second byte $B_1=m_7\ldots m_0$. The description of fields for specific messages is given in detail in clauses 12.3.3, 12.3.4, and 12.3.5. All fields that follow the fields defined for a specific message shall be ignored.

NOTE – If future versions of this Recommendation add extra fields to the ones already defined, for reasons of backward compatibility, these fields must be appended to the currently defined ones.

Some SOC messages may contain several fields. Some fields can be merged together to form a logical entity called a macro-field, such as "PSD descriptor" and "Bands descriptor", which are described in clause 12.3.3.2.1.1.

12.2.4 SOC idle (O-IDLE, R-IDLE)

When the VTU-O's SOC is in the active state but idle (i.e., it has no message to send), it shall send O-IDLE. Similarly, the VTU-R shall send R-IDLE when its SOC is in the active state but idle.

O-IDLE and R-IDLE shall consist of HDLC flags: $7E_{16}$. This octet shall be sent repeatedly instead of HDLC frames.

12.2.5 SOC messages

12.2.5.1 Message codes

The information payload of every SOC message shall start with a one byte field containing a unique code to identify the type of message. For one-byte messages the message code is the entire content of the message. The message codes for all defined messages are shown in Table 12-6.

NOTE – Other than O/R-REPEAT_REQUEST and O/R-ACK-SEG, which have special message codes, messages sent by the VTU-O have the MSB equal to ZERO, whilst messages sent by the VTU-R have the MSB equal to ONE.

Table 12-6 – Message codes for the SOC messages

SOC message	Message code	Notes
O/R-REPEAT_REQUEST	55_{16}	(Note)
O/R-ACK-SEG	$0F_{16}$	(Note)
VTU-O messages		
O-ACK	00_{16}	(Note)
O-SIGNATURE	01_{16}	see clause 12.3.3.2.1.1
O-UPDATE	02_{16}	see clause 12.3.3.2.1.2
O-MSG 1	03_{16}	see clause 12.3.5.2.1.1
O-PRM	04_{16}	see clause 12.3.3.2.1.3
O-TA_UPDATE	05_{16}	see clause 12.3.4.2.1.1
O-TPS	06_{16}	see clause 12.3.5.2.1.2
O-PMS	07_{16}	see clause 12.3.5.2.1.3
O-PMD	08_{16}	see clause 12.3.5.2.1.4
O-PRM-LD	09_{16}	see clause 12.4.2.1.1
O-MSG-LD	$0A_{16}$	see clause 12.4.3.1.1
VTU-R messages		
R-ACK	80_{16}	(Note)
R-MSG 1	81_{16}	see clause 12.3.3.2.2.1
R-UPDATE	82_{16}	see clause 12.3.3.2.2.2
R-MSG 2	83_{16}	see clause 12.3.5.2.2.1
R-PRM	84_{16}	see clause 12.3.3.2.2.3
R-TA_UPDATE	85_{16}	see clause 12.3.4.2.2.1
R-TPS-ACK	86_{16}	see clause 12.3.5.2.2.2
R-PMS	87_{16}	see clause 12.3.5.2.2.3
R-PMD	88_{16}	see clause 12.3.5.2.2.4
R-PRM-LD	89_{16}	see clause 12.4.2.1.2
R-MSG-LD	$8A_{16}$	see clause 12.4.3.1.2
NOTE – This is the entire payload of the message.		

12.2.5.2 O/R-REPEAT_REQUEST

This message shall be used in RQ mode to request the remote side to resend the last unacknowledged message (segment), as described in clause 12.2.2.2. The format of the message shall be as specified in clause 12.2.1, and the payload shall be as specified in Table 12-6.

In AR mode, O/R-REPEAT_REQUEST messages shall be ignored.

12.2.5.3 O/R-ACK-SEG

This message shall be used in RQ mode to acknowledge the reception of intermediate segments of a segmented message, as described in clause 12.2.2.2. The format of the message shall be as specified in clause 12.2.1 and the payload shall be as specified in Table 12-6.

In AR mode, and when no segmentation is used, any O/R-ACK-SEG messages shall be ignored.

12.2.5.4 VTU-O and VTU-R messages

These messages are described in detail in clauses 12.3.3, 12.3.4, and 12.3.5.

12.2.6 Segmentation of messages

Messages that are larger than the maximum allowed size (1024 bytes) shall be segmented before transmission; messages shorter than 1024 bytes may also be segmented to improve robustness. To allow segmentation, a segmentation index is included in the control field of the HDLC frame. The four MSBs of this field shall indicate the number of segments, to a maximum of 15, into which the message has been segmented. The four LSBs of this field shall indicate the index of the current segment, starting from 1_{16}. For example, a segmentation index value of 93_{16} indicates the third segment of a total of nine. In case the message is not segmented, the value of the field shall be 11_{16}.

In RQ mode, an acknowledgement (O/R-ACK-SEG) shall be sent for all but the last segment. Typically, the last segment signals the end of the message and will therefore be acknowledged by the reply to the message. The O/R-ACK-SEG message (see Table 12-6) shall be used to acknowledge the reception of the other segments. The O/R-ACK-SEG message shall have its message index assigned by the generic rule defined in clause 12.2.2.2 and shall be increased by 1 when a new segment is received. The segmentation index of each O/R-ACK-SEG message shall be set to 11_{16}. Once acknowledged, segments shall not be retransmitted and re-transmission shall not be requested.

In AR mode, segmentation shall be done in the same way, but there will be no acknowledgements (O/R-ACK-SEG) between different segments of the same message. Segments shall be sent in sequential order. All segments shall be sent before the message is repeated.

12.3 Initialization procedure

12.3.1 Overview

Initialization of a VTU-O/VTU-R pair includes the following main tasks:

- Definition of a common mode of operation (profile, band plan and initial values of basic modulation parameters);
- Synchronization (sample clock alignment and symbol alignment);
- Transfer from the VTU-O to the VTU-R of transmission parameters, including information on the PSD masks to be used, RFI bands (e.g., amateur radio bands) to be protected, and target data rates in both transmission directions;
- Channel identification;
- Noise identification;
- Calculation of framer, interleaver, and coding parameters, as well as the bit loading and gain tables; and
- Exchange of VTU parameters (including RS settings, interleaver parameters, framer settings, bit loading and gain tables).

The common mode of operation shall be negotiated during the ITU-T G.994.1 handshake phase. Information such as the PSD mask, locations of RFI bands to be notched, and target data rates shall be initially available at the VTU-O through the MIB.

The time line in Figure 12-5 provides an overview of the initialization procedure, which contains four phases. Following the initial ITU-T G.994.1 handshake phase, upstream power back-off is applied and a full duplex link between the VTU-O and the VTU-R is established during the channel discovery phase to set the PSDs of the transmit signals and the main modulation parameters. During the training phase, any time-domain equalizers (TEQs) and echo cancellers may be trained, and the timing advance is refined. During the channel analysis and exchange phase, the two VTUs shall measure the characteristics of the channel and exchange parameters to be used in showtime.

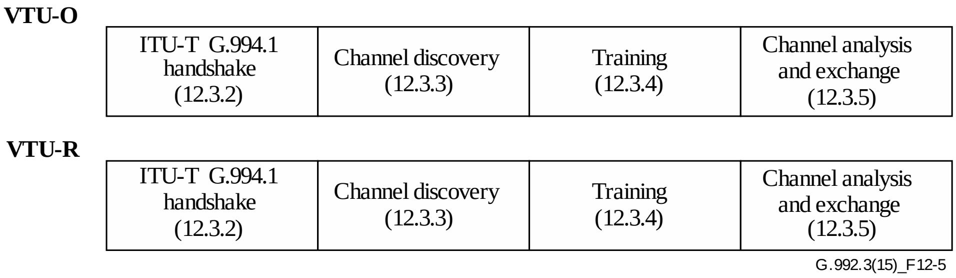

Figure 12-5 – Overview of initialization procedure

The transition to the next phase of initialization shall occur after all tasks in a phase have been completed. A time-out period is defined for each phase to avoid suspension of the initialization procedure. Violation of the time-out or an inability to complete a task results in abortion of the activation process (unsuccessful activation).

The initialization procedure shall be aborted immediately after any of the following events is discovered:

- Time-out of any phase;
- Missing or incomplete task during any phase;
- Violation of the initialization protocol during any phase (including time-out for acknowledging an SOC message); or
- Detection of 250 ms of unscheduled silence.

In all phases, the time-out counter shall be started as the VTU enters the phase and shall be reset upon completion of the phase. The following values for the time-outs shall be used:

- ITU-T G.994.1 handshake phase: As defined in [ITU-T G.994.1];
- Channel discovery phase: 10 s;
- Training phase: 10 s; and
- Channel analysis and exchange phase: 10 s.

Exchange of information between the VTU-O and VTU-R during all phases of initialization, excluding the ITU-T G.994.1 handshake phase, shall be performed using the messaging protocol over the special operations channel (SOC) defined in clause 12.2.

12.3.2 ITU-T G.994.1 handshake phase

The detailed procedures for the ITU-T G.994.1 handshake phase are defined in [ITU-T G.994.1].

12.3.2.1 Handshake – VTU-O

A VTU-O, after power-up, loss of signal, or recovery from errors during the initialization procedure, shall enter the initial ITU-T G.994.1 state, C-SILENT1. The VTU-O may either activate the link or respond to R-TONES-REQ (VTU-R initiated activation) by transitioning to C-TONES. Operation shall then proceed according to the procedures defined in [ITU-T G.994.1].

If ITU-T G.994.1 procedures select this Recommendation as the mode of operation, the VTU-O shall continue with ITU-T G.993.2 initialization at the conclusion of ITU-T G.994.1 operation.

12.3.2.1.1 CL messages

A VTU-O wishing to indicate ITU-T G.993.2 capabilities in an ITU-T G.994.1 CL message shall do so by setting to ONE the ITU-T G.993.2 SPar(1) bit as defined in Table 11.0.4 of [ITU-T G.994.1]. The NPar(2) (Table 11.67 of [ITU-T G.994.1]) and SPar(2) (Table 11.68 of [ITU-T G.994.1]) fields corresponding to the ITU-T G.993.2 Spar(1) bit are defined in Tables 12-7 and 12-8, respectively. For each ITU-T G.993.2 SPar(2) bit set to ONE, a corresponding NPar(3) field shall also be present (beginning with Table 11.68.1 in clause 9.4 of [ITU-T G.994.1]). Table 12-9 shows the definitions and coding for the VTU-O CL NPar(3) fields.

Table 12-7 – VTU-O CL message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	If set to ONE, signifies that the VTU-O supports all-digital mode.
Support of downstream virtual noise	If set to ONE, signifies that the VTU-O supports the use of the downstream virtual noise mechanism.
Lineprobe	Always set to ONE in a VTU-O CL message.
Loop Diagnostic mode	Set to ONE if the VTU-O requests loop diagnostic mode.
Support of PSD shaping in US0	Always set to ONE in a VTU-O CL message.
Support of equalized FEXT UPBO	If set to ONE, signifies that the VTU-O supports equalized FEXT UPBO.
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	See Annex X, Table X.1.
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	See Annex Y, Table Y.1.
Alternative electrical length estimation method	If set to ONE, signifies that the VTU-O supports the Alternative Electrical Length Estimation Method (ELE-M1)
Support of downstream SAVN	If set to ONE, signifies that the VTU-O supports the use of the downstream SAVN mechanism.

Table 12-8 – VTU-O CL message SPar(2) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of Spar(2) bit
Profiles	Always set to ONE.
Bands Upstream	Always set to ONE.
Bands Downstream	Always set to ONE.
RFI Bands	If set to ONE, indicates that RFI band transmit PSD reductions are enabled. If set to ZERO, indicates that RFI band transmit PSD reductions are disabled (Note 1).
Initial IDFT Size (2*N*)	Always set to ONE.
CE Lengths	If set to ZERO, indicates that the VTU-O can support only the mandatory CE length of 5*N*/32 for the IDFT size equal to 2*N*. If set to ONE, indicates that the VTU-O supports optional CE lengths in addition to the mandatory one.
Annex A US0 (Note 2)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex A are supported by the VTU-O.
Annex B US0 (Note 2)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex B are supported by the VTU-O.
Annex C US0 (Note 2)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex C are supported by the VTU-O.
Annex N US0 (Note 2)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex N are supported by the VTU-O.
NOTE 1 – The RFI Bands shall apply to both directions of transmission. NOTE 2 – At least one of these bits shall be set to ONE.	

Table 12-9 – VTU-O CL message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 8 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a and 30a. Each profile supported by the VTU-O is indicated by setting its corresponding bit to ONE.
Bands Upstream	For a given band plan as defined in the regional annexes, this NPar(3) field shall include all of the upstream bands in ascending order starting at f_2 (as shown in Figure A.1, Table B.1, Figure C.1) and ending at the highest band required for the highest frequency profile for which support is indicated. Up to four upstream bands may be defined. Each band shall be defined by a start subcarrier index and stop subcarrier index using 13 bits per index value. The subcarrier indices shall represent 4.3125 kHz subcarrier spacing. Adjacent upstream bands shall be coded as separate bands.
Bands Downstream	For a given band plan as defined in the regional annexes, this NPar(3) field shall include all of the downstream bands in ascending order starting at f_1 (as shown in Figure A.1, Table B.1, Figure C.1) and ending at the highest band required for the highest frequency profile for which support is indicated. Up to four downstream bands may be defined. Each band shall be defined by a start subcarrier index and stop subcarrier index using 13 bits per index value. The subcarrier indices shall represent 4.3125 kHz subcarrier spacing. Adjacent downstream bands shall be coded as separate bands.

Table 12-9 – VTU-O CL message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
RFI Bands	This NPar(3) shall indicate in ascending order the start subcarrier index and stop subcarrier index for each RFI band in which the transmit PSD is to be reduced below −80 dBm/Hz. Each index is represented by 13 bits. Up to 16 RFI bands may be defined. The subcarrier indices shall represent 4.3125 kHz subcarrier spacing.
Initial IDFT Size (2*N*)	This NPar(3) indicates the initial downstream IDFT size that the VTU-O shall use at the beginning of the channel discovery phase, encoded as a number from 7 to 13 representing *n*, where IDFTsize $2N = 2^n$
CE Lengths	This NPar(3) is a field of 15 bits representing the valid CE lengths: 2*N*/32, 3*N*/32, 4*N*/32, ..., 16*N*/32 inclusive. For each CE length that the VTU-O can support, the corresponding bit shall be set to ONE. The bit corresponding to 5*N*/32 shall always be set to ONE.
Annex A US0	A parameter block of 5 octets encoding the Annex A US0 capabilities. This block shall be coded as follows: – Bits 1-6 of octet 1 and bits 1-4 of octet 2 shall be individually set to ONE to indicate support by a VTU-O of the corresponding Annex A US0 masks EU-32 through EU-128. – Bits 1-6 of octet 3 and bits 1-4 of octet 4 shall be individually set to ONE to indicate support by the VTU-O of the corresponding Annex A US0 masks ADLU-32 through ADLU-128. – Bit 1 of octet 5 shall be set to ONE to indicate that all supported Annex A US0 masks are also supported by the VTU-O for profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 5 shall be set to ONE to indicate that all supported Annex A US0 masks are also supported by the VTU-O for profile 17a. This bit may be set to ONE if profile 17a is supported. – Bit 3 of octet 5 shall be set to ONE to indicate that all supported Annex A US0 masks are also supported by the VTU-O for profile 35b. This bit may be set to ONE if profile 35b is supported (Note).
Annex B US0	A parameter block of 2 octets encoding the Annex B US0 capabilities. This block shall be coded as follows: – Bits 1-3 of octet 1 shall be individually set to ONE to indicate support of the corresponding Annex B US0 masks by the VTU-O. – Bit 1 of octet 2 shall be set to ONE to indicate that all supported Annex B US0 masks are also supported by the VTU-O for profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 2 shall be set to ONE to indicate that all supported Annex B US0 masks are also supported by the VTU-O for profile 17a. This bit may be set to ONE if profile 17a is supported.

Table 12-9 – VTU-O CL message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Annex C US0	A parameter block of 3 octets encoding the Annex C US0 capabilities. This block shall be coded as follows: – Bits 1-2 of octet 1 shall be individually set to ONE to indicate the support of the corresponding Annex C US0 Type(b) masks by the VTU-O. – Bits 1-2 of octet 2 shall be individually set to ONE to indicate the support of the corresponding Annex C US0 Type(co) masks by the VTU-O. – Bit 1 of octet 3 shall be set to ONE to indicate that all supported Annex C US0 masks are also supported by the VTU-O in the profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 3 shall be set to ONE to indicate that all supported Annex C US0 masks are also supported by the VTU-O in the profile 17a. This bit may be set to ONE if profile 17a is supported.
Annex N US0	A parameter block of 2 octets encoding the Annex N US0 capabilities. This block shall be coded as follows: – Bits 1-3 of octet 1 shall be individually set to ONE to indicate support of the corresponding Annex N US0 masks by the VTU-O. – Bit 2 of octet 2 shall be set to ONE to indicate that all supported Annex N US0 masks are also supported by the VTU-O for profile 17a. This bit may be set to ONE if profile 17a is supported. – Bit 3 of octet 2 shall be set to ONE to indicate that all supported Annex N US0 masks are also supported by the VTU-O for profile 35b. This bit may be set to ONE if profile 35b is supported.
NOTE – The ADLU US0 masks are not applicable to profile 35b.	

12.3.2.1.2 MS messages

A VTU-O selecting the ITU-T G.993.2 mode of operation in an ITU-T G.994.1 MS message shall do so by setting to ONE the SPar(1) ITU-T G.993.2 bit as defined in Table 11.0.4 of [ITU-T G.994.1]. The NPar(2) (Table 11.67 of [ITU-T G.994.1]) and SPar(2) (Table 11.68 of [ITU-T G.994.1]) fields corresponding to this bit are defined in Tables 12-10 and 12-11, respectively. For each ITU-T G.993.2 SPar(2) bit set to ONE, a corresponding NPar(3) field shall also be present (beginning with Table 11.68.1 in clause 9.4 of [ITU-T G.994.1]). Table 12-12 shows the definitions and coding for the VTU-O MS NPar(3) fields.

Table 12-10 – VTU-O MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, indicates that both the VTU-O and the VTU-R shall be configured for operation in all-digital mode.
Support of downstream virtual noise	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the downstream virtual noise mechanism may be used.

Table 12-10 – VTU-O MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
Lineprobe	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the channel discovery phase of initialization shall include a lineprobe stage.
Loop Diagnostic mode	Set to ONE if either the last previous CLR or the last previous CL message has set this bit to ONE. Indicates that both VTUs shall enter loop diagnostic mode.
Support of PSD shaping in US0	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the VTU-R supports PSD shaping in the US0 band.
Support of equalized FEXT UPBO	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that both the VTU-O and the VTU-R shall use equalized FEXT UPBO.
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	See Table X.2
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	See Table Y.2.
Alternative electrical length estimation method	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that both the VTU-O and the VTU-R shall use electrical length estimation method ELE-M1.
Support of downstream SAVN	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the downstream SAVN mechanism may be used.

Table 12-11 – VTU-O MS message SPar(2) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of SPar(2) bit
Profiles	Always set to ONE.
Bands Upstream	Always set to ZERO.
Bands Downstream	Always set to ZERO
RFI Bands	Always set to ZERO.
Initial IDFT Size (2*N*)	Always set to ZERO.
CE Lengths	Shall be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, indicates that the initial CE length to be used by both the VTU-O and the VTU-R shall be communicated in the corresponding NPar(3) field. If set to ZERO, the mandatory value shall be used.
Annex A US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
Annex B US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
Annex C US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.

Table 12-11 – VTU-O MS message SPar(2) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of SPar(2) bit
Annex N US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
NOTE – One and only one of these bits shall be set to ONE.	

Table 12-12 – VTU-O MS message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 8 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a and 30a. The profile selected by the VTU-O is indicated by setting its corresponding bit to ONE.
CE Lengths	This NPar(3) is a field of 15 bits representing the valid CE lengths 2*N*/32, 3*N*/32, 4*N*/32, ..., 16*N*/32 inclusive. The VTU-O shall indicate by setting to ONE the bit corresponding to the selected initial CE length. All other bits shall be set to ZERO. The selected CE length shall be one whose bit was set to ONE in both the last previous CLR and the last previous CL messages.
Annex A US0 (Note)	A parameter block of 5 octets encoding the Annex A US0 selection. The VTU-O shall indicate its selection of the Annex A US0 mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-3 of octet 5 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
Annex B US0 (Note)	A parameter block of 2 octets encoding the Annex B US0 selection. The VTU-O shall indicate its selection of the Annex B US0 PSD mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages, and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-2 of octet 2 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
Annex C US0 (Note)	A parameter block of 3 octets encoding the Annex C US0 selection. The VTU-O shall indicate its selection of the Annex C US0 PSD mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages, and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-2 of octet 3 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.

Table 12-12 – VTU-O MS message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Annex N US0 (Note)	A parameter block of 2 octets encoding the Annex N US0 selection. The VTU-O shall indicate its selection of the Annex N US0 PSD mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages, and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-3 of octet 2 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
NOTE – Support of US0 means the capability of the VTU-R to transmit US0 and the capability of the VTU-O to receive it.	

12.3.2.2 Handshake – VTU-R

A VTU-R, after power-up, loss of signal, or recovery from errors during the initialization procedure, shall enter the initial ITU-T G.994.1 state, R-SILENT0. The VTU-R may activate the link by transitioning to R-TONES-REQ. Alternatively, upon detection of C-TONES (VTU-O initiated activation), the VTU-R may transition to R-TONE1. Operation shall then continue in accordance with the procedures defined in [ITU-T G.994.1].

If ITU-T G.994.1 procedures select this Recommendation as the mode of operation, the VTU-R shall continue with ITU-T G.993.2 initialization at the conclusion of ITU-T G.994.1 operation.

12.3.2.2.1 CLR messages

A VTU-R wishing to indicate ITU-T G.993.2 capabilities in an ITU-T G.994.1 CLR message shall do so by setting to ONE the ITU-T G.993.2 SPar(1) bit as defined in Table 11.0.4 of [ITU-T G.994.1]. The NPar(2) (Table 11.67 of [ITU-T G.994.1]) and SPar(2) (Table 11.68 of [ITU-T G.994.1]) fields corresponding to the ITU-T G.993.2 SPar(1) bit are defined in Tables 12-13 and 12-14, respectively. For each ITU-T G.993.2 SPar(2) bit set to ONE, a corresponding NPar(3) field shall also be present (beginning with Table 11.68.1 in clause 9.4 of [ITU-T G.994.1]). Table 12-15 shows the definitions and coding for the VTU-R CLR NPar(3) fields.

Table 12-13 – VTU-R CLR message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	If set to ONE, signifies that the VTU-R supports all-digital mode.
Support of downstream virtual noise	If set to ONE, signifies that the VTU-R supports the use of the downstream virtual noise mechanism.
Lineprobe	Set to ONE if the VTU-R requests the inclusion of a lineprobe stage in initialization.
Loop Diagnostic mode	Set to ONE if the VTU-R requests loop diagnostic mode.
Support of PSD shaping in US0	If set to ONE, signifies that the VTU-R supports PSD shaping in the US0 band.
Support of equalized FEXT	If set to ONE, signifies that the VTU-R supports equalized FEXT UPBO.
ITU-T G.993.5-friendly ITU-T G.993.2	If set to ONE, signifies that the VTU-R supports Annex X.

Table 12-13 – VTU-R CLR message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
operation in the downstream direction	
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	If set to ONE, signifies that VTU-R supports Annex Y.
Alternative electrical length estimation method	If set to ONE, signifies that the VTU-R supports the Alternative Electrical Length Estimation Method (ELE-M1)
Support of downstream SAVN	If set to ONE, signifies that the VTU-R supports the use of the downstream SAVN mechanism.

Table 12-14 – VTU-R CLR message SPar(2) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of SPar(2) bit
Profiles	Always set to ONE.
Bands Upstream	Always set to ZERO.
Bands Downstream	Always set to ZERO.
RFI Bands	Always set to ZERO.
Initial IDFT Size (2*N*)	Always set to ONE.
CE Lengths	If set to ZERO, indicates that the VTU-R can support only the mandatory CE length of 5*N*/32 for the IDFT size equal to 2*N*. If set to ONE, indicates that the VTU-R supports optional CE lengths in addition to the mandatory one.
Annex A US0 (Note)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex A are supported by the VTU-R.
Annex B US0 (Note)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex B are supported by the VTU-R.
Annex C US0 (Note)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex C are supported by the VTU-R.
Annex N US0 (Note)	If set to ONE, indicates that the corresponding NPar(3) shall indicate which of the US0 PSD masks described in Annex N are supported by the VTU-R.
NOTE – At least one of these bits shall be set to ONE.	

Table 12-15 – VTU-R CLR message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 8 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a and 30a. Each profile supported by the VTU-R is indicated by setting its corresponding bit to ONE.
Initial IDFT Size (2*N*)	This NPar(3) indicates the initial upstream IDFT size that the VTU-R shall use at the beginning of the channel discovery phase, encoded as a number from 6 to 13 representing *n*, where IDFTsize $2N = 2^n$
CE Lengths	This NPar(3) is a field of 15 bits representing the valid CE lengths 2*N*/32, 3*N*/32, 4*N*/32, ..., 16*N*/32, inclusive. For each supported CE length, the corresponding bit shall be set to ONE. The bit corresponding to 5*N*/32 shall always be set to ONE.
Annex A US0	A parameter block of 5 octets encoding the Annex A US0 capabilities. This block shall be coded as follows: – Bits 1-6 of octet 1 and bits 1-4 of octet 2 shall be individually set to ONE to indicate support by a VTU-R of Annex A US0 masks EU-32 through EU-128. If bit 4 of octet 2 is set to ONE, the VTU-R shall also set the "Support of PSD shaping in US0" NPar(2) bit to ONE (see Table 12-13). – Bits 1-6 of octet 3 and bits 1-4 of octet 4 shall be individually set to ONE to indicate support by the VTU-R of Annex A US0 masks ADLU-32 through ADLU-128. If bit 4 of octet 4 is set to ONE, the VTU-R shall also set the "Support of PSD shaping in US0" NPar(2) bit to ONE (see Table 12-13). – Bit 1 of octet 5 shall be set to ONE to indicate that all supported Annex A US0 masks are also supported by the VTU-R in the profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 5 shall be set to ONE to indicate that all supported Annex A US0 masks are also supported by the VTU-R in the profile 17a. This bit may be set to ONE if profile 17a is supported. – Bit 3 of octet 5 shall be set to ONE to indicate that all supported Annex A US0 masks are also supported by the VTU-R in the profile 35b. This bit may be set to ONE if profile 35b is supported (Note).
Annex B US0	A parameter block of 2 octets encoding the Annex B US0 capabilities. This block shall be coded as follows: – Bits 1-3 of octet 1 shall be individually set to ONE to indicate support of the corresponding Annex B US0 masks by the VTU-R. – Bit 1 of octet 2 shall be set to ONE to indicate that all supported Annex B US0 masks are also supported by the VTU-R for profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 2 shall be set to ONE to indicate that all supported Annex B US0 masks are also supported by the VTU-R for profile 17a. This bit may be set to ONE if profile 17a is supported.
Annex C US0	A parameter block of 3 octets encoding the Annex C US0 capabilities. This block shall be coded as follows: – Bits 1-2 of octet 1 shall be individually set to ONE to indicate the support of the corresponding Annex C US0 Type(b) masks by the VTU-R. – Bits 1-2 of octet 2 shall be individually set to ONE to indicate the support of the corresponding Annex C US0 Type(co) masks by the VTU-R.

Table 12-15 – VTU-R CLR message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
	– Bit 1 of octet 3 shall be set to ONE to indicate that all supported Annex C US0 masks are also supported by the VTU-R in the profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 3 shall be set to ONE to indicate that all supported Annex C US0 masks are also supported by the VTU-R in the profile 17a. This bit may be set to ONE if profile 17a is supported.
Annex N US0	A parameter block of 2 octets encoding the Annex N US0 capabilities. This block shall be coded as follows: – Bits 1-3 of octet 1 shall be individually set to ONE to indicate support of the corresponding Annex N US0 masks by the VTU-R. – Bit 1 of octet 2 shall be set to ONE to indicate that all supported Annex N US0 masks are also supported by the VTU-R for profile 12b. This bit may be set to ONE if profile 12b is supported. – Bit 2 of octet 2 shall be set to ONE to indicate that all supported Annex N US0 masks are also supported by the VTU-R for profile 17a. This bit may be set to ONE if profile 17a is supported. – Bit 3 of octet 2 shall be set to ONE to indicate that all supported Annex N US0 masks are also supported by the VTU-R for profile 35b. This bit may be set to ONE if profile 35b is supported.
NOTE – The ADLU US0 masks are not applicable to profile 35b.	

12.3.2.2.2 MS messages

A VTU-R selecting ITU-T G.993.2 mode of operation in an ITU-T G.994.1 MS message shall do so by setting to ONE the ITU-T G.993.2 SPar(1) bit as defined in Table 11.0.4 of [ITU-T G.994.1]. The NPar(2) (Table 11.67 of [ITU-T G.994.1]) and SPar(2) (Table 11.68 of [ITU-T G.994.1]) fields corresponding to the ITU-T G.993.2 Spar(1) bit are defined in Tables 12-16 and 12-17, respectively. For each ITU-T G.993.2 SPar(2) bit set to ONE, a corresponding NPar(3) field shall also be present (beginning with Table 11.68.1 in clause 9.4 of [ITU-T G.994.1]). Table 12-18 shows the definitions and coding for the VTU-R MS NPar(3) fields.

Table 12-16 – VTU-R MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
All-digital mode	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, indicates that both the VTU-O and the VTU-R shall be configured for operation in all-digital mode.
Support of downstream virtual noise	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the downstream virtual noise mechanism may be used.
Lineprobe	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the channel discovery phase of initialization shall include a lineprobe stage.
Loop Diagnostic mode	Set to ONE if either the last previous CLR or the last previous CL message has set this bit to ONE. Indicates that both VTUs shall enter loop diagnostic mode.

Table 12-16 – VTU-R MS message NPar(2) bit definitions

ITU-T G.994.1 NPar(2) Bit	Definition of NPar(2) bit
Support of PSD shaping in US0	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the VTU-R shall support PSD shaping in the US0 band.
Support of equalized FEXT	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that both the VTU-O and the VTU-R shall use equalized FEXT UPBO.
ITU-T G.993.5-friendly ITU-T G.993.2 operation in the downstream direction	See Table X.4
Full ITU-T G.993.5-friendly ITU-T G.993.2 operation	See Table Y.4.
Alternative electrical length estimation method	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that both the VTU-O and the VTU-R shall use ELE-M1.
Support of downstream SAVN	Set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. Indicates that the downstream SAVN mechanism may be used.

Table 12-17 – VTU-R MS message SPar(2) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of SPar(2) bit
Profiles	Always set to ONE.
Bands Upstream	Always set to ZERO.
Bands Downstream	Always set to ZERO
RFI Bands	Always set to ZERO.
Initial IDFT Size (2*N*)	Always set to ZERO.
CE Lengths	Shall be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE. If set to ONE, indicates that the initial CE length to be used by both the VTU-O and the VTU-R shall be communicated in the corresponding NPar(3) field. If set to ZERO, the mandatory value shall be used.
Annex A US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
Annex B US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
Annex C US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
Annex N US0 (Note)	May be set to ONE if and only if both the last previous CLR and the last previous CL messages have set this bit to ONE.
NOTE – One and only one of these bits shall be set to ONE.	

Table 12-18 – VTU-R MS message NPar(3) bit definitions

ITU-T G.994.1 SPar(2) Bit	Definition of NPar(3) bits
Profiles	Each valid profile is represented by one bit in a field of 8 bits. The valid profiles are: 8a, 8b, 8c, 8d, 12a, 12b, 17a and 30a. The profile selected by the VTU-R is indicated by setting its corresponding bit to ONE.
CE Lengths	This NPar(3) is a field of 15 bits representing the valid CE lengths 2N/32, 3N/32, 4N/32, ..., 16N/32, inclusive. The VTU-R shall indicate by setting to ONE the bit corresponding to the selected initial CE length. All other bits shall be set to ZERO. The selected CE length shall be one whose bit was set to ONE in both the last previous CLR and the last previous CL messages.
Annex A US0 (Note)	A parameter block of 5 octets encoding the Annex A US0 selection. The VTU-R shall indicate its selection of the Annex A US0 mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-3 of octet 5 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
Annex B US0 (Note)	A parameter block of 2 octets encoding the Annex B US0 selection. The VTU-R shall indicate its selection of the Annex B US0 mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-2 of octet 2 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
Annex C US0 (Note)	A parameter block of 3 octets encoding the Annex C US0 selection. The VTU-R shall indicate its selection of the Annex C US0 mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-2 of octet 3 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
Annex N US0 (Note)	A parameter block of 2 octets encoding the Annex N US0 selection. The VTU-R shall indicate its selection of the Annex N US0 mask by setting to ONE the bit corresponding to that PSD mask. No more than one bit in this NPar(3) shall be set to ONE. The selected bit shall be set to ONE if and only if it was set to ONE in both the last previous CLR and the last previous CL messages and the selected profile supports US0 either explicitly or implicitly by its definition in Table 6-1. Bits 1-3 of octet 2 shall always be set to ZERO. If all bits are set to ZERO, the US0 band shall not be enabled.
NOTE – Support of US0 means the capability of the VTU-R to transmit US0 and the capability of the VTU-O to receive it.	

12.3.3 Channel discovery phase

12.3.3.1 Overview

The channel discovery phase is the first phase when VDSL2 signals are exchanged between VTUs. The following tasks are completed during channel discovery:

- Timing recovery and selection of pilot tone(s);
- Establish communication between the VTUs over the SOC;
- Exchange information necessary to set up the PSDs for both transmission directions; and
- Verify, adjust and exchange various parameter values necessary to enter the training phase (IDFT sizes, CE length, window length and others).

During the channel discovery phase, if the optional equalized FEXT UPBO method is not supported, the VTU-R shall determine the required UPBO based on the estimation of the electrical length of the loop and on the values of parameters for the UPBO reference PSD (UPBOPSD) it receives from the VTU-O. If the optional equalized FEXT UPBO method is supported, the VTU-R shall use in addition the parameter UPBO reference electrical length (UPBOREFEL) it receives from the VTU-O, to determine the required UPBO. Both VTUs may perform additional PSD cut-back.

NOTE 1 – In regions of the spectrum not expected to be useable in showtime, the transceiver may reduce the value of the PSD from the beginning of channel discovery to prevent unnecessary crosstalk into other systems. A VTU may, for example, determine the tones where CDPSD can be reduced based on the received signal level and known transmit level of the ITU-T G.994.1 tones. A specific mechanism is vendor discretionary.

Figure 12-6 presents the timing diagram for the stages of the channel discovery phase. It gives an overview of the sequence of signals transmitted and the sequence of SOC messages sent by the VTU-O and VTU-R during the channel discovery phase. The two inner columns show the sequences of signals that are transmitted (see clause 12.3.3.3). The two outer columns show the messages that are sent over the SOC (see clause 12.3.3.2). The shaded areas correspond to periods of time when the SOC is in its inactive state.

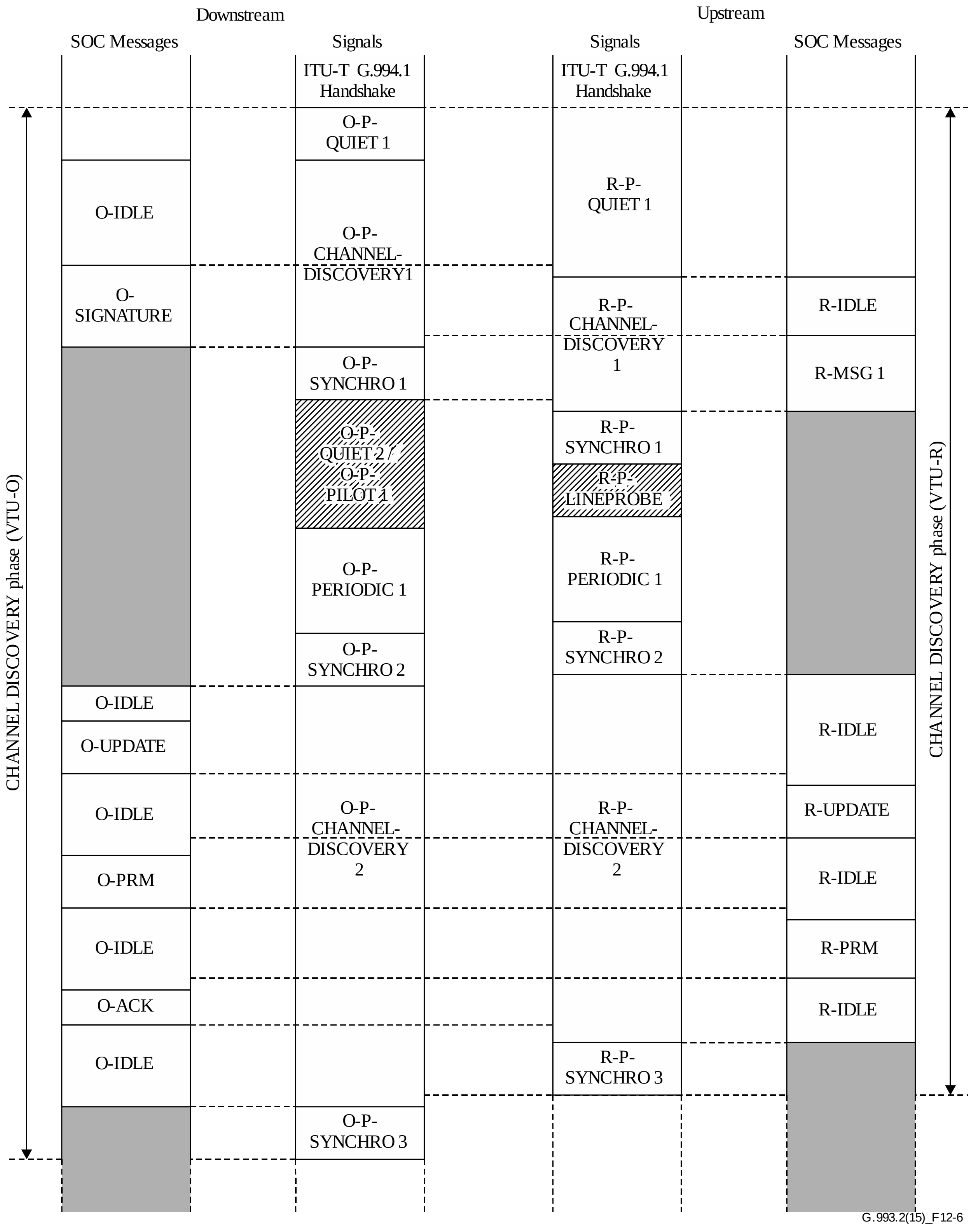

Figure 12-6 – Timing diagram for the stages of the channel discovery phase

NOTE 2 – In the exchange of the SOC messages identified in Figure 12-6, the rules of the communication protocol of clause 12.2.2 apply. Some messages sent in the SOC may require segmentation; although this is not shown in Figure 12-6, the segmented message elements and their corresponding acknowledgements are sent via the SOC per the communication protocol of clause 12.2.2.

The VTU-O shall initiate the start of the channel discovery phase with O-P-QUIET 1. During this stage, both VTUs are silent and a quiet line noise measurement can be performed. The duration of O-P-QUIET 1 shall be at least 512 symbols but not longer than 1024 symbols. After completing the O-P-QUIET 1 stage, the VTU-O shall start transmitting O-P-CHANNEL DISCOVERY 1. The VTU-O shall send O-IDLE for a period of between 1500 and 2000 DMT symbols. It shall then send its first message, O-SIGNATURE. O-SIGNATURE shall be sent over the SOC in AR mode, as described in clause 12.2.2.1, and carries the information listed in Table 12-21.

The VTU-R shall start the channel discovery phase with R-P-QUIET 1 (no signal) until it correctly receives the O-SIGNATURE message. During the R-P-QUIET 1 stage, the VTU-R shall complete the timing lock prior to transmitting R-P-CHANNEL DISCOVERY 1. Upon receiving the O-SIGNATURE message, the VTU-R has all of the necessary information needed to perform UPBO (see clause 7.2.1.3). If AELE-MODE = 1, 2, or 3, UPBO shall be performed according to AELE-MODE=1 until final kl_0 values are provided in the O-UPDATE message. After performing UPBO, the VTU-R shall transmit R-P-CHANNEL DISCOVERY 1. The VTU-R shall transmit R-P-CHANNEL DISCOVERY 1 using the initial timing advance value received in the O-SIGNATURE message. The VTU-R shall send R-IDLE for at least 512 DMT symbols. It shall then send its first message, R-MSG 1, in AR mode. The VTU-R shall send R-MSG 1 until the VTU-O indicates it has correctly received R-MSG 1. The R-MSG 1 message conveys to the VTU-O the upstream PSD and other VTU-R parameters, as presented in Table 12-32.

The VTU-O shall indicate correct reception of the R-MSG 1 message by transmitting O-P-SYNCHRO 1, which shall be followed by transmission of O-P-PERIODIC 1 if a lineprobe stage is not requested. If a lineprobe stage is requested, the VTU-O shall transmit O-P-QUIET 2/O-P-PILOT 1 and transition to O-P-PERIODIC 1 640 symbols after the end of transmission of O-P-SYNCHRO 1. The request for a lineprobe stage is indicated by the parameter "Lineprobe" during the ITU-T G.994.1 handshake phase (see clause 12.3.2).

The VTU-R shall reply to O-P-SYNCHRO 1 by transmitting R-P-SYNCHRO 1 within a time period of 64 symbols after detection of O-P-SYNCHRO 1. This shall be followed by transmission of either R-P-PERIODIC 1 if a lineprobe stage is not requested, or R-P-LINEPROBE if a lineprobe stage is requested. The duration of R-P-LINEPROBE shall be 512 symbols. After R-P-LINEPROBE, the VTU-R shall transmit R-P-PERIODIC 1.

The VTU-O shall transmit O-P-PERIODIC 1 for a duration of 2 048 symbols and shall then transition to O-P-SYNCHRO 2. The VTU-R shall transmit R-P-PERIODIC 1 for a duration of 2 048 symbols and shall then transition to R-P-SYNCHRO 2. During the period of time that O-P-PERIODIC 1 and R-P-PERIODIC 1 are transmitted, the VTUs may perform SNR measurements.

Immediately after transmission of O-P-SYNCHRO 2, the VTU-O shall transmit O-P-CHANNEL DISCOVERY 2 while sending O-IDLE over the SOC.

After detection of R-P-SYNCHRO 2 and the end of transmission of O-P-SYNCHRO 2, the VTU-O shall send O-UPDATE after a time period of between 48 and 64 symbols, inclusive, to update the parameters of the VTU-R, specifically the PSD of the VTU-R. The O-UPDATE message may also include corrections to the UPBO settings, and additional power cut-back. The parameters conveyed by O-UPDATE are presented in Table 12-28.

The O-UPDATE message and all subsequent SOC messages from the VTU-O shall be sent only once, using the RQ protocol described in clause 12.2.2.2, which allows the receiving VTU to ask for a retransmission of incorrectly received or missing messages.

The VTU-R shall start transmitting R-P-CHANNEL DISCOVERY 2 immediately after transmission of R-P-SYNCHRO 2, while sending R-IDLE over the SOC. All messages sent by the VTU-R starting from those sent during R-P-CHANNEL DISCOVERY 2 shall be sent using the RQ protocol described in clause 12.2.2.2.

After the VTU-R receives the O-UPDATE message, it shall send R-UPDATE to request an update of the downstream PSD and other parameters of the VTU-O, which may include downstream power cut-back. The list of parameters subject to update at the VTU-O and the VTU-R are listed in Table 12-35 and Table 12-28, respectively.

The R-UPDATE message shall be acknowledged by the VTU-O by sending O-PRM over the SOC. O-PRM shall contain the final values of the modulation parameters and PSDs to be used in the training phase. The content of O-PRM is presented in Table 12-30. The VTU-R shall acknowledge O-PRM by sending R-PRM (see Table 12-36), which reports settings of VTU-R modulation parameters, including those requested to be updated in O-UPDATE.

The VTU-O shall acknowledge the reception of the R-PRM message by sending O-ACK. Upon reception of the O-ACK message, the VTU-R shall complete the channel discovery phase in the upstream direction by transmitting R-P-SYNCHRO 3. The VTU-O shall reply by transmitting O-P-SYNCHRO 3 within a time period of 64 symbols. The transmission of O-P-SYNCHRO 3 completes the channel discovery phase in the downstream direction.

All parameter value changes and PSD changes negotiated during the channel discovery phase relative to those indicated in O-SIGNATURE and R-MSG 1 shall be applied in the downstream direction from the first symbol following O-P-SYNCHRO 3 and in the upstream direction from the first symbol following R-P-SYNCHRO 3.

NOTE 3 – A change in modulation parameters (such as CE length) may result in the transmission of several corrupt symbols in the downstream direction and a temporary loss of synchronization at the VTU-R receiver. At the start of the training phase, there is a period of time to recover synchronization.

The signals and SOC messages sent by the VTU-O during the channel discovery phase are summarized in Table 12-19, and the signals and SOC messages sent by the VTU-R during the channel discovery phase are summarized in Table 12-20. The protocol used for SOC messages is provided, where applicable, in parentheses in the column labelled "SOC state".

Table 12-19 – VTU-O signals and SOC messages in the channel discovery phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
O-P-QUIET 1	None	512 to 1024	None	Inactive
O-P-CHANNEL DISCOVERY 1	Non-periodic	Variable	O-SIGNATURE	Active (AR)
O-P-SYNCHRO 1	Non-periodic	15	None	Inactive
O-P-PILOT 1	Non-periodic	640	None	Inactive
O-P-QUIET 2	None	640	None	Inactive
O-P-PERIODIC 1	Periodic	2048	None	Inactive
O-P-SYNCHRO 2	Non-periodic	15	None	Inactive
O-P-CHANNEL DISCOVERY 2	Non-periodic	Variable	O-UPDATE, O-PRM, O-ACK	Active (RQ)
O-P-SYNCHRO 3	Non-periodic	15	None	Inactive

Table 12-20 – VTU-R signals and SOC messages in the channel discovery phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
R-P-QUIET 1	None	Variable	None	Inactive
R-P-CHANNEL DISCOVERY 1	Non-periodic	Variable	R-MSG 1	Active (AR)
R-P-SYNCHRO 1	Non-periodic	15	None	Inactive
R-P-LINEPROBE	Vendor Discretionary	512	None	Inactive
R-P-PERIODIC 1	Periodic	2048	None	Inactive
R-P-SYNCHRO 2	Non-periodic	15	None	Inactive
R-P-CHANNEL DISCOVERY 2	Non-periodic	Variable	R-UPDATE, R-PRM	Active (RQ)
R-P-SYNCHRO 3	Non-periodic	15	None	Inactive

12.3.3.2 SOC message exchange during the channel discovery phase

Figure 12-7 illustrates the SOC message exchange between the VTU-O and VTU-R during the channel discovery phase. It also summarizes the content of each message.

The messages sent by the VTU-O are described in detail in clause 12.3.3.2.1. The messages sent by the VTU-R are described in detail in clause 12.3.3.2.2.

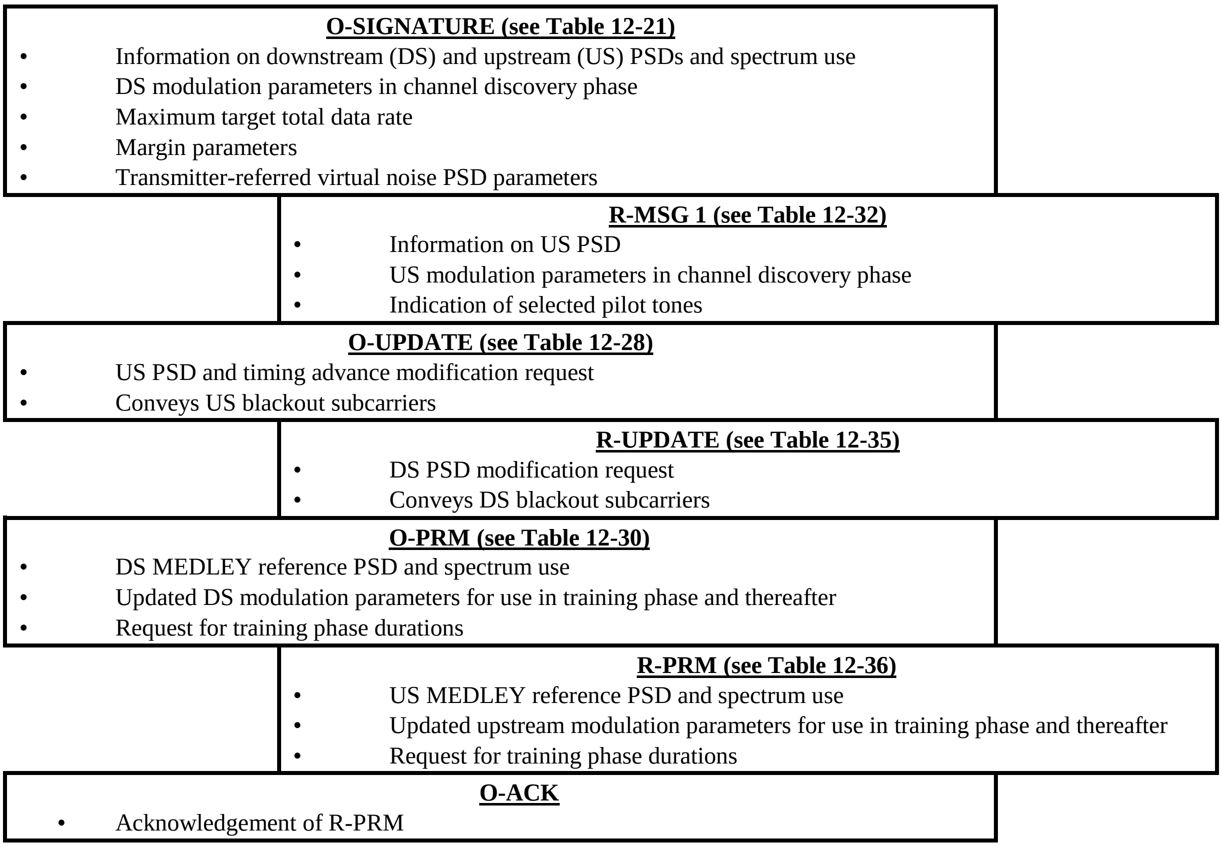

Figure 12-7 – SOC message exchange during the channel discovery phase

12.3.3.2.1 VTU-O messages sent during the channel discovery phase

12.3.3.2.1.1 O-SIGNATURE

The full list of parameters carried by the O-SIGNATURE message is shown in Table 12-21.

Table 12-21 – Description of message O-SIGNATURE

	Field name	Format
1	Message descriptor	Message code
2	Supported subcarriers in the downstream direction (SUPPORTEDCARRIERSds set)	Bands descriptor
3	Supported subcarriers in the upstream direction (SUPPORTEDCARRIERSus set)	
4	Downstream transmit PSD mask (PSDMASKds)	PSD descriptor
5	Upstream transmit PSD mask (PSDMASKus)	
6	Channel discovery downstream PSD (CDPSDds)	
7	Initial downstream PSD ceiling (CDMAXMASKds)	2 bytes
8	Downstream nominal maximum aggregate transmit power (MAXNOMATPds)	2 bytes
9	Parameters for UPBO reference PSD (UPBOPSD)	UPBOPSD descriptor
10	Maximum target total data rate	2 bytes
11	Downstream maximum SNR margin (MAXSNRMds)	2 bytes
12	Downstream target SNR margin (TARSNRMds)	2 bytes
13	Downstream transmit window length (β_{ds})	1 byte
14	Downstream cyclic prefix	2 bytes
15	Initial value of timing advance	2 bytes
16	Downstream transmitter-referred virtual noise PSD (TXREFVNds)	PSD descriptor
17	SNRM_MODE	1 byte
18	Upstream transmitter-referred virtual noise PSD (TXREFVNus)	PSD descriptor
19	UPBO reference electrical length (UPBOREFEL)	UPBOREFEL descriptor
20	ITU-T G.998.4 parameter field	Variable length
21	ITU-T G.993.5 parameter field A	Variable length
22	Alternative electrical length estimation mode control	2 bytes AELE-MODE Control descriptor
23	Reserved for operation according to Annex X	1 byte
24	ITU-T G.993.5 parameter field B	Variable length

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Supported subcarriers in the downstream direction (SUPPORTEDCARRIERSds)" conveys information about the subcarriers that are allocated for transmission in the downstream direction. It allows the operator to specify exactly which subcarriers are available for the downstream direction. No more than 32 bands shall be specified.

Field #3 "Supported subcarriers in the upstream direction (SUPPORTEDCARRIERSus)" conveys information about the subcarriers that are allocated for transmission in the upstream direction. It allows the operator to specify exactly which subcarriers are available for the upstream direction. No more than 32 bands shall be specified.

Fields #2 and #3 shall be formatted as "bands descriptors". The format of the bands descriptor shall be as shown in Table 12-22.

Table 12-22 – Bands descriptor

Octet	Content of field
1	Number of bands to be described
2-4	Bits 0-11: Index of the first subcarrier in band 1 Bits 12-23: Index of the last subcarrier in band 1
5-7 (if applicable)	Bits 0-11: Index of the first subcarrier in band 2 Bits 12-23: Index of the last subcarrier in band 2
etc.	etc.

The first octet of the bands descriptor shall contain the number of bands to be described. This number can be zero. In that case, there shall be no further octets in the descriptor. If the number of bands is not equal to zero, each group of three consecutive octets in the descriptor shall describe the first and last subcarrier in a band.

The first 12 bits (0-11) in the group of three octets shall contain the index of the subcarrier at the lower edge of the band. The last 12 bits (12-23) shall contain the index of the subcarrier at the upper edge of the band. The first and last subcarriers shall be included in the band. For example, a field value 400200_{16} means that all subcarriers from 200_{16} = 512 to 400_{16} = 1024, including subcarriers 512 and 1024, are included in the set.

Field #4 "Downstream transmit PSD mask (PSDMASKds)" indicates the PSD mask, for both the passband and the stopbands (see clauses 7.2.1 and 7.2.2), that is allowed in the downstream direction. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 48. This information shall be taken into account when performing the downstream PSD updates during the channel discovery phase. The VTU-O shall comply with this constraint at all times. In addition, VTU-O shall comply with the requirements in the RFI bands specified during the ITU-T G.994.1 handshake phase, as specified in clause 12.3.2.

Field #5 "Upstream transmit PSD mask (PSDMASKus)" indicates the PSD mask, for both the passband and the stopbands (see clauses 7.2.1 and 7.2.2), that is allowed in the upstream direction. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 32. This information shall be taken into account when performing the upstream PSD updates during the channel discovery phase. The VTU-R shall comply with this constraint at all times. In addition, the VTU-R shall always comply with the UPBO requirements, which may further reduce the upstream transmit PSD to below the upstream transmit PSD mask, as specified in clause 7.2.1.3, and with the requirements in the RFI bands specified during the ITU-T G.994.1 handshake phase, as specified in clause 12.3.2.

Field #6 "Channel discovery downstream PSD (CDPSDds)" indicates the PSD at the U interface in the downstream direction during the channel discovery phase. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 48. The only valid PSD values obtained by the receiver using the interpolation procedure specified are for those subcarriers that belong to the SUPPORTEDCARRIERSds set, excluding the RFI bands communicated during the ITU-T G.994.1 handshake phase. PSD values out of this set shall be ignored by the receiver. The valid CDPSDds values shall be at least 3.5 dB below the downstream transmit

PSD mask (Field #4) and at least 3.5 dB below the initial downstream PSD ceiling (Field #7). Moreover, the valid values of CDPSDds, either those which are directly communicated or those obtained at the receiver by interpolation, shall not deviate from the actual values of the transmit PSD, as measured in the reference impedance at the U interface, by more than 1 dB.

Table 12-23 – PSD descriptor

Octet	Content of field
1	Number of subcarriers (or breakpoints) being described
2-4	Bits 0-11: Index of first subcarrier being described Bits 12-23: PSD level in steps of 0.1 dB with an offset of −140 dBm/Hz
5-7 (if applicable)	Bits 0-11: Index of second subcarrier being described Bits 12-23: PSD level in steps of 0.1 dB with an offset of −140 dBm/Hz
etc.	etc.

The first octet of the descriptor shall contain the number of breakpoints being specified. This number can be zero. In that case, there shall be no additional octets in the descriptor. If the number of breakpoints is not equal to zero, each group of three consecutive octets shall describe one breakpoint as a PSD value at a certain subcarrier index.

The first 12 bits (0-11) in the group of three octets shall contain the index of the subcarrier. The last 12 bits (12-23) shall contain the PSD level. The PSD level shall be an integer multiple of 0.1 dB with an offset of −140 dBm/Hz. For example, a field value of 320400_{16} means a PSD of $320_{16} \times 0.1 - 140 = -60$ dBm/Hz on subcarrier index $400_{16} = 1024$. The PSD level of intermediate unspecified subcarriers shall be obtained using a linear interpolation between the given PSD points (in dBm/Hz) with the frequency axis expressed in a linear scale. The subcarrier indices of the specified breakpoints may be either determined by the CO-MIB or vendor discretionary.

NOTE 1 – Breakpoints should be selected such that the PSD between the breakpoints obtained using linear interpolation is sufficiently close to the PSD that is being described.

Field #7 "Initial downstream PSD ceiling (CDMAXMASKds)" indicates the PSD level that is used to impose a ceiling on the downstream transmit PSD mask to form the downstream PSD mask of the signals transmitted during the channel discovery phase, on which the downstream channel discovery PSD (CDPSDds) is based (see Field #6). The field shall be coded as a 16-bit value with the LSB weight of −0.1 dBm/Hz. The valid values are in the range from 0 dBm/Hz to −90 dBm/Hz in 0.1 dB steps.

Field #8 "Downstream nominal maximum aggregate transmit power (MAXNOMATPds)" indicates the maximum wide-band power that the VTU-O is allowed to transmit. The value shall be expressed in dBm (10.3.4.2.1). This field shall be coded as a 9-bit twos complement signed integer with the LSB weight of 0.1 dBm and the valid range from −25.6 dBm to +25.6 dBm. The spare MSBs shall be set to the value of the sign bit.

Field #9 "UPBO reference PSD (UPBOPSD)" contains the parameters to compute the reference PSD that shall be used for the calculation of UPBO as specified in clause 7.2.1.3. One set of UPBOPSD parameters (a', b') is defined per upstream band. The values of a' and b' are positive and shall be formatted as shown in Table 12-24.

Table 12-24 – UPBOPSD descriptor

Octet	Content of field
1	Number of US bands
2-4	bits 0-11: value of a' for US1 bits 12-23: value of b' for US1
5-7 (if applicable)	bits 0-11: value of a' for US2 bits 12-23: value of b' for US2
etc.	etc.
$3 \times n_{us} - 1$, $3 \times n_{us} + 1$	bits 0-11: value of a' for US(n_{us}) bits 12-23: value of b' for US(n_{us})

The length of the field is variable and depends on the number of upstream bands exchanged during the ITU-T G.994.1 handshake phase of initialization (n_{us}), except US0. Parameters a' and b' shall be coded as 12-bit unsigned integers. The value of a is obtained by multiplying a' by 0.01 and adding it to 40. The range of values for a is between 40 and 80.96. The value of b is obtained by multiplying b' by 0.01. This allows values of b between 0 and 40.96 (see clause 7.2.1.3.2). For those upstream bands in which UPBO shall not be applied, all 12 bits representing values a' and b' shall be set to ZERO (which corresponds to $a = 40$, $b = 0$).

NOTE 2 – The granularity of 0.01 may be finer than needed for practical purposes, but it has been chosen to be able to transmit the values of b specified in regional VDSL standards referred to in [ITU-T G.993.1].

Field #10 "Maximum target total data rate" is the VTU-O's estimate of the maximum downstream total data rate that will be required during the operation of the VTU. The VTU-R may use this information to determine the amount of downstream power cut-back (the downstream PSD ceiling) and the spectrum to be used for downstream transmission (e.g., the highest downstream subcarrier) that is allowed to be used during the channel discovery phase.

NOTE 3 – The CO should determine an appropriate value of the maximum target total data rate based on the configuration parameters of the bearer channels, such as minimum INP (INP_min_n), maximum delay ($delay\_max_n$), and minimum and maximum net data rates (net_min_n, net_max_n), provided in the MIB. The knowledge of the minimum INP and maximum delay can be used to estimate the coding overhead r_n, which is the main factor determining the relation between the net data rate assigned for the bearer channel n and the corresponding total data rate:

$$r_n = \frac{total\_data\_rate_n}{net\_data\_rate_n} = \frac{1}{1 - \dfrac{2 \times INP\_\min_n}{delay\_\max_n \times f_s}}$$

where $delay\_max_n$ is in milliseconds and f_s is the data symbol rate in ksymbols/s. Knowledge of the net data rates and of the overhead rates of the bearer channels in use allows the VTU-O to make an estimate of the maximum downstream total data rate.

The field shall be coded as an unsigned integer representing the total data rate as a multiple of 8 kbit/s.

Field #11 "Downstream maximum SNR margin (MAXSNRMds)" indicates the maximum SNR margin the VTU-R receiver shall try to sustain. The definition and use of this parameter shall be the same as for the parameter "downstream maximum noise margin (MAXSNRMds)" specified in [ITU-T G.997.1]. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 0.1 dB and the valid range between 0 and 31 dB. The special value defined in [ITU-T G.997.1] shall be coded as $FFFF_{16}$.

Field #12 "Downstream target SNR margin (TARSNRMds)" indicates the target SNR margin of the VTU-R receiver. The definition and use of this parameter shall be the same as for the parameter "downstream target noise margin (TARSNRMds)" specified in [ITU-T G.997.1]. The format used shall be the same as for Field #11 of the O-SIGNATURE message.

Field #13 "Downstream transmit window length (β_{ds})" shall contain the length of the downstream transmit window, (β_{ds}), expressed in samples at the downstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be coded as an 8-bit integer.

Field #14 "Downstream cyclic prefix" shall contain the length of the downstream cyclic prefix expressed in samples at the downstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be coded as a 16-bit integer.

Field #15 "Initial value of timing advance" indicates the initial timing advance and shall be expressed in samples at the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be encoded in a 16-bit field using twos complement format. The special value of $7FFF_{16}$ indicates that the VTU-R shall select the initial setting of the timing advance.

NOTE 4 – The optimal value of the timing advance is a function of loop length (see clause 10.4.5.3). The initial value should be applicable for most loop lengths. It is suggested to choose an initial value that corresponds to a loop length of 1500 m. This value can be updated later in the initialization.

Field #16 "Downstream transmitter referred virtual noise PSD (TXREFVNds)" indicates the PSD of the virtual noise in the downstream direction for SNRM_MODE=2 and SNRM_MODE=4. For SNRM_MODE=5, this field indicates the initial value of the downstream SAVN PSD (TXREFSAVNds, see clause 11.4.1.1.6.1.5). This information shall be taken into account when determining the SNR margin (for optional SNRM_MODE=2, optional SNRM_MODE=4, and optional SNRM_MODE=5), which in turn shall be taken into account in determining the possible power cutback during the channel discovery phase, and for performing the bit loading later in initialization. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 32. When SNRM_MODE = 1, the PSD descriptor field shall contain zero breakpoints (only 1 byte with a value of zero).

NOTE 5 – For SNRM_MODE=5, the TXREFVNds parameter provided by the CO-MIB may be taken into account by the VTU-O to determine the initial value of TXREFSAVNds (see clause 11.4.1.1.6.1.5).

Field #17 "SNRM_MODE" indicates the mode of downstream and upstream SNRM computation as described in clause 11.4.1.1.6. Bits 0 to 3 of the field shall be used to indicate the downstream SNR mode with valid values of 0_{16} (Downstream SNRM_MODE=1, mandatory), 1_{16} (Downstream SNRM_MODE=2, optional), 3_{16} (Downstream SNRM_MODE=4, optional), and 4_{16} (Downstream SNRM_MODE=5, optional). All other values are reserved. Bits 4 to 7 of the field shall be used to indicate the upstream SNR mode with valid values of 0_{16} (Upstream SNRM_MODE=1, mandatory), 1_{16} (Upstream SNRM_MODE=2, optional), 2_{16} (Upstream SNRM_MODE=3, optional), 3_{16} (Upstream SNRM_MODE = 4, optional), and 4_{16} (Upstream SNRM_MODE=5, optional). All other values are reserved.

Field #18 "Upstream transmitter referred virtual noise PSD (TXREFVNus)" indicates the PSD of the virtual noise in the upstream direction. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 16. When SNRM_MODE = 1, 3, 4 or 5, the PSD descriptor field shall contain zero breakpoints (only 1 byte with a value of zero).

NOTE 5 – Improper setting of TXREFVN or RXREFVN can interact with the setting of one or more of the following parameters: maximum net data rate, downstream maximum SNR margin, impulse noise protection, and maximum interleaving delay. This interaction can result in high levels of transmit power that can lead to high crosstalk experienced by DSLs on other pairs in the same binder.

Field #19 "UPBO reference electrical length (UPBOREFEL)" contains the kl_{0_REF} parameters for the calculation of UPBO according to the optional equalized FEXT UPBO method, as specified in clause 7.2.1.3. One value of the parameter kl_{0_REF} is defined per upstream band. The values of kl_{0_REF} shall be formatted as shown in Table 12-25.

The length of the field is variable and depends on the number of upstream bands (n_{us}) exchanged during the ITU-T G.994.1 handshake phase of initialization, except US0. The value shall be coded as a 16-bit unsigned integer with an LSB weight of 0.1 dB. The valid range of values is from 1.8 to 63.0 dB with a 0.1 dB step, and a special value 0. The use of the special value 0 is described in clause 7.2.1.3.

Table 12-25 – UPBOREFEL descriptor

Octet	Content of field
1	Number of US bands
2-3	bits 0-15: value of kl_{0_REF} for US1
4-5 (if applicable)	bits 0-15: value of kl_{0_REF} for US2
...	
$2 \times n_{us}$, $2 \times n_{us} + 1$	bits 0-15: value of kl_{0_REF} for US(n_{us})

Field #20 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #21 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Table 12-26 – Format of variable length fields #20 and #21

Octet	Name	Format	Description
1	Data length	1 byte	Number of bytes in the Data field (i.e., N-1). This is the number of bytes following this octet (see Note 1)
2-N	Data	N-1 bytes	N-1 data bytes, with N-1 being equal to the number contained in Octet #1 (see Note 2).
NOTE 1 – The number of bytes in the Data field could be zero. In that case, the variable length field consists of a single byte (i.e., N=1) with value 00_{16}. NOTE 2 – The N represents the length of the variable length field in bytes.			

The actual data in the variable length fields #20 and #21 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 00_{16}.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field A shall be a single byte with value 00_{16}.

Field #22 "Alternative Electrical Length Estimation Mode Control" has 2 bytes containing parameters: Alternative Electrical Length Estimation Mode (AELE-MODE), UPBO Electrical Length Minimum Threshold (UPBOELMT), and RXTHRSHDS as shown in Table 12-27, with the parameters specified in clause 7.2.1.3.2.1.2.

Table 12-27 – AELE-MODE Control Descriptor

Octet	Content of field
1	Bits 0 to 3: UPBOELEMT values expressed as 4-bits unsigned integer in percent (Note). Bits 4 to 5: reserved by ITU and set to 0. Bits 6 to 7: value AELE-MODE expressed as 2-bit unsigned integer.
2	RXTHRSHDS parameter coded as an eight bit signed integer *n*, with valid values being all integers in the range from -64 to 0, representing an offset from -100 dBm/Hz as RXTHRSHDS = (-100 + *n)* dBm/Hz.
NOTE – The only valid value of UPBOELEMT is 10. Other values are reserved for future use.	

Field #23 is reserved for operation according to Annex X (see clause X.2.2.1.1.1.1). This field shall be set to 00_{16} if the selected mode of operation is not according to Annex X, and have a value as defined in Table X.5a otherwise.

Field #24 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-27a.

Table 12-27a – Format of variable length field #24

Octet	Name	Format	Description
1-2	Data length	2 bytes	Number of bytes in the Data field (i.e., N-2). This is the number of bytes following these 2 octets (see Note 1).
3-N	Data	N-2 bytes	N-2 data bytes, with N-2 being equal to the number contained in Octets #1-2 (see Note 2).
NOTE 1 – The number of bytes in the Data field could be zero. In that case, the variable length field consists of 2 bytes long (i.e., N=2) with value 0000_{16}. NOTE 2 – The N represents the length of the variable length field in bytes.			

The actual data in the variable length field #24 is beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of [ITU-T G.993.5] is required. However, support of [ITU-T G.993.5] is not implied or required for compliance with this Recommendation.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field B shall be 2 bytes long with value 0000_{16}.

12.3.3.2.1.2 O-UPDATE

The full list of parameters carried by the O-UPDATE message is shown in Table 12-28.

Table 12-28 – Description of message O-UPDATE

	Field name	Format
1	Message descriptor	Message code
2	Final electrical length	2 bytes
3	Updated upstream PSD ceiling (MAXMASKus)	2 bytes
4	Highest allowed upstream subcarrier	2 bytes
5	Lowest allowed upstream subcarrier	2 bytes
6	BLACKOUTus set	Bands descriptor
7	Timing advance correction	2 bytes

Table 12-28 – Description of message O-UPDATE

	Field name	Format
8	ITU-T G.998.4 parameter field	Variable length
9	ITU-T G.993.5 parameter field	Variable length
10	Extended final electrical length	UPBOXFEL descriptor

Field #1 "Message descriptor" is a one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Final electrical length" contains the electrical length expressed in dB at 1 MHz (see clause 7.2.1.3.2) that the VTU-R shall use to set its upstream PSD starting from the training phase onward. The value shall be coded as a 16-bit number with the LSB weight of 0.1 dB. The valid range of values is from 0 dB to 128 dB with a 0.1 dB step. This value may be different from the value reported by the VTU-R in R-MSG 1 and shall be used by the VTU-R to determine the UPBOMASK, as specified in clause 7.2.1.3.2. This updated UPBOMASK shall be used to form the upstream MEDLEY reference PSD mask (Field #2 of R-PRM).

Field #3 "Updated upstream PSD ceiling (MAXMASKus)" indicates the PSD ceiling level of the upstream transmit PSD mask. This field shall be coded the same as Field #7 of O-SIGNATURE. If this level is lower than the upstream PSD ceiling indicated in R-MSG 1, the VTU-R shall apply this new ceiling level to PSDMASKus. Otherwise, the VTU-R may increase the ceiling of the upstream PSD mask up to MAXMASKus. This new ceiling level shall be used to form the upstream MEDLEY reference PSD mask (MREFMASKus). A special value 1000_{16} shall indicate no limit to the upstream PSD ceiling level (under the constraints of the upstream transmit PSD mask).

Field #4 "Highest allowed upstream subcarrier" contains the index of the highest frequency upstream subcarrier that is allowed to be used by the VTU-R. The format shall be a 16-bit value. The subcarrier index shall be described as 12 bits. The four MSBs of the field shall be set to ZERO. The VTU-R shall not allocate power to subcarriers above the highest allowed upstream subcarrier.

Field #5 "Lowest allowed upstream subcarrier" contains the index of the lowest-frequency upstream subcarrier that is allowed to be used by the VTU-R. The format shall be a 16-bit value. The subcarrier index shall be described as 12 bits. The four MSBs of the field shall be set to ZERO. The VTU-R shall not allocate power to subcarriers below the lowest allowed upstream subcarrier.

Field #6 "BLACKOUTus set" contains the BLACKOUT set of subcarriers in the upstream direction. The field shall be formatted as a "bands descriptor" (see Table 12-22) with a maximum number of 16 bands. If there are no blackout subcarriers, the field shall consist of one octet, 00_{16}.

Field #7 "Timing advance correction" contains the timing advance correction with respect to the currently used timing advance expressed in samples at the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be encoded in a 16-bit field using twos complement format. Positive values shall indicate that the transmitted symbol will be advanced more with respect to the received symbol.

Field #8 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #9 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 8 and 9 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

Field #10 "Extended final electrical length" contains the electrical length. The UPBOXFEL descriptor has the parameter kl_0*[band]* for each upstream band expressed in dB at 1 MHz (see Table 12-29, with the parameter specified in clause 7.2.1.3.2.1.2) that the VTU-R shall use to set its upstream PSD starting from the training phase onward. The value shall be coded as a 16-bit number with the LSB weight of 0.1 dB. The valid range of values is from 0 dB to 128 dB with a 0.1 dB step. This value may be different from the value reported by the VTU-R in R-MSG 1 and shall be used by the VTU-R to determine the UPBOMASK, as specified in clause 7.2.1.3.2.3. This updated UPBOMASK shall be used to form the upstream MEDLEY reference PSD mask (Field #2 of R-PRM).

One value of the parameter kl_0*[band]* is defined per upstream band. The values of kl_0 shall be formatted as shown in Table 12-29. If defined with a valid value, this parameter overrides "Final Electrical Length".

Table 12-29 – UPBOXFEL descriptor

Octet	Content of field
1	Number of US bands (n_{us})
2-3	bits 0-15: value of kl_0*[US1]* for US1
4-5 (if applicable)	bits 0-15: value of kl_0*[US2]* for US2
...	
$2 \times n_{us}$, $2 \times n_{us} + 1$	bits 0-15: value of $kl_0[US(n_{us})]$ for US(n_{us})

12.3.3.2.1.3 O-PRM

O-PRM contains the downstream MEDLEY reference PSD following the modifications proposed in the R-UPDATE message. It also contains the modulation parameters that shall be used in the downstream direction from the beginning of the training phase and requests for the durations of training periods in the training phase. The full list of parameters carried by the O-PRM message is shown in Table 12-30.

Table 12-30 – Description of message O-PRM

	Field name	Format
1	Message descriptor	Message code
2	Downstream MEDLEY reference PSD (MREFPSDds)	PSD descriptor
3	MEDLEYds set	Bands descriptor
4	Cyclic extension length	1 byte
5	Downstream cyclic prefix length	2 bytes
6	Downstream transmit window length (β_{ds})	1 byte
7	VTU-O IDFT size	1 byte
8	Duration of the VTU-O EC training period	1 byte
9	Requested duration of the VTU-O TEQ training period	1 byte
10	Requested duration of the VTU-R TEQ training period	1 byte
11	Requested minimum duration of the periodic signal	1 byte
12	Downstream frequency-domain spectrum shaping	Log_tss_i descriptor
13	ITU-T G.998.4 parameter field	Variable length
14	ITU-T G.993.5 parameter field	Variable length

Field #1 "Message descriptor" is a one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Downstream MEDLEY reference PSD (MREFPSDds)" indicates the updated PSD at the U interface, following the request from the VTU-R in R-UPDATE. This PSD shall be used in the downstream direction starting from the beginning of the training phase and for the remainder of initialization. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 48. The only valid PSD values obtained by the receiver using the interpolation procedure specified are those for subcarriers that belong to the MEDLEYds set (communicated in Field #3 of O-PRM), excluding the RFI bands communicated during the ITU-T G.994.1 handshake phase. PSD values out of this set shall be ignored by the VTU-R. The values of MREFPSDds shall be at least 3.5 dB below the downstream MEDLEY reference PSD mask (MREFMASKds, see clause 7.2.1), which, excluding the RFI bands, is the minimum of the transmit PSD mask (PSDMASKds, Field #4 of O-SIGNATURE), and the downstream PSD ceiling determined by the VTU-O. Moreover, the valid values of MREFPSDds, either those that are directly communicated or those obtained at the receiver by interpolation, shall not deviate from the downstream transmit PSD, as measured in the reference impedance at the U interface, by more than 1 dB.

Field #3 "MEDLEYds set" contains the MEDLEY set of subcarriers in the downstream direction. The MEDLEYds subcarriers shall be used starting from the beginning of the training phase. The "bands descriptor" format described in Table 12-22 shall be used. No more than 32 bands shall be specified.

Field #4 "Cyclic extension length" contains the value of L_{CE} that shall be used starting from the beginning of the training phase. This value may be different from the initial value that was exchanged during the ITU-T G.994.1 handshake phase if the VTUs have indicated that they support a change in CE length. The CE length shall be expressed as $L_{CE} = m \times N/32$. This field shall encode the value of m as an 8-bit value with valid values from 2 to 16.

NOTE – The duration of the CE is the same in the upstream and downstream directions. If the IDFT sizes used for both directions are the same, then the number of samples in the CE is also the same. If the IDFT sizes are not the same, then the number of samples in the CE in the downstream and upstream directions will differ but can be easily derived using the value of *m* provided by the VTU-O.

Field #5 "Downstream cyclic prefix length" contains the value of L_{CP} that shall be applied in the downstream direction starting from the beginning of the training phase. The value shall be expressed in samples of the downstream sampling rate corresponding to the IDFT size communicated in Field #7. The format shall be the same as for Field #14 of the O-SIGNATURE message (Table 12-21).

Field #6 "Downstream transmit window length (β_{ds})" contains the length of the transmit window that shall be used in the downstream direction starting from the beginning of the training phase. The value shall be expressed in samples of the downstream sampling rate corresponding to the IDFT size communicated in Field #7. The format shall be the same as for Field #13 of the O-SIGNATURE message (Table 12-21).

Field #7 "VTU-O IDFT size" indicates the updated size of the IDFT at the VTU-O that shall be used in the downstream direction starting from the beginning of the training phase. This value may be different from the initial value that was exchanged during the ITU-T G.994.1 handshake phase. The value shall be expressed as the IDFT size $2N_{ds}$. The format shall be an 8-bit field coded as $\log_2(2N_{ds})$ with valid values from 7 to 13.

Field #8 "Duration of VTU-O EC training period" indicates the duration of the EC training signal the VTU-O shall transmit, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 1024. The duration divided by 64 shall be encoded as an 8-bit value.

Field #9 "Requested duration of the VTU-O TEQ training period" indicates the minimum duration of the VTU-O TEQ training period that the VTU-O requests, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 16320. The duration divided by 64 shall be encoded as an 8-bit value.

Field #10 "Requested duration of the VTU-R TEQ training period" indicates the minimum duration of the VTU-R TEQ training period that the VTU-O requests, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 16320. The duration divided by 64 shall be encoded as an 8-bit value.

Field #11 "Requested minimum duration of the periodic signal" indicates the minimum duration of the R-P-PERIODIC 2 signal that the VTU-O requests, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 2048. The duration divided by 64 shall be encoded as an 8-bit value.

Field #12 "Downstream frequency-domain spectrum shaping" indicates the tss_i values used by the VTU-O. The field shall be formatted as a "Log_tss_i descriptor", shown in Table 12-31, with a maximum number of 64 breakpoints.

Table 12-31 – Log_tss_i descriptor

Octet	Content of field
1	Number of breakpoints (subcarriers) to be described
2-4	Bits 0-11: Subcarrier index of the first breakpoint Bits 12-23: log_tss_i value of the first breakpoint in steps of 0.1 dB
5-7 (if applicable)	Bits 0-11: Subcarrier index of the second breakpoint Bits 12-23: log_tss_i value of the second breakpoint in steps of 0.1 dB
etc.	etc.

The first octet of the descriptor shall contain the number of breakpoints being specified. This number can be zero. In that case, there shall be no further octets in the descriptor, and the field shall be interpreted as all $log\_tss_i = 0$ for all transmitted subcarriers. If the number of breakpoints is not equal to zero, each group of three consecutive octets shall describe one breakpoint as a log_tss_i value (see clause 10.3.4.3) at a certain subcarrier index. The tss_i values shall be determined by the transmitter such that, with combined frequency domain and time domain spectrum shaping, the downstream PSD at the U interface during the training phase and subsequent initialization phases shall be identical to the value MREFPSDds.

The first 12 bits (0-11) in the group of three octets shall contain the index of the subcarrier. The last 12 bits (12-23) shall contain the log_tss_i value of the subcarrier in dB calculated as specified in clause 10.3.4.3, such that the maximum log_tss_i value across all breakpoints shall be 0 dB. Each log_tss_i value shall be an integer multiple of −0.1 dB. The receiver shall obtain the log_tss_i values for unspecified subcarriers using a linear interpolation between the log_tss_i values of the assigned breakpoints as specified in clause 10.3.4.3.

The VTU-O shall provide non-zero tss_i values for all out-of-band subcarriers with indices from 1 to t_{DS1_stop} + 32, where t_{DS1_stop} is the highest-index subcarrier in DS1. The out-of-band tss_i values shall only be used during O-P-TEQ, as described in clause 12.3.4.3.1.4. The out-of-band tss_i values shall be set to ensure that the PSD of O-P-TEQ at the U interface is close to, but below, the relevant stopband limit PSD mask.

Field #13 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #14 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 13 and 14 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.3.2.1.4 O-ACK

O-ACK is a one-byte message that acknowledges correct reception of the R-PRM message. The format of the message shall be as specified in clause 12.2.1, and the payload shall be as specified in Table 12-6.

12.3.3.2.2 VTU-R messages sent during the channel discovery phase

12.3.3.2.2.1 R-MSG 1

The full list of parameters carried by the R-MSG 1 message is shown in Table 12-32.

Table 12-32 – Description of message R-MSG 1

	Field name	Format
1	Message descriptor	Message code
2	Estimate of electrical length	2 bytes
3	Initial upstream PSD ceiling (CDMAXMASKus)	2 bytes
4	Channel discovery upstream PSD (CDPSDus)	PSD descriptor
5	Initialization pilot tones	Tone descriptor
6	Timing advance	2 bytes

Table 12-32 – Description of message R-MSG 1

	Field name	Format
7	O-P-PILOT settings	1 byte
8	Upstream transmit window length (β_{us})	1 byte
9	Upstream cyclic prefix length	2 bytes
10	ITU-T G.998.4 parameter field	Variable length
11	ITU-T G.993.5 parameter field	Variable length
12	Extended estimate of electrical length	UPBOXEEL descriptor

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Estimate of electrical length" shall convey the estimate of the electrical length, expressed in dB at 1 MHz (see clause 7.2.1.3.2), as determined by the VTU-R. The value shall be coded as a 16-bit number. The value of the electrical length is obtained by multiplying this 16-bit value by 0.1 dB. The valid range of the electrical length is from 0 dB to 128 dB in 0.1 dB steps. Using this estimate of the electrical length, the VTU-R shall derive the upstream power back-off (UPBO) as described in clause 7.2.1.3. When using the alternative electrical length estimation method (ELE-M1) this parameter contains the value ELEDS.

Field #3 "Initial upstream PSD ceiling (CDMAXMASKus)" indicates the PSD level that is used to impose a ceiling on the upstream transmit PSD mask (after UPBO is performed) to form the upstream PSD mask for the signals transmitted during the channel discovery phase. The upstream channel discovery PSD (CDPSDus, see Field #4) is derived using the value of CDMAXMASKus. This field shall be coded the same as Field #7 of O-SIGNATURE.

Field #4 "Channel discovery upstream PSD (CDPSDus)" indicates the PSD at the U interface transmitted in the upstream direction during the channel discovery phase. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤32. The only valid PSD values obtained by the receiver using the interpolation procedure specified are those for subcarriers that belong to the SUPPORTEDCARRIERSus set, excluding the RFI bands communicated during the ITU-T G.994.1 handshake phase. PSD values out of this set shall be ignored by the receiver. The CDPSDus values shall be at least 3.5 dB below the upstream transmit PSD mask (Field #5 of O-SIGNATURE), and at least 3.5 dB below the initial upstream PSD ceiling (Field #3 of R-MSG 1), and at least 3.5 dB below the UPBOMASK that corresponds to the electrical length value defined in Field #2. Moreover, the valid values of CDPSDus, either those which are directly communicated or those obtained at the receiver by interpolation, shall not deviate from the actual value of the transmit PSD, as measured in the reference impedance at the U interface, by more than 1 dB.

Field #5 "Initialization pilot tones" indicates the selection of pilot tones by the VTU-R for timing recovery during the O-P-PILOT 1, O-P-PILOT 2, O-P-PILOT 3 and O-P-ECT stages. This information shall be used by the VTU-O during the lineprobe stage (if selected), and during the TEQ and echo canceller training stages of the training phase. The field shall be formatted as shown in Table 12-33. The total number of initialization pilot tones shall not exceed 16.

Table 12-33 – Tone descriptor

Octet	Content of field
1	Number of tones
2-4	Bits 0-11: index of tone 1 Bits 12-23: index of tone 2
5-7 (if applicable)	Bits 0-11: index of tone 3 Bits 12-23: index of tone 4
etc.	etc.

The first octet of the tone descriptor shall contain the number of pilot tones selected by the VTU-R. If this number is zero, there shall be no further octets in the descriptor. If the number of tones is not equal to zero, each group of three consecutive octets in the descriptor shall describe the location of two pilot tones.

The first 12 bits (0-11) and the last 12 bits (12-23) in each group of three octets shall contain the indices of two tones. For example, a field value 400200_{16} means tone 200_{16} = 512 and tone 400_{16} = 1024. If the number of pilot tones is odd, the last 12 bits in the field shall be set to ZERO.

Field #6 "Timing advance" indicates the timing advance selected by the VTU-R (which is either the initial value conveyed by the O-SIGNATURE message or a vendor-discretionary setting if no initial value was set by the VTU-O). It shall be expressed in samples at the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be encoded in a 16-bit field using twos complement format.

Field #7 "O-P-PILOT settings" indicates the setting of pilot tone power in O-P-PILOT signals during various stages. The format is one byte with the following encoding:

- the first MSB indicates whether the selected pilot tone(s) shall be allocated power in O-P-PILOT 1 during the channel discovery phase (1=ON, 0=OFF);
- the second and third MSBS indicate, respectively, whether the selected pilot tone(s) shall be allocated power in O-P-PILOT 2 and O-P-PILOT 3 during the training phase (1=ON, 0=OFF);
- other bits shall be set to ZERO.

Field #8 "Upstream transmit window length (β_{us})" contains the length of the transmit window that shall be used in the upstream direction during the channel discovery phase. The value shall be expressed in the samples of the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The format shall be the same as for Field #13 of the O-SIGNATURE message (Table 12-21).

Field #9 "Upstream cyclic prefix length" contains the length of the upstream cyclic prefix expressed in samples of the upstream sampling rate corresponding to the IDFT size communicated during the ITU-T G.994.1 handshake phase. The value shall be coded as a 16-bit unsigned integer.

Field #10 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #11 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 10 and 11 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

Field #12 "Extended estimated electrical length" contains the estimated electrical length. The UPBOXEEL descriptor has the parameter ELE[*band*] in dB for each downstream band (see Table 12-34, with the parameter specified in clause 7.2.1.3.2.1.2). The value shall be coded as a 16-bit number with the LSB weight of 0.1 dB. The valid range of values is from 0 dB to 128 dB with a 0.1 dB step.

Table 12-34 – UPBOXEEL descriptor

Octet	Content of field
1	Number of DS bands (n_{ds})
2-3	bits 0-15: value of *ELE[DS1]*
4-5 (if applicable)	bits 0-15: value of *ELE[DS2]*
...	
$2 \times n_{ds}$, $2 \times n_{ds} + 1$	bits 0-15: value of $ELE[DS(n_{ds})]$

12.3.3.2.2.2 R-UPDATE

The R-UPDATE message is a request to modify the downstream PSD. The full list of parameters carried by the R-UPDATE message is shown in Table 12-35.

Table 12-35 – Description of message R-UPDATE

	Field name	Format
1	Message descriptor	Message code
2	Updated downstream PSD ceiling (MAXMASKds)	2 bytes
3	Proposed highest downstream subcarrier	2 bytes
4	Proposed lowest downstream subcarrier	2 bytes
5	BLACKOUTds set	Bands descriptor
6	Suggested cyclic extension length	1 byte
7	ITU-T G.998.4 parameter field	Variable length
8	ITU-T G.993.5 parameter field	Variable length

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Updated downstream PSD ceiling (MAXMASKds)" indicates the PSD ceiling level of the downstream transmit PSD mask. This field shall be coded the same as Field #7 of O-SIGNATURE. If this level is lower than the downstream PSD ceiling indicated in O-SIGNATURE, the VTU-O shall apply this new ceiling level to PSDMASKds. Otherwise, the VTU-O may increase the ceiling of the downstream PSD mask up to MAXMASKds. This new ceiling level shall be used to form the downstream MEDLEY reference PSD mask (MREFMASKds). A special value 1000_{16} shall indicate that there is no limit on the downstream PSD ceiling level (under the constraints of the downstream transmit PSD mask).

Field #3 "Proposed highest downstream subcarrier" contains an estimate by the VTU-R of the highest-index downstream subcarrier that can be loaded with data bits. The format shall be the same as for Field #4 of the O-UPDATE message. The VTU-O may transmit subcarriers with indices higher than this value, as long as those subcarriers are in the SUPPORTEDCARRIERSds set.

Field #4 "Proposed lowest downstream subcarrier" contains an estimate by the VTU-R of the lowest-index downstream subcarrier that can be loaded with data bits. The format shall be the same as for Field #5 of the O-UPDATE message. The VTU-O may transmit subcarriers with indices lower than this value, as long as those subcarriers are in the SUPPORTEDCARRIERSus set.

Field #5 "BLACKOUTds set" contains the BLACKOUT set of subcarriers in the downstream direction. The field shall be formatted as a "bands descriptor" (see Table 12-22), with a maximum number of 16 bands. If there are no blackout subcarriers, the field shall consist of one octet, 00_{16}.

Field #6 "Suggested cyclic extension length" contains the value of the CE length suggested by the VTU-R. This value may be different from the initial value exchanged during the ITU-T G.994.1 handshake phase if both VTUs support a change in CE length. The final CE length shall be decided by the VTU-O (see O-PRM message in clause 12.3.3.2.1.3). The format shall be the same as for Field #4 of the O-PRM message (Table 12-30).

Field #7 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #8 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 7 and 8 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.3.2.2.3 R-PRM

The R-PRM message is sent in response to the O-PRM message. It contains the upstream MEDLEY reference PSD following the modifications proposed in the O-UPDATE message. It also contains the modulation parameters that shall be used in the upstream direction from the beginning of the training phase and requests for the durations of training periods in the training phase. The full list of parameters carried by the R-PRM message is shown in Table 12-36.

Table 12-36 – Description of message R-PRM

	Field name	Format
1	Message descriptor	Message code
2	Upstream MEDLEY reference PSD (MREFPSDus)	PSD descriptor
3	MEDLEYus set	Bands descriptor
4	Upstream cyclic prefix length	2 bytes
5	Upstream transmit window length (β_{us})	1 byte
6	VTU-R IDFT size	1 byte
7	Duration of the VTU-R EC training period	1 byte
8	Requested duration of the VTU-R TEQ training period	1 byte
9	Requested duration of the VTU-O TEQ training period	1 byte

Table 12-36 – Description of message R-PRM

	Field name	Format
10	Requested minimum duration of the periodic signal	1 byte
11	Minimum duration of the R-P-TRAINING 1 signal ($T_{MIN-R-P-Train}$)	1 byte
12	Upstream frequency-domain spectrum shaping	Log_tss_i descriptor
13	ITU-T G.998.4 parameter field	Variable length
14	ITU-T G.993.5 parameter field	Variable length

Field #1 "Message descriptor" is a one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Upstream MEDLEY reference PSD (MREFPSDus)" indicates the updated PSD at the U interface following the request from the VTU-O in O-UPDATE. This PSD shall be used in the upstream direction from the beginning of the training phase and for the remainder of initialization. The "PSD descriptor" format specified in Table 12-23 shall be used, and the number of subcarriers being described shall be limited to ≤ 32. The only valid PSD values obtained by the receiver using the interpolation procedure specified are those for the subcarriers that belong to the MEDLEYus set (communicated in Field #3), excluding the RFI bands communicated during the ITU-T G.994.1 handshake phase. PSD values out of this set shall be ignored by the VTU-O. The values of MREFPSDus shall be at least 3.5 dB below the upstream MEDLEY reference PSD mask (MREFMASKus, see clause 7.2.1) which, excluding the RFI bands, is the minimum of the transmit PSD mask (PSDMASKus, Field #5 of O-SIGNATURE), the UPBOMASK determined by the VTU-R (which corresponds to the electrical length value defined in Field #2 of O-UPDATE), and the upstream PSD ceiling determined by the VTU-R. Moreover, the valid values of MREFPSDus, either those that are directly communicated or those obtained at the receiver by interpolation, shall not deviate from the upstream transmit PSD, as measured in the reference impedance at the U interface, by more than 1 dB.

Field #3 "MEDLEYus set" contains the MEDLEY set of subcarriers in the upstream direction. The MEDLEYus subcarriers shall be used starting from the beginning of the training phase. The "bands descriptor" format described in Table 12-22 shall be used. No more than 32 bands shall be specified.

Field #4 "Upstream cyclic prefix length" contains the value of the cyclic prefix that shall be applied in the upstream direction starting from the beginning of the training phase. The value shall be expressed in samples of the upstream sampling rate corresponding to the IDFT size communicated in Field #6. The format of the selected cyclic prefix length shall be the same as for Field #14 of the O-SIGNATURE message (Table 12-21).

NOTE – The value of the CE length used in the calculation of the upstream cyclic prefix length is the value communicated in O-PRM, not the one sent in R-UPDATE.

Field #5 "Upstream transmit window length (β_{us})" contains the length of the transmit window that shall be used in the upstream direction starting from the beginning of the training phase. The value shall be expressed in samples of the upstream sampling rate corresponding to the IDFT size communicated in Field #6. The format shall be the same as for Field #13 of the O-SIGNATURE message (Table 12-21).

Field #6 "VTU-R IDFT size" communicates the IDFT size, $2N_{us}$, that shall be used by the VTU-R starting from the beginning of the training phase. The format shall be an 8-bit field coded as $\log_2(2N_{us})$, with valid values from 6 to 13. This value may be different from the initial value that was exchanged during the ITU-T G.994.1 handshake phase.

Field #7 "Duration of VTU-R EC training period" indicates the duration of the VTU-R EC training signal that the VTU-R shall transmit, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 1024. The duration divided by 64 shall be encoded as an 8-bit value.

Field #8 "Requested duration of the VTU-R TEQ training period" indicates the minimum duration of the VTU-R TEQ training period that the VTU-R requests, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 16320. The duration divided by 64 shall be encoded as an 8-bit value.

Field #9 "Requested duration of the VTU-O TEQ training period" indicates the minimum duration of the VTU-O TEQ training period that the VTU-R requests, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 16320. The duration divided by 64 shall be encoded as an 8-bit value.

Field #10 "Requested minimum duration of the periodic signal" indicates the minimum duration of the O-P-PERIODIC 2 signal the VTU-R requests, expressed in DMT symbols. It shall be an integer multiple of 64 in the range from 0 to 2048. The duration divided by 64 shall be encoded as an 8-bit value.

Field #11 "Minimum duration of the R-P-TRAINING 1 signal ($T_{MIN-R-P-Train}$)" indicates the minimum duration of the R-P-TRAINING 1 signal that the VTU-R shall transmit. The value, $T_{MIN-R-P-Train}$, shall be expressed in DMT symbols. The duration shall be an integer multiple of 64 symbols. The integer multiple (i.e., the duration divided by 64) shall be encoded as an 8-bit value.

Field #12: "Upstream frequency-domain spectrum shaping" indicates the updated tss_i values used by the VTU-R. The field shall be formatted as a "Log_tss$_i$ descriptor" as shown in Table 12-31.

The VTU-R shall provide non-zero tss_i values for all out-of-band subcarriers with indices from 1 to t_{US0_stop} + 32, where t_{US0_stop} is the highest-index subcarrier in US0. The out-of-band tss_i values (virtual values, since no out-of-band subcarriers are transmitted during channel discovery) shall only be used during R-P-TEQ, as described in clause 12.3.4.3.2.4. The out-of-band tss_i values shall be set to ensure that the PSD of R-P-TEQ at the U interface is close to, but below, the relevant stopband Limit PSD mask.

Field #13 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #14 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 13 and 14 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.3.3 Signals transmitted during the channel discovery phase

All signals transmitted during the channel discovery phase shall use only subcarriers from the SUPPORTEDCARRIERSds set in the downstream direction and subcarriers from the SUPPORTEDCARRIERSus set in the upstream direction.

The transmit PSD of all downstream signals with non-zero output power shall comply with the downstream transmit PSD mask (PSDMASKds), in both the passband and the stopbands, capped at the level of the initial downstream PSD ceiling (Field #7 of O-SIGNATURE). The downstream PSD shall not exceed −80 dBm/Hz in any RFI bands that were defined during the ITU-T G.994.1 handshake phase. The values of CE and $2N_{ds}$ shall be as defined during the ITU-T G.994.1 handshake phase. The values of β_{ds} and the cyclic prefix length shall be as communicated in Fields #13 and #14 of O-SIGNATURE, respectively.

The transmit PSD of all upstream signals with non-zero output power shall comply with the upstream transmit PSD mask (PSDMASKus), in both the passband and the stopbands, capped at the level of the initial upstream PSD ceiling (Field #3 of R-MSG 1). The upstream PSD shall comply with UPBO requirements specified in clause 7.2.1.3 and shall not exceed −80 dBm/Hz in any RFI bands that were defined during the ITU-T G.994.1 handshake phase. The values of CE and $2N_{us}$ shall be as defined during the ITU-T G.994.1 handshake phase. The values of β_{us} and timing advance shall be as communicated in Field #8 and Field #6 of R-MSG 1, respectively. The cyclic prefix length shall be as communicated in Field #9 of R-MSG 1.

12.3.3.3.1 Signals transmitted by the VTU-O

12.3.3.3.1.1 O-P-QUIET 1

O-P-QUIET 1 shall provide a zero output voltage at the U reference point. All subcarriers shall be allocated zero power.

The duration of O-P-QUIET 1 is variable between 512 and 1 024 symbols. Its duration is at the discretion of the VTU-O.

12.3.3.3.1.2 O-P-CHANNEL DISCOVERY 1

O-P-CHANNEL DISCOVERY 1 is a signal that allows the VTU-R to synchronize and to measure the attenuation of the channel. During transmission of O-P-CHANNEL DISCOVERY 1, the SOC is in its active state.

The duration of O-P-CHANNEL DISCOVERY 1 is variable. O-P-CHANNEL DISCOVERY 1 is terminated by transmission of O-P-SYNCHRO 1.

O-P-CHANNEL DISCOVERY 1 shall be composed of all subcarriers in SUPPORTEDCARRIERSds modulated by 4-QAM. Each DMT symbol of O-P-CHANNEL DISCOVERY 1 shall carry one byte of information. The mapping of bits to subcarriers shall be as summarized in Table 12-37.

Table 12-37 – Bit mapping for O-P-CHANNEL DISCOVERY 1

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10*n*+1, ...	SOC message bits 0 and 1
3, 13, 23, ..., 10*n*+3, ...	SOC message bits 2 and 3
5, 15, 25, ..., 10*n*+5, ...	SOC message bits 4 and 5
7, 17, 27, ..., 10*n*+7, ...	SOC message bits 6 and 7
9, 19, 29, ..., 10*n*+9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds} + L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of the subcarriers from the SUPPORTEDCARRIERSds set of the O-P-CHANNEL DISCOVERY 1 signal shall be equal to CDPSDds (communicated in Field #6 of O-SIGNATURE).

12.3.3.3.1.3 O-P-SYNCHRO 1

O-P-SYNCHRO 1 is a signal that provides an exact time marker for transitions from O-P-CHANNEL DISCOVERY 1 to either O-P-QUIET 2/O-P-PILOT 1 or O-P-PERIODIC 1. During transmission of O-P-SYNCHRO 1, the SOC is in its inactive state.

The duration of O-P-SYNCHRO 1 is 15 DMT symbols.

O-P-SYNCHRO 1 shall use all subcarriers in the SUPPORTEDCARRIERSds set modulated by 4-QAM. The value 11 shall be mapped to all of the SUPPORTEDCARRIERSds subcarriers for the first 5 and the last 5 DMT symbols. The value 00 shall be mapped to all SUPPORTEDCARRIERSds subcarriers for the middle 5 DMT symbols. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of the SUPPORTEDCARRIERSds subcarriers in O-P-SYNCHRO 1 shall be the same as for O-P-CHANNEL DISCOVERY 1.

12.3.3.3.1.4 O-P-PILOT 1

The O-P-PILOT 1 signal is intended to allow the VTU-R to maintain loop timing during the lineprobe stage. During the transmission of O-P-PILOT 1, the SOC is in its inactive state.

The duration of O-P-PILOT 1 is 640 DMT symbols with CE.

O-P-PILOT 1 consists only of the pilot tones that were chosen by the VTU-R and communicated to the VTU-O in Field #5 of R-MSG 1. A value of 00 shall be mapped to all pilot tones with 4-QAM modulation during every symbol of O-P-PILOT 1.

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of O-P-PILOT 1 shall comply with the downstream transmit PSD mask (PSDMASKds) capped at the level of the initial downstream PSD ceiling communicated in Field #7 of O-SIGNATURE. The transmit power of the pilot tones shall be set to 0 if the first MSB of the O-P-PILOT settings field of R-MSG 1 is set to ZERO.

12.3.3.3.1.5 O-P-QUIET 2

O-P-QUIET 2 is identical to O-P-QUIET 1 except that its duration shall be a fixed 640 DMT symbols with CE.

12.3.3.3.1.6 O-P-PERIODIC 1

O-P-PERIODIC 1 is a periodic signal intended to allow both VTUs to make accurate SNR measurements. During transmission of O-P-PERIODIC 1, the SOC is in its inactive state.

The duration of O-P-PERIODIC 1 shall be 2048 DMT symbols with CE.

O-P-PERIODIC 1 shall be composed of all subcarriers in the SUPPORTEDCARRIERSds set. These subcarriers shall be modulated by 4-QAM. The value 11 shall be mapped to all subcarriers in the SUPPORTEDCARRIERSds set. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

O-P-PERIODIC 1 shall be constructed as described in clause 12.3.6.1.

The transmit PSD of the SUPPORTEDCARRIERSds subcarriers in O-P-PERIODIC 1 shall be the same as for O-P-CHANNEL DISCOVERY 1.

12.3.3.3.1.7 O-P-SYNCHRO 2

O-P-SYNCHRO 2 is a signal that provides an exact time marker for transitions from O-P-PERIODIC 1 to O-P-CHANNEL DISCOVERY 2. During transmission of O-P-SYNCHRO 2, the SOC is in its inactive state.

O-P-SYNCHRO 2 shall be identical to O-P-SYNCHRO 1.

12.3.3.3.1.8 O-P-CHANNEL DISCOVERY 2

O-P-CHANNEL DISCOVERY 2 allows the VTU-O to send updated modulation parameters as well as information needed for the training phase (such as signal durations). During transmission of O-P-CHANNEL DISCOVERY 2, the SOC is in its active state.

The duration of O-P-CHANNEL DISCOVERY 2 is variable. O-P-CHANNEL DISCOVERY 2 is terminated by the transmission of O-P-SYNCHRO 3.

The symbols of O-P-CHANNEL DISCOVERY 2 shall be constructed in the same manner as the symbols of O-P-CHANNEL DISCOVERY 1 (see clause 12.3.3.3.1.2).

The transmit PSD of the subcarriers from the SUPPORTEDCARRIERSds set of the O-P-CHANNEL DISCOVERY 2 signal shall be equal to CDPSDds (communicated in Field #6 of O-SIGNATURE).

12.3.3.3.1.9 O-P-SYNCHRO 3

O-P-SYNCHRO 3 is a signal that provides an exact time marker for transitions from O-P-CHANNEL DISCOVERY 2 to O-P-TRAINING 1 (training phase).

O-P-SYNCHRO 3 shall be identical to O-P-SYNCHRO 1.

12.3.3.3.2 Signals transmitted by the VTU-R

12.3.3.3.2.1 R-P-QUIET 1

R-P-QUIET 1 shall provide a zero output voltage at the U reference point. All subcarriers shall be allocated zero power. The duration of R-P-QUIET 1 is variable. Its duration is at the discretion of the VTU-R.

12.3.3.3.2.2 R-P-CHANNEL DISCOVERY 1

R-P-CHANNEL DISCOVERY 1 is a signal used by the VTU-R to send information about the upstream PSD, timing advance, and its selection of pilot tones (if any). During transmission of R-P-CHANNEL DISCOVERY 1, the SOC is in its active state.

The duration of R-P-CHANNEL DISCOVERY 1 is variable. R-P-CHANNEL DISCOVERY 1 is terminated by transmission of R-P-SYNCHRO 1.

R-P-CHANNEL DISCOVERY 1 shall be composed of all subcarriers in SUPPORTEDCARRIERSus modulated by 4-QAM. Each DMT symbol of R-P-CHANNEL DISCOVERY 1 shall carry one byte of information. The mapping of bits to subcarriers is summarized in Table 12-38.

Table 12-38 – Bit mapping for R-P-CHANNEL DISCOVERY 1

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10*n*+1, ...	SOC message bits 0 and 1
3, 13, 23, ..., 10*n*+3, ...	SOC message bits 2 and 3
5, 15, 25, ..., 10*n*+5, ...	SOC message bits 4 and 5
7, 17, 27, ..., 10*n*+7, ...	SOC message bits 6 and 7
9, 19, 29, ..., 10*n*+9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

The constellation points of all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us} + L_{CE}$ samples. The overall window length shall be equal to β_{us}.

The transmit PSD of the subcarriers from the SUPPORTEDCARRIERSus set of the R-P-CHANNEL DISCOVERY 1 signal shall be equal to CDPSDus (communicated in Field #4 of R-MSG 1).

12.3.3.3.2.3 R-P-SYNCHRO 1

R-P-SYNCHRO 1 is a signal that provides an exact time marker for transitions from R-P-CHANNEL DISCOVERY 1 to R-P-PERIODIC 1 or R-P-LINEPROBE if requested during the G.994.1 handshake phase. During transmission of R-P-SYNCHRO 1, the SOC is in its inactive state.

The duration of R-P-SYNCHRO 1 is 15 DMT symbols.

R-P-SYNCHRO 1 shall use all subcarriers in the SUPPORTEDCARRIERSus set modulated by 4-QAM. The value 11 shall be mapped to all SUPPORTEDCARRIERSus subcarriers for the first 5 and the last 5 DMT symbols. The value 00 shall be mapped to all of the SUPPORTEDCARRIERSus subcarriers for the middle 5 DMT symbols. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us} + L_{CE}$ samples. The overall window length shall be equal to β_{us}.

The transmit PSD of the SUPPORTEDCARRIERSus subcarriers in R-P-SYNCHRO 1 shall be the same as for R-P-CHANNEL DISCOVERY 1.

12.3.3.3.2.4 R-P-LINEPROBE

R-P-LINEPROBE is a vendor-discretionary signal that allows the VTU-R to perform line probing. During transmission of R-P-LINEPROBE, the SOC is in its inactive state.

The duration of R-P-LINEPROBE is 512 DMT symbols with CE.

The transmit PSD of R-P-LINEPROBE shall respect PSDMASKus, in both the passband and the stopbands, capped at the level of the initial upstream PSD ceiling (Field #3 of R-MSG 1). The PSD of R-P-LINEPROBE shall comply with UPBO requirements specified in clause 7.2.1.3 and shall not exceed −80 dBm/Hz in any RFI bands that were defined during the ITU-T G.994.1 handshake phase.

12.3.3.3.2.5 R-P-PERIODIC 1

R-P-PERIODIC 1 is a periodic signal intended to allow both VTUs to make accurate SNR measurements. During transmission of R-P-PERIODIC 1, the SOC is in its inactive state.

The duration of R-P-PERIODIC shall be 2048 DMT symbols with CE.

R-P-PERIODIC 1 shall be composed of all subcarriers in the SUPPORTEDCARRIERSus set. These subcarriers shall be modulated by 4-QAM. The value 11 shall be mapped to all subcarriers in the SUPPORTEDCARRIERSus set. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

R-P-PERIODIC 1 shall be constructed as described in clause 12.3.6.1.

The transmit PSD of the SUPPORTEDCARRIERSus subcarriers in R-P-PERIODIC 1 shall be the same as for R-P-CHANNEL DISCOVERY 1.

12.3.3.3.2.6 R-P-SYNCHRO 2

R-P-SYNCHRO 2 is a signal that provides an exact time marker for transitions from R-P-PERIODIC 1 to R-P-CHANNEL DISCOVERY 2. During transmission of R-P-SYNCHRO 2, the SOC is in its inactive state.

R-P-SYNCHRO 2 shall be identical to R-P-SYNCHRO 1.

12.3.3.3.2.7 R-P-CHANNEL DISCOVERY 2

R-P-CHANNEL DISCOVERY 2 allows the VTU-R to request modifications to the downstream transmit signal, to send updated modulation parameters, and to send information needed for the training phase (such as signal durations). During transmission of R-P-CHANNEL DISCOVERY 2, the SOC is in its active state.

The duration of R-P-CHANNEL DISCOVERY 2 is variable. R-P-CHANNEL DISCOVERY 2 is terminated by the transmission of R-P-SYNCHRO 3.

The symbols of R-P-CHANNEL DISCOVERY 2 shall be constructed in the same manner as the symbols of R-P-CHANNEL DISCOVERY 1 (see clause 12.3.3.3.2.2).

The transmit PSD of the subcarriers from the SUPPORTEDCARRIERSus set of the R-P-CHANNEL DISCOVERY 2 signal shall be equal to CDPSDus (communicated in Field #4 of R-MSG 1).

12.3.3.3.2.8 R-P-SYNCHRO 3

R-P-SYNCHRO 3 is a signal that provides an exact time marker for transitions from R-P-CHANNEL DISCOVERY 2 to R-P-QUIET 2 (training phase).

R-P-SYNCHRO 3 shall be identical to R-P-SYNCHRO 1.

12.3.4 Training phase

12.3.4.1 Overview

During the training phase, the VTUs may train their TEQ and echo canceller (EC). In the case that a TEQ or EC or both are not required, the corresponding stages may be shortened to accelerate completion of the initialization procedure. Also, the value of timing advance may be adjusted during this phase.

Figure 12-8 presents the timing diagram for the stages of the training phase. It gives an overview of the sequence of signals transmitted and SOC messages sent by the VTU-O and VTU-R during the training phase. The two inner columns show the sequences of signals that are transmitted (see clause 12.3.4.3). The two outer columns show the messages that are sent over the SOC (see clause 12.3.4.2). The shaded areas correspond to periods of time when the SOC is in its inactive state.

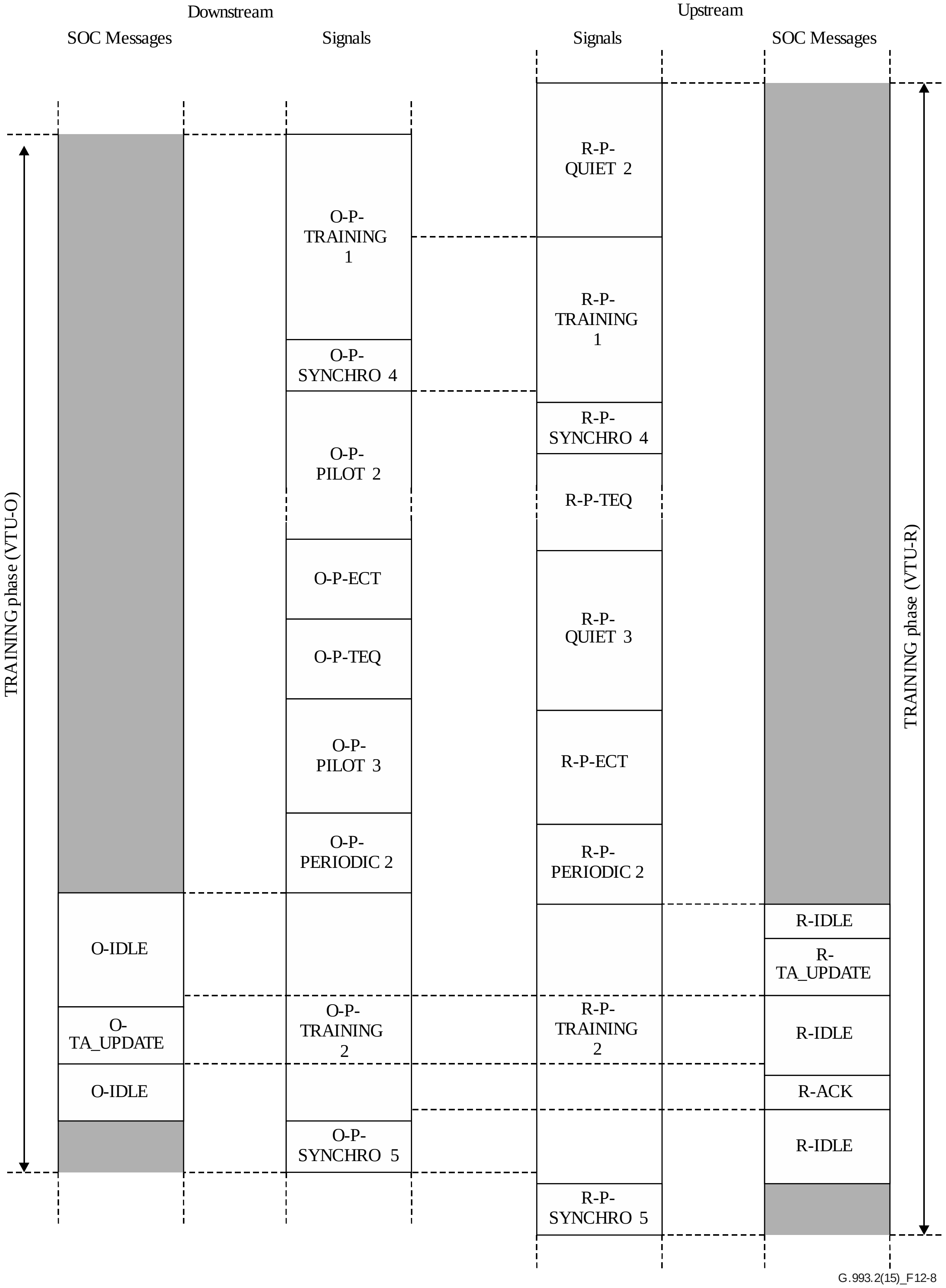

Figure 12-8 – Timing diagram for the stages of the training phase

NOTE 1 – In the exchange of the SOC messages identified in Figure 12-8, the rules of the communication protocol of clause 12.2.2 apply. Some messages sent in the SOC may require segmentation; although this is not shown in Figure 12-8, the segmented message elements and their corresponding acknowledgements are sent via the SOC per the communication protocol of clause 12.2.2.

At the start of the training phase, the VTU-O shall transmit O-P-TRAINING 1, and the VTU-R shall be silent (R-P-QUIET 2). This time may be used by the VTU-R to recover timing or symbol boundaries in case one or more of the modulation parameters (CE length, IDFT size, etc.) was changed at the completion of the channel discovery phase.

After not more than 4 096 symbols, the VTU-R shall transition from R-P-QUIET 2 to transmitting R-P-TRAINING 1. During the period that R-P-TRAINING 1 is transmitted, both VTUs can re-adjust their AGC settings to adapt to changes in the transmit PSD at the completion of the channel discovery phase. After the VTU-O receives at least $T_{MIN\text{-}R\text{-}P\text{-}Train}$ R-P-TRAINING 1 symbols (Field #11 of R-PRM, see clause 12.3.3.2.2.3), it shall transmit O-P-SYNCHRO 4 to indicate the start of the TEQ and EC training stages. After detecting O-P-SYNCHRO 4, the VTU-R shall respond within a time period between 48 and 64 symbols by transmitting R-P-SYNCHRO 4.

The durations of the TEQ training signals, the EC training signals, and the periodic signal transmitted after TEQ and EC training are determined from the values requested by the VTU-O and VTU-R during the channel discovery phase. They shall be defined as:

- $T_{VTU\text{-}O\_TEQ}$: duration of the VTU-O TEQ training, equal to the greater of the values requested by the VTU-O in Field # 9 of O-PRM and by the VTU-R in Field #9 of R-PRM;
- $T_{VTU\text{-}R\_TEQ}$: duration of the VTU-R TEQ training, equal to the greater of the values requested by the VTU-O in Field #10 of O-PRM and by the VTU-R in Field #8 of R-PRM;
- $T_{VTU\text{-}O\_EC}$: duration of the VTU-O EC training, equal to the value communicated by the VTU-O in Field #8 of O-PRM;
- $T_{VTU\text{-}R\_EC}$: duration of the VTU-R EC training, equal to the value communicated by the VTU-R in Field #7 of R-PRM; and
- $T_{Periodic}$: duration of the O-P-PERIODIC 2 and R-P-PERIODIC 2 signals following TEQ and EC training, equal to the greater of the values requested by the VTU-O in Field #11 of O-PRM and by the VTU-R in Field #10 of R-PRM.

The VTUs shall determine when to transition from one stage to the next by counting the number of symbols transmitted during each stage.

Immediately after transmission of O-P-SYNCHRO 4, the VTU-O shall transmit O-P-PILOT 2 and shall continue transmitting O-P-PILOT 2 for $T_{VTU\text{-}O\_TEQ}$ symbols. Immediately after transmission of R-P-SYNCHRO 4, the VTU-R shall transmit R-P-TEQ for $T_{VTU\text{-}O\_TEQ}$ symbols. During this stage, the VTU-O may train its TEQ.

NOTE 2 – It is expected that the timing recovery at the VTU-R will be stable during the last 512 symbols of R-P-TEQ transmission.

Immediately after all $T_{VTU\text{-}O\_TEQ}$ symbols of O-P-PILOT 2 have been transmitted, the VTU-O shall transmit O-P-ECT for $T_{VTU\text{-}O\_EC}$ symbols. During transmission of O-P-ECT, the VTU-O may train its echo canceller.

After all $T_{VTU\text{-}O\_EC}$ symbols of O-P-ECT have been transmitted, the VTU-O shall transmit O-P-TEQ for $T_{VTU\text{-}R\_TEQ}$ symbols. The VTU-R shall transmit $T_{VTU\text{-}O\_EC} + T_{VTU\text{-}R\_TEQ}$ symbols of R-P-QUIET 3 immediately after all $T_{VTU\text{-}O\_TEQ}$ symbols of R-P-TEQ have been transmitted. During the transmission of O-P-TEQ, the VTU-R may train its TEQ.

Immediately after the VTU-O has transmitted all $T_{VTU\text{-}R\_TEQ}$ symbols of O-P-TEQ, it shall transmit O-P-PILOT 3 for $T_{VTU\text{-}R\_EC}$ symbols. After the VTU-R has transmitted all $T_{VTU\text{-}O\_EC} + T_{VTU\text{-}R\_TEQ}$ symbols of R-P-QUIET 3, it shall transmit R-P-ECT for $T_{VTU\text{-}R\_EC}$ symbols. During this stage, the VTU-R may train its echo canceller.

After transmitting the last symbol of O-P-PILOT 3, the VTU-O shall transmit $T_{Periodic}$ symbols of O-P-PERIODIC 2. After transmitting the last symbol of R-P-ECT, the VTU-R shall likewise transmit $T_{Periodic}$ symbols of R-P-PERIODIC 2. During this stage, there is bidirectional transmission of periodic signals that may be used to make further adjustments to the TEQ at each receiver. After transmitting the last symbol of O-P-PERIODIC 2, the VTU-O shall transmit O-P-TRAINING 2. After transmitting the last symbol of R-P-PERIODIC 2, the VTU-R shall transmit R-P-TRAINING 2. At this point, the SOC shall be re-activated and the VTU-O shall send O-IDLE and the VTU-R shall send R-IDLE.

The VTU-R shall send R-IDLE for at least the first 128 symbols of R-P-TRAINING 2. The first message after that shall be R-TA_UPDATE. R-TA_UPDATE is used to communicate the current setting of the timing advance and to indicate the preferred and maximum values of the timing advance that the VTU-R can accommodate. The VTU-O shall acknowledge the reception of R-TA_UPDATE by sending O-TA_UPDATE containing the final value of the timing advance. The VTU-R shall acknowledge the reception of the O-TA_UPDATE message by sending R-ACK. The adjusted timing advance value shall be activated 5 symbols after the completion of R-ACK. The messages R-TA_UPDATE and O-TA_UPDATE also establish the number of SOC bytes per DMT symbol that will be used during the channel analysis and exchange phase.

To provide high robustness, both VTUs shall use the RQ protocol, as described in clause 12.2.2.2. Thus, the receiving VTU may ask for a retransmission of any message that was not correctly received.

After receiving R-ACK, the VTU-O shall continue to transmit O-P-TRAINING 2 for a duration of at least 64 symbols, and then shall indicate the end of the training phase by transmitting O-P-SYNCHRO 5. The VTU-R shall acknowledge the detection of O-P-SYNCHRO 5 by transmitting R-P-SYNCHRO 5 within a time period of 64 DMT symbols. After that, the VTU-R shall transition into the channel analysis and exchange phase. The VTU-O shall transition to the channel analysis and exchange phase after transmission of O-P-SYNCHRO 5.

NOTE 3 – Figure 12-8 shows the complete training phase with TEQ and EC training stages, both upstream and downstream. The training phase may be shortened if some or all of these stages are not required. Since the lengths are determined based on the values communicated by the VTU-O and VTU-R during the channel discovery phase, one or more of the training stages can be reduced to the minimum length, thereby shortening the overall training time.

From the start of the training phase and for the remainder of initialization, the VTU-O and VTU-R shall transmit signals with the PSDs that are determined at the end of the channel discovery phase (i.e., including power cut-backs in the upstream and downstream transmission directions), as described in clause 12.3.4.3.

The signals and SOC messages sent by the VTU-O during the training phase are summarized in Table 12-39, and the signals and SOC messages sent by the VTU-R during the training phase are summarized in Table 12-40. The protocol used for SOC messages is provided, where applicable, in parentheses in the column labelled "SOC state".

Table 12-39 – VTU-O signals and SOC messages in the training phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages and IDLE flags	SOC state
O-P-TRAINING 1	Non-periodic	Variable	None	Inactive
O-P-SYNCHRO 4	Non-periodic	15	None	Inactive
O-P-PILOT 2	Non-periodic	$T_{VTU\text{-}O\_TEQ}$	None	Inactive
O-P-TEQ	Periodic	$T_{VTU\text{-}R\_TEQ}$	None	Inactive
O-P-ECT	Vendor discretionary	$T_{VTU\text{-}O\_EC}$	None	Inactive
O-P-PILOT 3	Non-periodic	$T_{VTU\text{-}R\_EC}$	None	Inactive

Table 12-39 – VTU-O signals and SOC messages in the training phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages and IDLE flags	SOC state
O-P-PERIODIC 2	Periodic	$T_{Periodic}$	None	Inactive
O-P-TRAINING 2	Non-periodic	Variable	O-IDLE, O-TA_UPDATE	Active (RQ)
O-P-SYNCHRO 5	Non-periodic	15	None	Inactive

Table 12-40 – VTU-R signals and SOC messages in the training phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages and IDLE flags	SOC state
R-P-QUIET 2	None	Variable, $\leqslant$ 4 096	None	Inactive
R-P-TRAINING 1	Non-periodic	Variable, $>T_{MIN\text{-}R\text{-}P\text{-}Train}$	None	Inactive
R-P-SYNCHRO 4	Non-periodic	15	None	Inactive
R-P-TEQ	Periodic	$T_{VTU\text{-}O\_TEQ}$	None	Inactive
R-P-QUIET 3	None	$T_{VTU\text{-}R\_TEQ} + T_{VTU\text{-}O\_EC}$	None	Inactive
R-P-ECT	Vendor discretionary	$T_{VTU\text{-}R\_EC}$	None	Inactive
R-P-PERIODIC 2	Periodic	$T_{Periodic}$	None	Inactive
R-P-TRAINING 2	Non-periodic	Variable	R-IDLE, R-TA_UPDATE	Active (RQ)
R-P-SYNCHRO 5	Non-periodic	15	None	Inactive

12.3.4.2 SOC message exchange during the training phase

Figure 12-9 illustrates the SOC message exchange between the VTU-O and VTU-R during the training phase. It also summarizes the content of each message.

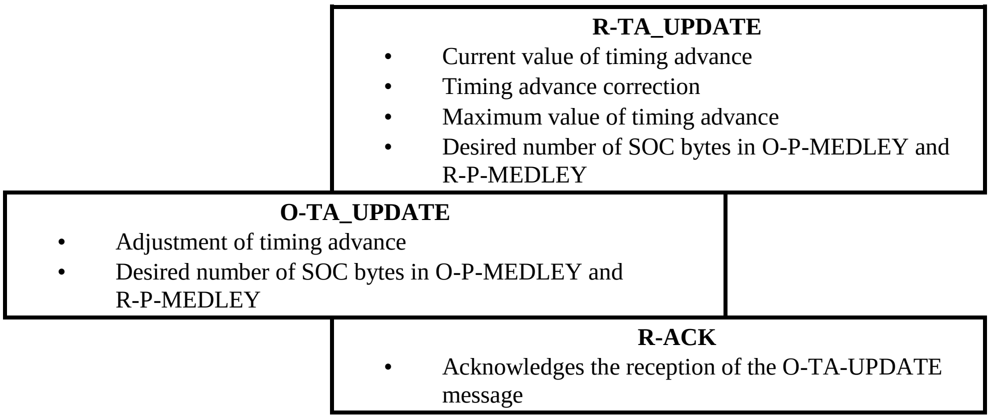

Figure 12-9 – SOC message exchange during the training phase

12.3.4.2.1 VTU-O messages sent during the training phase

12.3.4.2.1.1 O-TA_UPDATE

The full list of parameters carried by the O-TA_UPDATE message is shown in Table 12-41.

Table 12-41 – Description of message O-TA_UPDATE

	Field name	Format
1	Message descriptor	Message code
2	Timing advance correction	2 bytes
3	$B_{ex\text{-}ds\text{-}O}$ (Desired number of SOC bytes per DMT symbol in O-P-MEDLEY)	1 byte
4	$B_{ex\text{-}us\text{-}O}$ (Desired number of SOC bytes per DMT symbol in R-P-MEDLEY)	1 byte
5	ITU-T G.998.4 parameter field	Variable length
6	ITU-T G.993.5 parameter field	Variable length

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Timing advance correction" defines the timing advance correction that shall be used with respect to the current timing advance. It shall be expressed in samples at the upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format. Positive values shall indicate that the transmitted symbol will be advanced more with respect to the received symbol.

Field #3 "$B_{ex\text{-}ds\text{-}O}$" specifies the VTU-O's choice for the number of SOC bytes per DMT symbol that should be used to modulate O-P-MEDLEY. This number shall be either one or two. The actual number of SOC bytes per DMT symbol shall be the minimum of the values indicated in O-TA_UPDATE and R-TA_UPDATE (i.e., equal to min($B_{ex\text{-}ds\text{-}O}$, $B_{ex\text{-}ds\text{-}R}$)).

Field #4 "$B_{ex\text{-}us\text{-}O}$" specifies the VTU-O's choice for the number of SOC bytes per DMT symbol that should be used to modulate R-P-MEDLEY. This number shall be either one or two. The actual number of SOC bytes per DMT symbol shall be the minimum of the values indicated in O-TA_UPDATE and R-TA_UPDATE (i.e., equal to min($B_{ex\text{-}us\text{-}O}$, $B_{ex\text{-}us\text{-}R}$)).

Field #5 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #6 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 5 and 6 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.4.2.2 VTU-R messages sent during the training phase

12.3.4.2.2.1 R-TA_UPDATE

The full list of parameters carried by the R-TA_UPDATE message is shown in Table 12-42.

Table 12-42 – Description of message R-TA_UPDATE

	Field name	Format
1	Message descriptor	Message code
2	Current timing advance	2 bytes
3	Timing advance correction	2 bytes
4	Maximum value of timing advance	2 bytes
5	$B_{ex\text{-}ds\text{-}R}$ (Desired number of SOC bytes per DMT symbol in O-P-MEDLEY)	1 byte
6	$B_{ex\text{-}us\text{-}R}$ (Desired number of SOC bytes per DMT symbol in R-P-MEDLEY)	1 byte
7	ITU-T G.998.4 parameter field	Variable length
8	ITU-T G.993.5 parameter field	Variable length

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Current timing advance" gives the timing advance currently being used by the VTU-R. The field is expressed in samples at the upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format.

Field #3 "Timing advance correction" indicates the timing advance correction, with respect to the current timing advance, preferred by the VTU-R in samples at the upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format. Positive values shall indicate that the transmitted symbol will be advanced more with respect to the received symbol.

Field #4 "Maximum value of timing advance" indicates the maximum value of timing advance that the VTU-R can accommodate in samples at the current upstream sampling rate corresponding to the IDFT size communicated in Field #6 of R-PRM. The value shall be encoded in a 16-bit field using twos complement format.

Field #5 "$B_{ex\text{-}ds\text{-}R}$" specifies the VTU-R's choice for the number of SOC bytes per DMT symbol that should be used to modulate O-P-MEDLEY. This number shall be either one or two. The actual number of SOC bytes per DMT symbol shall be the minimum of the values indicated in O-TA_UPDATE and R-TA_UPDATE (i.e., equal to min($B_{ex\text{-}ds\text{-}O}$, $B_{ex\text{-}ds\text{-}R}$)).

Field #6 "$B_{ex\text{-}us\text{-}R}$" specifies the VTU-R's choice for the number of SOC bytes per DMT symbol that should be used to modulate R-P-MEDLEY. This number shall be either one or two. The actual number of SOC bytes per DMT symbol shall be the minimum of the values indicated in O-TA_UPDATE and R-TA_UPDATE (i.e., equal to min($B_{ex\text{-}us\text{-}O}$, $B_{ex\text{-}us\text{-}R}$)).

Field #7 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #8 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 7 and 8 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.4.2.2.2 R-ACK

R-ACK is a one-byte message that acknowledges correct reception of the O-TA_UPDATE message. The format of the message shall be as specified in clause 12.2.1, and the payload shall be as specified in Table 12-6.

12.3.4.3 Signals transmitted during the training phase

All signals transmitted during the training phase, except O-P-TEQ and R-P-TEQ, shall use only subcarriers from the MEDLEYds set in the downstream direction and subcarriers from the MEDLEYus set in the upstream direction. O-P-TEQ and R-P-TEQ also use out-of-MEDLEY subcarriers, as described in clauses 12.3.4.3.1.4 and 12.3.4.3.2.4.

The transmit PSD of downstream signals with non-zero output power shall comply with the downstream MEDLEY reference PSD mask (MREFMASKds) that was established at the end of the channel discovery phase in both the passband and the stopbands. The values of $2N_{ds}$ and CE shall be those determined at the end of the channel discovery phase and communicated in Fields #7 and #4 in O-PRM, respectively. The values of β_{ds} and cyclic prefix length shall be as communicated in Field #6 and Field #5 of O-PRM, respectively.

The transmit PSD of all upstream signals with non-zero output power shall comply with the upstream MEDLEY reference PSD mask (MREFMASKus) that was established at the end of the channel discovery phase in both the passband and the stopbands. The values of $2N_{us}$ and CE shall be those determined at the end of the channel discovery phase and communicated in Field #6 of R-PRM and Field #4 in O-PRM, respectively. The values of β_{us} and cyclic prefix length shall be those communicated in Fields #5 and #4 of R-PRM, respectively.

12.3.4.3.1 Signals transmitted by the VTU-O

12.3.4.3.1.1 O-P-TRAINING 1

The O-P-TRAINING 1 signal allows the VTU-R to re-synchronize and establish correct symbol timing. During transmission of O-P-TRAINING 1, the SOC is in its inactive state.

The duration of O-P-TRAINING 1 is variable. The VTU-O terminates O-P-TRAINING 1 by transmitting O-P-SYNCHRO 4.

O-P-TRAINING 1 shall be composed of all subcarriers in the MEDLEYds set. These subcarriers shall be modulated by 4-QAM. O-P-TRAINING 1 carries one byte per DMT symbol. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

The one byte carried by O-P-TRAINING 1 shall be the output of a PRBS generator with the same polynomial as the PRBS used for the quadrant scrambler (see clause 12.3.6.2). This PRBS generator shall not be reset and shall not skip any bits between DMT symbols. The initial state of this PRBS (for the first symbol of O-P-TRAINING 1) shall be all ones. The mapping of bits to subcarriers shall be as shown in Table 12-43.

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of the MEDLEYds subcarriers shall be equal to the downstream MEDLEY reference PSD (MREFPSDds) communicated in Field #2 of O-PRM.

Table 12-43 – Bit mapping for O-P-TRAINING 1

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10*n*+1, ...	First 2 bits from the PRBS byte
3, 13, 23, ..., 10*n*+3, ...	Second 2 bits from the PRBS byte
5, 15, 25, ..., 10*n*+5, ...	Third 2 bits from the PRBS byte
7, 17, 27, ..., 10*n*+7, ...	Fourth 2 bits from the PRBS byte
9, 19, 29, ..., 10*n*+9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

12.3.4.3.1.2 O-P-SYNCHRO 4

O-P-SYNCHRO 4 provides an exact time marker for transitions from O-P-TRAINING 1 to O-P-PILOT 2. During transmission of O-P-SYNCHRO 4, the SOC is in its inactive state.

The duration of O-P-SYNCHRO 4 is 15 DMT symbols.

O-P-SYNCHRO 4 shall use all subcarriers in the MEDLEYds set modulated by 4-QAM. The value 11 shall be mapped to all MEDLEYds subcarriers for the first 5 and the last 5 DMT symbols. The value 00 shall be mapped to all of the MEDLEYds subcarriers for the middle 5 DMT symbols. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of the MEDLEYds subcarriers in O-P-SYNCHRO 4 shall be the same as for O-P-TRAINING 1.

12.3.4.3.1.3 O-P-PILOT 2

The O-P-PILOT 2 signal is intended to allow the VTU-R to maintain loop timing during VTU-O TEQ training. During O-P-PILOT 2 the SOC is in its inactive state.

The duration of O-P-PILOT 2 is $T_{VTU\text{-}O\_TEQ}$ DMT symbols with CE. The value of $T_{VTU\text{-}O\_TEQ}$ shall be set to the maximum of the durations requested by the VTU-R in R-PRM and by the VTU-O in O-PRM.

O-P-PILOT 2 consists only of the pilot tones that were chosen by the VTU-R and communicated to the VTU-O in the Field #5 of R-MSG 1 during the channel discovery phase. A value of 00 shall be mapped to all pilot tones with 4-QAM modulation during every symbol of O-P-PILOT 2.

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The O-P-PILOT 2 signal shall respect MREFMASKds as established at the conclusion of the channel discovery phase. The transmit power of pilot tones shall be set to 0 if the second MSB of the O-P-PILOT settings field of R-MSG 1 during the channel discovery phase is set to ZERO.

12.3.4.3.1.4 O-P-TEQ

O-P-TEQ is a periodic signal. It allows the VTU-R to train its TEQ. During the transmission of O-P-TEQ, the SOC is in its inactive state.

The duration of O-P-TEQ is $T_{VTU\text{-}R\_TEQ}$ DMT symbols with CE. The value of $T_{VTU\text{-}R\_TEQ}$ shall be set to the maximum of the durations requested by the VTU-R in R-PRM and by the VTU-O in O-PRM.

O-P-TEQ shall use all subcarriers from the MEDLEYds set, as well as the out-of-MEDLEYds subcarriers with indices between 1 and t_{DS1_stop} + 32, where t_{DS1_stop} is the highest-index subcarrier in the MEDLEYds set included in DS1.

O-P-TEQ shall map the 4-QAM value of 11 on each subcarrier. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

O-P-TEQ shall be constructed as described in clause 12.3.6.1.

The transmit PSD of the MEDLEYds subcarriers in O-P-TEQ shall be the same as for O-P-TRAINING 1. The transmit PSD shall incorporate the tss_i values that were sent by the VTU-O during the channel discovery phase (see clause 12.3.3.2.1.3).

12.3.4.3.1.5 O-P-ECT

The O-P-ECT signal allows the VTU-O to train its echo canceller. During transmission of O-P-ECT, the SOC is in its inactive state.

The duration of O-P-ECT is $T_{VTU\text{-}O\_EC}$ DMT symbols with CE. The value of $T_{VTU\text{-}O\_EC}$ shall be as indicated by the VTU-O in O-PRM.

O-P-ECT is a vendor-discretionary signal. However, in order to allow the VTU-R to maintain loop timing, O-P-ECT shall include any pilot tones selected by the VTU-R during the channel discovery phase.

The PSD of O-P-ECT shall respect MREFMASKds as established at the conclusion of the channel discovery phase.

12.3.4.3.1.6 O-P-PILOT 3

The O-P-PILOT 3 signal is intended to allow the VTU-R to maintain loop timing during echo canceller training. During the transmission of O-P-PILOT 3, the SOC is in its inactive state.

The duration of O-P-PILOT 3 is $T_{VTU\text{-}R\_EC}$ DMT symbols with CE. The value of $T_{VTU\text{-}R\_EC}$ shall be as indicated by the VTU-R in R-PRM.

O-P-PILOT 3 consists only of the pilot tones that were chosen by the VTU-R and communicated to the VTU-O in Field #5 of R-MSG 1 during the channel discovery phase. A value of 00 shall be mapped to all pilot tones with 4-QAM modulation during every symbol of O-P-PILOT 3.

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The O-P-PILOT 3 signal shall respect MREFMASKds as established at the conclusion of the channel discovery phase. The transmit power of pilot tones shall be set to 0 if the third MSB of the O-P-PILOT settings field of R-MSG 1 during the channel discovery phase is set to ZERO.

12.3.4.3.1.7 O-P-PERIODIC 2

O-P-PERIODIC 2 is a periodic signal. During the transmission of O-P-PERIODIC 2, the SOC is in its inactive state.

The duration of O-P-PERIODIC 2, $T_{Periodic}$ DMT symbols with CE, is the maximum of the durations requested by the VTU-R in R-PRM and by the VTU-O in O-PRM.

O-P-PERIODIC 2 shall be composed of all subcarriers in the MEDLEYds set. These subcarriers shall be modulated by 4-QAM. The value 11 shall be mapped to all of the subcarriers. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

O-P-PERIODIC 2 shall be constructed as described in clause 12.3.6.1.

The transmit PSD of the MEDLEYds subcarriers in O-P-PERIODIC 2 shall be the same as for O-P-TRAINING 1.

12.3.4.3.1.8 O-P-TRAINING 2

The O-P-TRAINING 2 signal allows the VTU-R to re-establish SOC message exchange between the VTU-O and VTU-R. During the transmission of O-P-TRAINING 2, the SOC is in its active state.

The duration of O-P-TRAINING 2 is variable. The VTU-O terminates O-P-TRAINING 2 by transmitting O-P-SYNCHRO 5, which completes the training phase.

O-P-TRAINING 2 shall be composed of all subcarriers in the MEDLEYds set modulated by 4-QAM.

O-P-TRAINING 2 shall carry one byte of information per DMT symbol. The mapping of bits to subcarriers shall be as summarized in Table 12-44.

Table 12-44 – Bit mapping for O-P-TRAINING 2

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10*n*+1, ...	SOC message bits 0 and 1
3, 13, 23, ..., 10*n*+3, ...	SOC message bits 2 and 3
5, 15, 25, ... , 10*n*+5, ...	SOC message bits 4 and 5
7, 17, 27, ..., 10*n*+7, ...	SOC message bits 6 and 7
9, 19, 29, ..., 10*n*+9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of the MEDLEYds subcarriers in O-P-TRAINING 2 shall be the same as for O-P-TRAINING 1.

12.3.4.3.1.9 O-P-SYNCHRO 5

The O-P-SYNCHRO 5 is a signal that provides an exact time marker for transitions from O-P-TRAINING 2 to O-P-MEDLEY (the beginning of the channel analysis and exchange phase).

O-P-SYNCHRO 5 shall be identical to O-P-SYNCHRO 4.

12.3.4.3.2 Signals transmitted by the VTU-R

12.3.4.3.2.1 R-P-QUIET 2

R-P-QUIET 2 shall provide a zero output voltage at the U reference point. All subcarriers shall be transmitted at zero power. The duration of R-P-QUIET 2 is left to the discretion of the VTU-R but shall not exceed 4 096 DMT symbols with CE.

12.3.4.3.2.2 R-P-TRAINING 1

The R-P-TRAINING 1 signal is the first signal sent by the VTU-R after re-establishing synchronization. During transmission of R-P-TRAINING 1, the SOC is in its inactive state.

The duration of R-P-TRAINING 1 is variable.

R-P-TRAINING 1 shall be composed of all subcarriers in the MEDLEYus set. These subcarriers shall be modulated by 4-QAM. R-P-TRAINING 1 carries one byte per DMT symbol. The one byte and the mapping of bits to subcarriers shall be as shown in Table 12-45.

Table 12-45 – Bit mapping for R-P-TRAINING 1

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10*n*+1, ...	01
3, 13, 23, ..., 10*n*+3, ...	11
5, 15, 25, ..., 10*n*+5, ...	11
7, 17, 27, ..., 10*n*+7, ...	10
9, 19, 29, ..., 10*n*+9, ...	00

The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us}+L_{CE}$ samples. The overall window length shall be equal to β_{us}.

The transmit PSD of the MEDLEYus subcarriers in R-P-TRAINING 1 shall be equal to the upstream MEDLEY reference PSD (MREFPSDus) communicated in Field #2 of R-PRM.

12.3.4.3.2.3 R-P-SYNCHRO 4

R-P-SYNCHRO 4 provides an exact time marker for transition from R-P-TRAINING 1 to R-P-TEQ. During transmission of R-P-SYNCHRO 4, the SOC is in its inactive state.

The duration of R-P-SYNCHRO 4 is 15 DMT symbols.

R-P-SYNCHRO 4 shall use all subcarriers in the MEDLEYus set modulated by 4-QAM. The value 11 shall be mapped to all MEDLEYus subcarriers for the first 5 and the last 5 DMT symbols. The value 00 shall be mapped to all MEDLEYus subcarriers for the middle 5 DMT symbols. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us}+L_{CE}$ samples. The overall window length shall be equal to β_{us}.

The transmit PSD of the MEDLEYus subcarriers in R-P-SYNCHRO 4 shall be the same as for R-P-TRAINING 1.

12.3.4.3.2.4 R-P-TEQ

R-P-TEQ is a periodic signal. It allows the VTU-O to train its TEQ. During the transmission of R-P-TEQ, the SOC is in its inactive state.

The duration of R-P-TEQ is $T_{VTU\text{-}O\_TEQ}$ DMT symbols with CE. The value of $T_{VTU\text{-}O\_TEQ}$ shall be set to the maximum of the durations requested by the VTU-R in R-PRM and by the VTU-O in O-PRM.

R-P-TEQ shall use all of the subcarriers from the MEDLEYus set, as well as the out-of-MEDLEYus subcarriers with indices between 1 and t_{US0_stop} + 32, where t_{US0_stop} is the highest-index subcarrier included in US0.

R-P-TEQ shall map the 4-QAM value of 11 on each subcarrier. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

R-P-TEQ shall be constructed as described in clause 12.3.6.1.

The transmit PSD of the MEDLEYus subcarriers in R-P-TEQ shall be the same as for R-P-TRAINING 1. The transmit PSD shall incorporate the tss_i values that were sent by the VTU-R during the channel discovery phase (see clause 12.3.3.2.2.3).

12.3.4.3.2.5 R-P-QUIET 3

R-P-QUIET 3 shall provide a zero output voltage at the U reference point. All subcarriers shall be transmitted at zero power. The duration of R-P-QUIET 3 shall be T_{VTU-R_TEQ} + T_{VTU-O_EC} DMT symbols with CE.

12.3.4.3.2.6 R-P-ECT

The R-P-ECT signal allows the VTU-R to train its echo canceller. R-P-ECT is a vendor-discretionary signal. During transmission of R-P-ECT, the SOC is in its inactive state.

The duration of R-P-ECT is T_{VTU-R_EC} DMT symbols with CE. The value T_{VTU-R_EC} shall be as indicated by the VTU-R in R-PRM.

The PSD of R-P-ECT shall respect MREFMASKus as established at the conclusion of the channel discovery phase.

12.3.4.3.2.7 R-P-PERIODIC 2

R-P-PERIODIC 2 is a periodic signal. During the transmission of R-P-PERIODIC 2, the SOC is in its inactive state.

The duration of R-P-PERIODIC 2, $T_{Periodic}$ DMT symbols with CE, is the maximum of the durations requested by the VTU-O in O-PRM and by the VTU-R in R-PRM.

R-P-PERIODIC 2 shall be composed of all subcarriers in the MEDLEYus set. These subcarriers shall be modulated by 4-QAM. The value 11 shall be mapped to each subcarrier. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

R-P-PERIODIC 2 shall be constructed as described in clause 12.3.6.1.

The transmit PSD of the MEDLEYus subcarriers in R-P-PERIODIC 2 shall be the same as for R-P-TRAINING 1.

12.3.4.3.2.8 R-P-TRAINING 2

The R-P-TRAINING 2 signal re-establishes SOC message exchange between the VTU-O and VTU-R. During transmission of R-P-TRAINING 2, the SOC is in its active state.

The duration of R-P-TRAINING 2 is variable. The VTU-R terminates R-P-TRAINING 2 when it receives O-P-SYNCHRO 5.

R-P-TRAINING 2 shall be composed of all subcarriers in the MEDLEYus set. These subcarriers shall be modulated by 4-QAM. R-P-TRAINING 2 shall carry one byte of information per DMT symbol. The bit mapping shall be as summarized in Table 12-46.

Table 12-46 – Bit mapping for R-P-TRAINING 2

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10*n*+1, ...	SOC message bits 0 and 1
3, 13, 23, ..., 10*n*+3, ...	SOC message bits 2 and 3
5, 15, 25, ..., 10*n*+5, ...	SOC message bits 4 and 5
7, 17, 27, ..., 10*n*+7, ...	SOC message bits 6 and 7
9, 19, 29, ..., 10*n*+9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us}+L_{CE}$ samples. The overall window length shall be equal to β_{us}.

The transmit PSD of the MEDLEYus subcarriers in R-P-TRAINING 2 shall be the same as for R-P-TRAINING 1.

12.3.4.3.2.9 R-P-SYNCHRO 5

R-P-SYNCHRO 5 is a signal that provides an exact time marker for transition from R-P-TRAINING 2 to R-P-MEDLEY (the beginning of the channel analysis and exchange phase).

R-P-SYNCHRO 5 shall be identical to R-P-SYNCHRO 4.

12.3.5 Channel analysis and exchange phase

12.3.5.1 Overview

During the channel analysis and exchange phase, SNR estimation is performed. Both VTUs exchange their capabilities and the final configuration for both upstream and downstream transmission is selected on the basis of these capabilities.

Figure 12-10 presents the timing diagram for the stages of the channel analysis and exchange phase. It gives an overview of the sequence of signals transmitted and the sequence of SOC messages sent by the VTU-O and VTU-R during the channel analysis and exchange phase. The two inner columns show the sequences of signals that are transmitted (see clause 12.3.5.3). The two outer columns show the messages that are sent over the SOC (see clause 12.3.5.2). The shaded areas correspond to periods of time when the SOC is in its inactive state.

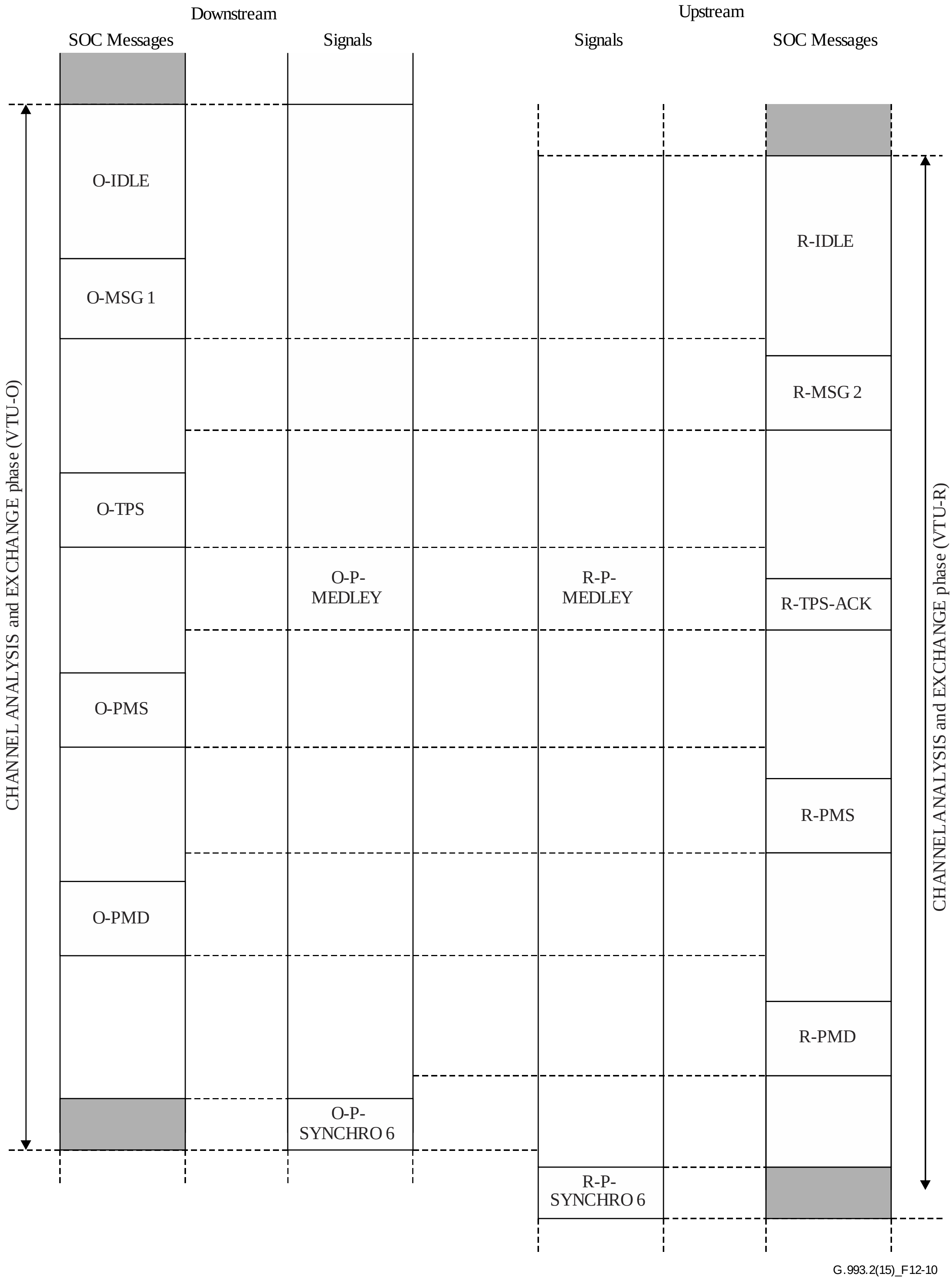

Figure 12-10 – Timing diagram for the stages of the channel analysis and exchange phase

NOTE – In the exchange of the SOC messages identified in Figure 12-10, the rules of the communication protocol of clause 12.2.2 apply. Some messages sent in the SOC may require segmentation; although this is not shown in Figure 12-10, the segmented message elements and their corresponding acknowledgements are sent via the SOC as per the communication protocol of clause 12.2.2.

The channel analysis and exchange phase involves the following steps as shown in Figure 12-10:

1) The VTU-O sends the O-MSG 1 message, which contains its capabilities and a number of (downstream) configuration parameters.
2) The VTU-R replies by sending the R-MSG 2 message, which indicates its capabilities.
3) The VTU-O sends the O-TPS message to indicate the configuration of the bearer channels and their required capabilities for both the upstream and the downstream directions.
4) The VTU-R acknowledges the O-TPS message with the R-TPS-ACK message.
5) The VTU-O conveys the upstream PMS-TC (framing) parameters by sending the O-PMS message.
6) The VTU-R conveys the downstream PMS-TC (framing) parameters by sending the R-PMS message.
7) The VTU-O sends the O-PMD message, which contains the bits, gains and tone ordering tables for the upstream PMD.
8) The VTU-R sends the R-PMD message, which contains the bits, gains and tone ordering tables for the downstream PMD.

After sending R-PMD, the VTUs are ready to transition to showtime. The trigger for stepping into showtime shall be given by O-P-SYNCHRO 6 and R-P-SYNCHRO 6 for the downstream and upstream transmission directions, respectively. R-P-SYNCHRO 6 shall be transmitted within 64 symbols of detecting O-P-SYNCHRO 6.

The first DMT symbol following O-P-SYNCHRO 6 shall be the first downstream symbol of showtime. Likewise, the first DMT symbol following R-P-SYNCHRO 6 shall be the first upstream symbol of showtime. The PMD, PMS-TC and TPS-TC parameter settings negotiated during the channel analysis and exchange phase shall be set starting from the first symbol of showtime.

The signals and SOC messages sent by the VTU-O during the channel analysis and exchange phase are summarized in Table 12-47, and the signals and SOC messages sent by the VTU-R during the channel analysis and exchange phase are summarized in Table 12-48. The protocol used for SOC messages is provided, where applicable, in parentheses in the column labelled "SOC state".

Table 12-47 – VTU-O signals and SOC messages in the channel analysis and exchange phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
O-P-MEDLEY	Non-periodic	Variable	O-MSG 1, O-TPS, O-PMS, O-PMD	Active (RQ)
O-P-SYNCHRO 6	Non-periodic	15	None	Inactive

Table 12-48 – VTU-R signals and SOC messages in the channel analysis and exchange phase

Signal	Signal type	Signal duration in DMT symbols with CE	SOC messages	SOC state
R-P-MEDLEY	Non-periodic	Variable	R-MSG 2, R-TPS-ACK, R-PMS, R-PMD	Active (RQ)
R-P-SYNCHRO 6	Non-periodic	15	None	Inactive

12.3.5.2 SOC messages exchanged during channel analysis and exchange phase

Figure 12-11 illustrates the SOC message exchange between the VTU-O and VTU-R during the channel analysis and exchange phase. It also summarizes the content of each message.

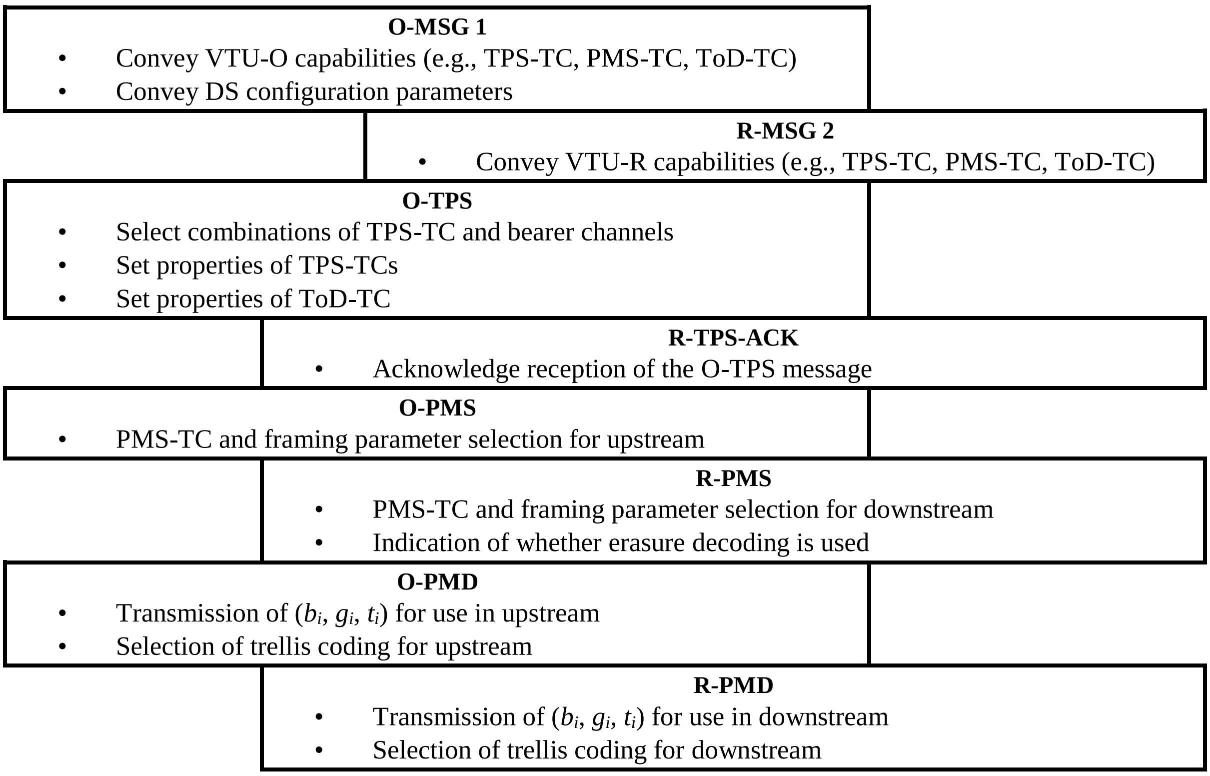

Figure 12-11 – SOC messages exchanged during the channel analysis and exchange phase

12.3.5.2.1 VTU-O messages sent during the channel analysis and exchange phase

12.3.5.2.1.1 O-MSG 1

The O-MSG 1 message contains the capabilities of the VTU-O and the requirements for downstream transmission (such as margin). The full list of parameters carried by the O-MSG 1 message is shown in Table 12-49.

Table 12-49 – Description of message O-MSG 1

	Field name	Format
1	Message descriptor	Message code
2	Downstream target SNR margin (TARSNRMds)	2 bytes
3	Downstream minimum SNR margin (MINSNRMds)	2 bytes
4	Downstream maximum SNR margin (MAXSNRMds)	2 bytes
5	RA-MODE	1 byte
6	NTR	1 byte
7	TPS-TC capabilities	see Table 12-50
8	PMS-TC capabilities	see Table 12-52
9	Downstream Rate adaptation downshift SNR margin (RA-DSNRMds)	2 bytes
10	Downstream Rate adaptation downshift time interval (RA-DTIMEds)	2 bytes
11	Downstream Rate adaptation upshift SNR margin (RA-USNRMds)	2 bytes
12	Downstream Rate adaptation upshift time interval (RA-UTIMEds)	2 bytes
13	Support of "Flexible OH frame Type 2" downstream and INM_INPEQ_FORMATds	1 byte
14	SOS Multi-step activation downstream	1 byte
15	SOS Multi-step activation upstream	1 byte
16	MIN-SOS-BR-ds0	2 bytes
17	MIN-SOS-BR-ds1	2 bytes
18	SOS-TIME-ds	1 byte
19	SOS-NTONES-ds	1 byte
20	SOS-CRC-ds	2 bytes
21	MAX-SOS-ds	1 byte
22	SNRMOFFSET-ROC-ds	2 bytes
23	INPMIN-ROC-ds	1 byte
24	ITU- T G.998.4 parameter field	Variable length
25	ITU-T G.993.5 parameter field	Variable length
26	REINIT_TIME_THRESHOLDds	1 byte
27	Time synchronization capability	1 byte

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Downstream target SNR margin (TARSNRMds)" indicates the target SNR margin of the VTU-R receiver. The definition and use of this parameter shall be the same as for the parameter "Downstream Target Noise Margin (TARSNRMds)" specified in [ITU-T G.997.1]. The value and format of this parameter shall be the same as that in Field #12 of O-SIGNATURE (see clause 12.3.3.2.1.1).

Field #3 "Downstream minimum SNR margin (MINSNRMds)" is the minimum SNR margin the VTU-R shall tolerate. The definition and use of this parameter shall be the same as for the parameter "Downstream Minimum Noise Margin (MINSNRMds)" specified in [ITU-T G.997.1]. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 0.1 dB and a valid range between 0 and 31 dB.

Field #4 "Downstream maximum SNR margin (MAXSNRMds)". The value and format for this parameter shall be the same as in Field #11 of O-SIGNATURE (see clause 12.3.3.2.1.1).

NOTE – Improper setting of one or more of the following parameters – maximum net data rate, downstream maximum SNR margin, impulse noise protection, maximum interleaving delay (in SNRM_MODE=1), and TXREFVN (in SNRM_MODE=2) – can result in high levels of transmit power that can lead to high crosstalk experienced by DSLs on other pairs in the same binder. Specifically, high values of maximum net data rate, downstream maximum SNR margin, impulse noise protection, low values of maximum interleaving delay (in SNRM_MODE=1), and high values of TXREFVN (in SNRM_MODE=2) are of concern.

Field #5 "RA-MODE" specifies the mode of operation of a rate-adaptive VTU-O in the downstream direction as defined in [ITU-T G.997.1]. This field shall be coded as an 8-bit integer with valid values 01_{16}, 02_{16}, 03_{16} and 04_{16} for RA-MODE 1, 2, 3 and 4, respectively.

Field #6 "NTR" shall be set to 01_{16} if the VTU-O is transporting the NTR signal in the downstream direction, otherwise it shall be set to 00_{16}.

Field #7 "TPS-TC capabilities" indicates the TPS-TC capabilities of the VTU-O as shown in Table 12-50.

Field #8 "PMS-TC capabilities" indicates the PMS-TC capabilities of the VTU-O. This includes the supported latency paths at the VTU-O (DS and US) and the capabilities per path (such as supported coding and interleaver parameters), as shown in Table 12-52.

Field #9 "Downstream Rate adaptation downshift SNR margin (RA-DSNRMds)": The definition and use of this parameter is specified in clause 13.4. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 0.1 dB and has a valid range between 0 and 31.0 dB.

Field #10 "Downstream Rate adaptation downshift time interval (RA-DTIMEds)": The definition and use of this parameter is specified in clause 13.4. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 1 s and has a valid range between 0 and 16 383 s.

Field #11 "Downstream Rate adaptation upshift SNR margin (RA-USNRMds)": The definition and use of this parameter is specified in clause 13.4. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 0.1 dB and has a valid range between 0 and 31.0 dB.

Field #12 "Downstream Rate adaptation upshift time interval (RA-UTIMEds)": The definition and use of this parameter is specified in clause 13.4. The field shall be formatted as a 16-bit unsigned integer with LSB weight of 1 s and has a valid range between 0 and 16 383 s.

Field #13 indicates the support by the VTU-O of the "Flexible OH Frame Type 2" and INM_INPEQ_FORMATds in the downstream direction. The field shall be formatted as [0000 00ba]. The VTU-O shall indicate support by setting, respectively, a=1 and b=1 in this field. Other bits shall be set to 0 and are reserved by ITU-T.

Field #14 indicates the capabilities of the VTU-O to execute the SOS request in one step or in multiple steps in the downstream direction. The field is formatted as [gggg 0000]. The first four MSBs [gggg] indicate the maximum number of tones (G_{SOS}) that can be executed in a single step in the downstream direction. The valid values are:

– [0000]: All tones
– [0010]: G_{SOS} = 256 tones
– [0011]: G_{SOS} = 512 tones
– [0100]: G_{SOS} = 1 024 tones

If SOS is supported, value G_{SOS} = 256 tones is a mandatory capability. If the VTU supports a particular value of G_{SOS}, it shall support all smaller values of G_{SOS} (and values T_{SOS} associated with them, as presented in Table 13-4).

Each G_{SOS} has a value of T_{SOS} associated with it, where T_{SOS} is the time (in symbols) between the execution of two successive groups of tones (see clause 13.3).

If the CO does not support SOS in the downstream direction, this field shall contain a value within the specified valid range. This value shall be ignored at the receiver.

Field #15 indicates the capabilities of the VTU-O to execute the SOS request in one step or in multiple steps in the upstream direction. The format of the field and the valid values shall be the same as for field #14.

If the CO does not support SOS in the upstream direction, this field shall contain a value within the specified valid range. This value shall be ignored at the receiver. Field #16 Contains the value of the MIN-SOS-BR-ds0 as specified in the MIB. The parameter MIN-SOS-BR-ds0 is defined as the minimum net data rate required for a valid SOS request in the downstream direction (see clause 13.4) for bearer channel 0. The value shall be coded as an unsigned integer representing the data rate as a multiple of 8 kbit/s.

Field #17 Contains the value of the MIN-SOS-BR-ds1 as specified in the MIB. The parameter MIN-SOS-BR-ds1 is defined as the minimum net data rate required for a valid SOS request in the downstream direction (see clause 13.4) for bearer channel 1. The value shall be coded as an unsigned integer representing the data rate as a multiple of 8 kbit/s.

When only one bearer channel is supported, the value of Field #16 or Field #17 corresponding to the other bearer channel shall be set to $FFFF_{16}$. When two bearer channels are supported (as would be the case for dual latency or single latency with two bearer channels mapped into the single latency path) both fields shall contain valid values.

Field #18 Contains the value of the SOS triggering parameter SOS-TIME-ds as specified in the MIB. The parameter is used in the specification of the receiver initiated SOS (see clause 13.4.3). The special value zero, indicates that the standard SOS triggering criteria are disabled. If the value of this parameter is not zero, the standard SOS triggering criteria are enabled, and the value corresponds with duration of the time window used in the standard SOS triggering criteria.

The value shall be coded as an unsigned integer representing the duration of the time window as a multiple of 64 ms. The valid range of the non-zero values is from 64 to 16 320 ms.

Field #19 Contains the value of the SOS triggering parameter SOS-NTONES-ds as specified in the MIB. The parameter is used in the specification of the receiver initiated SOS (see clause 13.4.3). The parameter SOS-NTONES-ds is defined as a percentage of tones.

The valid range of values is from 0 to 100 in steps of 1. A special value of 0 indicates that SOS-NTONES-ds is not used in the decision criteria.

Field #20 Contains the value of the SOS triggering parameter SOS-CRC-ds as specified in the MIB. The parameter is used in the specification of the receiver initiated SOS (see clause 13.4.3).

The valid range of SOS-CRC-ds values is 0.02 to ((2^16)-1)×0.02, in steps of 0.02.

Field #21 Contains the value of MAX-SOS-ds as specified in the MIB. This parameter contains the maximum allowed number of successful SOS procedures within 120 seconds before the VTU-R shall transition to L3 state (see clause 12.1.4). The valid range of values is from 0 to 15. A special value of 0 indicates that there is no limit on the maximum allowed number of SOS recoveries within this time interval.

If the CO does not support SOS in the downstream direction, the fields #16 to #21 shall contain a value within the specified valid range for each of the parameters. These values shall be ignored at the receiver.

Field #22 contains the value of SNRMOFFSET-ROCds as specified in the MIB. The parameter is defined as the SNR Margin offset for the ROC in the downstream direction. This means that the target margin for the ROC is obtained by adding this value to TARSNRM (i.e., TARSNRM-ROC = TARSNRM + SNRMOFFSET-ROC).

The parameter TARSNRM-ROC is used in the specification of the channel initialization policy (see clause 12.3.7.1).

The value shall be coded as an 16 bit unsigned integer with LSB weight of 0.1 dB. The valid range of values is from 0 to 31 dB with 0.1 dB steps.Field #23 contains the value of INPMIN-ROCds expressed in multiples of T_{4k} as specified in the MIB. The value of INPMIN-ROCds expressed in DMT symbols (as to be used by the VTU-R receiver as specified in clause 9.6), is calculated as follows:

For 4.3125 kHz subcarrier spacing:

INPMIN-ROCds in DMT symbols = INPMIN-ROCds in multiples of T_{4k}.

For 8.625 kHz subcarrier spacing:

INPMIN-ROCds in DMT symbols = 2 × (INPMIN-ROCds in multiples of T_{4k}).

with T_{4k} as defined in clause 10.4.4.

The parameter INPMIN-ROCds (in DMT symbols) is defined as the required INP_no_erasure value for the ROC (see clause 9.6). The value of field #23 is an integer in the range from 0 to 8.

If the CO does not support a robust overhead channel in the downstream direction, the fields #22 and #23 shall contain a value within the specified valid range for each of the parameters. These values shall be ignored at the receiver.

Field #24 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #25 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 24 and 25 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

Field #26 control parameter "*REINIT_TIME_THRESHOLDds*" contains the threshold for re-initialization based on SES as specified in the CO-MIB, to be used in downstream by the VTU-R receiver when Re-Initialization Policy 1 is used (see clause 12.4.1). The value shall be coded as an unsigned integer representing the maximum number of SES. The valid range is from 5 to 31.

Field #27 "Time Synchronization capability" indicates the time synchronization capability of the VTU-O. The field shall be coded as a single byte [0000 000t], where:

- t=0 indicates that time synchronization is not supported;
- t=1 indicates that time synchronization is supported.

Table 12-50 – TPS-TC capabilities of the VTU-O

Field name	Format	Description
Maximum number of downstream TPS-TCs of each type	1 byte: [ssaapp00]	Indicates the maximum number of TPS-TCs of each type that the VTU-O supports in the downstream direction: • ss=max number of downstream STM TPS-TCs (0,1,2); • aa=max number of downstream ATM TPS-TCs (0,1,2); and • pp=max number of downstream PTM TPS-TCs (0,1,2)
Maximum number of upstream TPS-TCs of each type	1 byte: [ssaapp00]	Indicates the maximum number of TPS-TCs of each type that the VTU-O supports in the upstream direction: • ss=max number of upstream STM TPS-TCs (0,1,2); • aa=max number of upstream ATM TPS-TCs (0,1,2); and • pp=max number of upstream PTM TPS-TCs (0,1,2)
Supported combinations of downstream bearer channels and TPS-TCs	1 byte: [$s_0a_0p_0$ 0 $s_1a_1p_1$ 0]	s_0: equal to 1 if STM can be supported on bearer channel 0 a_0: equal to 1 if ATM can be supported on bearer channel 0 p_0: equal to 1 if PTM can be supported on bearer channel 0 s_1: equal to 1 if STM can be supported on bearer channel 1 a_1: equal to 1 if ATM can be supported on bearer channel 1 p_1: equal to 1 if PTM can be supported on bearer channel 1
Supported combinations of upstream bearer channels and TPS-TCs	1 byte: [$s_0a_0p_0$ 0 $s_1a_1p_1$ 0]	s_0: equal to 1 if STM can be supported on bearer channel 0 a_0: equal to 1 if ATM can be supported on bearer channel 0 p_0: equal to 1 if PTM can be supported on bearer channel 0 s_1: equal to 1 if STM can be supported on bearer channel 1 a_1: equal to 1 if ATM can be supported on bearer channel 1 p_1: equal to 1 if PTM can be supported on bearer channel 1
For each supported TPS-TC, a bearer channel descriptor (see Table 12-51) shall be appended to the message.		
Downstream STM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported downstream STM TPS-TCs.
Downstream ATM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported downstream ATM TPS-TCs.
Downstream PTM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported downstream PTM TPS-TCs.
Upstream STM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported upstream STM TPS-TCs.
Upstream ATM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported upstream ATM TPS-TCs.
Upstream PTM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported upstream PTM TPS-TCs.
NOTE – The number of bearer channel descriptors for the TPS-TC capabilities depends on the fields "Maximum number of downstream/upstream TPS-TCs".		

Table 12-51 – Bearer channel descriptor

Octet	Content of field
1-2	Minimum net data rate (net_min_n)
3-4	Maximum net data rate (net_max_n)
5-6	Reserved net data rate ($net\_reserve_n$) (Note)
7	Maximum interleaving delay
8	Impulse noise protection and dynamic interleaver reconfiguration
9	TPS-TC options
NOTE – This parameter is not used in this version of this Recommendation and shall be set to the value of the minimum net data rate in octets 1 and 2. The OLR procedures that utilize this parameter will be defined in a future revision of this Recommendation.	

In the fields "Minimum net data rate", "Maximum net data rate" and "Reserved net data rate", the parameter values for net_min_n, net_max_n and $net\_reserve_n$, respectively, shall be coded as unsigned integers representing the data rate as a multiple of 8 kbit/s.

The fields "Maximum interleaving delay" and "Impulse noise protection" are not applicable in O-MSG 1 (which communicates capabilities), and the values of octets 7 and 8 in each bearer channel descriptor shall be ignored by the VTU-R receiver.

The field "TPS-TC options" shall contain one octet to negotiate and select the options for this bearer. The content depends on the type of TPS-TC mapped on this bearer.

For a bearer mapped to a PTM TPS-TC, the octet shall be coded as follows:

- Bit 0: If the VTU-O supports pre-emption in this bearer (N.3.1.2 of [ITU-T G.992.3]), the bit shall be set to ONE.
- Bit 1: If the VTU-O supports short packets in this bearer (N.3.1.3 of [ITU-T G.992.3]), the bit shall be set to ONE.
- Bits 2-7 are reserved by ITU-T and set to ZERO.

For a bearer mapped to an ATM or STM TPS-TC, the TPS-TC options field is reserved by the ITU-T and shall be set to 00_{16}.

Table 12-52 – PMS-TC capabilities of the VTU-O

Field name	Format	Description
Downstream OLR capabilities	1 byte [rrufdsii]	Indicates the support of optional OLR mechanisms in the downstream direction. f = 0 if downstream framing reconfiguration (change of T_p, G_p and B_{p0}) is not supported, f = 1 otherwise (Note 1). d is reserved by ITU-T for future use and shall be set to ZERO. s = 0 if downstream SRA (change of L_p, b_i, g_i) is not supported, s = 1 otherwise. ii = 00 if interleaver reconfiguration (change of D_p) is not supported, ii = 01 if interleaver reconfiguration is supported on one downstream latency path, ii = 11 if interleaver reconfiguration is supported on both downstream latency paths (Note 2). ii = 10 is reserved by the ITU-T. u =0 if downstream SOS is not supported, u=1 otherwise (Notes 3, 4) rr=00 indicates that the ROC in the downstream direction is not supported at the VTU-O. rr=01 indicates that the ROC in the downstream direction is supported, but dual latency mode is not. rr=11 indicates that both the ROC and dual latency mode shall be supported in the downstream direction, but only one of these can be enabled at a given time. rr = 10 is reserved by the ITU-T.
Upstream OLR capabilities	1 byte [rrufdsii]	Indicates the support of optional OLR mechanisms in the upstream direction. f = 0 if upstream framing reconfiguration (change in T_p, G_p and B_{p0}) is not supported, f = 1 otherwise (Note 1). d is reserved by ITU-T for future use and shall be set to ZERO. s = 0 if upstream SRA (change of L_p, b_i, g_i) is not supported, s = 1 otherwise. ii = 00 if interleaver reconfiguration (change of D_p) is not supported, ii = 01 if interleaver reconfiguration is supported on one upstream latency path, ii = 11 if interleaver reconfiguration is supported on both upstream latency paths (Note 2). ii = 10 is reserved by the ITU-T. u =0 if upstream SOS is not supported, u=1 otherwise (Notes 3, 4) rr=00 indicates that the ROC in the upstream direction is not supported at the VTU-O. rr=01 indicates that the ROC in the upstream direction is supported, but dual latency mode is not. rr=11 indicates that both the ROC and dual latency mode shall be supported in the upstream direction, but only one of these can be enabled at a given time. rr = 10 is reserved by the ITU-T.
Downstream message overhead data rate (Note 5)	1 byte	Minimum message overhead data rate that is needed by the VTU-O in the downstream direction. The unsigned 8-bit value is the message overhead data rate divided by 1 000 bits per second minus 1 (covering the range 1 to 256 kbit/s).

Table 12-52 – PMS-TC capabilities of the VTU-O

Field name	Format	Description
Upstream message overhead data rate (Note 5)	1 byte	Minimum message overhead data rate that is needed by the VTU-O in the upstream direction. The unsigned 8-bit value is the message overhead data rate divided by 1 000 bits per second minus 1 (covering the range 1 to 256 kbit/s).
Max DS net data rate for latency path 0	2 bytes	Parameter block of 2 octets that describes the maximum downstream net data rate supported in latency path #0. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
Max US net data rate for latency path 0	2 bytes	Parameter block of 2 octets that describes the maximum upstream net data rate supported in latency path #0. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
Max DS net data rate for latency path 1	2 bytes	Parameter block of 2 octets that describes the maximum downstream net data rate supported in latency path #1. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
Max US net data rate for latency path 1	2 bytes	Parameter block of 2 octets that describes the maximum upstream net data rate supported in latency path #1. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
DS $(1/S)_{max}$	1 byte	Parameter block of 1 octet that describes the maximum value of 1/S supported by the VTU-O in the downstream direction as defined in clause 9.5.5. The unsigned 8-bit value is coded as 1 to 64 in steps of 1.
US $(1/S)_{max}$	1 byte	Parameter block of 1 octet that describes the maximum value of 1/S supported by the VTU-O in the upstream direction as defined in clause 9.5.5. The unsigned 8-bit value is coded as 1 to 64 in steps of 1.

NOTE 1 – If support for SOS is indicated, support for framing reconfiguration (change of T_p, G_p and B_{p0}) shall also be indicated.

NOTE 2 – In the case of single latency mode (i.e., without the ROC), the values for latency path 1 shall be set to ZERO. In the case of single latency with ROC mode, the values for latency path 0 shall be set to ZERO.

NOTE 3 – If downstream SOS is supported, support for interleaver depth reconfiguration in the downstream direction shall also be indicated. If upstream SOS is supported, support for interleaver depth reconfiguration in the upstream direction shall also be indicated.

NOTE 4 – If support for SOS is indicated, support for SRA shall also be indicated.

NOTE 5 – When the ROC is enabled, all overhead data shall be carried in latency path #0 (the ROC).

12.3.5.2.1.2 O-TPS

The O-TPS message conveys the TPS-TC configuration for both the upstream and the downstream directions. It is based on the capabilities that were indicated in O-MSG 1 and R-MSG 2. The full list of parameters carried by the O-TPS message is shown in Table 12-53.

Table 12-53 – Description of message O-TPS

	Field name	Format
1	Message descriptor	Message code
2	TPS-TC configuration	See Table 12-54
3	Maximum delay variation	See Table 12-55
4	ROC and SOS enable	1 byte
5	ITU-T G.998.4 parameter field	Variable length
6	ITU-T G.993.5 parameter field	Variable length
7	Time synchronization enable	1 byte
8	*attndr_method*	1 byte

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "TPS-TC configuration" specifies the TPS-TC configuration in the upstream and downstream directions, and is structured as shown in Table 12-54.

Field #3 "Maximum delay variation" specifies the maximum delay variation for each active bearer channel in the downstream direction, and is structured as shown in Table 12-55.

Field #4 indicates whether the ROC and SOS are enabled. It is a one byte value [ssss rrrr].

The value rrrr shall be coded as follows:

- A value rrrr=0000 indicates that the ROC is not enabled in either upstream or downstream;
- A value rrrr=0001 indicates that the ROC is enabled in upstream but not in downstream;
- A value rrrr=0010 indicates that the ROC is enabled in downstream but not in upstream;
- A value rrrr=0011 indicates that the ROC is enabled in both upstream and downstream.

The value ssss shall be coded as follows:

- A value ssss=0000 indicates that SOS is not enabled;
- A value ssss=0001 indicates that SOS is enabled in upstream but not in downstream;
- A value ssss=0010 indicates that SOS is enabled in downstream but not in upstream;
- A value ssss=0011 indicates that SOS is enabled in both upstream and downstream.

The value of ssss shall be set in accordance with ITU-T G.997.1 parameters RA-MODEds and RA-MODEus and the OLR capabilities in O-MSG 1 and R-MSG 2.

Table 12-54 – TPS-TC configuration

Field name	Format	Description
Mapped configurations of downstream bearer channels and TPS-TC types (Note 1)	1 byte: [aaaa bbbb]	aaaa = TPS-TC type that is mapped to DS bearer channel 0 • aaaa=1000: STM-TC • aaaa=0100: ATM-TC • aaaa=0010: PTM-TC • aaaa =0000: inactive bearer channel bbbb = TPS-TC type that is mapped to DS bearer channel 1 • bbbb =1000: STM-TC • bbbb =0100: ATM-TC • bbbb =0010: PTM-TC • bbbb =0000: inactive bearer channel
Mapped configurations of upstream bearer channels and TPS-TC types (Note 1)	1 byte: [cccc dddd]	cccc = TPS-TC type that is mapped to US bearer channel 0 • cccc =1000: STM-TC • cccc =0100: ATM-TC • cccc =0010: PTM-TC • cccc =0000: inactive bearer channel dddd = TPS-TC type that is mapped to US bearer channel 1 • dddd =1000: STM-TC • dddd =0100: ATM-TC • dddd =0010: PTM-TC • dddd =0000: inactive bearer channel
Downstream rate adaptation ratio	1 byte	This field contains the rate adaptation ratio of downstream bearer channel 0 as specified in [ITU-T G.997.1]. This field shall be coded as an unsigned integer in the range from 0 to 100. A value of 100 means that the whole excess capacity is allocated to bearer channel 0.
For each active bearer channel in each direction, a bearer channel descriptor (see Table 12-51) shall be appended to the message:		
Downstream bearer channel 0 configuration	0, or 1 bearer channel descriptor	Contains the required configuration of the downstream bearer 0
Downstream bearer channel 1 configuration	0, or 1 bearer channel descriptor	Contains the required configuration of the downstream bearer 1
Upstream bearer channel 0 configuration	0, or 1 bearer channel descriptor	Contains the required configuration of the upstream bearer 0
Upstream bearer channel 1 configuration	0 or 1 bearer channel descriptor	Contains the required configuration of the upstream bearer 1
NOTE 1 – Some simultaneous mappings of TPS-TCs are invalid (see clause 8.1.3.1). NOTE 2 – The number of bearer channel descriptors for the bearer channel configurations depends on the number of active bearer channels in each direction.		

In each bearer channel descriptor, the fields "Minimum net data rate", "Maximum net data rate" and "Reserved net data rate" shall contain the values for net_min_n, net_max_n and $net\_reserve_n$, respectively, selected by the VTU-O. Each shall be coded as an unsigned integer representing the data rate as a multiple of 8 kbit/s.

In the field "Maximum interleaving delay", the parameter $delay\_max_n$ shall be coded as an unsigned integer expressing delay in ms as follows:

- The valid values are $0 \leq delay\_max_n \leq 63$, and $delay\_max_n = 255$;
- The value $delay\_max_n = 1$ is a special value indicating that the interleaver depth D_p shall be set to $D_p = 1$, corresponding to the lowest possible delay;
- The value $delay\_max_n = 0$ is a special value indicating that no bound on the maximum delay is being imposed;
- The value $delay\_max_n = 255$ is a special value indicating an interleaving delay of 1 ms.

If the bearer channel is operated without physical layer retransmission as defined in [ITU-T G.998.4], then the field "Impulse noise protection and dynamic interleaver reconfiguration" shall be coded as follows:

- Bits 0-5 shall contain the required INP_min_n value expressed in DMT symbols;
- The valid values are $0 \leq INP\_min_n \leq 16$;
- The value $INP\_min_n = 0$ is a special value indicating that no minimum level of impulse noise protection is required;
- Bit 6 shall be set to 1 to indicate that the bearer should be mapped in a latency path that supports dynamic interleaver reconfiguration. When no latency paths support dynamic interleaver reconfiguration or when the bearer chooses not to use it, the value of this bit shall be ZERO;

  NOTE 1 – For both upstream and downstream transmission, the number of bearer channels that set the value of bit 6 to ONE cannot be higher than the number of latency paths that support interleaver reconfiguration.
- Bit 7: INP_no_erasure_required (see clause 9.6)
  - When set to ONE, it indicates that the VTU-R receiver shall set $INP_p = INP\_no\_erasure_p$;
  - When set to ZERO, it indicates that the VTU-R receiver is not required to set $INP_p = INP\_no\_erasure_p$.

If the bearer channel is operated with physical layer retransmission, as defined in [ITU-T G.998.4], then the field "Impulse noise protection and dynamic interleaver reconfiguration" shall be coded as follows:

- Bits 0-6 shall contain the required INP_min_n value expressed in DMT symbols;
- Bit 7 shall be reserved for use by ITU-T and shall be set to ZERO.

NOTE 2 – Improper setting of one or more of the following parameters – maximum net data rate, downstream maximum SNR margin, impulse noise protection, maximum interleaving delay (in SNRM_MODE=1), TXREFVN (in SNRM_MODE=2 and SNRM_MODE=4), RXREFVN (in SNRM_MODE=3 and SNRM_MODE=4), and TXREFVNSF and RXREFVNSF (in SNRM_MODE=4) can result in high levels of transmit power that can lead to high crosstalk experienced by DSLs on other pairs in the same binder. Specifically, high values of maximum net data rate, downstream maximum SNR margin, impulse noise protection, low values of maximum interleaving delay (in SNRM_MODE=1), and high values of TXREFVN (in SNRM_MODE=2 and SNRM_MODE=4), RXREFVN (in SNRM_MODE=3 and SNRM_MODE=4), and TXREFVNSF and RXREFVNSF (in SNRM_MODE=4) are of concern.

The field "TPS-TC options" shall be coded as follows:

- Bit 0: The bit shall be set to ONE to enable pre-emption in this bearer, if and only if the bit was set to ONE for this bearer in both O-MSG 1 and R-MSG 2;

- Bit 1: The bit shall be set to ONE to enable short packets in this bearer, if and only if the bit was set to ONE for this bearer in both O-MSG 1 and R-MSG 2.

For a bearer mapped to an ATM or STM TPS-TC, bits 0 and 1 of the TPS-TC options field are reserved by ITU-T and shall be set to ZERO.

For the upstream bearer channel(s), bits 2-7 shall be set to ZERO.

For the downstream bearer channel(s), bits 2-7 shall be coded as follows:

- Bits 3-2 contains the selection of the CIpolicy that shall be used in the downstream direction. A value of 00_2 indicates that the mandatory CIpolicy shall be used. A value of 01_2 indicates that the optional CIpolicy 1 (see clause 12.3.7) shall be used. A value of 10_2 indicates that the optional CIpolicy 2 (see clause 12.3.7) shall be used. The CO shall only select optional CIpolicies for which the VTU-R has indicated support (see clause 12.3.5.2.2.1). A value different from 00_2 can only be selected if no more than one bearer channel is active;
- Bit 4 contains the selection of the Re-Initialization Policy that shall be used in the downstream direction for that bearer channel ($RIpolicyds_n$). A value of ZERO indicates that the mandatory Re-Initialization Policy 0 shall be used. A value of ONE indicates that the optional Re-Initialization Policy 1 (see clause 12.1.4) shall be used. The same value shall be indicated for all bearer channels. The CO shall only select optional Re-Initialization Policies for which the VTU-R has indicated support (see clause 12.3.5.2.2.1);
- Bits 5-7 are reserved by the ITU-T and shall be set to ZERO.

Table 12-55 – Maximum delay variation

Field name	Format	Description
For each active bearer channel in downstream direction, a maximum delay variation field shall be present in this message:		
Downstream bearer channel 0 DV_max	0, or 1 byte (Note)	Contains the required DV_max of the downstream bearer 0
Downstream bearer channel 1 DV_max	0, or 1 byte (Note)	Contains the required DV_max of the downstream bearer 1
NOTE – The number of bytes is 0 if the bearer is disabled and is 1 if the bearer is enabled.		

The fields "Downstream bearer channel 0 DV_max" and "Downstream bearer channel 1 DV_max" describe the maximum allowed value for the delay variation and shall be coded as an unsigned integer equal to the DV_max divided by 0.1 ms.

- The valid values are $0 \leq DV\_max_n \leq 25.4$;
- The value FF_{16} is a special value indicating that no delay variation bound is imposed.

Field #5 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #6 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 5 and 6 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

Field #7 "Time Synchronization enable" indicates whether time synchronization is enabled. The field shall be formatted as [0000 00b_1b_0]. The valid values are:

- If b_1b_0=00, time synchronization is not enabled;
- If b_1b_0=01, frequency synchronization with the PMD sampling clock being frequency locked to the ToD network clock is used for time synchronization;
- If b_1b_0=10, frequency synchronization via the processing of ToD phase difference values is used for time synchronization;
- b_1b_0=11 is reserved by ITU-T.

Field #8 describes which method shall be used for the calculation of ATTNDR in the downstream direction. The field shall be formatted as [0000 00mm].

The value mm=00_b, respectively 01_b, respectively 10_b indicates that the VTU-R shall calculate the downstream ATTNDR using *attndr_method* = 0, respectively 1, respectively 2, as defined in clause 11.4.1.1.7.1, respectively clause 11.4.1.1.7.2.

The value mm=11_b is reserved by the ITU-T.

12.3.5.2.1.3 O-PMS

The O-PMS message conveys the initial PMS-TC parameter settings that shall be used in the upstream direction during Showtime. It also specifies the portion of shared interleaver memory that the VTU-R can use to de-interleave the downstream data stream. The full list of parameters carried by the O-PMS message is shown in Table 12-56.

Table 12-56 – Description of message O-PMS

	Field name	Format
1	Message descriptor	Message code
2	MSGLP (Note 1)	1 byte
3	Mapping of bearer channels to latency paths	1 byte
4	B_{x0}	1 byte
5	B_{x1}	1 byte
6	LP_0 (Note 2)	Latency path descriptor
7	LP_1	Latency path descriptor
8	$max\_delay\_octet_{DS,0}$	3 bytes
9	$max\_delay\_octet_{DS,1}$	3 bytes
10	$max\_delay\_octet_{US,0}$	3 bytes
11	$max\_delay\_octet_{US,1}$	3 bytes
12	Upstream SOS tone groups	Band descriptor
13	Upstream ROC parameters	ROC descriptor
14	ITU-T G.998.4 parameter field	Variable length
15	ITU-T G.993.5 parameter field	Variable length
16	$ATTNDR\_max\_delay\_octets_{DS,p}$	3 bytes
NOTE 1 – If the ROC is enabled, MSGLP shall be equal to 0. NOTE 2 – If the ROC is enabled, the framing parameters for latency path #0 shall be contained in the ROC descriptor.		

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "MSGLP" is a one-byte field that indicates which latency path is selected for OH frames of Type 1 (which carries message overhead) in the upstream direction. The seven MSBs of the byte shall always be set to ZERO. The LSB shall be set to ZERO to indicate latency path #0 or ONE to indicate latency path #1.

Field #3 "Mapping of bearer channels to latency paths" is a one-byte field that indicates which bearer channels shall be carried in each of the upstream latency paths. The byte is denoted as [cccc dddd]. The bits cccc shall be set to 0000 if bearer channel #0 is to be carried in latency path #0, and to 0001 if bearer channel #0 is to be carried in latency path #1. The bits cccc shall be set to 1111 if the bearer channel #0 is disabled. The bits dddd indicate which latency path carries bearer channel #1 using the same encoding method as used for cccc.

Field #4 "B_{x0}" is a one-byte field that indicates the number of octets from bearer channel #0 that shall be transported in each MDF in the upstream direction. The value shall be either zero or the non-zero value from the set {B_{00}, B_{10}}.

Field #5 "B_{x1}" is a one-byte field that indicates the number of octets from bearer channel #1 that shall be transported in each MDF in the upstream direction. The value shall be either zero or the non-zero value from the set {B_{01}, B_{11}}.

Field #6 "LP_0" is a 10-byte field that contains the PMS-TC parameters for latency path #0 in the upstream direction. The "Latency path descriptor" format specified in Table 12-57 shall be used.

Field #7 "LP_1" is a 10-byte field that contains the PMS-TC parameters for latency path #1 in the upstream direction. The "Latency path descriptor" format specified in Table 12-57 shall be used. If latency path #1 is not used, all bytes of LP_1 shall be set to ZERO.

Field #8 "$max\_delay\_octet_{DS,0}$" is a 3-byte field that specifies the maximum value of $delay\_octet_{DS,0}$ (defined in clause 6.2.8), specified in bytes as an unsigned integer.

Field #9 "$max\_delay\_octet_{DS,1}$" is a 3-byte field that specifies the maximum value of $delay\_octet_{DS,1}$ (defined in clause 6.2.8), specified in bytes as an unsigned integer. If the value of this field is set to the special value $FFFFFF_{16}$, the Field #8 ($max\_delay\_octet_{DS,0}$) specifies the maximum value of ($delay\_octet_{DS,0}$ + $delay\_octet_{DS,1}$) and the VTU-R shall autonomously partition the number of octets between both downstream latency paths. The value $FFFFFF_{16}$ is not allowed if the VTU intends to use interleaver reconfiguration in the downstream direction.

Field #10 "$max\_delay\_octet_{US,0}$" is a 3-byte field that specifies the maximum value of $delay\_octet_{US,0}$ (defined in clause 6.2.8), specified in bytes as an unsigned integer.

Field #11 "$max\_delay\_octet_{US,1}$" is a 3-byte field that specifies the maximum value of $delay\_octet_{US,1}$ (defined in clause 6.2.8), specified in bytes as an unsigned integer.

The values exchanged in Fields #8 to #11 shall be valid during initialization and showtime. In particular, interleaver reconfiguration in a given latency path shall not lead to an interleaver delay that exceeds the values exchanged in O-PMS for that latency path. Any OLR command that results in a delay value that is higher than the one exchange during initialization shall be rejected.

Field #12 contains the start and stop frequencies of the SOS tone groups (as defined in clause 13.3) for the upstream direction. It shall be formatted as a band descriptor (see Table 12-22), with a maximum of 64 bands.

If SOS is not enabled in the upstream direction, the band descriptor shall contain zero bands (see Table 12-22) and shall be ignored by the receiver.

Field #13 specifies the parameters that define the ROC in the upstream direction. It is formatted as an ROC descriptor, as defined in Table 12-58.

If the ROC is not enabled in the upstream direction, the values in the ROC descriptor shall all be set to zero and shall be ignored by the receiver.

The latency path descriptor is described in Table 12-57. It contains the primary parameters of the framer, as specified in Table 9-8, and the interleaver settings for one latency path. All values are unsigned integers.

Table 12-57 – Latency path descriptor

Octet	Field	Format	Description
1	T	1 byte	The number of MDFs in an OH subframe for the latency path; $T = k \times M$, where k is an integer. The value of T shall not exceed 64.
2	G	1 byte	The total number of overhead octets in an OH subframe for the latency path; $1 \leq G \leq 32$.
3	F	1 byte	Number of OH frames in the OH superframe for the latency path. $1 \leq F \leq 255$.
4	M	1 byte	The number of MDFs in an RS codeword for the latency path. Only the values 1, 2, 4, 8, 16 are allowable.
5 and 6	L	2 bytes	Contains the value of *L* for the latency path.
7	R	1 byte	Contains the value of *R* for the latency path.
8	I	1 byte	Contains the value of *I* for the latency path.
9 and 10	D	2 bytes	Interleaver depth *D* for the latency path.

Table 12-58 – ROC descriptor

Octet	Field	Format	Description
1	T	1 byte	The number of MDFs in an OH subframe of the ROC. $T = k \times M$, where *k* is an integer. The value of *T* shall not exceed 64.
2	G	1 byte	The total number of overhead octets in an OH subframe of the ROC; The valid values of *G* are $1 \leq G \leq 32$.
3	F	1 byte	Number of OH frames in the OH superframe for the ROC. The value of *F* shall be 1.
4	M	1 byte	The number of MDFs in an RS codeword for the ROC. The valid values of *M* are 1, 2, 4, 8 and 16.
5 and 6	L	2 bytes	Contains the value of *L* for the ROC. The valid values of *L* are from 8 to 128 in multiples of 8.
7	R	1 byte	Contains the value of *R* for the ROC. The value of R shall be 16.
8	I	1 byte	Contains the value of *I* for the ROC. *I* shall be set to $I=M \times (G/T)+R$. The valid values of I are $32 \leq I \leq 66$.
9 and 10	D	2 bytes	Interleaver depth *D* for the ROC. The valid values of *D* are $1 \leq D \leq 20$.

Field #14 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #15 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 14 and 15 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

Field #16 "ATTNDR_max_delay_octet$_{DS,p}$" is a 3-byte field that specifies the maximum of delay_octet$_{DS,p}$ that the VTU-R shall assume in the calculation of ATTNDR in downstream, for the latency path carrying the single bearer channel (see clause 11.4.1.1.7.2). The ATTNDR_max_delay_octet$_{DS,p}$ shall be specified in bytes as an unsigned integer.

12.3.5.2.1.4 O-PMD

The O-PMD message conveys the initial PMD parameter settings that shall be used in the upstream direction during showtime. The full list of parameters carried by the O-PMD message is shown in Table 12-59.

Table 12-59 – Description of message O-PMD

	Field name	Format
1	Message descriptor	Message code
2	Trellis	1 byte
3	Bits and gains table	$2 \times NSC_{us}$ bytes
4	Tone ordering table	$3 \times \lceil NSC_{us}/2 \rceil$ bytes coded as follows: • Bits 0-11: t_{2n-1} • Bits 12-23: t_{2n}
5	Initialization status	1 byte
6	ITU-T G.998.4 parameter field	Variable length
7	ITU-T G.993.5 parameter field	Variable length
NOTE – The $\lceil x \rceil$ notation represents rounding to the nearest greater integer.		

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Trellis" indicates whether trellis coding shall be used in the upstream direction (00_{16} = trellis disabled, 01_{16} = trellis enabled).

Field #3 "Bits and gains table" contains the b_i and g_i values for every subcarrier in MEDLEYus. The b_i shall indicate the number of bits to be mapped by the VTU-R to the subcarrier i; the g_i shall indicate the scale factor that shall be applied to subcarrier i, relative to the gain that was used for that subcarrier during the transmission of R-P-MEDLEY.

The b_i's and g_i's shall only be defined for subcarriers from the MEDLEYus set (as indicated in R-PRM), and shall be sent in ascending order of subcarrier indices i.

Each b_i value shall be represented as an unsigned 4-bit integer. Each g_i value shall be represented as an unsigned 12-bit fixed-point quantity, with the binary point assumed just to the right of the third most significant bit. For example, a g_i with binary representation (MSB listed first) 001.010000000_2 would instruct the VTU-R to scale the constellation for subcarrier i by a gain of 1.25, so that the power of that subcarrier would be 1.94 dB higher than it was during R-P-MEDLEY.

Each pair of b_i and g_i values shall be mapped on a 16-bit field as follows: [$b_M$bbb $g_M$ggg gggg gggg], where b_M and g_M are the MSBs of the b_i and g_i binary representations, respectively.

Field #4 "Tone ordering table" contains the tone ordering table *t* for the upstream direction. The tone ordering table contains the order in which the subcarriers shall be assigned bits in the upstream direction. The table shall include all subcarriers of the MEDLEYus set and only these subcarriers. Each subcarrier index shall be represented as a 12-bit value. Pairs of subcarrier indices shall be mapped to a field of 3 bytes as shown in Table 12-59. For example, if the value of the n^{th} field is 400200_{16}, $t_{2n-1} = 200_{16} = 512$ and $t_{2n} = 400_{16} = 1\,024$. If the number of subcarriers in the MEDLEYus set is odd, the last 12 bits of the field shall be set to ZERO (and ignored by the receiver). The value of the first index sent shall be equal to the index of the first entry in the tone ordering table (t_1, see clause 10.3.1). The remaining indices shall be sent in increasing order of the tone ordering table *t* entries (t_2, t_3, ... t_{NSCus}).

Field #5: indicates the "Initialization status".

If, within the constraints of the channel initialization policies defined in clause 12.3.7, the receiver is unable to select a set of configuration parameters, the "Initialization success/failure code" indicates the initialization failure cause as defined in [ITU-T G.997.1]. If, within the constraints of the channel initialization policies defined in clause 12.3.7, the receiver is able to select a set of configuration parameters, the "Initialization success/failure code" indicates the initialization success. Valid Initialization success/failure codes are as follows:

- 80_{16}: Initialization success;
- 81_{16}: Configuration error;
- 82_{16}: Configuration not feasible on line;
- 00_{16}: Feature not supported.

Other values are reserved by the ITU-T.

If an initialization success/failure code 81_{16} or 82_{16} is set:

- All values in Field #2 to 4 shall be set to 0; and
- The VTU-O shall return to L3 link state instead of L0 link state at the completion of the initialization procedures.

Field #6 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #7 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 6 and 7 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-O does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-O does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.5.2.2 VTU-R messages sent during the channel analysis and exchange phase

12.3.5.2.2.1 R-MSG 2

The R-MSG 2 message conveys VTU-R information to the VTU-O. The full list of parameters carried by the R-MSG 2 message is shown in Table 12-60.

Table 12-60 – Description of message R-MSG 2

	Field name	Format
1	Message descriptor	Message code
2	TPS-TC capabilities	See Table 12-61
3	PMS-TC capabilities	See Table 12-62
4	Support of "Flexible OH frame Type 2" upstream and INM_INPEQ_FORMATds	1 byte
5	SOS multi-step activation downstream	1 byte
6	SOS multi-step activation upstream	1 byte
7	ITU- T G.998.4 parameter field	Variable length
8	ITU-T G.993.5 parameter field	Variable length
9	Time synchronization capability	1 byte
10	Time synchronization period (TSP)	1 byte
11	ATTNDR method capability	1 byte

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "TPS-TC capabilities" indicates the TPS-TC capabilities of the VTU-R, as shown in Table 12-61.

Field #3 "PMS-TC capabilities" indicates the PMS-TC capabilities of the VTU-R. This includes the supported latency paths at the VTU-R (DS and US) and the capabilities per path (such as supported coding and interleaver parameters), as shown in Table 12-62.

Field #4 indicates the support by the VTU-R of the "Flexible OH Frame Type 2" in the upstreamdirection and the INM_INPEQ_FORMATds in the downstream direction. The field shall be formatted as [0000 00ba]. The VTU-R shall indicate support by setting, respectively, a=1 and b=1 in this field. Other bits shall be set to 0 and are reserved by ITU-T.

Field #5 indicates the capabilities of the VTU-R to execute the SOS request in one step or in multiple steps in the downstream direction. The field is formatted as [gggg 0000]. The first four MSBs [gggg] indicate the maximum number of tones (G_{SOS}) that can be executed in a single step in the downstream direction. The valid values are:

- [0000]: No limitation;
- [0010]: G_{SOS} = 256 tones;
- [0011]: G_{SOS} = 512 tones;
- [0100]: G_{SOS} = 1 024 tones.

If SOS is supported, value G_{SOS} = 256 tones is a mandatory capability. If the VTU supports a particular value of G_{SOS}, it shall support all smaller values of G_{SOS} (and values T_{SOS} associated with them, as presented in Table 13-4).

Each G_{SOS} has a value of T_{SOS} associated with it, where T_{SOS} is the time (in symbols) between the execution of two successive groups of tones (see clause 13.3).

If the CPE does not support SOS in the downstream direction, this field shall contain a value within the specified valid range. This value shall be ignored by the receiver.

Field #6 indicates the capabilities of the VTU-R to execute the SOS request in one step or in multiple steps in the upstream direction. The format of the field and the valid values shall be the same as for field #5.

If the CPE does not support SOS in the upstream direction, this field shall contain a value within the specified valid range. This value shall be ignored by the receiver.

Field #7 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #8 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 7 and 8 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

Field #9 "Time Synchronization capability" indicates the time synchronization capability of the VTU-R. The field shall be coded as a single byte [0000 00pt], where:

- t=0 indicates that time synchronization is not supported;
- t=1 indicates that time synchronization is supported;
- p = 0 indicates that, if time synchronization is enabled, the ToD phase difference values shall be transported through the OH frame;
- p = 1 indicates that, if time synchronization is enabled, the ToD phase difference values shall be transported through the eoc.

NOTE – If time synchronization is not supported, then t=0 and the value of p and the contents of field #10 should be ignored by the VTU-O.

Field #10 indicates the Time Synchronization Period (*TSP*), defined as maximum increment in number of superframes of the t_1 instant number contained in two consecutive transmissions of the time synchronization eoc message. *TSP* is represented in one byte with valid values $n = 10…255$, indicating $TSP = 16 \times n$.

Field #11 indicates the ATTNDR method capability of the VTU-R in the downstream direction. The field shall be formatted as [0000 000m].

A value m=1 indicates the VTU-R supports the improved method as defined in clause 11.4.1.1.7.2.

A value m=0 indicates the VTU-R does not support the improved method, and therefore only supports the basic method as defined in clause 11.4.1.1.7.1.

Other bits shall be set to 0 and are reserved by ITU-T.

Table 12-61 – TPS-TC capabilities of VTU-R

Field name	Format	Description
Maximum number of downstream TPS-TCs of each type	1 byte: [ssaapp00]	Indicates the maximum number of TPS-TCs of each type that the VTU-R supports in the downstream direction: • ss=max number of downstream STM TPS-TCs (0,1,2); • aa=max number of downstream ATM TPS-TCs (0,1,2); and • pp=max number of downstream PTM TPS-TCs (0,1,2).
Maximum number of upstream TPS-TCs of each type	1 byte: [ssaapp00]	Indicates the maximum number of TPS-TCs of each type that the VTU-R supports in the upstream direction: • ss=max number of upstream STM TPS-TCs (0,1,2); • aa=max number of upstream ATM TPS-TCs (0,1,2); and • pp=max number of upstream PTM TPS-TCs (0,1,2).
Supported combinations of downstream bearer channels and TPS-TCs	1 byte: [$s_0a_0p_0$ 0 $s_1a_1p_1$ 0]	s_0: equal to 1 if STM can be supported on bearer channel 0 a_0: equal to 1 if ATM can be supported on bearer channel 0 p_0: equal to 1 if PTM can be supported on bearer channel 0 s_1: equal to 1 if STM can be supported on bearer channel 1 a_1: equal to 1 if ATM can be supported on bearer channel 1 p_1: equal to 1 if PTM can be supported on bearer channel 1
Supported combinations of upstream bearer channels and TPS-TCs	1 byte: [$s_0a_0p_0$ 0 $s_1a_1p_1$ 0]	s_0: equal to 1 if STM can be supported on bearer channel 0 a_0: equal to 1 if ATM can be supported on bearer channel 0 p_0: equal to 1 if PTM can be supported on bearer channel 0 s_1: equal to 1 if STM can be supported on bearer channel 1 a_1: equal to 1 if ATM can be supported on bearer channel 1 p_1: equal to 1 if PTM can be supported on bearer channel 1
For each supported TPS-TC, a bearer channel descriptor (see Table 12-51) shall be appended to the message.		
Downstream STM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported downstream STM TPS-TCs.
Downstream ATM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported downstream ATM TPS-TCs.
Downstream PTM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported downstream PTM TPS-TCs.
Upstream STM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported upstream STM TPS-TCs.
Upstream ATM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported upstream ATM TPS-TCs.
Upstream PTM TPS-TC capabilities	0, 1, or 2 bearer channel descriptors	Contains the capabilities of the supported upstream PTM TPS-TCs.
NOTE – The number of bearer channel descriptors for the TPS-TC capabilities depends on the fields "Maximum number of downstream/upstream TPS-TCs".		

Each bearer channel descriptor (see Table 12-51) shall be coded as follows.

In the fields "Minimum net data rate", "Maximum net data rate" and "Reserved net data rate", the parameter values for net_min_n, net_max_n and $net\_reserve_n$, respectively, shall be coded as unsigned integers representing the data rate as a multiple of 8 kbit/s.

The fields "Maximum interleaving delay" and "Impulse noise protection" are not applicable in R-MSG 2 (which communicates capabilities), and the values of octets 7 and 8 in each bearer channel descriptor shall be ignored by the VTU-O receiver.

The field "TPS-TC options" shall be coded as follows:

- Bit 0: If the VTU-R supports pre-emption in this bearer (N.3.1.2 of [ITU-T G.992.3]), the bit shall be set to ONE;
- Bit 1: If the VTU-R supports short packets in this bearer (N.3.1.3 of ITU-T [G.992.3]), the bit shall be set to ONE.

For a bearer mapped to an ATM or STM TPS-TC, bits 0 and 1 shall be set to ZERO at the transmitter and ignored by the receiver.

Bit 2 indicates whether the optional channel initialization policy 1 is supported for that bearer channel. This bit shall be set to ONE to indicate support for this policy.

Bit 3 indicates whether the optional channel initialization policy 2 is supported for that bearer channel. This bit shall be set to ONE to indicate support for this policy.

Bit 4 indicates whether the optional Re-Initialization Policy 1 (i.e., $RIpolicyds_n$=1) is supported (see clause 12.1.4) for that bearer channel. This bit shall be set to ONE to indicate support for this policy. This bit shall be set to the same value for all bearer channels.

Bits 5-7 are reserved by ITU-T and shall be set to ZERO.

Table 12-62 – PMS-TC capabilities of VTU-R

Field name	Format	Description
Downstream OLR capabilities	1 byte [rrufdsii]	Indicates the support of optional OLR mechanisms in the downstream direction. f = 0 if downstream framing reconfiguration (change of T_p, G_p and B_{p0}) is not supported, f = 1 otherwise (Note 1). d is reserved by ITU-T for future use and shall be set to zero. s = 0 if downstream SRA (change of L_p, b_i, g_i) is not supported, s = 1 otherwise. ii = 00 if interleaver reconfiguration (change of D_p) is not supported, ii = 01 if interleaver reconfiguration is supported on one downstream latency path, ii = 11 if interleaver reconfiguration is supported on both downstream latency paths (Note 2). ii = 10 is reserved by the ITU-T. u =0 if downstream SOS is not supported, u=1 otherwise (Notes 3, 4) rr=00 indicates that the ROC in the downstream direction is not supported at the VTU-R. rr=01 indicates that the ROC in the downstream direction is supported, but dual latency mode is not. rr=11 indicates that both the ROC and dual latency mode shall be supported in the downstream direction, but only one of these can be enabled at a given time. rr = 10 is reserved by the ITU-T.

Table 12-62 – PMS-TC capabilities of VTU-R

Field name	Format	Description
Upstream OLR capabilities	1 byte [rrufdsii]	Indicates the support of optional OLR mechanisms in the upstream direction. f = 0 if upstream framing reconfiguration (change of T_p, G_p and B_{p0}) is not supported, f = 1 otherwise (Note 1). d is reserved by ITU-T for future use and shall be set to zero. s = 0 if upstream SRA (change of L_p, b_i, g_i) is not supported, s = 1 otherwise. ii = 00 if interleaver reconfiguration (change of D_p) is not supported, ii = 01 if interleaver reconfiguration is supported on one upstream latency path, ii = 11 if interleaver reconfiguration is supported on both upstream latency paths (Note 2). ii = 10 is reserved by the ITU-T. u =0 if upstream SOS is not supported, u=1 otherwise (Notes 3, 4) rr=00 indicates that the ROC in the upstream direction is not supported at the VTU-R. rr=01 indicates that the ROC in the upstream direction is supported, but dual latency mode is not. rr=11 indicates that both the ROC and dual latency mode shall be supported in the upstream direction, but only one of these can be enabled at a given time. rr = 10 is reserved by the ITU-T.
Downstream message overhead data rate (Note 5)	1 byte	Minimum message overhead data rate that is needed by the VTU-R in the downstream direction. The unsigned 8-bit value is the message overhead data rate divided by 1 000 bits per second minus 1 (covering the range 1 to 256 kbit/s).
Upstream message overhead data rate (Note 5)	1 byte	Minimum message overhead data rate that is needed by the VTU-R in the upstream direction. The unsigned 8-bit value is the message overhead data rate divided by 1 000 bits per second minus 1 (covering the range 1 to 256 kbit/s).
Max DS net data rate for latency path 0	2 bytes	The maximum downstream net data rate supported in latency path #0. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
Max US net data rate for latency path 0	2 bytes	The maximum upstream net data rate supported in latency path #0. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
Max DS net data rate for latency path 1	2 bytes	Parameter block of 2 octets that describes the maximum downstream net data rate supported in latency path #1. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
Max US net data rate for latency path 1	2 bytes	Parameter block of 2 octets that describes the maximum upstream net data rate supported in latency path #1. The unsigned 16-bit value is the net data rate divided by 8 000 bits per second.
DS $(1/S)_{max}$	1 byte	Parameter block of 1 octet that describes the maximum value of 1/S supported by the VTU-R in the downstream direction as defined in clause 9.5.5. The unsigned 8-bit value is coded as 1 to 64 in steps of 1.

Table 12-62 – PMS-TC capabilities of VTU-R

Field name	Format	Description
US $(1/S)_{max}$	1 byte	Parameter block of 1 octet that describes the maximum value of 1/S supported by the VTU-R in the upstream direction as defined in clause 9.5.5. The unsigned 8-bit value is coded as 1 to 64 in steps of 1.

NOTE 1 – If support for SOS is indicated, support for framing reconfiguration (change of T_p, G_p and B_{p0}) shall also be indicated.

NOTE 2 – In the case of single latency mode (i.e., without the ROC), the values for latency path 1 shall be set to ZERO. In the case of single latency with ROC mode, the values for latency path 0 shall be set to ZERO.

NOTE 3 – If upstream SOS is supported, support for interleaver depth reconfiguration in the upstream direction shall also be indicated. If downstream SOS is supported, support for interleaver depth reconfiguration in the downstream direction shall also be indicated.

NOTE 4 – If support for SOS is indicated, support for SRA shall also be indicated.

NOTE 5 – When the ROC is enabled, all overhead data shall be carried in latency path #0 (the ROC).

12.3.5.2.2.2 R-TPS-ACK

R-TPS-ACK is a message that acknowledges correct reception of the O-TPS message. The content shall be as specified in Table 12-63.

Table 12-63 – Description of message R-TPS-ACK

	Field name	Format
1	Message descriptor	Message code
2	ITU-T G.998.4 parameter field	Variable length
3	ITU-T G.993.5 parameter field	Variable length

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #3 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 2 and 3 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.5.2.2.3 R-PMS

The R-PMS message conveys the initial PMS-TC parameter settings that shall be used in the downstream direction during showtime. The full list of parameters carried by the R-PMS message is shown in Table 12-64.

Table 12-64 – Description of message R-PMS

	Field name	Format
1	Message descriptor	Message code
2	MSGLP (Note 1)	1 byte
3	Mapping of bearer channels to latency paths	1 byte
4	B_{x0}	1 byte
5	B_{x1}	1 byte
6	LP_0 (Note 2)	Latency path descriptor
7	LP_1	Latency path descriptor
8	Erasure decoding used	1 byte
9	Downstream SOS tone groups	Band descriptor
10	Downstream ROC parameters	ROC descriptor
11	ITU-T G.998.4 parameter field	Variable length
12	ITU-T G.993.5 parameter field	Variable length
NOTE 1 – If the ROC is enabled, MSGLP shall be equal to 0. NOTE 2 – If the ROC is enabled, the framing parameters for latency path #0 shall be contained in the ROC descriptor.		

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "MSGLP" is a one-byte field that indicates which latency path is selected for OH frames of Type 1 (which carries message overhead) in the downstream direction. The seven MSBs of the byte shall always be set to ZERO. The LSB shall be set to ZERO to indicate latency path #0 or ONE to indicate latency path #1.

Field #3 "Mapping of bearer channels to latency paths" is a one-byte field that indicates which bearer channels shall be carried in each of the downstream latency paths. The byte is denoted as [cccc dddd]. The bits cccc shall be set to 0000 if bearer channel #0 is to be carried in latency path #0, and to 0001 if bearer channel #0 is to be carried in latency path #1. The bits cccc shall be set to 1111 if the bearer channel #0 is disabled. The bits dddd indicate which latency path carries bearer channel #1 using the same encoding method as used for cccc.

Field #4 "B_{x0}" is a one-byte field that indicates the number of octets from bearer channel #0 that shall be transported in each MDF in the downstream direction. The value shall be either zero or the non-zero value from the set {B_{00}, B_{10}}.

Field #5 "B_{x1}" is a one-byte field that indicates the number of octets from bearer channel #1 that shall be transported in each MDF in the downstream direction. The value shall be either zero or the non-zero value from the set {B_{01}, B_{11}}.

Field #6 "LP_0" is a 10-byte field that contains the PMS-TC parameters for latency path #0 in the downstream direction. The "Latency path descriptor" format specified in Table 12-57 shall be used.

Field #7 "LP_1" is a 10-byte field that contains the PMS-TC parameters for latency path #1 in the downstream direction. The "Latency path descriptor" format specified in Table 12-57 shall be used. If latency path #1 is not used, all bytes of LP_1 shall be set to ZERO.

Field #8 "Erasure decoding used" is a 1-byte field that indicates whether the VTU-R is using erasure decoding. The value shall be:

- 00_{16} if erasure decoding is not used on any downstream latency path;
- 01_{16} if erasure decoding is used on downstream latency path #0;

- 10_{16} if erasure decoding is used on downstream latency path #1; or
- 11_{16} if erasure decoding is used on both downstream latency paths.

Field #9 contains the start and stop frequencies of the SOS tone groups (as defined in clause 13.3) for the downstream direction. It shall be formatted as a band descriptor (see Table 12-22), with a maximum of 64 bands.

If SOS is not activated in the downstream direction, the band descriptor shall contain zero bands (see Table 12-22) and shall be ignored by the receiver.

Field #10 specifies the parameters that define the ROC in the downstream direction. It is formatted as an ROC descriptor, as defined in Table 12-58.

If the ROC is not enabled in the downstream direction, the values in the ROC descriptor shall all be set to zero and shall be ignored by the receiver.

Field #11 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #12 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 11 and 12 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.5.2.2.4 R-PMD

The R-PMD message conveys the initial PMD parameter settings that shall be used in the downstream direction during showtime. The content of R-PMD is shown in Table 12-65.

Table 12-65 – Description of message R-PMD

	Field name	Format
1	Message descriptor	Message code
2	Trellis	1 byte
3	Bits and gains table	$2 \times NSC_{ds}$ bytes
4	Tone ordering table	$3 \times \lceil NSC_{ds}/2 \rceil$ bytes coded as follows: • Bits 0-11: t_{2n-1} • Bits 12-23: t_{2n}
5	Showtime pilot tones	Tone descriptor
6	Initialization status	1 byte
7	ITU-T G.998.4 parameter field	Variable length
8	ITU-T G.993.5 parameter field	Variable length
NOTE – The $\lceil x \rceil$ notation represents rounding to the nearest greater integer.		

Field #1 "Message descriptor" is a unique one-byte code that identifies the message. See Table 12-6 for a complete list of codes.

Field #2 "Trellis" indicates whether trellis coding shall be used in the downstream direction (00_{16} = trellis disabled, 01_{16} = trellis enabled).

Field #3 "Bits and gains table" contains the b_i and g_i values for every subcarrier in MEDLEYds. The b_i shall indicate the number of bits to be mapped by the VTU-O to the subcarrier *i*; the g_i shall indicate the scale factor that shall be applied to subcarrier *i*, relative to the gain that was used for that subcarrier during the transmission of O-P-MEDLEY.

The b_i's and g_i's shall only be defined for subcarriers from the MEDLEYds set (as indicated in O-PRM), and shall be sent in ascending order of the subcarrier indices *i*.

Each b_i value shall be represented as an unsigned 4-bit integer. Each g_i value shall be represented as an unsigned 12-bit fixed-point quantity, with the binary point assumed just to the right of the third most significant bit. For example, a g_i with binary representation (MSB listed first) 001.010000000_2 would instruct the VTU-O to scale the constellation for subcarrier *i* by a gain of 1.25, so that the power of that subcarrier would be 1.94 dB higher than it was during O-P-MEDLEY.

Each pair of b_i and g_i values shall be mapped on a 16-bit field as follows: [$b_M$bbb $g_M$ggg gggg gggg], where b_M and g_M are the MSBs of the b_i and g_i binary representations, respectively.

Field #4 "Tone ordering table" contains the tone ordering table *t* for the downstream direction. The tone ordering table contains the order in which the subcarriers shall be assigned bits in the downstream direction. The table shall include all subcarriers of the MEDLEYds set and only these subcarriers. Each subcarrier index shall be represented as a 12-bit value. Pairs of subcarrier indices shall be mapped to a field of 3 bytes as shown in Table 12-65. For example, if the value of the n^{th} field is 400200_{16}, $t_{2n-1} = 200_{16} = 512$ and $t_{2n} = 400_{16} = 1\,024$. If the number of subcarriers in the MEDLEYds set is odd, the last 12 bits of the field shall be set to ZERO (and ignored by the receiver). The value of the first index sent shall be equal to the index of the first entry in the tone ordering table (t_1, see clause 10.3.1). The remaining indices shall be sent in increasing order of the tone ordering table *t* entries (t_2, t_3, ... t_{NSCds}).

Field #5 "Showtime pilot tones" indicates the selection of pilot tones that the VTU-R intends to use during showtime. The field shall be formatted as a tone descriptor, as shown in Table 12-33. The first octet of the tone descriptor shall contain the number of pilot tones selected by the VTU-R. If this number is zero, there shall be no further octets in the descriptor. If the number of tones is not equal to zero, each group of three consecutive octets in the descriptor shall describe the location (i.e., the subcarrier index) of two pilot tones. If the number of pilot tones is odd, the last 12 bits shall be ignored.

The VTU-R shall only select a tone as a pilot tone if the bit loading for that tone, as given in the bits and gains table (Field #3), is equal to zero. The showtime pilot tones shall be modulated as specified in clause 10.4.5.1. The total number of showtime pilot tones shall not exceed 16.

Field #6: indicates the "Initialization status".

If, within the constraints of the channel initialization policies defined in clause 12.3.7, the receiver is unable to select a set of configuration parameters, the "Initialization success/failure code" indicates the initialization failure cause as defined in [ITU-T G.997.1]. If, within the constraints of the channel initialization policies defined in clause 12.3.7, the receiver is able to select a set of configuration parameters, the "Initialization success/failure code" indicates the initialization success. Valid Initialization success/failure codes are as follows:

- 80_{16}: Initialization success;
- 81_{16}: Configuration error;
- 82_{16}: Configuration not feasible on line;
- 00_{16}: Feature not supported.

Other values are reserved by the ITU-T.

If an initialization success/failure code 81_{16} or 82_{16} is set:

- all values in Field #2 to 4 shall be set to 0; and

- the VTU-R shall return to L3 link state instead of L0 link state at the completion of the initialization procedures.

Field #7 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

Field #8 is a variable length field consisting of an integer number of bytes. It is formatted as shown in Table 12-26.

The actual data in the variable length fields 5 and 6 are beyond the scope of this Recommendation. For a correct interpretation at the receiver, support of either [ITU-T G.998.4] or [ITU-T G.993.5] or both is required. However, support of those Recommendations is not implied or required for compliance with Recommendation ITU-T G.993.2.

If the VTU-R does not support [ITU-T G.998.4], the ITU-T G.998.4 parameter field shall be a single byte with value 0.

If the VTU-R does not support [ITU-T G.993.5], the ITU-T G.993.5 parameter field shall be a single byte with value 0.

12.3.5.3 Signals transmitted during the channel analysis and exchange phase

All signals transmitted during the channel analysis and exchange phase shall use only subcarriers from the MEDLEYds set in the downstream direction and subcarriers from the MEDLEYus set in the upstream direction.

The transmit PSD of downstream signals shall comply with the downstream MEDLEY reference PSD mask (MREFMASKds) that was established at the end of the channel discovery phase in both the passband and the stopbands. The values of $2N_{ds}$ and CE shall be those determined at the end of the channel discovery phase and communicated in Fields #7 and #4 in O-PRM, respectively. The values of β_{ds} and cyclic prefix length shall be as communicated in Field #6 and Field #5 of O-PRM, respectively.

The transmit PSD of all upstream signals shall comply with the upstream MEDLEY reference PSD mask (MREFMASKus) that was established at the end of the channel discovery phase in both the passband and the stopbands. The values of $2N_{us}$ and CE shall be those determined at the end of the channel discovery phase and communicated in Field #6 of R-PRM and Field #4 in O-PRM, respectively. The values of β_{us} and cyclic prefix length shall be those communicated in Fields #5 and #4 of R-PRM, respectively.

12.3.5.3.1 Signals transmitted by the VTU-O

12.3.5.3.1.1 O-P-MEDLEY

O-P-MEDLEY is used by the VTU-R to estimate the downstream SNR and to communicate the SOC messages specified in clause 12.3.5.2.1. During transmission of O-P-MEDLEY, the SOC is in its active state.

The duration of O-P-MEDLEY is variable. The VTU-O terminates O-P-MEDLEY by transmitting O-P-SYNCHRO 6.

O-P-MEDLEY shall use all MEDLEYds subcarriers modulated by 4-QAM. O-P-MEDLEY shall carry either one byte ($b_7\, b_6\, ...\, b_0$) or two bytes ($b_{15}\, b_{14}\, ...\, b_0$) of information per DMT symbol. The bits shall be mapped to the subcarriers as described in Table 12-66 for two bytes per DMT symbol and in Table 12-67 for one byte per DMT symbol. The number of bytes per DMT symbol shall be the minimum of the values of $B_{ex\text{-}ds\text{-}O}$ and $B_{ex\text{-}ds\text{-}R}$ requested by the VTU-O and VTU-R in O-TA_UPDATE and R-TA_UPDATE, respectively.

The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in free-running mode (see clause 12.3.6.2.2). The scrambler shall reset when the VTU-O enters the channel analysis and exchange phase.

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be β_{ds}.

Table 12-66 – Bit mapping for O-P-MEDLEY with two bytes per DMT symbol

Subcarrier index	Constellation point
5, 10, 15, ..., 5 *n*, ...	00
1, 11, 21, ..., 10 *n* + 1, ...	SOC message bits 0 and 1
2, 12, 22, ..., 10 *n* + 2, ...	SOC message bits 2 and 3
3, 13, 23, ..., 10 *n* + 3, ...	SOC message bits 4 and 5
4, 14, 24, ..., 10 *n* + 4, ...	SOC message bits 6 and 7
6, 16, 26, ..., 10 *n* + 6, ...	SOC message bits 8 and 9
7, 17, 27, ..., 10 *n* + 7, ...	SOC message bits 10 and 11
8, 18, 28, ..., 10 *n* + 8, ...	SOC message bits 12 and 13
9, 19, 29, ..., 10 *n* + 9, ...	SOC message bits 14 and 15
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1, b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

Table 12-67 – Bit mapping for O-P-MEDLEY with one byte per DMT symbol

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10 *n* + 1, ...	SOC message bits 0 and 1
3, 13, 23, ..., 10 *n* + 3, ...	SOC message bits 2 and 3
5, 15, 25, ..., 10 *n* + 5, ...	SOC message bits 4 and 5
7, 17, 27, ..., 10 *n* + 7, ...	SOC message bits 6 and 7
9, 19, 29, ..., 10 *n* + 9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

The transmit PSD of the MEDLEYds subcarriers in O-P-MEDLEY shall be equal to the downstream MEDLEY reference PSD (MREFPSDds) communicated in Field #2 of O-PRM.

12.3.5.3.1.2 O-P-SYNCHRO 6

O-P-SYNCHRO 6 is a signal that provides an exact time marker for the transition from O-P-MEDLEY to Showtime. During transmission of O-P-SYNCHRO 6, the SOC is in its inactive state.

The duration of O-P-SYNCHRO 6 is 15 DMT symbols.

O-P-SYNCHRO 6 shall use all subcarriers in the MEDLEYds set modulated by 4-QAM. The value 11 shall be mapped to all of the MEDLEYds subcarriers for the first 5 and the last 5 DMT symbols. The value 00 shall be mapped to all of the MEDLEYds subcarriers for the middle 5 DMT symbols. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{ds}+L_{CE}$ samples. The overall window length shall be equal to β_{ds}.

The transmit PSD of the MEDLEYds subcarriers in O-P-SYNCHRO 6 shall be the same as for O-P-MEDLEY.

12.3.5.3.2 Signals transmitted by the VTU-R

12.3.5.3.2.1 R-P-MEDLEY

R-P-MEDLEY is used by the VTU-O to estimate the upstream SNR and to communicate the SOC messages specified in clause 12.3.5.2.2. During transmission of R-P-MEDLEY, the SOC is in its active state.

The duration of R-P-MEDLEY is variable. The VTU-R terminates R-P-MEDLEY by transmitting R-P-SYNCHRO 6.

R-P-MEDLEY shall use all MEDLEYus subcarriers modulated by 4-QAM. R-P-MEDLEY shall carry either one byte ($b_7\, b_6\, ...\, b_0$) or two bytes ($b_{15}\, b_{14}\, ...\, b_0$) of information per DMT symbol. The bits shall be mapped to subcarriers as described in Table 12-68 for two bytes per DMT symbol and in Table 12-69 for one byte per DMT symbol. The number of bytes per DMT symbol shall be the minimum of the values of $B_{ex\text{-}us\text{-}O}$ and $B_{ex\text{-}us\text{-}R}$ requested by the VTU-O and VTU-R in O-TA_UPDATE and R-TA_UPDATE, respectively.

The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in free-running mode (see clause 12.3.6.2.2). The scrambler shall reset when the VTU-R enters the channel analysis and exchange phase.

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us}+L_{CE}$ samples. The overall window length shall be β_{us}.

Table 12-68 – Bit mapping for R-P-MEDLEY with two bytes per DMT symbol

Subcarrier index	Constellation point
5, 10, 15, ..., 5 *n*, ...	00
1, 11, 21, ..., 10 *n* + 1, ...	SOC message bits 0 and 1
2, 12, 22, ..., 10 *n* + 2, ...	SOC message bits 2 and 3
3, 13, 23, ..., 10 *n* + 3, ...	SOC message bits 4 and 5
4, 14, 24, ..., 10 *n* + 4, ...	SOC message bits 6 and 7
6, 16, 26, ..., 10 *n* + 6, ...	SOC message bits 8 and 9
7, 17, 27, ..., 10 *n* + 7, ...	SOC message bits 10 and 11
8, 18, 28, ..., 10 *n* + 8, ...	SOC message bits 12 and 13
9, 19, 29, ..., 10 *n* + 9, ...	SOC message bits 14 and 15
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1,b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

Table 12-69 – Bit mapping for R-P-MEDLEY with one byte per DMT symbol

Subcarrier index	Constellation point
Even	00
1, 11, 21, ..., 10 *n* + 1, ...	SOC message bits 0 and 1
3, 13, 23, ..., 10 *n* + 3, ...	SOC message bits 2 and 3
5, 15, 25, ..., 10 *n* + 5, ...	SOC message bits 4 and 5
7, 17, 27, ..., 10 *n* + 7, ...	SOC message bits 6 and 7
9, 19, 29, ..., 10 *n* + 9, ...	00
NOTE – The byte is given as (b7, b6, b5, b4, b3, b2, b1, b0), where b7 is the MSB and b0 is the LSB. Mapping, e.g., "SOC message bits 0 and 1" to subcarriers 10*n*+1 means that the two-bit value (b1, b0) shall be used to determine the constellation point in accordance with the encoding rules given in clause 10.3.3.2. This constellation point will then be scrambled using the quadrant scrambler described in clause 12.3.6.2.	

The transmit PSD of the MEDLEYus subcarriers in R-P-MEDLEY shall be equal to the upstream MEDLEY reference PSD (MREFPSDus) communicated in the Field #2 of R-PRM.

12.3.5.3.2.2 R-P-SYNCHRO 6

R-P-SYNCHRO 6 is a signal that provides an exact time marker for the transition from R-P-MEDLEY to Showtime. During transmission of R-P-SYNCHRO 6, the SOC is in its inactive state.

The duration of R-P-SYNCHRO 6 is 15 DMT symbols.

R-P-SYNCHRO 6 shall use all subcarriers in the MEDLEYus set modulated by 4-QAM. The value 11 shall be mapped to all of the MEDLEYus subcarriers for the first 5 and the last 5 DMT symbols. The value 00 shall be mapped to all of the MEDLEYus subcarriers for the middle 5 DMT symbols. The constellation points on all subcarriers shall be rotated based on the 2-bit number provided by the quadrant scrambler described in clause 12.3.6.2. The scrambler shall be used in reset mode (see clause 12.3.6.2.1).

Symbols shall be generated as described in clause 10.4.4. The symbol length shall be $2N_{us}+L_{CE}$ samples. The overall window length shall be equal to β_{us}.

The transmit PSD of the MEDLEYus subcarriers in R-P-SYNCHRO 6 shall be the same as for R-P-MEDLEY.

12.3.6 General initialization signal requirements

12.3.6.1 Periodic signal requirements

The periodic signals used in initialization (O-P-PERIODIC 1, R-P-PERIODIC 1, and others) shall meet the requirements specified in this clause.

Implementers may choose to generate periodic signals using cyclically extended symbols or directly using the $2N$ samples out of the IDFT. The duration of each periodic signal shall be selected by a VTU such that it contains an integer number of cyclically extended symbols and an integer multiple of $2N$ samples. Specifically, $N_{\text{Sym\_CE}} \times (2N + L_{CE}) = k \times 2N$, where $N_{\text{Sym\_CE}}$ is the number of cyclically extended symbols needed to construct the periodic signal, and k is the number of periodic symbols in the periodic signal.

To ensure a smooth transition from an initialization signal with cyclically extended symbols to one that is periodic, the first symbol of each periodic signal shall be prepended by a cyclic prefix of β samples, where $\beta = \beta_{ds}$ for downstream signals and $\beta = \beta_{us}$ for upstream signals. These β samples shall be windowed and overlapped with the last β samples of the last symbol of the previous signal, as described in clause 10.4.4. Likewise, to ensure a smooth transition from a periodic signal to a signal using cyclically extended symbols, the last β samples of the last symbol in the periodic signal shall be windowed and overlapped with the first β samples of the first symbol of the next signal.

12.3.6.2 Quadrant scrambler

The constellation point of each subcarrier shall be pseudo-randomly rotated by 0, π/2, π or 3π/2 depending on the value of a 2-bit pseudo-random number. The subcarrier with index 0 (DC) shall not be rotated. The rotation shall be implemented by transforming the (*X*, *Y*) coordinates of the constellation point as shown in Table 12-70, where *X* and *Y* are the coordinates before scrambling.

Table 12-70 – Pseudo-random transformation

d_{2n}, d_{2n+1}	Angle of rotation	Final coordinates
0 0	0	(X, Y)
0 1	π/2	$(-Y, X)$
1 1	π	$(-X, -Y)$
1 0	3π/2	$(Y, -X)$

The 2-bit values shown in the first column of Table 12-70 shall be the output of a PRBS generator defined by the equation:

$$d_n = d_{n-9} \oplus d_{n-11}$$

The bit generator is illustrated in Figure 12-12.

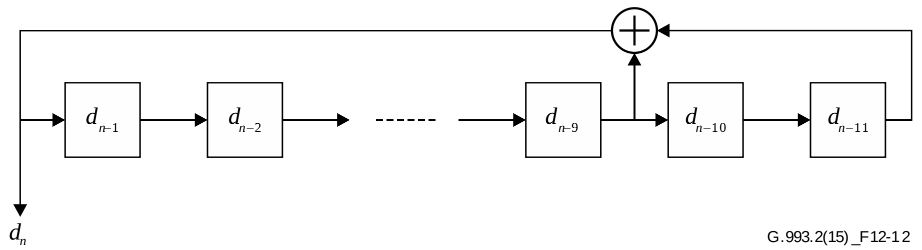

Figure 12-12 – Bit generator

Two bits from the scrambler shall be mapped to each subcarrier, including DC. The two bits corresponding to DC shall be overwritten with 00.

For a VDSL2 system that uses an IDFT size = 2*N*, 2*N* bits shall be generated by the scrambler every DMT symbol (b_0 b_1 b_2 ... b_{2N-2} b_{2N-1}) in each transmission direction. The first two bits (b_0 b_1) shall correspond to subcarrier 0, the next two bits (b_2 b_3) to subcarrier 1, and so on; bits (b_{2i} b_{2i+1}) shall correspond to subcarrier *i*. Bits shall be generated for all subcarriers, not just those being transmitted. Bits generated for subcarriers that are not in use shall be discarded.

At the beginning of initialization, all registers of the scrambler shall be set to ONE. Two modes of scrambler operation are used: reset mode and free-running mode.

12.3.6.2.1 Reset mode

In reset mode, the scrambler shall be reset at the beginning of every symbol period. Therefore, the same 2*N* bits will be generated for each symbol, and each subcarrier will be assigned the same two-bit pseudo-random number for rotation of its constellation point in successive symbols.

12.3.6.2.2 Free-running mode

In free-running mode, the scrambler shall not be reset at the beginning of each symbol period, but instead shall continue running from one symbol to the next. As a result, there should be no correlation between the two bits that are mapped on subcarrier *i* during symbol *s* and the two bits mapped to subcarrier *i* during symbol *s*+1. To guarantee that the bits on a particular subcarrier are uncorrelated from one DMT symbol to the next, for all values of IDFT size, four scrambler bits shall be skipped between symbols *s* and *s*+1. Practically, this means the scrambler generates 2*N* bits that are allocated to symbol *s*. The next four bits generated by the scrambler are not used. The next 2*N* bits from the scrambler are then allocated to symbol *s*+1.

12.3.7 Channel initialization policies

The method used by the receiver to select the values of transceiver parameters described in this clause is implementation dependent. However, within the limit of the total data rate provided by the local PMD, the selected values shall meet all of the constraints communicated by the transmitter prior to the channel analysis and exchange phase, including:

- Message overhead data rate ≥ Minimum message overhead data rate;
- Net data rate ≥ Minimum net data rate for all bearer channels;
- Impulse noise protection ≥ Minimum impulse noise protection for all bearer channels;
- Delay ≤ Maximum delay for all bearer channels;
- SNR Margin ≥ TARSNRM.

Within those constraints, the receiver shall select the values as to optimize in the priority given in one of the priority lists below, where the selection of the list is configured through the CO-MIB channel initialization policy parameter (CIPOLICY, see clause 7.3.2.10 of [ITU-T G.997.1]). The channel initialization policy applies only for the selection of the values exchanged during initialization, and does not apply during showtime.

Due to use of the specific modulation pattern of O/R-P-MEDLEY signal (modulation with SOC bytes followed by a quadrant scrambler), after the VTU enters the SHOWTIME state, the reported SNRM value can be inaccurate and lower than the TARSNRM value.

If OLR type 3 (SRA) is supported and enabled, the VTU may initiate an SRA with vendor discretionary triggering criteria for a period of 10 seconds after the VTU has entered the SHOWTIME state in order to achieve a more accurate reported SNRM value greater than or equal to the TARSNRM value.

The following channel initialization policies are defined:

- Policy ZERO if $CIpolicy_n$=0, then:
  1) Maximize net data rate for all bearer channels, per the allocation of the net data rate, in excess of the sum of the minimum net data rates over all bearer channels (see clause 12.3.5).
  2) Minimize excess margin with respect to the maximum SNR margin (MAXSNRM) through gain adjustments (see clause 10.3.4.2). Other control parameters may be used to achieve this (e.g., MAXMASK, see clause 7.2.3).
- Policy ONE if $CIpolicy_n$=1, then:
  a) If the minimum net data rate (see clause 7.3.2.1.1 of [ITU-T G.997.1]) is set equal to the maximum net data rate (see clause 7.3.2.1.3 of [ITU-T G.997.1]) then
     1) Maximize INP_act_n for bearer channel #*n*.
  b) If the minimum net data rate (see clause 7.3.2.1.1 of [ITU-T G.997.1]) is not set equal to the maximum net data rate (see clause 7.3.2.1.3 of [ITU-T G.997.1]) then

1) Maximize net data rate for all the bearer channels, per the allocation of the net data rate, in excess of the sum of the minimum net data rates over all bearer channels (see clause 12.3.5).
2) If such maximized net data rate is equal to the maximum net data rate (see clause 7.3.2.1.3 of [ITU-T G.997.1]), maximize INP_act_n for the bearer channel #*n*.
3) Minimize excess margin with respect to the maximum noise margin MAXSNRM through gain scalings (see clause 10.3.4.2). Other control parameters may be used to achieve this (e.g., MAXMASK, see clause 7.2.3).

- Policy TWO if $CIpolicy_n$ = 2, then:
  1) Maximize net data rate for all the bearer channels, per the allocation of the net data rate, in excess of the sum of the minimum net data rates over all bearer channels (see clause 12.3.5).
  2) If such maximized net data rate is equal to the maximum net data rate (see clause 7.3.2.1.3 of [ITU-T G.997.1]), maximize $SNRM_n$ for the bearer channel #*n*.
  3) Minimize excess margin with respect to the maximum noise margin MAXSNRM through gain scalings (see clause 10.3.4.2). Other control parameters may be used to achieve this (e.g., MAXMASK, see clause 7.2.3).

If only a single bearer channel is configured through the CO-MIB, then the CIPOLICY shall be set to ZERO, ONE or TWO. If multiple bearer channels are configured through the CO-MIB, then the CIPOLICY shall be set to ZERO for each of the bearer channels. The use of the channel initialization policy ONE or TWO with multiple bearer channels is for further study.

Support of channel initialization policy ZERO is mandatory. Support of channel initialization policy ONE or TWO is optional. Additional channel initialization policies are for further study. The $CIpolicy_n$ parameter values other than 0, 1 and 2 are reserved for use by the ITU-T.

12.3.7.1 Channel initialization policies with ROC

The method used by the receiver to select the values of transceiver parameters described in this clause is implementation dependent. However, within the limit of the total data rate provided by the local PMD, the selected values shall meet all of the constraints communicated by the transmitter prior to the channel analysis and exchange phase, including:

- Message overhead data rate ≥ Minimum message overhead data rate;
- Net data rate ≥ Minimum net data rate for all bearer channels;
- Impulse noise protection ≥ Minimum impulse noise protection for all bearer channels;
- Delay ≤ Maximum delay for all bearer channels;
- SNR Margin ≥ TARSNRM;
- SNR Margin for the ROC ≥ TARSNRM.

Within those constraints, the receiver shall select the values as to optimize in the priority given in one of the priority lists below, where the selection of the list is configured through the CO-MIB channel initialization policy parameter (CIPOLICY, see clause 7.3.2.10 of [ITU-T G.997.1]). The channel initialization policy applies only for the selection of the values exchanged during initialization and does not apply during SHOWTIME.

Due to use of the specific modulation pattern of O/R-P-MEDLEY signal (modulation with SOC bytes followed by a quadrant scrambler), after the VTU enters the SHOWTIME state, the reported SNRM-ROC value can be inaccurate and lower than the TARSNRM value.

If OLR type 3 (SRA) is supported and enabled, the VTU may initiate an SRA with vendor discretionary triggering criteria for a period of 10 seconds after the VTU has entered the SHOWTIME state in order to achieve a more accurate reported SNRM-ROC value greater than or equal to the TARSNRM value, preferably up to TARSNRM-ROC, as defined in the channel initialization policy below.

The following channel initialization policy is defined:

- Policy ZERO if $CIpolicy_n$=0, then:
  1) Maximize the SNR Margin for the ROC up to TARSNRM-ROC.
  2) Maximize net data rate for all bearer channels, per the allocation of the net data rate, in excess of the sum of the minimum net data rates over all bearer channels (see clause 12.3.5).
  3) Maximize the SNR Margin for the ROC above TARSNRM-ROC.
  4) Minimize excess margin with respect to the maximum SNR margin MAXSNRM through gain adjustments (see clause 10.3.4.2). Other control parameters may be used to achieve this (e.g., MAXMASK, see clause 7.2.3).

Support of channel initialization policy ZERO is mandatory. Additional channel initialization policies are for further study. The $CIpolicy_n$ parameter values other than 0 are reserved for use by the ITU-T.

12.4 Loop diagnostic mode procedures

12.4.1 Overview

The built-in loop diagnostic function defined in this clause enables the immediate measurement of channel conditions at both ends of the loop without dispatching maintenance technicians to attach test equipment to the loop. The resulting information helps to isolate the location (inside the premises, near the customer end of the loop, or near the network end of the loop) and the sources (crosstalk, radio frequency interference, and bridged taps) of impairments.

The loop diagnostic mode shall be entered after completion of the ITU-T G.994.1 handshake phase, when the loop diagnostic mode codepoint in the MS message is set (see clauses 12.3.2.1.2 and 12.3.2.2.2). Loop diagnostic mode shall be entered upon request by either VTU. Both VTUs shall support the loop diagnostic mode.

The sequence of stages in the loop diagnostic mode shall be the same as for initialization (defined in clause 12.3) up to the channel analysis and exchange phase, where the test parameters listed in Table 12-71 and defined in clause 11.4.1 are exchanged. However, the test parameters for the quiet line noise (QLN) and the channel characteristics function (Hlog) shall be measured and exchanged during the channel discovery phase, as described in clause 12.4.3.

The time-outs specified in clause 12.3.1 do not apply to loop diagnostic mode. Time-out values are for further study.

Table 12-71 – Test parameters exchanged during the loop diagnostic mode

Abbreviation	Name
Hlin($k \times G \times \Delta f$)	Channel characteristics per subcarrier group, linear
Hlog($k \times G \times \Delta f$)	Channel characteristics per subcarrier group, $\log_{10}$
QLN($k \times G \times \Delta f$)	Quiet line noise per subcarrier group
SNR($k \times G \times \Delta f$)	Signal-to-noise ratio per subcarrier group
LATN-pb	Loop attenuation per band
SATN-pb	Signal attenuation per band
SNRM-pb	Signal-to-noise ratio margin per band
ATTNDR	Attainable net data rate
ACTATP	Actual aggregate transmit power (far-end)

The test parameters are mapped to messages using an integer number of octets per parameter value.

In case the parameter value as defined in clause 11.4.1 is represented by a number of bits that is not an integer number of octets, the parameter value shall be mapped to the LSBs of the message octets. Unused more significant bits shall be set to ZERO for unsigned parameter values and shall be set to the sign bit for signed parameter values.

12.4.1.1 SOC message mapping during loop diagnostic mode

In order to increase the robustness of the messages exchanged during the channel discovery and training phases of the loop diagnostic mode, all SOC messages shall be sent using 1 information bit per DMT symbol, where each bit is sent 5 times in 5 consecutive DMT symbols. The mapping of the SOC bits to subcarriers during loop diagnostic mode shall be as summarized in Table 12-72.

Table 12-72 – Bit mapping during loop diagnostic mode

Subcarrier index	Constellation bits for SOC bit = 0	Constellation bits for SOC bit = 1
Even	00	00
1, 11, 21, …,10*n*+1,...	00	11
3, 13, 23, …,10*n*+3,...	00	11
5, 15, 25, ... ,10*n*+5,...	00	11
7, 17, 27, …,10*n*+7,...	00	11
9, 19, 29, …,10*n*+9,...	00	00

When the SOC is inactive, the symbols shall be transmitted as described in clause 12.3.3 without modification.

12.4.2 Channel discovery and training phases of loop diagnostic mode

12.4.2.1 SOC messages exchanged during the channel discovery and training phases of loop diagnostic mode

Other than O-PRM and R-PRM, the SOC messages for the channel discovery phase and the training phase of the loop diagnostic mode shall be the same as for the initialization procedure described in clauses 12.3.3 and 12.3.4, respectively. The test parameters for the quiet line noise (QLN) and the channel characteristics function (Hlog) shall be measured and exchanged during the channel discovery phase in the O-PRM-LD and R-PRM-LD messages, which replace O-PRM and R-PRM. The test parameters are listed in Table 12-73 and defined in clause 11.4.1.

Table 12-73 – Test parameters exchanged during the channel discovery phase in loop diagnostic mode

Abbreviation	Name
Hlog($k \times G \times \Delta f$)	Channel characteristics per subcarrier group, dB
QLN($k \times G \times \Delta f$)	Quiet line noise per subcarrier group, dBm/Hz

12.4.2.1.1 VTU-O message O-PRM-LD

Table 12-74 – Description of message O-PRM-LD

	Field name	Format
1	Message descriptor	Message code
2	Downstream MEDLEY reference PSD (MREFPSDds)	PSD descriptor

Table 12-74 – Description of message O-PRM-LD

	Field name	Format
3	MEDLEYds set	Bands descriptor
4	Cyclic extension length	1 byte
5	Downstream cyclic prefix length	2 bytes
6	Downstream transmit window length (β_{ds})	1 byte
7	VTU-O IDFT size	1 byte
8	Duration of the VTU-O EC training period	1 byte
9	Requested duration of the VTU-O TEQ training period	1 byte
10	Requested duration of the VTU-R TEQ training period	1 byte
11	Requested minimum duration of the periodic signal	1 byte
12	Downstream frequency-domain spectrum shaping	Log_tss_i descriptor
13	Quiet line noise per subcarrier group, QLN($k \times G \times \Delta f$)	512 bytes
14	Channel characteristics function Hlog per subcarrier group, Hlog($k \times G \times \Delta f$)	2 × 512 bytes

Fields #1 to #12 shall be formatted the same as O-PRM (see clause 12.3.3.2.1.3).

Field #13 "Quiet line noise per subcarrier group, QLN($k \times G \times \Delta f$)" indicates the parameter QLN for 512 subcarrier groups in the upstream direction (measured at the VTU-O receiver). The parameter QLN for each group shall be represented as an 8-bit value as specified in clause 11.4.1.1.2, mapped to a single octet. The octets representing QLN values for different groups shall be mapped to Field #13 so that they are transmitted in ascending order of group index k, for $k = 0$ to 511. The groups shall be formed as specified in clause 11.4.1.

Field #14 "Channel characteristics function Hlog per subcarrier, Hlog($k \times G \times \Delta f$)" indicates the parameter Hlog for 512 subcarrier groups in the upstream direction. The parameter Hlog for each group shall be represented as a 10-bit value as specified in clause 11.4.1.1.1, mapped to 2 octets by adding six MSBs equal to 0. The pairs of octets representing Hlog values for different groups shall be mapped to Field #14 so that they are transmitted in ascending order of group index k, for $k = 0$ to 511. The groups shall be formed as specified in clause 11.4.1.

12.4.2.1.2 VTU-R message R-PRM-LD

Table 12-75 – Description of message R-PRM-LD

	Field name	Format
1	Message descriptor	Message code
2	Upstream MEDLEY reference PSD (MREFPSDus)	PSD descriptor
3	MEDLEYus set	Bands descriptor
4	Upstream cyclic prefix length	2 bytes
5	Upstream transmit window length (β_{us})	1 byte
6	VTU-R IDFT size	1 byte
7	Duration of the VTU-R EC training period	1 byte
8	Requested duration of the VTU-R TEQ training period	1 byte
9	Requested duration of the VTU-O TEQ training period	1 byte

Table 12-75 – Description of message R-PRM-LD

	Field name	Format
10	Requested minimum duration of the periodic signal	1 byte
11	Minimum duration of the R-P-TRAINING 1 signal ($T_{MIN\text{-}R\text{-}P\text{-}Train}$)	1 byte
12	Upstream frequency-domain shaping	Log_tss_i descriptor
13	Quiet line noise per subcarrier, QLN($k \times G \times \Delta f$)	512 bytes
14	Channel characteristics function Hlog per subcarrier, Hlog($k \times G \times \Delta f$)	2 × 512 bytes

Fields #1 to #12 shall be formatted the same as R-PRM (see clause 12.3.3.2.2.3).

Field #13 "Quiet line noise per subcarrier group, QLN($k \times G \times \Delta f$)" indicates the parameter QLN for 512 subcarrier groups in the downstream direction (measured at the VTU-R receiver). The parameter QLN for each group shall be represented as an 8-bit value as specified in clause 11.4.1.1.2, mapped into a single octet. The octets representing QLN values for different groups shall be mapped to Field #13 so that they are transmitted in ascending order of group index k, for k = 0 to 511. The groups shall be formed as specified in clause 11.4.1.

Field #14 "Channel characteristics function Hlog per subcarrier, Hlog($k \times G \times \Delta f$)" indicates the parameter Hlog for 512 subcarrier groups in the downstream direction. The parameter Hlog for each group shall be represented as a 10-bit value as specified in clause 11.4.1.1.1, mapped into 2 octets by adding six MSBs equal to 0. The pairs of octets representing Hlog values for different groups shall be mapped to Field #14 so that they are transmitted in ascending order of group index k, for k = 0 to 511. The groups shall be formed as specified in clause 11.4.1.

12.4.2.2 Signals transmitted during the channel discovery and training phases

The signals transmitted during the channel discovery and training phases are the same as defined in initialization (see clauses 12.3.3 and 12.3.4) with the following exceptions:

- The SOC message mapping shall be as defined in clause 12.4.1.1;
- The duration of O-P-QUIET 1 shall be at least 8 192 symbols but not longer than 16 384 symbols.

12.4.3 Channel analysis and exchange phase of loop diagnostic mode

Figure 12-13 presents the timing diagram for the stages of the channel analysis and exchange phase of the loop diagnostic mode. It gives an overview of the sequence of signals transmitted and the sequence of SOC messages sent by the VTU-O and VTU-R during the channel analysis and exchange phase of the loop diagnostic mode. The shaded areas correspond to periods of time when the SOC is in its inactive state.

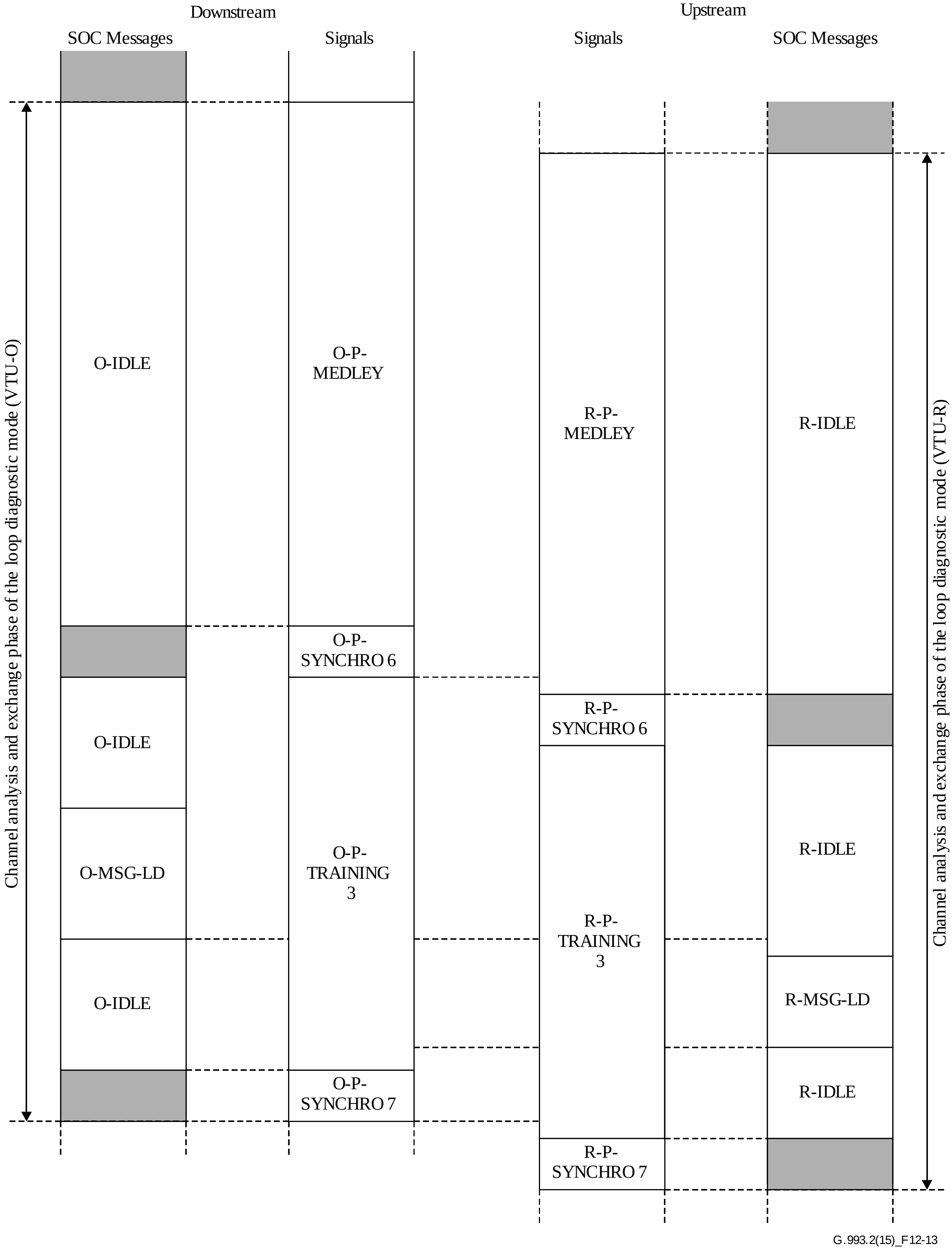

Figure 12-13 – Timing diagram for the stages of the channel analysis and exchange phase of the loop diagnostic mode

Upon entering this phase the VTU-O shall transmit 80 000 DMT symbols of O-P-MEDLEY with O-IDLE being sent over the SOC. Upon entering this phase the VTU-R shall transmit 80 000 DMT symbols of R-P-MEDLEY with R-IDLE being sent over the SOC.