CableLabs®

DOCSIS® 3.1 Pocket Guide

DOCSIS 3.1
PHYSICAL & MAC Layer
Quick Reference Pocket Guide

CableLabs®

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TRADEMARKS

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Introduction

The DOCSIS™ 3.1 specification is the fifth generation of the DOCSIS™ family of specifications. This handbook provides a quick reference to various features within the Physical and MAC layers of the DOCSIS™ 3.1 specifications developed by CableLabs®. The information contained within this handbook is based on the I03 release of the specification and associated engineering changes as of September 19, 2014.

Quick Reference Guide

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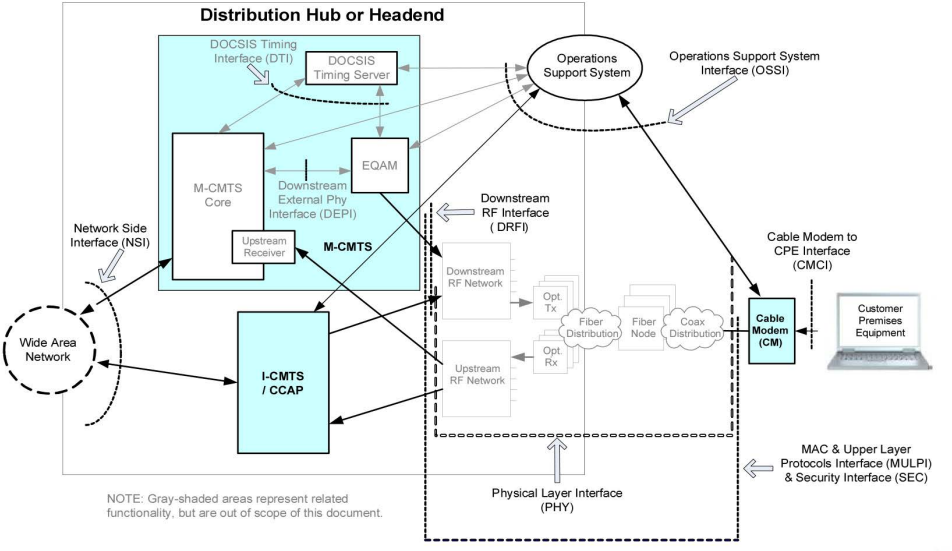
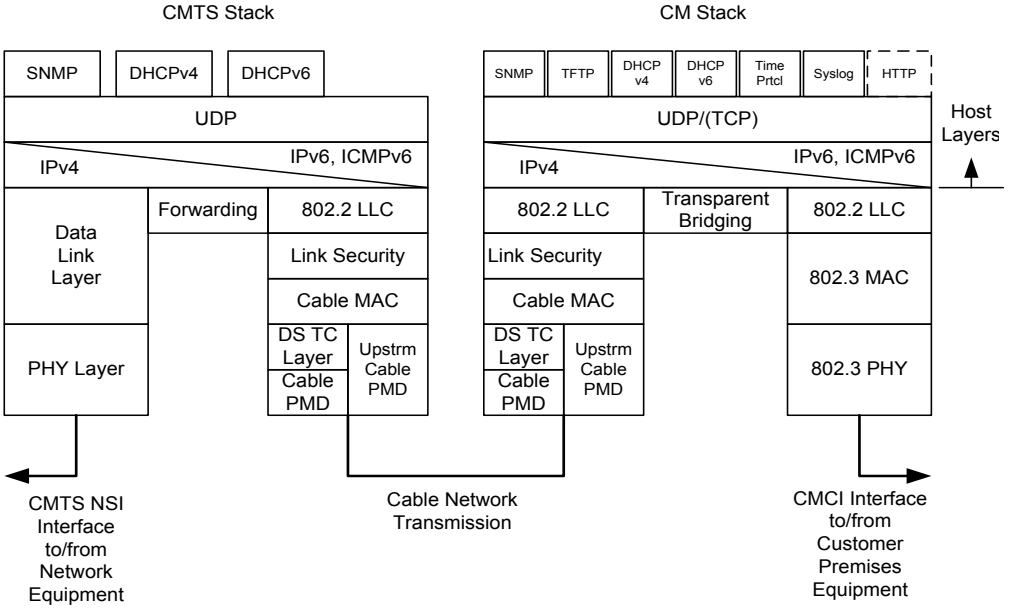
DOCSIS Reference Architecture

1 DOCSIS REFERENCE ARCHITECTURE



1.1 DOCSIS Protocol Stacks



Physical Layer: Upstream

2

2 Upstream

The new upstream for D3.1 consists of two physical layer technologies including legacy SC-QAM channels and the new OFDMA channels. The SC-QAM PHY is based on the D3.0 technology and all parameters and configurations carry forward from D3.0 with the exception of S-CDMA, which is optionally supported for D3.1 CMs and CMTSs.

Section 1 covers the parameters and key points of the new OFDMA physical layer.

2.1 Frequency Range and Bandwidths

2.1.1 CM Output

The CM modulator MUST support upstream transmissions from 5 to at least 204 MHz and agile placement of the OFDMA channels within that range.

Individual CM implementations may limit the spectrum over which the CM is able to transmit upstream signals. A CM MUST support one or more of the following upstream upper band edges, as long as one of the upstream upper band edges supported is 85 MHz or greater.

CM Upstream Band Options	
Lower Band Edge	**Upper Band Edge**
5 MHz	42 MHz
	65 MHz
	85 MHz
	117 MHz
	204 MHz

The CM MUST be configurable to operate with any supported upstream upper band edge. The nature and operation of this configurability is vendor-specific. Possible forms of configurability include a hardware switch on the modem housing, a software-controlled diplex filter responsive to OSSI commands, or other forms.

The CM MAY support additional spectrum beyond 204 MHz for the upstream.

The CM MUST NOT cause harmful interference to any downstream signals that might exist above its configured upstream upper band edge.

The CM MUST be capable of transmitting 192 MHz of active channels when operating with the 204 MHz upstream upper band edge.

In DOCSIS 3.1 upstream mode the CM MUST be capable of transmitting OFDMA channels and legacy SC-QAM channels at the same time (as controlled by the CMTS). In all cases the CM is not required to transmit legacy SC-QAM channels above a frequency of 85 MHz.

2.1.2 CMTS Input

The CMTS MUST support upstream transmissions from 5 to at least 204 MHz and agile placement of the OFDMA blocks within that range.

CMTS Upstream Band Options	
Lower Band Edge	**Upper Band Edge**
5 MHz	204 MHz

The CMTS MUST capable of receiving 192 MHz of active channels when operating with the 204 MHz upstream upper band edge. In DOCSIS 3.1 upstream mode the CM is capable of transmitting OFDMA channels and legacy SC-QAM channels at the same time (as controlled by the CMTS). In all cases the CMTS MUST NOT configure the CM to transmit legacy SC-QAM channels above a frequency of 85 MHz.

2.1.3 Channel Bandwidth

The CM and CMTS both MUST support a minimum of 2 upstream OFDMA channels. A DOCSIS 3.1 upstream OFDMA channel bandwidth may be as much as 96 MHz.

The CMTS MUST ensure that the encompassed spectrum of a 96 MHz upstream OFDMA channel does not exceed 95 MHz. Therefore the number of contiguous active subcarriers in an upstream OFDMA channel MUST NOT exceed 1900 for 2K FFT and 3800 for 4K FFT. When configured for 2K FFT, the CMTS MUST only use subcarriers in the range $74 \leq k \leq 1973$, where k is the spectral index of the subcarrier in the IDFT equation defining the OFDMA signal. When configured for 4K FFT, the CMTS MUST only use subcarriers in the range $148 \leq k \leq 3947$, where k is the spectral index of the subcarrier in the IDFT equation defining the OFDMA signal.

Minimum Upstream Channel Bandwidth	
2k FFT	**4k FFT**
10 MHz	6.4 MHz

***NOTE: Encompassed spectrum** is defined for an OFDM or OFDMA channel as: the range of frequencies from the center frequency of the channel's lowest active subcarrier minus half the subcarrier spacing, to the center frequency of the channel's highest active subcarrier plus half the subcarrier spacing.*

2.1.4 Excluded Subcarriers and Bands

Excluded subcarriers will only occur between minislots.

Subcarrier exclusions between minislots can be any integer number of subcarriers. There is no minimum subcarrier exclusion restriction. See section 3.1.4 for definition of excluded subcarrier.

***NOTE:** For more on **minislots** in in upstream OFDMA channels see section 2.5.*

2.2 OFDM Parameters

2.2.1 IDFT

The upstream OFDMA signal transmitted by the CM is described using the following IDFT equation:

$$x(i) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k)\, exp\,(j \frac{2\pi i \left(k - \frac{N}{2}\right)}{N}), \quad for\ i = 0, 1, \ldots, (N-1)$$

Where N is the FFT size. The resulting time domain discrete signal, $x(i)$, is a baseband complex-valued signal. In this definition of the IDFT $X(0)$ is the lowest frequency component; and $X(N\text{-}1)$ is the highest frequency component.

2.2.2 Upstream OFDM Numerology

The CM MUST output an RF Modulated signal with characteristics defined in Table 7–11 of the PHYv3.1 specification. The fundamental OFDM time and frequency parameters of the upstream signal are in the following table.

Upstream OFDM Time/Frequency Numerology			
Sample Rate (Symbol Clock)	**FFT Size (N)**	**Subcarrier Spacing**	**FFT Time Duration**
102.4 Msps (102.4 MHz)	2048 (2K FFT)	50 kHz	20 µs
	4096 (4K FFT)	25 kHz	40 µs

2.2.3 Cyclic Prefix & Windowing

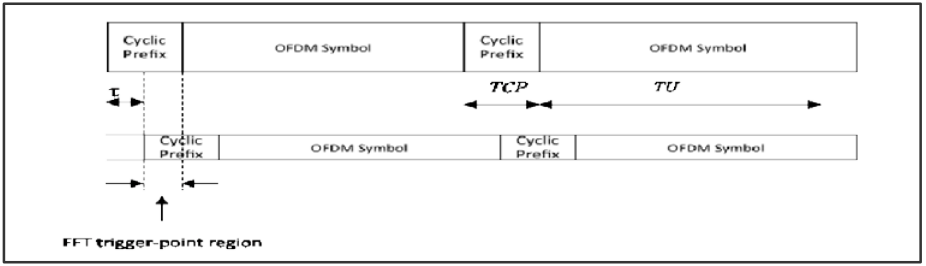
Cyclic prefix and windowing are applied in the upstream transmission.

Cyclic prefix is added in order to enable the receiver to overcome the effects of inter-symbol interference (ISI) and caused by micro-reflections in the channel.

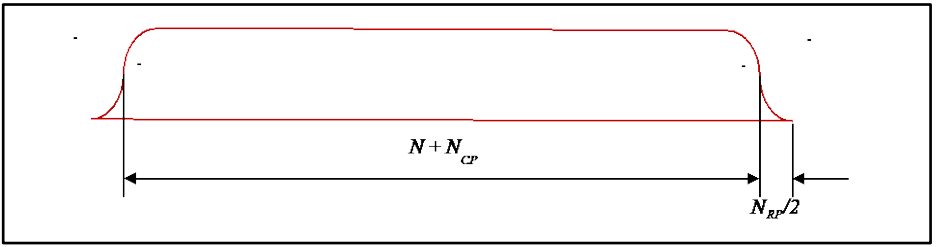
Windowing is applied in order to maximize channel capacity by sharpening the edgesof the spectrum of the OFDMA signal.

Spectral edges occur at the two ends of the spectrum of the OFDM symbol, as well as at the ends of internal exclusion bands.

In the presence of a micro-reflection in the transmission medium, the received signal is the sum of the main signal and the delayed and attenuated micro-reflection. As long as this delay (τ) is less than the time duration of the cyclic prefix (T_{CP}), the CMTS receiver can trigger the FFT to avoid any inter-symbol or inter-carrier interference due to this micro reflection, as shown in the following figure.



Signal with Micro-Reflection at Receiver



Tapering Window

The CM transmitter and the CMTS receiver MUST support the cyclic prefix values defined in the following table.

Cyclic Prefix (µs)	Cyclic Prefix Samples (N_{cp})
0.9375	96
1.25	128
1.5625	160
1.875	192
2.1875	224
2.5	256
2.8125	288
3.125	320
3.75	384
5.0	512
6.25	640

The CM transmitter and the CMTS receiver MUST support the roll-off period values defined in the following table. The CMTS MUST NOT allow a configuration in which the Roll-Off Period value is ≥ the Cyclic Prefix value.

Roll-Off Period (µs)	Roll-Off Period Samples (N_{rp})
0	0
0.3125	32
0.625	64
0.9375	96
1.25	128
1.5625	160
1.875	192
2.1875	224

The Cyclic Prefix and Roll-Off Period sample values above are found using the sample rate of 102.4 Msamples/s.

2.2.4 Bit Loading / Modulation Formats

The CM modulator and CMTS demodulator MUST support the following modulation formats for subcarriers of upstream OFDMA channels.

US CM Modulation Formats	US CMTS Modulation Formats
BPSK	BPSK
QPSK	QPSK
8-QAM	8-QAM
16-QAM	16-QAM
32-QAM	32-QAM
64-QAM	64-QAM
128-QAM	128-QAM
256-QAM	256-QAM
512-QAM	512-QAM
1024-QAM	1024-QAM
2048-QAM	
4096-QAM	

The CMTS demodulator SHOULD support 2048-QAM and 4096-QAM for subcarriers of upstream OFDMA channels.

NOTE: *BPSK is used for pilots and complimentary pilots only, and not used for data transmission.*

CMs are granted transmission opportunities by minislots, and minislots are associated with subcarriers. All subcarriers of a specific type (i.e., data subcarriers, pilots, complementary pilots or zero-valued subcarriers) within a minislot have the same modulation order, although different minislots may have different modulation orders; the modulation order to be used is determined by the Profile associated with the minislot.

The CM modulator and CMTS demodulator MUST support zero valued subcarriers of upstream OFDMA channels.

Some minislots may be specified as zero-valued in some profiles. The CM MUST NOT transmit anything in the minislots of these profiles. The CM MUST set all subcarriers, including data subcarriers, pilots and complementary pilots to zero in these minislots of these profiles. A zero-valued minislot in one profile may not be zero-valued in another profile.

NOTE: For more on minislots in in upstream OFDMA channels see section 2.5.

2.3 Power

2.3.1 CM Tx Power Requirements

The transmit power requirements in D3.1 are a function of the number and occupied bandwidth of the OFDMA and legacy channels in the TCS.

Maximum Tx Power Limits	
Total Power	$\geq$ 65dBmV
$P_{1.6Max}$	P_{max} dBmV – $10\log_{10}(N_{eq})$
$P_{1.6Max}$ if modulated spectrum $\leq$ 24 MHz	53.2 dBmV+ (P_{max} - 65)

NOTE: Modulated Spectrum *for the upstream is defined as spectrum comprising all non-zero-valued subcarriers of a cable modem's OFDMA transmission, resulting from the exercised transmit opportunities.*

As shown in the first row of table above, the minimum highest value of the total power output of the CM P_{max} is 65 dBmV, although higher values are allowed.

The second row shows how to calculate the maximum equivalent channel power.

The third row enforces a maximum power spectral density of P_{max} dBmV per 24 MHz for a CM operating in DOCSIS 3.1 mode, even on a SC-QAM channel. This limit on power spectral density does not apply for a CM operating in DOCSIS 3.0 mode, where the fidelity requirements are the DOCSIS 3.0 fidelity requirements and not the fidelity requirements of the DOCSIS 3.1 mode.

Minimum Equivalent Channel Tx Power Limits ($P_{1.6Min}$)	
Non-boosted Pilots	17 dBmV
Boosted Pilots w/ 50 kHz subcarrier spacing	17.5 dBmV
Boosted Pilots w/ 25 kHz subcarrier spacing	18 dBmV

The CM's actual transmitted power per equivalent channel MUST be within +/- 2 dB of the target power, $P_{1.6r\_n}$, with Pre-Equalization off taking into account whether pilots are present and symbol constellation values.

2.3.2 CMTS Rx Input Power Requirements

The CMTS Upstream Demodulator MUST operate with an average input signal level, including ingress and noise to the upstream demodulator, up to 31 dBmV.

The CMTS MUST be settable according to the following table for intended received power normalized to 6.4 MHz of bandwidth.

Modulation	Minimum Set Point	Maximum Set Point	Range
QPSK	-4 dBmV	10 dBmV	-9 / +3
8-QAM	-4 dBmV	10 dBmV	-9 / +3
16-QAM	-4 dBmV	10 dBmV	-9 / +3
32-QAM	-4 dBmV	10 dBmV	-9 / +3
64-QAM	-4 dBmV	10 dBmV	-9 / +3
128-QAM	0 dBmV	10 dBmV	-9 / +3
256-QAM	0 dBmV	10 dBmV	-9 / +3
512-QAM	0 dBmV	10 dBmV	-3 / +3
1024-QAM	0 dBmV	10 dBmV	-3 / +3
2048-QAM	7 dBmV	10 dBmV	-3 / +3
4096-QAM	10 dBmV	10 dBmV	-3 / +3

The CMTS Upstream demodulator MUST operate within its defined performance specifications with received bursts within the ranges defined in the previous table of the set power.

2.3.3 Maximum Scheduled Minislots

While transmitting on the large upstream spectrum supported by DOCSIS 3.1, a CM can encounter large upstream attenuation and can have a power deficit when attempting to reach the CMTS receiver at the nominal OFDMA channel set power. A CMTS has several options in dealing with such CMs: it can limit the TCS to the channel set that will enable the CM to reach the CMTS receiver at the nominal set power; it can assign the CM a profile which includes reduced modulation depth enabling proper reception even at lower received power; or, it can operate that CM under Maximum Scheduled Minislots (MSM).

Complete control of MSM operation is under the CMTS. The CMTS does not inform the CM when it decides to assign it to MSM operation in a specific OFDMA channel. Instead, the CMTS instructs the CM to transmit with a higher power spectral density than the CM is capable of with a 100% grant. In addition, the CMTS limits the number of minislots concurrently scheduled to the CM, such that the CM is not given transmit opportunities on that OFDMA channel that will result in overreaching its reported transmission power capability.

Note that when operating under MSM, it is expected that a CM that normally meets the fidelity and performance requirements will only exhibit graceful degradation. Also the CMTS is expected to discriminate between a CM whose fidelity degrades gracefully and a CM whose fidelity does not, and provide the capability to disallow a CM whose fidelity does not degrade gracefully from operating under MSM.

2.4 Forward Error Correction (FEC)

2.4.1 FEC Codes for OFDMA Channels

DOCSIS 3.1 uses three Quasi-Cyclic Low-Density Parity-Check codes (QC-LDPC) for the upstream transmission.

The following table provides the key attributes of the 3 QC-LDPC codes used by the upstream:

Code	Code rate	Codeword size in bits (N_i)	Information bits (K_i)	Parity bits (P_i)
Long code	89% (8/9)	16200	14400	1800
Medium code	85% (28/33)	5940	5040	900
Short code	75% (3/4)	1120	840	280

Shortening of LDPC codewords is useful in order to optimize FEC protection for the payload. If a shortened codeword is required, the CM MUST construct it as follows:

1. Binary zeros are appended to a reduced number of information bits at the input of the encoder.
2. The encoder calculates the parity bits.
3. The appended binary zeros are removed from the transmitted shortened codeword.

2.4.2 US Codeword Selection Algorithm

The DOCSIS 3.1 specification includes a FEC codeword selection algorithm that the CM and CMTS use to determine the exact number, type, and size of the codewords to be used, and in what order. Codewords are filled and transmitted in the following order, with codeword shortening applied:

1. Full long codewords (if present)
2. Shortened long codeword (if present)
3. Full medium codewords (if present)
4. Shortened medium codeword (if present)
5. Full short codewords (if present)
6. Shortened short codewords (if present)
7. Zero-pad (if present)

2.5 OFDMA Minislots

Minislots are defined by a size in terms of the number of symbols and number of subcarriers. They include data carried on data subcarriers, pilots carried on pilot subcarriers and complementary pilots that can carry data but at a lower modulation order.

In this section, BW is defined as the encompassed spectrum on a single OFDMA channel.

The CMTS communicates minislot definition to the CM in UCD messages as defined in DOCSIS MULPIv3.1.

Minislot Parameters 2k FFT (20µs FFT duration)	
Parameter	**Allowable Range**
K (symbols per frame)	6 – 18 (BW ≥ 72 MHz)
Q (subcarriers per minislot)	8
Minislot Parameters 4k FFT (40µs FFT duration)	
Parameter	**Allowable Range**
K (symbols per frame)	6 – 9 (BW ≥ 72 MHz)
Q (subcarriers per minislot)	16

NOTE: *In the above tables, a minislot is always 400 kHz wide.*

2.5.1 US Profiles

Upstream profiles are comprised of multiple minislots, and are characterized by bit loading and pilot pattern. Bit loading and pilot patterns can vary between minislots within the profile. The bit loading and pilot pattern assignment of minislots can also vary between profiles. An upstream profile maps to an Interval Usage Code defined in an Upstream Channel Descriptor Message.

Different FEC codeword sizes may use portions of a single minislot. FEC codewords can cross minislot and frame boundaries.

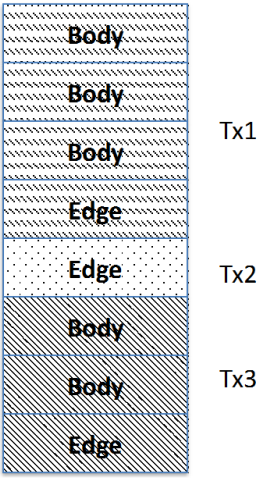
2.5.2 Pilot Subcarriers

Pilots are subcarriers that do not carry data. Instead, a pilot subcarrier encodes a pre-defined BPSK symbol known to the receiver. Pilots are used by the CMTS receiver to adapt to channel conditions and frequency offset. Two types of minislots are defined for each minislot size: edge minislots and body minislots.

The CM MUST use an edge minislot as the first minislot in a transmission burst.

The CM MUST use body minislots for all other minislots in a transmission burst with the following two exceptions:

1. The CM MUST use an edge minislot for the first minislot of an OFDMA frame that is not a zero valued minislot.
2. The CM MUST use an edge minislot for the first minislot after an exclusion band or after one or more contiguous skipped subcarriers or after a zero valued minislot.



Edge and Body Minislots in a Transmission Burst

Complementary pilots are subcarriers that carry data, but with a lower modulation order than other data subcarriers in the minislot. The CMTS receiver MAY use complementary pilots to enhance its signal processing, such as to improve the accuracy of the center frequency offset acquisition.

The modulation order for the complementary pilots is determined by the following equation:

$$M_{cp} = \max(M_{data} - 4, 1)$$

where M_{cp} and M_{data} are the modulation order used for complementary pilots and data subcarriers respectively.

For example if the bit loading in a minislot is 12 (4096-QAM), complementary pilots use 8 bits (256-QAM). If the bit loading is 4 (16-QAM), complementary pilots will use BPSK.

2.5.3 Pilot Patterns

When using a 2k FFT, the CM MUST support pilot patterns 1-7. The CMTS MUST support pilot patterns 1-4. The CMTS MUST use either pilots pattern 1-4 or pilot patterns 5-7 on the same OFDMA channel. The CMTS MUST NOT use a mixture of pilot patterns 1-4 and 5-7 on the same OFDMA channel.

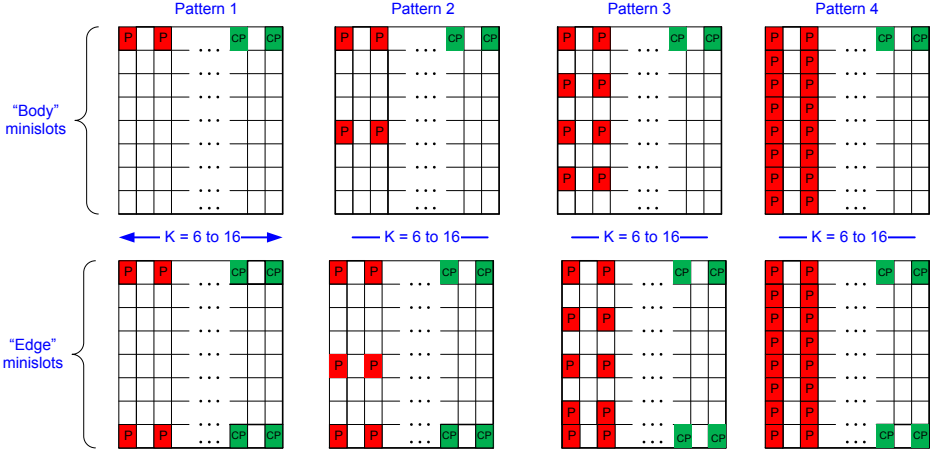
When using a 4k FFT, the CM MUST support pilot patterns 8-14. The CMTS MUST support pilot patterns 8-11. The CMTS MUST use either pilots pattern 8-11 or pilot patterns 12-14 on the same OFDMA channel. The CMTS MUST NOT use a mixture of pilot patterns 8-11 and 12-14 on the same OFDMA channel.

In each figure, the horizontal axis represents OFDMA symbols, and the vertical axis represents the subcarriers. Each square in a figure represents a subcarrier at a specific symbol time. Pilots are designated by "P" and complementary pilots by "CP". All other subcarriers carry data with the modulation order of the minislot.

The CM MUST use higher power (pilot boost) when transmitting pilots and complementary pilots with pilot patterns 5-7 and patterns 12-14, with the following exception:

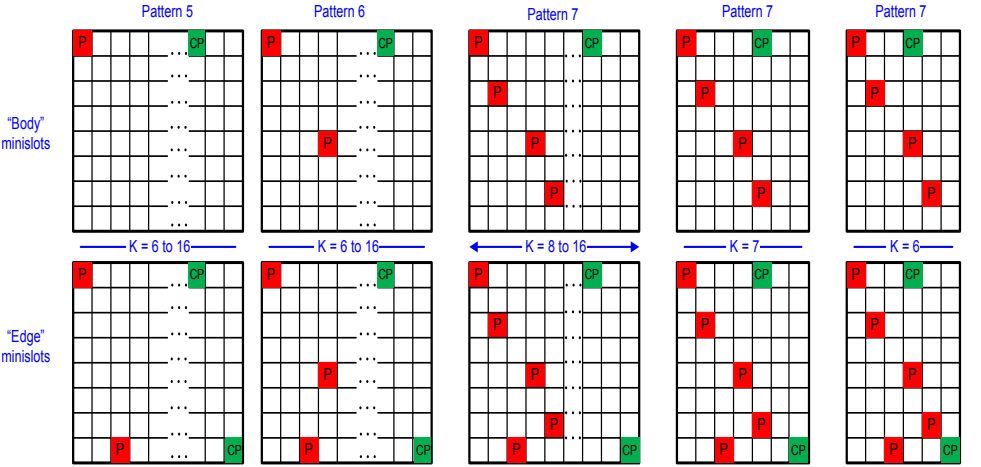
- The CM MUST use boosted power for the pilot and normal power for the complementary pilot when both are used in the same symbol and in the same minislot.

The CM MUST boost pilots and complementary pilots by a factor of 3 in power (about 4.7 dB).



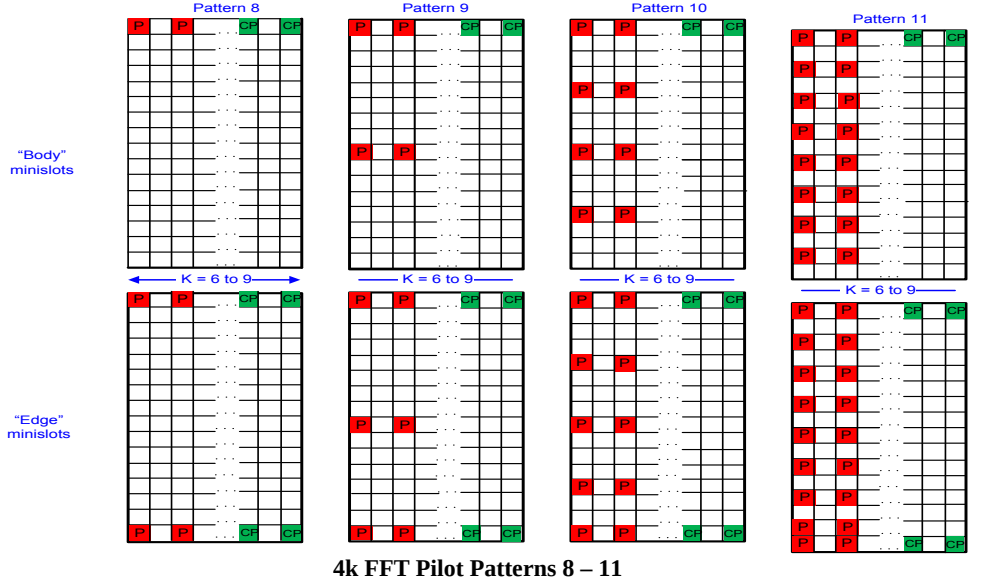
2k FFT Pilot Patterns 1 – 4

The figures show patterns for K between 6 and 16. For K>16 the complementary pilots are always located in the 14th and 16th symbols, all symbols from the 17th symbol to the end of the frame carry data only. Pilot locations are the same for any K.



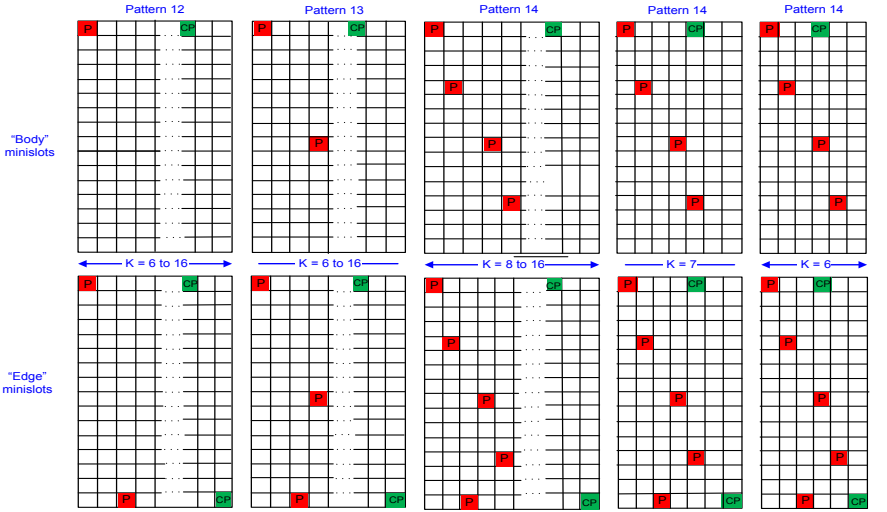
2k FFT Pilot Patterns 5 – 7

The figures show patterns for K between 6 and 16. For K>16 the complementary pilots are always located in the 14th and 16th symbols, all symbols from the 17th symbol to the end of the frame carry data only. Pilot locations are the same for any K.



4k FFT Pilot Patterns 8 – 11

The figures show patterns for K between 6 and 9. For K>9, the complementary pilots are always located in the 7th and 9th symbols, all symbols from the 10th symbol to end of frame carry data only. Pilot locations are the same for any K.



4k FFT Pilot Patterns 12 – 14

The figures show patterns for K between 6 and 9. For K>9, the complementary pilots are always located in the 7th and 9th symbols, all symbols from the 10th symbol to end of frame carry data only. Pilot locations are the same for any K.

2.6 Fidelity and Performance

The following requirements assume that any pre-equalization is disabled, unless otherwise noted.

2.6.1 Downstream and Other Band Spurious Emissions

Downstream and Other Band Spurious Emissions **(see PHYv3.1 Table 7-6 for notes)**				
	Parameter	**Frequency Region**	**During Bursts**	**Between Bursts**
5 – 42 MHz Operation	Integrated (4MHz BW)	42 to 54 MHz	-40 dBc	-26 dBmV
		54 to 60 MHz	-35 dBmV	-40 dBmV
		60 to 88 MHz	-40 dBmV	-40 dBmV
		88 to 1218 MHz	-45 dBmV	max(-45 dBmV, -40 dB ref downstream)
	Discrete	42 to 54 MHz	-50 dBc	-36 dBmV
		54 to 88 MHz	-50 dBmV	-50 dBmV
		88 to 1218 MHz	-50 dBmV	-50 dBmV

Downstream and Other Band Spurious Emissions

(see PHYv3.1 Table 7-6 for notes)

	Parameter	Frequency Region	During Bursts	Between Bursts
5 – 85 MHz Operation	Integrated (4MHz BW)	85 to 108 MHz	-45 dBc	-31 dBmV
		85 to 108 MHz (Should)	-50 dBc	-36 dBmV
		108 to 136 MHz	-40 dBmV	-40 dBmV
		136 to 1218 MHz	-45 dBmV	max(-45 dBmV, -40 dB ref downstream)
	Discrete	85 to 108 MHz	-50 dBc	-36 dBmV
		108 to 1218 MHz	-50 dBmV	-50 dBmV
5 – 204 MHz Operation	Integrated (4MHz BW)	85 to 108 MHz	-45 dBc	-31 dBmV
		85 to 108 MHz (Should)	-50 dBc	-36 dBmV
		108 to 136 MHz	-45 dBmV	max(-45 dBmV, -40 dB ref downstream)
	Discrete	85 to 108 MHz	-50 dBc	-36 dBmV
		108 to 1218 MHz	-50 dBmV	-50 dBmV

2.6.2 Upstream Frequency Band Spurious

In the upstream frequency band spurious emissions band table, the following equations are referenced:

EQ1. SpurFloor = max{ -57 + 10*$\log_{10}$(100% Grant Spectrum/192 MHZ), -60} dBc
EQ2. Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }
EQ3. 100% Grant Spectrum/40
EQ4. 100% Grant Spectrum)/(Under-grant Hold Number of Users)
EQ5. Round{ SpurFloor + 10*$\log_{10}$(Measurement Bandwidth/Under-grant Hold Bandwidth),0.1}

In addition, the Under-grant Hold values used in EQ 4&5 are defined as:

Under-grant Hold Number of Users = Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }

Under-grant Hold Bandwidth = (100% Grant Spectrum)/(Under-grant Hold Number of Users)

Upstream Frequency Band Spurious Emissions
(see PHYv3.1 Table 7-7 for notes)

100% Grant Spectrum (MHz)	SpurFloor (dBc)	Under-grant Hold #Users	Under-grant Hold Bandwidth (MHz)	Measurement Bandwidth (MHz)	Specification in the Interval (dBc)
100%_BW ≤ 64	-60.0	40	EQ3	1.6	EQ5
64 < 100%_BW ≤ 96	-60.0	40	EQ3	3.2	EQ5
96 < 100%_BW ≤	EQ1	EQ2	EQ4	9.6	EQ5
192 192 < 100%_BW	EQ1	EQ2	EQ4	12.8	EQ5

The following table provides example values for the upstream frequency band spurious requirements.

Upstream Frequency Band Spurious Emissions[Examples]					
100% Grant Spectrum (MHz)	SpurFloor (dBc)	Under-grant Hold #Users	Under-grant Hold Bandwidth (MHz)	Measurement Bandwidth (MHz)	Specification in the Interval (dBc)
22	-60.0	40	0.55	1.6	-55.4
46	-60.0	40	1.15	1.6	-58.6
94	-60.0	40	2.35	3.2	-58.7
142	-58.3	27	5.3	9.6	-55.7
190	-57	20	9.5	9.6	-57.0
200	-56.8	19	10.5	12.8	-55.9

2.6.3 Adjacent Channel Spurious Emissions

The following table lists the required adjacent channel spurious emission levels when there is a transmitted burst with bandwidth at the Under-grant Hold Bandwidth.

For transmission bursts with modulation spectrum greater than the Under-grant Hold Bandwidth the spurious power requirement in the adjacent 400 kHz is calculated by using the upstream frequency band spurious and the values found in the adjacent channel spurious table. For more detail refer to section 7.4.13.5.1.2 of PHYv3.1.

In the adjacent channel spurious emissions table, the following equations are referenced:

EQ6. 100% Grant Spectrum/40
EQ7. Round{10*$\log_{10}$(((10^(SpurFloor/10)) + (10^(-57/10)))*(0.4MHz/Under-grant Hold BW)),0.1}
EQ8. max{ -57 + 10*$\log_{10}$(100% Grant Spectrum/192 MHZ), -60}
EQ9. Floor{ 0.2 + 10^((-44 - SpurFloor)/10) }
EQ10. 100% Grant Spectrum)/Under-grant Hold Number of Users

Adjacent Channel Spurious Emissions (see PHYv3.1 Table 7-8 for notes)					
100% Grant Spectrum (MHz)	**SpurFloor (dBc)**	**Under-grant Hold #Users**	**Under-grant Hold Bandwidth (MHz)**	**Measurement Bandwidth (MHz)**	**Specification in the Interval (dBc)**
100%_BW ≤ 64	-60.0	40	EQ6	0.4	EQ7
64 < 100%_BW ≤ 96	-60.0	40	EQ6	0.4	EQ7
96 < 100%_BW	EQ8	EQ9	EQ10	0.4	EQ7

Adjacent Channel Spurious Emissions [Examples]					
100% Grant Spectrum (MHz)	**SpurFloor (dBc)**	**Under-grant Hold #Users**	**Under-grant Hold Bandwidth (MHz)**	**Measurement Bandwidth (MHz)**	**Specification in the Interval (dBc)**
22	-60.0	40	0.55	0.4	-56.6
46	-60.0	40	1.15	0.4	-59.8
94	-60.0	40	2.35	0.4	-62.9
142	-58.3	27	5.3	0.4	-65.8
190	-57	20	9.5	0.4	-67.7
200	-56.8	19	10.5	0.4	-68.1

2.6.4 MER and Inband Spurious Emission

Inband spurious emissions includes noise, carrier leakage, clock lines, synthesizer spurious products, and other undesired transmitter products. It does not include ISI. The measurement bandwidth for inband spurious for OFDM is equal to the Subcarrier Clock Frequency (25 kHz or 50 kHz) and is not a synchronous measurement.

MER is defined as follows for OFDMA. The transmitted RF waveform at the F connector of the CM (after appropriate down conversion) is filtered, converted to baseband, sampled, and processed using standard OFDMA receiver methods, with the exception that receiver equalization is not provided. The processed values are used in the following formula. No external noise (AWGN) is added to the signal.

MER_i is computed as an average of all the subcarriers in a minislot for the i^{th} minislot in the OFDMA grant:

$$\text{MER}_\text{i}\ (\text{dB}) = 10 \cdot \log_{10}\left(\frac{E_{avg}}{\frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{M}\sum_{k=1}^{M}\left|e_{j,k}\right|^2\right)}\right)$$

where:

E_{avg} is the average constellation energy for equally likely symbols,

M is the number of symbols averaged,

N is the number of subcarriers in a minislot,

$e_{j,k}$ is the error vector from the jth subcarrier in the minislot and kth received symbol to the ideal transmitted QAM symbol of the appropriate modulation order.

Inband Spurious Emissions and MER		
Parameter	**100% Grant**	**5% Grant**
Inband	-45 dBc	- 51 dBc
MER w/ Pre-EQ	MER ≥ 44 dB	MER ≥ 50 dB
MER w/o Pre-EQ	MER ≥ 40 dB	MER ≥ 40 dB

2.6.5 CMTS Receiver Error Ratio Performance

The required level for CMTS upstream post-FEC error ratio is defined for AWGN as less than or equal to 10^{-6} PER (packet error ratio) with 1500 byte Ethernet packets. See Section 7.4.15.2 of PHYv3.1 for further channel condition requirements.

Constellation	CNR(dB)	Set Point	Offset
QPSK	11.0	-4 dBmV	0 dB
8-QAM	14.0	-4 dBmV	0 dB
16-QAM	17.0	-4 dBmV	0 dB
32-QAM	20.0	-4 dBmV	0 dB
64-QAM	23.0	-4 dBmV	0 dB
128-QAM	26.0	0 dBmV	0 dB
256-QAM	29.0	0 dBmV	0 dB
512-QAM	32.5	0 dBmV	0 dB
1024-QAM	35.5	0 dBmV	0 dB
2048-QAM	39.0	7 dBmV	0 dB
4096-QAM	43.0	10 dBmV	0 dB

***NOTE: CNR** is defined here as the ratio of average signal power in occupied bandwidth to the average noise power in the occupied bandwidth given by the noise power spectral density integrated over the same occupied bandwidth.*

Physical Layer: Downstream

3

3 Downstream

This section specifies the downstream electrical and signal processing requirements for the transmission of OFDM modulated RF signals from the CMTS to the CM.

3.1 Frequency Range and Bandwidths

3.1.1 CMTS Output

The CMTS downstream upper and lower band edge requirements are defined as:

CMTS Downstream Band Options		
Requirement	**Lower Band Edge**	**Upper Band Edge**
MUST	258 MHz	1218 MHz
SHOULD	108 MHz	1794 MHz

3.1.2 CM Input

The CM downstream input upper and lower band edge requirements are defined as:

CM Downstream Band Options		
Requirement	**Lower Band Edge**	**Upper Band Edge**
MUST	258 MHz	1218 MHz
MAY		1794 MHz
SHOULD	108 MHz	

The CM SHOULD support a downstream lower band edge of 108 MHz when the CM is configured to use an upstream upper band edge of 85 MHz or less.

3.1.3 Channel Bandwidth

The CMTS and CM MUST support a minimum of two independently configurable OFDM channels each occupying a spectrum of up to 192 MHz in the downstream.

The CMTS MUST ensure that the encompassed spectrum of a 192 MHz downstream OFDM channel does not exceed 190 MHz. Therefore the CMTS MUST ensure that the number of contiguous active subcarriers in a downstream OFDM channel does not exceed 3800 for 4K FFT and 7600 for 8K FFT. When configured for 4K FFT, the CMTS MUST only use subcarriers in the range $148 \leq k \leq 3947$, where k is the spectral index of the subcarrier in the IDFT equation defining the OFDM signal. When configured for 8K FFT, the CMTS MUST only use subcarriers in the range $296 \leq k \leq 7895$, where k is the spectral index of the subcarrier in the IDFT equation defining the OFDM signal.

The CMTS MUST ensure that there is at least 1 MHz of exclusion band between the spectral edge of a legacy SC-QAM channel and the center frequency of the nearest OFDM subcarrier.

NOTE: *This SC-QAM channel may be external to the OFDM channel or may be embedded within the OFDM channel.*

The CMTS MUST also ensure that there is at least 2 MHz exclusion band between any two adjacent asynchronous OFDM channels.

The downstream OFDM channel bandwidth can vary from 24 MHz to 192 MHz.

Downstream OFDM Channel Bandwidth	
Minimum Modulated BW	**Maximum Modulated BW**
22 MHz	190 MHz

3.1.4 Excluded Subcarriers and Bands

When configuring an OFDM channel, subcarriers and bands of subcarriers can be excluded from use in the channel. The following are the definitions for the excluded subcarrier and exclusion band.

Excluded Subcarrier: Subcarrier that cannot be used because another type of service is using the subcarrier's frequency or a permanent ingressor is present on the frequency. The CMTS or cable modem is administratively configured to not transmit on excluded subcarriers.

Exclusion Band: A set of contiguous subcarriers within the OFDM or OFDMA channel bandwidth that are set to zero-value by the transmitter to reduce interference to other co-existing transmissions such as legacy SC-QAM signals.

The following rules apply to exclusions bands:

1. There has to be at least one contiguous modulated OFDM bandwidth of 22 MHz or greater.
2. Exclusion bands separate contiguous modulation bands.
3. The minimum contiguous modulation band has to be 2 MHz.
4. Exclusion bands and individually excluded subcarriers are common to all downstream profiles.
5. Exclusion bands are a minimum of 1 MHz but increment above 1 MHz by granularity of individual subcarrier.
6. Exclusion bands plus individually excluded subcarriers are limited to 20% or less of spanned modulation spectrum.

In addition, the number of individually excluded subcarriers is limited by the following:

1. The total spectrum of individually excluded subcarriers cannot exceed 5% of any contiguous modulation spectrum.
2. The total spectrum of individually excluded subcarriers cannot exceed 5% of a 6 MHz moving window across the contiguous modulation spectrum.
3. The total spectrum of individually excluded subcarriers cannot exceed 20% of a 1 MHz moving window across the contiguous modulation spectrum.

For example, 500 kHz of consecutive excluded subcarriers cannot be an excluded band (< 1 MHz), and cannot be categorized as individually excluded subcarriers (> 0.05*6 = 0.3 MHz), but 250 kHz of consecutive excluded subcarriers can be categorized as individually excluded subcarriers (assuming there are no other individually excluded subcarriers nearby).

The 6 MHz of contiguous spectrum reserved for the PLC cannot have any exclusion bands or excluded subcarrier.

The ONLY exception to the above is for exclusion bands that are allowed to occupy the following frequency ranges in alignment with FCC regulations.

Exclusion Rule Exempt FCC Exclusion Bands	
Start Frequency	**Stop Frequency**
121.400 MHz	121.600 MHz
156.750 MHz	156.850 MHz
242.950 MHz	243.050 MHz
405.925 MHz	406.176 MHz

3.2 OFDM Parameters

3.2.1 IDFT

The OFDM downstream physical layer for DOCSIS 3.1 uses the same IDFT definition as the upstream physical layer. The CMTS transmitter MUST use the IDFT definition and subcarrier referencing method described in Section 1.2.1.

3.2.2 Downstream OFDM Numerology

The CMTS MUST output an RF Modulated signal with characteristics defined in Table 7–39 of the PHYv3.1 specification.

The fundamental OFDM time and frequency parameters of the downstream signal are in the following table.

Downstream OFDM Time/Frequency Numerology			
Sample Rate (Symbol Clock)	**FFT Size (N)**	**Subcarrier Spacing**	**FFT Time Duration**
204.8 Msps (204.8 MHz)	4096 (4K FFT)	50 kHz	20 µs
	8192 (8K FFT)	25 kHz	40 µs

3.2.3 Cyclic Prefix & Windowing

This section describes how cyclic prefixes are inserted and how a window is applied to the output of the IDFT at the CMTS and how they are handled by the CM.

The addition of a cyclic prefix enables the receiver to overcome the effects of inter-symbol-interference caused by micro-reflections in the channel.

Windowing maximizes channel capacity by sharpening the edges of the spectrum of the OFDM signal. Spectral edges occur at the two ends of the spectrum of the OFDM symbol, as well as at the ends of internal exclusion bands.

The number of active OFDM subcarriers can be increased by sharpening these spectral edges. However, sharper spectral edges in the frequency domain imply longer tapered regions in the time domain, resulting in increased symbol duration and reduction in throughput.

Therefore, there is an optimum amount of tapering that maximizes channel capacity. This optimum is a function of channel bandwidth as well as the number of exclusion bands.

The CMTS transmitter and the CM receiver MUST support the cyclic prefix values defined in the following table.

Cyclic Prefix (µs)	Cyclic Prefix Samples (N_{cp})
0.9375	192
1.25	256
2.5	512
3.75	768
5.0	1024

The CMTS transmitter and the CM receiver MUST support the roll-off period values defined in the following table. The CMTS MUST NOT allow a configuration in which the Roll-Off Period value is ≥ the Cyclic Prefix value.

Roll-Off Period (µs)	Roll-Off Period Samples (N_{rp})
0	0
0.3125	32
0.625	64
0.9375	96
1.25	128

The Cyclic Prefix and Roll-Off Period sample values above are found using the sample rate of 102.4 Msamples/s.

3.2.4 Bit Loading / Modulation Formats

The bit loading pattern defines the QAM constellations assigned to each of the 4096 or 8192 subcarriers of the OFDM transmission. This bit loading pattern can change from profile to profile. Continuous pilot locations, PLC locations and exclusion bands are defined separately, and override the values defined in the bit-loading profile.

The CMTS modulator and CM demodulator MUST support the following modulation formats for subcarriers of downstream OFDM channels.

DS CM Modulation Formats	DS CMTS Modulation Formats
BPSK	BPSK
QPSK	QPSK
16-QAM	16-QAM
64-QAM	64-QAM
128-QAM	128-QAM
256-QAM	256-QAM
512-QAM	512-QAM
1024-QAM	1024-QAM
2048-QAM	2048-QAM
4096-QAM	4096-QAM

The CMTS modulator MAY support 8192-QAM and 16384-QAM for subcarriers of downstream OFDM channels.

NOTE: *BPSK is used for pilots only. QPSK is used for the PLC preamble and NCP messages only. Neither modulation format is used for data transmission.*

3.2.5 Profiles

A profile is a list of modulations that are used for the subcarriers within an OFDM channel. The downstream can use different profiles for different groups of CMs. Generally, a group of CMs that have similar SNR performance will be grouped into the same profile.

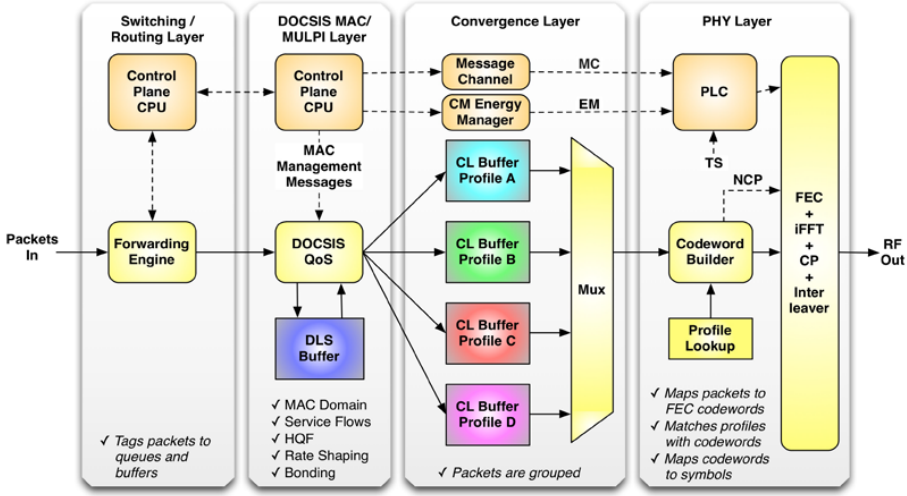
Profile A is the boot profile that CMs first begin receiving when they initialize and register. Profile A should be the receivable by all CMs within the MAC domain.

There is one convergence layer buffer per profile. These are shallow buffers that hold only a few packets so as to not build up any significant latency. The output of these buffers is fed to the codeword builder.

The codeword builder uses the same profile for an entire codeword. It can change profiles at each codeword boundary. The convergence layer buffers do not have to be serviced in any particular order.

The following figure illustrates the convergence layer at the block level.

Downstream Convergence Layer Block Diagram

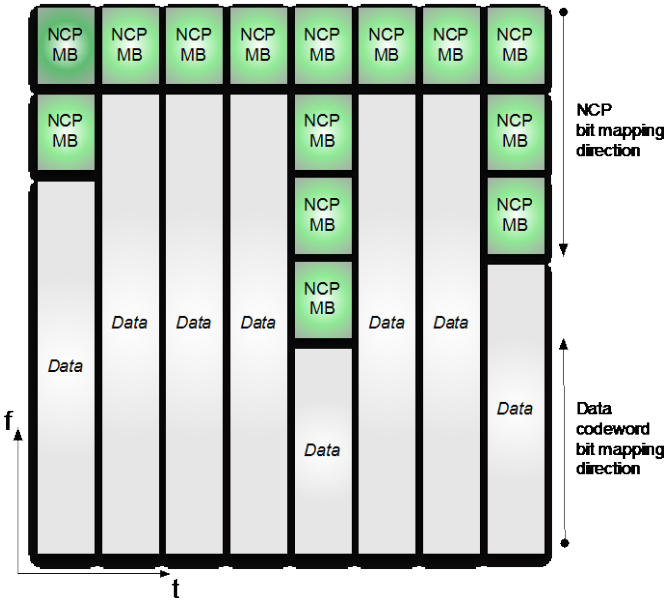


The convergence layer buffers are packets in – bytes out. The codeword builder combines bytes from one buffer, adds FEC, and then using the profile modulation vector, it maps the codeword onto one or more OFDM symbols (or partial symbols).

***NOTE: Profiles** are defined by the DPD message which is described Section 4.12.1*

3.2.6 Next Codeword Pointer (NCP)

When the data codewords are mapped to subcarriers within a symbol, a pointer is needed to identify where a data codeword starts. This is known as the Next Codeword Pointer (NCP). There are a variable number of NCP message blocks (MBs) on each OFDM symbol.



The NCP structure is predicated upon the following facts:

- FEC codewords are mapped continuously across successive symbols.
- The PHY can determine the first subcarrier of the first NCP message block.
- The PHY can determine the first subcarrier of the data field in the current symbol.

Based upon these facts and combined with the information in the NCP fields, then

- The PHY can determine the last subcarrier of the last NCP message block.
- The next subcarrier after the last NCP message block CRC is last subcarrier of the data field.

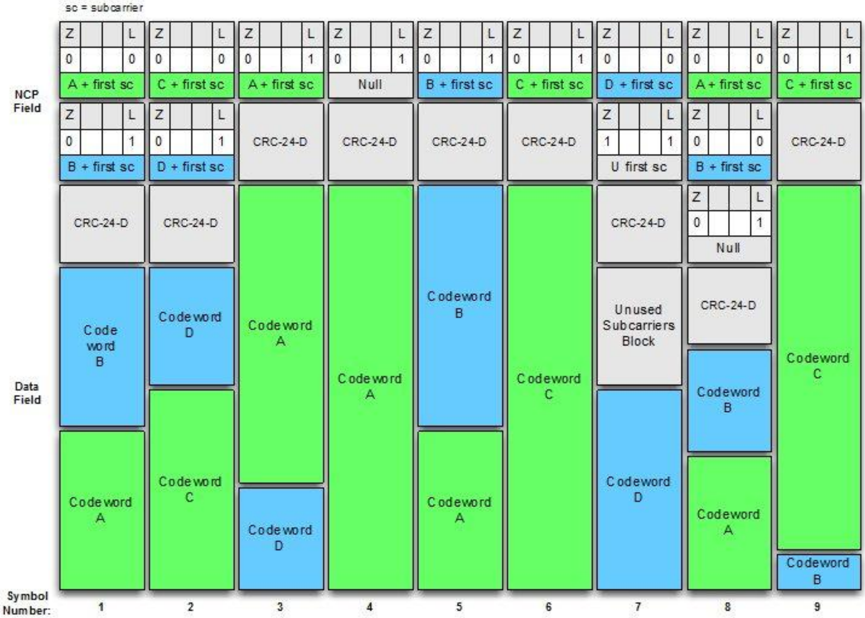
The main task of the NCP message block is to provide a reference to the appropriate profile and a start pointer for codewords. The length of a codeword is determined by the difference between the subcarrier pointer in two successive NCP message blocks.

The CMTS MUST NOT place more than 11 NCP data message blocks plus a CRC for a total of 12 NCP MBs in an 8K OFDM symbol.

The CMTS MUST NOT place more than 12 NCP data message blocks plus two CRCs for a total of 14 NCP MBs in any two successive 4K OFDM symbols.

For small bandwidths it is possible that there may not be a beginning or an end of a FEC codeword in a symbol. That is, a codeword may begin in the previous symbol and end in the following symbol. In such a case the CMTS MUST insert a NULL NCP in the current symbol.

The following diagram shows 9 examples of how the NCP field is used. This view is prior to interleaving. NCP blocks are mapped to sub-carriers starting with the first non-excluded subcarrier at the top of the spectrum and then down in frequency. After the last NCP MB is a CRC-24-D. Data is mapped to the first non-excluded subcarrier at the bottom of the frequency range and then continuing upwards in frequency.


sc = subcarrier
NCP Field
Data Field
Symbol Number:
Z
L
A + first sc
C + first sc
B + first sc
D + first sc
U first sc
Null
CRC-24-D
Codeword A
Codeword B
Codeword C
Codeword D
Unused Subcarriers Block
1
2
3
4
5
6
7
8
9

In symbol 1, Codeword A starts at the beginning of the symbol and has a start pointer. Codeword B starts after codeword A and has a start pointer. The length of codeword A is the difference between the codeword A start pointer and the codeword B start pointer.

In symbol 2, Codeword C starts at the beginning of the symbol and has a start pointer. The length of the previous codeword B is derived from the difference between the codeword B start pointer and the codeword C start pointer, taking into account where the last data subcarrier was in symbol 1. Codeword D gets a start pointer.

In symbol 3, Codeword D continues from symbol 2 and finishes. Codeword A follows and is given a start pointer. The length of codeword D is derived from the difference between the codeword C start pointer and the codeword D start pointer, taking into account where the last data subcarrier was in symbol 2.

In symbol 4, Codeword A continues. Since there is no start pointer required, but at least one NCP block is required, an NCP block with a null pointer is included.

In symbol 5, Codeword A ends. Codeword B begins and ends. A single NCP block is created with a start pointer to codeword B.

In symbol 6, Codeword C both starts and ends. A single NCP block is created with a start pointer to codeword C.

In symbol 7, Codeword D starts and ends. There are no more data packets to send, so the remaining subcarriers are unused. A NCP block is assigned for the codeword D start pointer. A second NCP block is assigned to the start pointer of the unused subcarriers. This start pointer is used to determine the length of codeword D.

In symbol 8, Codeword A begins and ends. Codeword B begins and tried to end with a few subcarriers unused between the end of the data codeword and the end of the NCP field. Since no subcarriers can be left unused, and since an NCP would not fit, an NCP with a null pointer was inserted and some of the last few bytes of codeword B were forced into the next symbol. There is an NCP message block for codeword A, codeword B, and the null NCP.

In symbol 9, Codeword C starts a few subcarriers into the symbol. There is one NCP block for codeword C.

The NCP MUST use one of three modulation formats. Depending on the modulation format used the fixed size NCP message block can take a variable number of subcarriers in a symbol.

NCP Bits w/ FEC	NCP Modulation Formats	Number of Subcarriers
48	QPSK	24
	16-QAM	12
	64-QAM	8

3.2.7 Pilot Subcarriers

There are two types of pilots: continuous and scattered. Continuous pilots occur at fixed frequencies in every symbol. Scattered pilots occur at different frequency locations in different symbols.

Scattered Pilots

The scattered pilot pattern is synchronized to the PLC as shown in the following figure. The first OFDM symbol after the PLC preamble has a scattered pilot in the subcarrier just after the highest frequency subcarrier of the PLC.

Mathematically, the scattered pilot pattern for a 4K FFT is defined as follows. Let a subcarrier (depicted in the above figure just below and right of the PLC preamble) be referred to as $x(m,n)$, where:

m is the frequency index
n is the time index (i.e., the OFDM symbol number)

The scattered pilots in the 128 symbols following (and including symbol n) are given by:

Symbol n: $x(n, m \pm 128i)$, for all non-negative integers i

Symbol (n+1): $x(n+1, m \pm 128i + 1)$, for all non-negative integers i

Symbol (n+2): $x(n+2, m \pm 128i + 2)$, for all non-negative integers i

⋮

Symbol (n+127): $x(n+127, m \pm 128i + 127)$, for all non-negative integers i

Mathematically, the scattered pilot pattern for an 8K FFT is defined as follows. Let the subcarrier (depicted in the figure above just below and right of the PLC preamble) be referred to as *(,)* where:

m is the frequency index
n is the time index (i.e., the OFDM symbol number)

The scattered pilots in the first 64 symbols following and including symbol *n* are given by:

Symbol n: $x(n, m \pm 128i)$, for all non-negative integers i

Symbol (n+1): $x(n+1, m \pm 128i + 2)$, for all non-negative integers i

Symbol (n+2): $x(n+2, m \pm 128i + 4)$, for all non-negative integers i

⋮

Symbol (n+63): $x(n+63, m \pm 128i + 126)$, for all non-negative integers i

The scattered pilot sequence of the next 64 symbols is the same as above, but with a single subcarrier shift in the frequency dimension.

Symbol (n+64): $x(n+64, m \pm 128i + 1)$, for all non-negative integers i

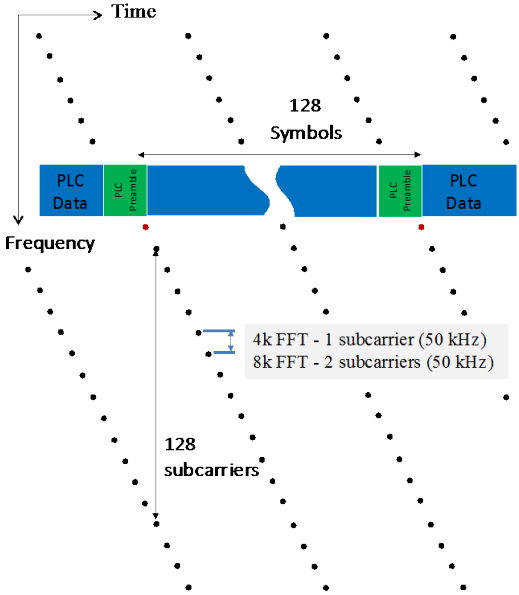
Symbol (n+65): $x(n+65, m \pm 128i + 3)$, for all non-negative integers i

Symbol (n+66): $x(n+66, m \pm 128i + 5)$, for all non-negative integers i

⋮

Symbol (n+127): $x(n+127, m \pm 128i + 127)$, for all non-negative integers i

⋮



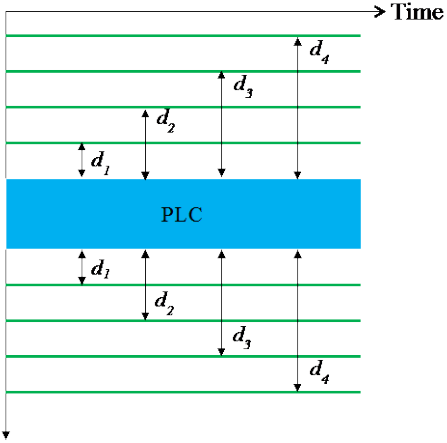
The remainder of the scattered pilot pattern is linked to the scattered pilot synchronized to the PLC preamble, using the following rules:

1. In each symbol scattered pilots are placed every 128 subcarriers.
2. From symbol to symbol, scattered pilots are shifted by one subcarrier position in the increasing direction of the frequency axis. This will result in scattered pilots placed in the exclusion band and in the PLC band.
3. Scattered pilots are zero-valued in the exclusion bands.
4. Scattered pilots are zero-valued when these coincide with excluded subcarriers.
5. In the PLC, normal PLC signals (i.e., PLC data or the PLC preamble) are transmitted instead of scattered pilots. The CMTS MUST NOT transmit scattered pilots in the PLC band.

Continuous Pilots

Continuous pilots occur at the same frequency location in all symbols and are used for receiver synchronization. Placement of continuous pilots is determined in two ways:

- Predefined continuous pilot placement around the PLC
- Continuous pilot placement defined via PLC messages



In the figure above the distances referenced are enumerated in the following table.

Subcarrier Distances for Placement of Predefined Pilots					
		d_1	d_2	d_3	d_4
4K FFT	PLC 8 subcarriers	15	24	35	47
8K FFT	PLC 16 subcarriers	30	48	70	94

Pilot Boosting

The CMTS MUST multiply the real and imaginary components of continuous and scattered pilots by a real-valued number such that the amplitude of the continuous and scattered pilots is twice the root-mean-square value of the amplitude of other subcarriers of the OFDM symbol; That is, continuous and scattered pilots are boosted by approximately 6 dB with reference to other subcarriers.

3.3 Power

3.3.1 CMTS Tx Power Requirements

A CMTS MUST generate an RF output with power capabilities as defined in the following table. In the table N^* is defined as

$$\mathbf{N}^* \equiv \begin{cases} \boldsymbol{minimum}[4\mathbf{N_{eq}}', \mathbf{ceiling}\left[\frac{\mathbf{N_{eq}}}{4}\right]], & \mathbf{N_{eq}}' < \mathbf{N_{eq}}/4 \\ \mathbf{N_{eq}}', & \mathbf{N_{eq}}' \geq \mathbf{N_{eq}}/4 \end{cases}$$

and is referred to as the adjusted number of active channel combined per RF port.

NOTE: *For the power table the device is said to be capable of generating N_{eq}-channels per RF port, where $N_{eq} = N + 32*N_{OFDM}$ "equivalent legacy DOCSIS channels." Also, N_{eq}' is the active channels on the RF port capable of N_{eq} channels.*

CMTS Output Power Requirements	
Parameter	**Value**
Required power per channel for N_{eq}' channels combined onto a single RF port:	60 – ceil [3.6*$\log_2$(N*)] dBmV/channel
Range of commanded transmit power per channel	≥ 8 dB below required power level
Range of commanded power per channel; adjusted on a per channel basis	CMTS MUST: 0 dBc to -2 dBc relative to the highest commanded transmit power per channel, within an 8 dB absolute window below the highest commanded power.
Commanded power per channel step size	≤ 0.2 dB Strictly monotonic
Power difference between any two adjacent channels in the 108-1218 MHz downstream spectrum	≤ 0.5 dB
Power difference between any two non-adjacent channels in a 48 MHz contiguous bandwidth block	≤ 1 dB
Power difference (normalized for bandwidth) between any two channels OFDM channel blocks or legacy DOCSIS channels in the 108 - 1218 MHz downstream spectrum	≤ 2 dB
Power per channel absolute accuracy	±2 dB

NOTE: *For the three power difference rows in the table above, where applicable the commanded power difference is removed if channel power is independently adjustable and/or accounting for pilot density variation and subcarrier exclusions.*

3.3.2 CM Rx Input Power Requirements

The CM receiver input power requirements are covered in the following table.

CM Input Power Requirements	
Parameter	**Value**
Total Input Power	< 40 dBmV, 54 MHz – 1.794 GHz ** Assuming negligible power outside this range*
Level Range	-9 dBmV/24 MHz to 21 dBmV/24 MHz

Further restrictions on channel conditions regarding additional demodulated bandwidth and non-demodulated bandwidth region power levels are contained in Table 7-40 of the PHYv3.1 specification.

In addition level range does not imply anything about BER performance or capability vs. QAM. CM BER performance is separately described.

NOTE: Level Range *above is equivalent in PSD to SC-QAM of -15 dBmV to + 15 dBmV per 6 MHz*

3.4 Forward Error Correction (FEC)

[DVB-C2] section 6.1, FEC Encoding, describes the FEC encoding requirements for the CMTS transmitter. The CMTS MUST meet the portion of [DVB-C2] section 6.1, FEC Encoding, as described below:

The CMTS MUST support the 8/9 code rate for the short codeword (N_{ldpc} = 16,200 bits) only. Support for other code rates and codeword sizes is not required.

NOTE: Short Codeword *as referenced in this FEC section refers to the 16,200 bit codeword length as defined in DVB-C2. This is different than "shortened" codewords. For information on DOCSIS 3.1 support for shortened codewords see Section 7.5.4.2.3 in PHYv3.1.*

Outer Encoding

[DVB-C2] section 6.1.1, Outer Encoding (BCH), details the outer encoding requirements for normal and short codewords (FECFrames). For the CMTS, only short codewords are required. The CMTS MUST meet the outer encoding requirements for short FECFrames specified in [DVB-C2] section 6.1.1, Outer Encoding (BCH).

[DVB-C2] sections 6.1.2, Inner Encoding, and 6.1.2.2, Inner Coding for Short FECFrame, detail the inner coding requirements for short codewords. For DOCSIS 3.1 codewords, the CMTS MUST meet the inner coding requirements for short codewords and code rate 8/9 specified in [DVB-C2] sections 6.1.2, Inner Encoding, and 6.1.2.2, Inner Coding for Short FECFrame.

The CMTS MUST support the FEC coding parameters specified in the table below. This table is based on Table 3(b), from [DVB-C2].

Downstream FEC Parameters	
Parameter	**Value**
LDPC Code Rate	8/9
BCH Uncoded Block Size K_{bch}	14,232
BCH Coded Block N_{bch}	14,400
LDPC Uncoded Block Size K_{ldpc}	14,400
LDPC Coded Block Size N_{ldpc}	16,200

3.4.1 Fidelity and Performance

3.4.2 Inband Spurious Emission and MER

Inband Spurious Emissions and MER Requirements						
Measurement Range	Below 600 MHz		600 MHz to 1002 MHz		1002MHz to 1218MHz	
Inband Distortion and Noise 528 MHz total occupied bandwidth, 6 MHz gap (Internal Excluded subcarriers) Average over center 400 kHz subcarriers within gap.	≤ -50 dBr		≤ -47 dBr		≤ -45 dBr	
MER in 192 MHz OFDM channel occupied bandwidth 528 MHz total occupied bandwidth,	Per Subcarrier	Average	Per Subcarrier	Average	Per Subcarrier	Average
	≥ 48 dB	≥ 50 dB	≥ 45 dB	≥ 47 dB	≥ 43 dB	≥ 45 dB
MER in 24 MHz OFDM channel occupied bandwidth, single OFDM channel only	≥ 48 dB		≥ 45 dB		≥ 43 dB	
Average over the complete OFDM channel.						

3.4.3 Phase Noise

CMTS Transmitter Phase Noise Requirements					
Integrated Measurement Range	1 kHz – 10 kHz	10 kHz – 100 kHz	100 kHz – 1 MHz	1 MHz – 10 MHz	10 MHz – 100 MHz
Phase noise, double sided maximum, Full power CW signal 1002 MHz or lower	-48 dBc	-56 dBc	-60 dBc	-54 dBc	-60 dBc
Full power 192 MHz OFDM channel block with 6 MHz in center as Internal Exclusion subband + 0 dBc CW in center, with block not extending beyond 1002 MHz. [CW not processed via FFT]	-48 dBc	-56 dBc			
Full power 192 MHz OFDM channel block with 24 MHz in center as Internal Exclusion subband + 0 dBc CW in center, with block not extending beyond 1002 MHz. [CW not processed via FFT]			-60 dBc		
Full power 192 MHz OFDM channel block with 30 MHz in center as Internal Exclusion subband + 7 dBc CW in center, with block not extending beyond 1002 MHz. [CW not processed via FFT]				-53 dBc	

The contents of the previous table are subject to multiple notes, please see Table 7-36 in PHYv3.1 for more information.

3.4.4 CMTS Output Out-of-Band Noise and Spurious Emissions

For the following table, the adjusted number of active channels combined per RF port N^* is defined as:

$$N^* \equiv \begin{cases} minimum[4N_{eq}', \text{ceiling}\left[\frac{N_{eq}}{4}\right]], & N_{eq}' < N_{eq}/4 \\ N_{eq}', & N_{eq}' \geq N_{eq}/4 \end{cases}$$

CMTS Output Out-of-Band Noise and Spurious Emissions		
	Band	**Requirement (in dBc)**
1	Adjacent channel up to 750 kHz from channel block edge	For N* = 1, 2, 3, 4: ≤ -58; For N* ≥ 5: ≤ 10*log10 [$10^{-58/10}$ +(0.75/6)*($10^{-65/10}$ + (*N**-2)*$10^{-73/10}$)]
2	Adjacent channel (750 kHz from channel block edge to 6 MHz from channel block edge)	For N* = 1: ≤ -62; For N* ≥ 2: ≤ 10*log10 [$10^{-62/10}$ +(5.25/6)*($10^{-65/10}$ +(*N**-2)*$10^{-73/10}$)]
3	Next-adjacent channel (6 MHz from channel block edge to 12 MHz from channel block edge)	≤ 10*log10 [$10^{-65/10}$ +(*N**-1)*$10^{-73/10}$]

CMTS Output Out-of-Band Noise and Spurious Emissions		
	Band	**Requirement (in dBc)**
4	Third-adjacent channel (12 MHz from channel block edge to 18 MHz from channel block edge)	For *N** = 1: ≤ -73; For *N** = 2: ≤ -70; For *N** = 3: ≤ -67; For *N** = 4: ≤ -65; For *N** = 5: ≤ -64.5; For *N** = 6, 7: ≤ -64; For *N'** ≥ 8: ≤-73 + 10*log10 (*N**)
5	Noise in other channels (47 MHz to 1218 MHz) Measured in each 6 MHz channel excluding the following: a) Desired channel(s) b) 1st, 2nd, and 3rd adjacent channels (see Items 1, 2, 3, 4 in this table) c) Channels coinciding with 2nd and 3rd harmonics (see Item 6 in this table)	For *N** = 1: ≤ -73; For *N** = 2: ≤ -70; For *N** = 3: ≤ -68; For *N** = 4: ≤ -67; For *N'** ≥ 5: ≤ -73 + 10*log10 (*N**)

CMTS Output Out-of-Band Noise and Spurious Emissions		
	Band	**Requirement (in dBc)**
6	In each of 2N' contiguous 6 MHz channels or in each of 3N' contiguous 6 MHz channels coinciding with 2nd harmonic and with 3rd harmonic components respectively (up to 1218 MHz)	≤ -73 + 10*log10(*N**) dBc, or -63, whichever is greater
7	Lower out of band noise in the band of 5 MHz to 47 MHz Measured in 6 MHz channel bandwidth	≤ -50 + 10*$\log_{10}$(*N**)
8	Higher out of band noise in the band of 1218 MHz to 3000 MHz Measured in 6 MHz channel bandwidth	For *N** ≤ 8: ≤ -55 + 10*$\log_{10}$(*N**) For *N** > 8: ≤ -60 + 10*$\log_{10}$(*N**)

The contents of the previous table are subject to multiple notes, please see Table 7-38 in PHYv3.1 for more information.

3.4.5 CM Receiver Error Ratio Performance

The required level for CM downstream post-FEC error ratio is defined as less than or equal to 10^{-6} PER (packet error ratio) with 1500 byte Ethernet packets. This section describes the conditions at which the CM is required to meet this error ratio.

Implementation loss of the CM MUST be such that the CM achieves the required error ratio when operating at a CNR as shown in the following table, under input load and channel conditions as follows:

- Any valid transmit combination (frequency, subcarrier clock frequency, transmit window, cyclic prefix, pilot, PLC, subcarrier exclusions, interleaving depth, multiple modulation profile configuration, etc.) as defined in this spec.
- P6AVG (the measured channel power divided by number of occupied CEA channels) ≤ 15 dBmV.
- Up to fully loaded spectrum of 54 - 1218 MHz, including up to 48 analog channels placed lower in the spectrum than the digital channels.
- Power in (both above and below) 4 adjacent 6 MHz channels ≤ P6AVG+3 dB.
- Power in any 6 MHz channel over the spectrum ≤ P6AVG+6 dB.
- Peak envelope power in any analog channel over the spectrum ≤ P6AVG+6 dB
- Average power per channel across spectrum ≤ P6AVG+3 dB.
- OFDM channel phase noise as in CMTS spec.
- No other artifacts (reflections, burst noise, tilt, etc.).

In the table that follows, three notes apply:

1. CNR is defined here as total signal power in occupied bandwidth divided by total noise in occupied bandwidth
2. Channel CNR is adjusted to the required level by measuring the source inband noise including phase noise component and adding the required delta noise from an external AWGN generator
3. Applicable to an OFDM channel with 192 MHz of occupied bandwidth

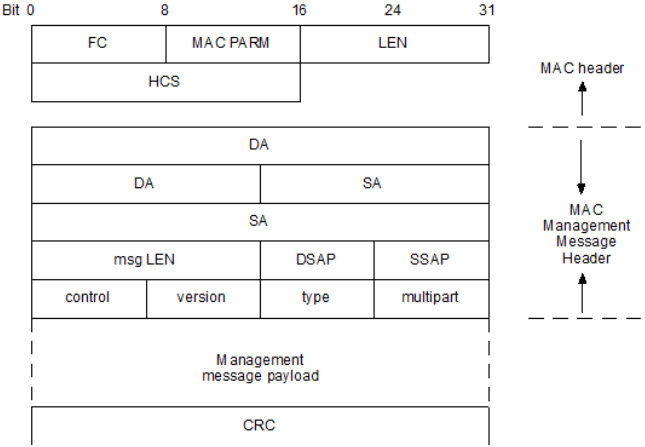
CM Minimum CNR Performance in AWGN Channel			
Constellation	CNR (dB) Up to 1 GHz	CNR (dB) 1 GHz to 1.2 GHz	Min P_{6AVG} dBmV
4096	41.0	41.5	-6
2048	37.0	37.5	-9
1024	34.0	34.0	-12
512	30.5	30.5	-12
256	27.0	27.0	-15
128	24.0	24.0	-15
64	21.0	21.0	-15
16	15.0	15.0	-15

MAC Management Messages

4

4 MAC Management Messages (MMM)

4.1 MMM Header



4.2 MMM Type Summary

Type	Version	A*	Name	Description
1	1	M	SYNC	Timing Synchronization
2 29 35 51	1 3 4 5	M	UCD	Upstream Channel Descriptor • A UCD for a DOCSIS 3.1 Only channel (OFDM) uses a type of 51 and a version of 5. • A UCD for a DOCSIS 3.0 Only channel uses a type of 35 and a version of 4. • A UCD for a DOCSIS 2.0/3.0 Only Channel uses a type of 29 and a version of 3. • All other UCDs use a type of 2 and a version of 1

Type	Version	A*	Name	Description
3 3	1 5	M	MAP	Upstream Bandwidth Allocation • A Map of version 1 is understood by DOCSIS 3.1/3.0/2.0/1.1/1.0 equipment. • A Map of version 5 is understood by DOCSIS 3.1 equipment only. (If the CAT field is 0x1, this is a P-MAP)
4 4	1 5	U	RNG-REQ	Ranging Request • A RNG-REQ for DOCSIS 3.1 : When sending a RNG-REQ to a DOCSIS 3.1 CMTS, a DOCSIS 3.1 CM uses a type of 4 and a version of 5. • All other RNG-REQs use a type of 4 and a version of 1

Type	Version	A*	Name	Description
5 5	1 5	U	RNG-RSP	Ranging Response • A RNG-RSP of version 1 is understood by DOCSIS 3.1/3.0/2.0/1.1/1.0 equipment. • A RNG-RSP of version 5 is understood by DOCSIS 3.1 equipment only.
6	1	U	REG-REQ	Registration Request
7	1	U	REG-RSP	Registration Response
8-11	1	x		Reserved (deprecated)
12	1	U	BPKM-REQ	Privacy Key Management Request
13	1	U	BPKM-RSP	Privacy Key Management Response
14	2	U	REG-ACK	Registration Acknowledge
15	2	U	DSA-REQ	Dynamic Service Addition Request
16	2	U	DSA-RSP	Dynamic Service Addition Response

Type	Version	A*	Name	Description
17	2	U	DSA-ACK	Dynamic Service Addition Acknowledge
18	2	U	DSC-REQ	Dynamic Service Change Request
19	2	U	DSC-RSP	Dynamic Service Change Response
20	2	U	DSC-ACK	Dynamic Service Change Acknowledge
21	2	U	DSD-REQ	Dynamic Service Deletion Request
22	2	U	DSD-RSP	Dynamic Service Deletion Response
23	2	U	DCC-REQ	Dynamic Channel Change Request
24	2	U	DCC-RSP	Dynamic Channel Change Response
25	2	U	DCC-ACK	Dynamic Channel Change Acknowledge
26	2	x		Reserved (deprecated)
27	2	x		Reserved (deprecated)
28	2	x		Reserved (deprecated)
29	3	M		(See entry for UCD above)

Type	Version	A*	Name	Description
30	3	U	INIT-RNG-REQ	Initial Ranging Request
31	3	U	TST-REQ	Test Request Message
32	3	M	DCD	Downstream Channel Descriptor
33	4	M	MDD	MAC Domain Descriptor
34 34	4 5	U	B-INIT-RNG-REQ	Bonded Initial Ranging Request • A B-INIT-RNG-REQ for DOCSIS 3.1: When sending a B-INIT-RNG-REQ to a DOCSIS 3.1 CMTS, a DOCSIS 3.1 CM uses a type of 34 and a version of 5. • All other B-INIT-RNG-REQs use a type of 34 and a version of 3
35	4	U		(See entry for UCD above)
36	4	U	DBC-REQ	Dynamic Bonding Change Request
37	4	U	DBC-RSP	Dynamic Bonding Change Response

Type	Version	A*	Name	Description
38	4	U	DBC-ACK	Dynamic Bonding Change Acknowledge
39	4	U	DPV-REQ	DOCSIS Path Verify Request
40	4	U	DPV-RSP	DOCSIS Path Verify Response
41	4	U	CM-STATUS	Status Report
42	4	U	CM-CTRL-REQ	CM Control
43	4	U	CM-CTRL-RSP	CM Control Response
44	4	U	REG-REQ-MP	Multipart Registration Request
45	4	U	REG-RSP-MP	Multipart Registration Response
46	4	U	EM-REQ	Energy Management Request
47	4	U	EM-RSP	Energy Management Response
48	4	U	CM-STATUS-ACK	Status Report Acknowledge

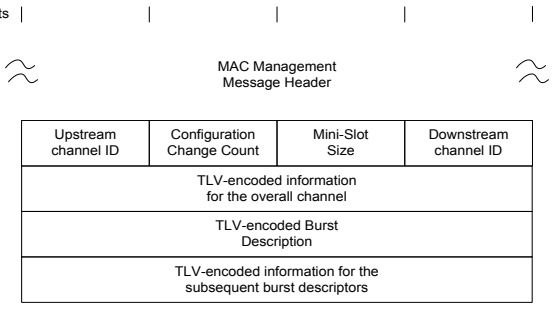
Type	Version	A*	Name	Description
--	--	--	O-INIT-RNG-REQ	OFDM Initial Ranging Request
49	5	M	OCD	OFDM Channel Descriptor
50	5	M	DPD	Downstream Profile Descriptor
51	5	M		(See entry for UCD above)
52	5	U	ODS-REQ	OFDM Downstream Spectrum Request
53	5	U	ODS-RSP	OFDM Downstream Spectrum Response
54	5	U	OPT-REQ	OFDM Downstream Profile Test Request
55	5	U	OPT-RSP	OFDM Downstream Profile Test Response
56	5	U	OPT-ACK	OFDM Downstream Profile Test Acknowledge
57	5	U	DTP-REQ	DOCSIS Time Protocol Request
58	5	U	DTP-RSP	DOCSIS Time Protocol Response
59	5	U	DTP-ACK	DOCSIS Time Protocol Acknowledge

Type	Version	A*	Name	Description
60	5	U	DTP-INFO	DOCSIS Time Protocol Information
61–255				Reserved for future use

Table Notes: A*: Ethernet Destination MAC Address Type
M = Multicast message
U = Unicast message
x = not used in DOCSIS 3.1

4.3 Upstream Channel Descriptor (UCD)

Name	T	L	V
Modulation Rate	1	1	Multiples of base rate of 160 kHz. For TDMA channels, valid Values 1, 2, 4, 8, 16, or 32.
Frequency	2	4	Upstream center frequency (Hz).
Preamble Pattern	3	1-128	The Value field defines the first portion of the Preamble Superstring..
Burst Descriptor (DOCSIS 1.x)	4	n	
Burst Descriptor (DOCSIS 2.0/3.0)	5	n	
Extended Preamble Pattern	6	1-64	512 Bit Preamble Superstring extension.
S-CDMA Mode Enable	7	1	1 = on; 2 = off.



Name	**T**	**L**	**V**
Modulation Rate	1	1	Multiples of base rate of 160 kHz. For TDMA channels, valid Values 1, 2, 4, 8, 16, or 32.
Frequency	2	4	Upstream center frequency (Hz).
Preamble Pattern	3	1-128	The Value field defines the first portion of the Preamble Superstring..
Burst Descriptor (DOCSIS 1.x)	4	n	
Burst Descriptor (DOCSIS 2.0/3.0)	5	n	
Extended Preamble Pattern	6	1-64	512 Bit Preamble Superstring extension.
S-CDMA Mode Enable	7	1	1 = on; 2 = off.

S-CDMA Spreading Intervals per frame	8	1	Number of consecutive spreading intervals mapped onto a two-dimensional frame. (Value is 1 through 32).
S-CDMA Codes per Minislot	9	1	Number of consecutive codes mapped into a two-dimensional minislot. (Value is 2 through 32).
S-CDMA Number of Active Codes	10	1	Number of codes available to carry data payload. (Value is 64 through 128). This value is a multiple of Codes per Minislot (TLV type 9).
S-CDMA Code Hopping Seed	11	2	15-bit seed to initialize code hopping sequence. The value is left-justified in the 2-byte field. Set seed = 0 to disable code hopping.
S-CDMA US ratio numerator 'M'	12	2	The numerator (M) of the M/N ratio relating the downstream symbol clock to the upstream modulation clock.
S-CDMA US ratio denominator 'N'	13	2	The denominator (N) of the M/N ratio relating the downstream symbol clock to the upstream modulation clock.
S-CDMA Timestamp Snapshot	14	9	Snapshot of the timestamp, minislot, and S-CDMA frame taken at an S-CDMA frame boundary at the CMTS.
Maintain Power Spectral Density	15	1	1=on; 2=off.

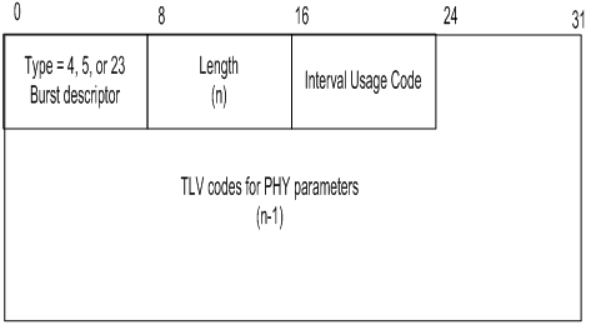
Ranging Required	16	1	0= no ranging required 1= unicast initial ranging required 2= broadcast initial ranging required 3= probing required (Only applicable for OFDMA channels)
S-CDMA Maximum Scheduled Codes enabled	17	1	1=Maximum Scheduled Codes is enabled. 2=Maximum Scheduled Codes is disabled.
Ranging Hold-Off Priority Field	18	4	Bit Field with values representing device classes,
Channel Class ID	19	4	Bit Field with values representing device classes
S-CDMA selection mode for active codes and code hopping	20	1	0,1,2,3= Selectable active codes mode x enabled and code hopping disabled.
S-CDMA selection string for active codes	21	16	128-bit string indicating which codes are active.
Higher UCD for the same UCID present bitmap	22	1	Bit 0: 1 if UCD35 is present for this UCID; 0 if UCD35 is not present Bits 1-7: Reserved for future use, set to 0; Not applicable to an OFDMA channel.
Burst Descriptor (DOCSIS 3.1)	23	n	

UCD Change Indicator Bitmask	24	2	Bit #0 UCD contains changes in the Subcarrier Exclusion Band TLV Bit #1 UCD contains changes in the Unused Subcarrier Specification TLV Bit #2 UCD contains changes in Channel TLV Parameters other than Subcarrier Exclusion Band and Unused Subcarrier Specification TLVs. Bit #3 UCD contains changes in the burst attributes associated with IUC 5 Bit #4 UCD contains changes in the burst attributes associated with IUC 6 Bit #5 UCD contains changes in the burst attributes associated with IUC 9 Bit #6 UCD contains changes in the burst attributes associated with IUC 10 Bit #7 UCD contains changes in the burst attributes associated with IUC 11 Bit #8 UCD contains changes in the burst attributes associated with IUC 12 Bit #9 UCD contains changes in the burst attributes associated with IUC 13 Bit #10 UCD contains changes in the burst attribute TLVs for IUC3 or IUC4 All other bits are reserved.
OFDMA Timestamp Snapshot	25	9	Snapshot of the timestamp and minislot taken at an OFDMA frame boundary at the CMTS.

OFDMA Cyclic Prefix Size	26	1	1: 96 samples 2: 128 samples 3: 160 samples 4: 192 samples 5: 224 samples 6: 256 samples 7: 288 samples 8: 320 samples 9: 384 samples 10: 512 samples 11: 640 samples
OFDMA Rolloff Period Size	27	1	1: 0 samples 2: 32 samples 3: 64 samples 4: 96 samples 5: 128 samples 6: 160 samples 7; 192 samples 8: 224 samples
Subcarrier Spacing	28	1	1: 25 kHz (corresponds to 4096 subcarriers and 16 subcarriers per minislot) 2: 50 kHz (corresponds to 2048 subcarriers and 8 subcarriers per minislot)

Center Frequency of Subcarrier 0	29	4	Center frequency in Hz of lowest frequency subcarrier in the IDFT block (subcarrier 0) Value is a multiple of 25 kHz or 50 kHz,
Subcarrier Exclusion Band	30	4*n	starting subcarrier index of exclusion band (2 most significant bytes) | ending subcarrier index of exclusion band (2 least significant bytes)
Unused Subcarrier Specification	31	4*n	starting subcarrier index of unused subcarrier band (2 most significant bytes) | ending subcarrier index of unused subcarrier band (2 least significant bytes).
Symbols in OFDMA frame	32	1	Number of symbols in time in an OFDMA frame (6-36).
Randomization Seed	33	3	23-bit randomization seed for OFDMA channels.

4.3.1 Burst Attributes



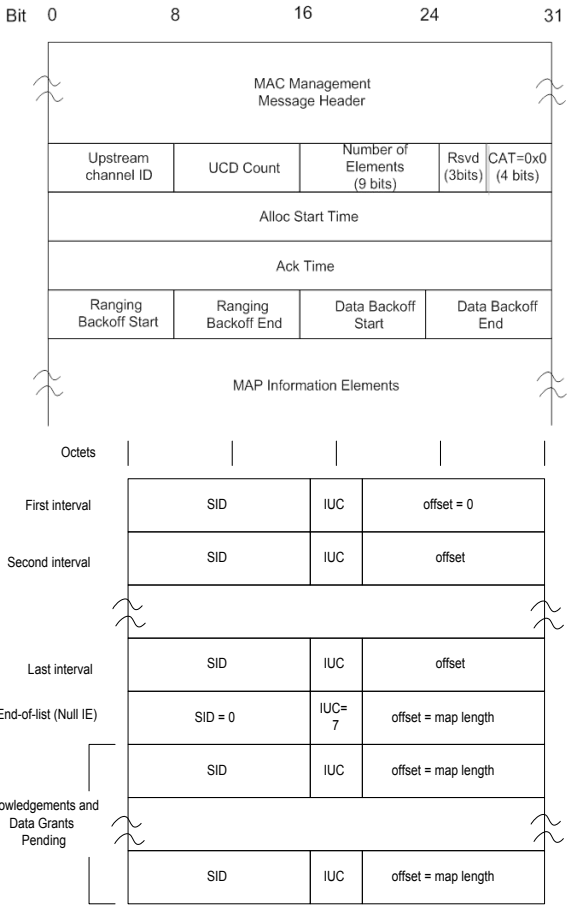
Name	T	L	V
Modulation Type	1	1	1 = QPSK 2 = 16-QAM 3 = 8-QAM 4 = 32-QAM 5 = 64-QAM 6 = 128-QAM (S-CDMA only) 7 = Reserved for C-DOCSIS
Differential Encoding	2	1	1 = on, 2 = off
Preamble Length	3	2	Up to 1536 bits for a type 5 Burst Descriptor. Up to 1024 bits for a type 4 Burst Descriptor. Up to 512 bits for a Type 23 Burst Descriptor.
Preamble Value Offset	4	2	Identifies the bits to be used in the preamble.
FEC Error Correction (T)	5	1	0-16 for descriptors encoded in a type 5 Burst Descriptor. 0-10 for descriptors encoded in a type 4 Burst Descriptor. (0 implies no FEC. The number of codeword parity bytes is 2*T).
FEC Codeword Information Bytes (k)	6	1	Fixed: 16 to 253 (assuming FEC on). Shortened: 16 to 253 (assuming FEC on). (Not used if no FEC, T=0.)
Scrambler Seed	7	2	The 15-bit seed value left justified in the 2 byte field.
Maximum Burst Size	8	1	The maximum number of minislots that can be transmitted during this burst type.

Name	T	L	V
Guard Time Size	9	1	For TDMA channels, the number of modulation intervals measured from the end of the last symbol of one burst to the beginning of the first symbol of the preamble of an immediately following burst.
Last Codeword Length	10	1	1 = fixed; 2 = shortened.
Scrambler on/off	11	1	1 = on; 2 = off.
R-S Interleaver Depth (Ir)	12	1	Reed-Solomon block interleaving depth. A depth of 0 indicates Dynamic Mode; a depth of 1 indicates RS Interleaving Disabled
R-S Interleaver Block Size (Br)	13	2	Reed-Solomon block interleaving size in Dynamic Mode. (2*Nr through 2048 where Nr=k+2T).
Preamble Type	14	1	1 = QPSK0 2 = QPSK1
S-CDMA Spreader on/off	15	1	1 = on; 2 = off.
S-CDMA Codes per Subframe	16	1	Number of codes per sub-frame used in the S-CDMA framer (1 through 128).
S-CDMA Framer Interleaving Step Size	17	1	Size of interleaving steps used in S-CDMA framer (1 through 31
TCM Encoding	18	1	1 = on; 2 = off.

Name	T	L	V
Subcarriers (N_{ir}) Initial Ranging	19	2	Number (even number only) of subcarriers for Initial Ranging;
Subcarriers (N_{fr}) Fine Ranging	20	2	Number (even number only) of subcarriers for Fine Ranging;
OFDMA Profile	21	2*n	Modulation order indexing that is encoded in the 4 bits for subcarrier bit-loading in the first byte: 0= no bit-loading 1 = BPSK 2 = QPSK 3 = 8-QAM 4 = 16-QAM 5 = 32-QAM 6 = 64-QAM 7 = 128-QAM 8 = 256-QAM 9 = 512-QAM 10 = 1024-QAM 11 = 2048-QAM 12 = 4096-QAM

4.4 MAP

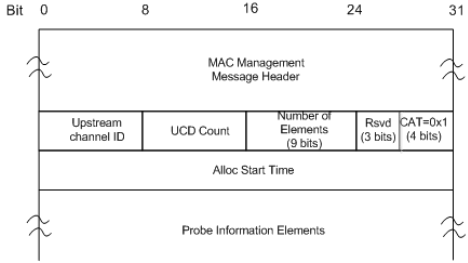
4.4.1 MAP Version 5



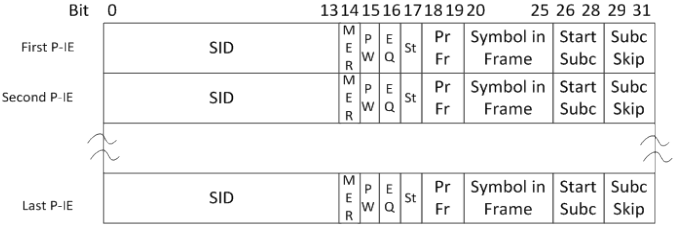
4.4.2 MAP IE

IE Name	IUC	SID (14 bits)
Request	1	any
Request_2	2	multicast
Initial Maintenance	3	broadcast or unicast
Station Maintenance	4	unicast
Data Profile IUC5	5	unicast
Data Profile IUC6	6	unicast
Null IE	7	zero
Reserved	8	unicast
Data Profile IUC9	9	unicast
Data Profile IUC10	10	unicast
Data Profile IUC11 (UGS)	11	unicast
Data Profile IUC12	12	unicast
Data Profile IUC13	13	unicast
Reserved	14	any
Expansion	15	expanded IUC

4.4.3 P-MAP Message



4.4.3.1 Probe IE Structure



4.4.3.2 Probe IE Definition

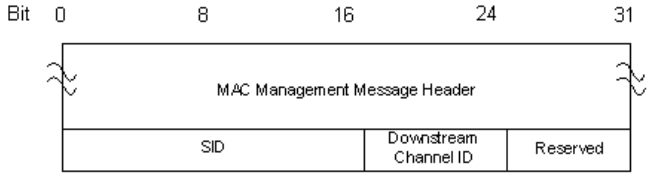
Field	**L**	**Definition**
SID	14 bits	Ranging SID for CM assigned to use this probe
MER	1 bit	CMTS RxMER Measurement Control (ignored by CM) 0= do not measure RxMER at the CMTS on this probe 1= measure RxMER at the CMTS on this probe

Field	L	Definition
PW (Power)	1 bit	Power Control for Probe 0= transmit using normal power settings. 1= transmit using alternate power
EQ (Tx Equalization)	1 bit	Transmit Equalization for Probe 0= equalizer enabled 1= equalizer disabled
St (Stagger)	1 bit	If this bit is 1, repeat the pattern in this P-IE in the next number of symbols equal in quantity to "Subc skip" and by moving the pattern up by one subcarrier in each symbol and wrapping the pattern back to the beginning. If this value is zero, no stagger is to be used.
Probe Frame	2 bits	Number of frames offset from the frame beginning at the allocation start time of this MAP; this indicates the first frame for which this P-IE is applicable. A value of zero indicates the first probe frame of the MAP.
Symbol in Frame	6 bits	Number of symbols offset from the beginning of the probe frame specified in the Probe Frame Field. A value of zero indicates the first symbol of the probe frame. Valid values are 0 to K-1 where K is the number of symbols in a frame.

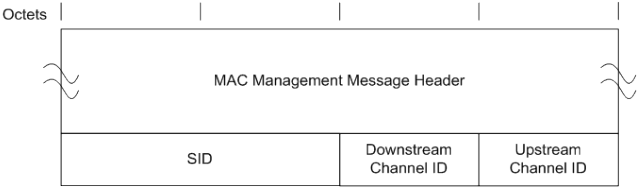
Field	L	Definition
Start Subc	3 bits	Starting Subcarrier – this value represents the starting subcarrier to be used by the probe. A value of zero indicates the first subcarrier in the symbol. Start Subc must be less than or equal to the Subc Skip value when PW=0. For PW=1, the following power per subcarrier MUST be used for the probe transmission: Start Subc, power per subcarrier reduced by, 0, 2 dB, 1, 3 dB, 2, 4 dB, 3, 5 dB, 4, 6 dB, 5, 7 dB, 6, 8 dB, 7, 9 dB.
Subc Skip	3 bits	Subcarrier Skipping is the number of subcarriers to be skipped between successive pilots in the probe. A value of zero implies no skipping of subcarriers and that all non-excluded subcarriers are used for probing. For staggered patterns, Subc Skip performs an additional function. (Subc Skip + 1) is the total number of symbols for which the staggered P-IE allocation applies.

4.5 Ranging

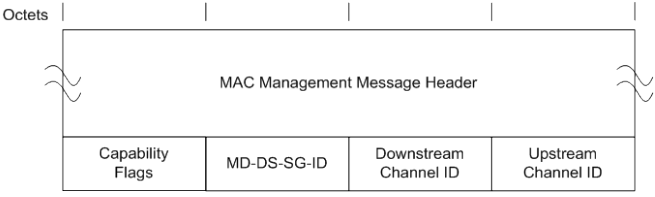
4.5.1 Formats



RNG-REQ



INIT-RNG-REQ



B-INIT-RNG-REQ

O-INIT-RNG-REQ

4.5.2 CM RNG-REQ Usage

Ranging Situation	**Channel Type**	
	1, 2, 3, 4	**5**
CM initializing on first channel, and transmitting in a broadcast Initial Maintenance opportunity.	B-INIT-RNG-REQ	O-INIT-RNG-REQ
CM initializing on secondary channel, and transmitting in a broadcast or unicast Initial Maintenance opportunity	RNG-REQ	O-INIT-RNG-REQ
CM transmitting in a Station Maintenance opportunity	RNG-REQ	B-INIT-RNG-REQ, or RNG-REQ

4.5.3 RNG-RSP Encodings

Name	**Type**	**L**	**Value**
Timing Adjust, Integer Part	1	4	TX timing offset adjustment [signed 32-bit, units of (6.25 microsec/64) for TDMA and S-CDMA channels, units of (1/204.8 MHz) for OFDMA channels.]
Power Level Adjust	2	1	TX Power offset adjustment (signed 8-bit, 1/4-dB units).

Name	Type	L	Value
Offset Frequency Adjust	3	2	TX frequency offset adjustment (signed 16-bit, Hz units). For an OFDMA channel, the CM MUST ignore the TX frequency offset adjustment.
Transmit Equalization Adjust	4	n	TX equalization data to be convolved with current values
Ranging Status	5	1	1 = continue, 2 = abort, 3 = success.
Downstream frequency override	6	4	For SC-QAM channels, the center frequency of the SC-QAM channel. For OFDM channels, the center frequency of the lowest subcarrier of the 6 MHz encompassed spectrum containing the PHY Link Channel (PLC) at its center.
Upstream channel ID override	7	1	Identifier of the new upstream channel.
Timing Adjust, Fractional Part	8	1	TX timing fine offset adjustment.
Transmit Equalization Set	9	n	TX equalization data to be loaded in place of current values

Name	T	L	V
S-CDMA Maximum Scheduled Codes	10	1	A value of 0 means no code limit. Other possible values range from 4 to number_active_codes inclusive.
S-CDMA Power Headroom	11	1	The units are dB. The range of this TLV is from 0 to 4*10log $\left(\frac{Number\_Active\_Codecs}{Maximum\_Scheduled\_Codecs}\right)$
Upstream Channel Adjustments	12	n	
Upstream Channel ID	12.1	1	The ID of the channel.
Temp SID	12.2	2	SID to be used on the new channel.
Initialization Technique	12.3	1	1 = Perform broadcast initial ranging 2 = Perform unicast ranging 3 = Perform either broadcast or unicast 4 = Reserved 5 = Perform probing (OFDMA upstream) 0, 6 – 255: reserved
Ranging Parameters	12.4	n	Contains sub-TLVs for ranging adjustments.

Name	Type	L	Value
Ranging Parameters	12.4	n	Contains sub-TLVs for ranging adjustments.
Deprecated	12.4.1	1	Deprecated
Timing Offset, Integer Part	12.4.2	4	TX timing offset adjustment (signed 32-bit, units of (6.25 microsec/64)) for TDMA and S-CDMA channels, units of (1/204.8 MHz) for OFDMA channels.
Timing Offset, Fractional Part	12.4.3	1	TX timing fine offset adjustment. 8-bit unsigned value specifying the fine timing adjustment in units of 1/(256*10.24 MHz) for S-CDMA and TDMA or 1/(256*204.8 MHz) for OFDMA.
Power Offset	12.4.4	1	TX Power offset adjustment (signed 8-bit, 1/4-dB units).
Frequency Offset	12.4.5	2	TX frequency offset adjustment (signed 16-bit, Hz units). This TLV is not applicable for OFDMA channels.
Ranging Status	12.4.6		1 = continue, 2 = abort, 3 = success.

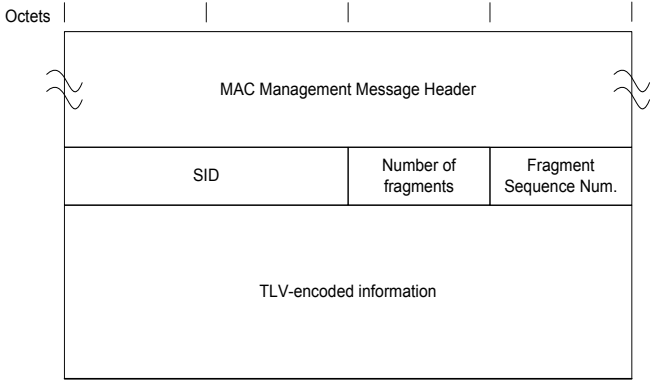
Name	Type	L	Value
T4 Timeout Multiplier	13	1	Multiplier of the default T4 Timeout as defined earlier in this section.
Dynamic Range Window Upper Edge	14	1	The upper edge of the Dynamic Range Window expressed in units ¼ db below the max allowable setting (Phi)
	15-16	2	Defined in table below due to 2-byte length field
Commanded Power	17	5 + 3 * n	This TLV contains the Dynamic Range Window value, Pload_min_set as well as the Transmit Power Level for each of the channels in the CM's Transmit Channel Set, expressed in units of quarter dBmV.
Reserved		n	Reserved for future use.

4.5.3.1 Ranging Response Message Encodings with 2-Byte Length Field

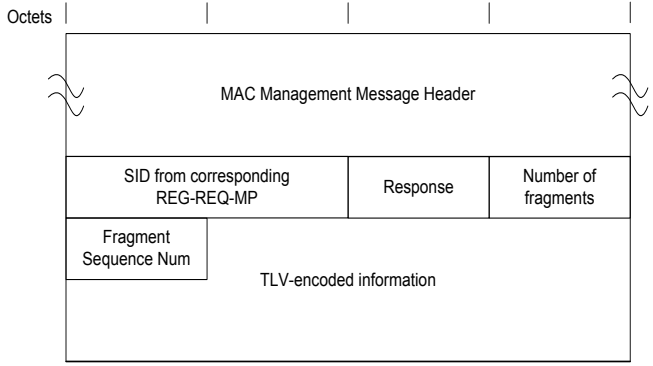
Name		Value (Variable Length)
Transmit Equalization Adjust for OFDMA Channels	Type 15, Length =2	TX equalization data to be multiplied with current values. Lowest subcarrier number for which coefficient is being adjusted (12 bits) Highest subcarrier number for which coefficient is being adjusted (12 bits) List of coefficients in order from lowest to highest subcarrier with 2 byte real coefficients followed by 2 byte imaginary coefficients.
Transmit Equalization Set for OFDMA Channels	Type 15, Length =2	TX equalization data to be loaded in place of current values. Lowest subcarrier number for which coefficient is being loaded (12 bits) Highest subcarrier number for which coefficient is being loaded (12 bits) List of coefficients in order from lowest to highest subcarrier with 2 byte real coefficients followed by 2 byte imaginary coefficients.

4.6 Registration

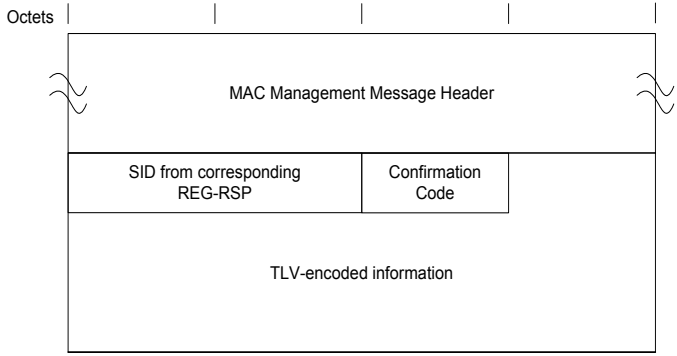
4.6.1 REG-REQ-MP



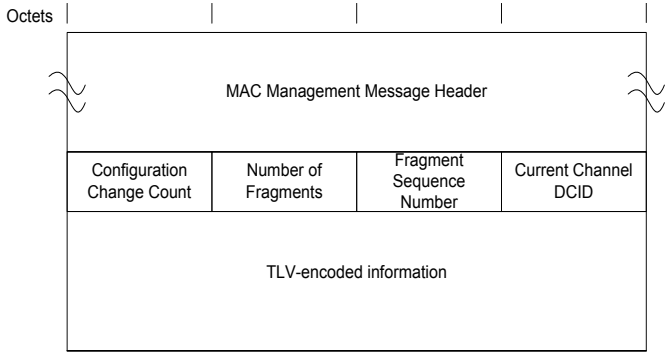
4.6.2 REG-RSP-MP



4.6.3 REG-ACK



4.7 MAC Domain Descriptor (MDD)



4.7.1 Downstream Active Channel List TLV

T	L	V
1	# of bytes including in sub-TLVs	See sub-TLVs

4.7.1.1 Sub-TLVs

T	L	V
1.1	1	Channel ID
1.2	4	The center frequency of the downstream channel (Hz).
1.3	1	Modulation Order. Not present on an OFDM channel.
1.4	1	Primary capable: 0 = channel is not primary-capable 1 = channel is primary-capable
1.5	2	CM-STATUS Event Enable Bitmask: 0 - Reserved (unused) 1 - MDD timeout 2 - QAM/FEC lock failure 3 - Reserved (used for non-channel-specific events) 4 - MDD Recovery 5 - QAM/FEC Lock Recovery 6 – 8 - Reserved 9 – 10 - Reserved 11 – 15 - Reserved
1.6	1	MAP and UCD Transport Indicator. 0 = channel cannot carry MAPs and UCDs for the MAC domain for which the MDD is sent 1 = channel can carry MAPs and UCDs for the MAC domain for which the MDD is sent 2 – 255 = Reserved

1.7	1	OFDM PLC parameters: Bit 7 Reserved Bit 6 – Sub carrier spacing: 0 = 25Khz 1 = 50KHz Bits 5 – 3:Cyclic Prefix 0 = 0.9375 µs (192 * Ts) 1 = 1.25 µs (256 * Ts) 2 = 2.5 µs (512 * Ts) 3 = 3.75 µs (768 * Ts) 4 = 5 µs (1024 * Ts) 5 – 7 = Reserved Bits 2 – 0: Tukey raised cosine window, embedded into cyclic prefix 0 = 0 µs (0 * Ts) 1 = 0.3125 µs (64 * Ts) 2 = 0.625 µs (128 * Ts) 3 = 0.9375 µs (192 * Ts) 4 = 1.25 µs (256 * Ts) 5 – 7 = Reserved

4.7.2 MAC Domain Downstream Service Group TLV

Type	Length	Value
2	# of bytes including in sub-TLVs	See sub-TLVs

4.7.2.1 Sub-TLVs

Type	Length	Value
2.1	1	MD_DS_SG_ID
2.2	N (where N = 1 byte for each downstream channel	Each byte contains DCID which is part of this MD-DS-SG

4.7.3 Downstream Ambiguity Resolution Frequency List

Type	Length	Value
3	N (N = 4 bytes times number of frequencies listed)	Consists of concatenated 4-byte fields. Each 4-byte field contains a center frequency in Hz.

4.7.4 Receive Channel Profile Reporting Control

Type	Length	Value
4	# of bytes including in sub-TLVs	See sub-TLVs

4.7.4.1 Sub-TLVs

T	L	V
4.1	1	RCP SC-QAM Center Frequency Spacing. 0 = report only RCPs with 6 MHz center frequency spacing. 1 = report only RCPs with 8 MHz center frequency spacing.
4.2	1	Verbose RCP reporting. 1 byte: 0 = do not verbose report 1= provide verbose reporting
4.3	1	Fragmented RCP transmission. 1 byte: 0 = Reserved 1= CM MAY transmit RCPs requiring fragmentation in addition to those that do not

4.7.4.2 IP Initialization Parameters

T	L	V
5	# of bytes including in sub-TLVs	See sub-TLVs

4.7.4.3 Sub-TLVs

T	L	V
5.1	1	IP Provisioning Mode 0 = IPv4 Only 1 = IPv6 Only 2 = Alternate (APM) 3 = Dual-stack (DPM

T	L	V
5.2	3	Pre-Registration DSID. Three bytes: bits 23 – 20: Reserved (set to zero). bits 19 – 0: DSID value to be used by the CM for filtering and forwarding Downstream Link-Local Multicast used for IPv6 stack initialization and Neighbor Solicitation prior to registration

4.7.5 Early Authentication and Encryption (EAE) Enable/Disable

T	L	V
6	1	One byte: 0 = EAE disabled; 1= EAE enabled;

4.7.6 Field definitions for Active Upstream Channel List

T	L	V
7	# bytes including sub-TLVs	See sub-TLVs

4.7.6.1 Sub-TLVs

T	L	V
7.1	1	The upstream channel ID for a channel being listed
7.2	2	CM-STATUS Event Enable Bitmask: 2 bytes. 0 = Reserved (unused) 1 – 2 = Reserved (used for downstream specific events) 3 = Reserved (used for non-channel-specific events) 4 – 5 = Reserved (used for downstream specific events) 6 = T4 timeout 7 = T3 re-tries exceeded 8 = Successful ranging after T3 re-tries exceeded 9 – 10 = Reserved (used for non-channel-specific events) 11 – 15 = Reserved for future use
7.3	1	Upstream Channel Priority

4.7.7 Upstream Ambiguity Resolution Channel List

T	L	V
8	N (where N = the number of channel IDs)	Each byte contains a UCID for a channel

4.7.8 Upstream Frequency Range

T	L	V
9	1	Upstream Frequency Range: 1 byte. 0 = Standard Upstream Frequency Range 1 = Extended Upstream Frequency Range

4.7.9 Symbol Clock Locking Indicator

T	L	V
10	1	Symbol Clock Locking Indicator 0 = Symbol Clock is not locked to Master Clock 1 = Symbol Clock is locked to Master Clock

4.7.10 CM-STATUS Event Control TLV

T	L	V
11	10	Event Control Encoding
11.1	1	Event Type Code
11.2	2	Maximum Event Holdoff Timer in units of 20 milliseconds. Valid range: 1..65535.
11.3	1	Maximum Number of Reports per event: 0: Unlimited number of reports 1 – 255: Maximum number of reports for an event type reporting transaction.
11.4	1	CM-STATUS-ACK Reports per event 1: CM-STATUS-ACK stops unlimited number of reports for this event

4.7.11 Upstream Transmit Power Reporting

T	L	V
12	1	0: CM does not report transmit power in RNG-REQ, INIT-RNG-REQ, and B-INIT-RNG-REQ 1: CM reports transmit power in RNG-REQ, INIT-RNG-REQ, and B-INIT-RNG-REQ

4.7.12 DSG DA-to-DSID Association Entry

T	L	V
13	# of bytes including sub-TLVs	See sub-TLVs

4.7.12.1 Sub-TLVs

T	L	V
13.1	6	DA: MAC DA to which this association applies.
13.2	3	Bits 23-20: Reserved. Bits 19-0: 20-bit DSID associated with the DA contained in 13.1.

4.7.13 CM-STATUS Event Enable for Non-Channel-Specific Events

T	L	V
15	2	CM-STATUS Event Enable Bitmask for Non-Channel-Specific Events; 2 bytes. 0 - Reserved (unused) 1 – 2 - Reserved (used for downstream specific events) 3 - Sequence out-of-range 4 – 5 - Reserved (used for downstream specific events) 6 – 8 - Reserved (used for upstream specific events) 9 - CM operating on battery backup 10 - CM returned to A/C power 11 - CM MAC Address Removal 12 – 15 - Reserved for future use

4.7.14 Extended Upstream Transmit Power Support

T	L	V
16	1	Extended Upstream Transmit Power Support 0 = Extended Upstream Transmit Power Support Off 1 = Extended Upstream Transmit Power Support On

4.7.15 CMTS DOCSIS Version TLV

T	L	V
17	N	CMTS DOCSIS Version

4.7.15.1 Sub-TLVs

T	L	V
17.1	1	CMTS Major DOCSIS Version
17.2	1	CMTS Minor DOCSIS Version

4.7.16 CM Periodic Maintenance Timeout Indicator

T	L	V
18	1	CM Periodic Maintenance Timeout Indicator: 1 byte. 0 = use Unicast Ranging opportunity 1 = use Probe opportunity 2 = use Unicast Ranging or Probe opportunity 3 – 255 = Reserved

4.7.17 DLS Broadcast and Multicast Delivery Method

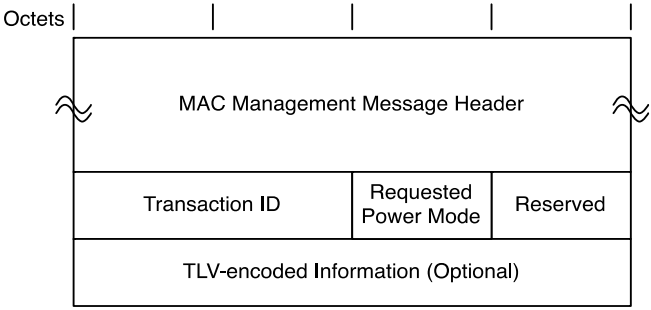
T	L	V
19	1	DLS Broadcast and Multicast Delivery Method: 1 byte. 1 = delayed selected multicast method 2 = selectively replicated multicast method All other values = Reserved

4.7.18 CM-STATUS Event Enable for DOCSIS 3.1 Events

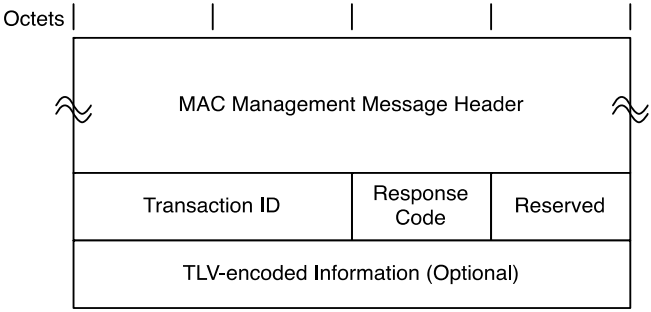
T	L	V
20	4	CM-STATUS Event Enable Bitmask for DOCSIS 3.1 Events. 0 – Downstream OFDM Profile Failure 1 – Primary Downstream Channel Change 2 – DPD Mismatch 3 – Invalid DPD message 4 – NCP Profile Failure 5 – Loss of FEC lock on PLC 6 – NCP Profile Recovery 7 – FEC Recovery on PLC 8 – FEC Recovery on OFDM Profile 9 – OFDMA Profile Failure 10 – MAP Storage Overflow Indicator 11 – MAP Storage Almost Full Indicator 12 – 31 - Reserved for future use

4.8 Energy Management

4.8.1 EM-REQ



4.8.2 EM-RSP



4.9 EM-RSP TLVs

4.9.1 Hold-Off Timer

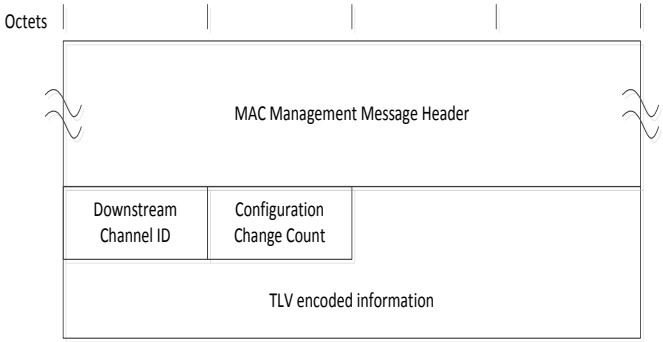
This TLV specifies the amount of time to delay in seconds before transmitting an EM-REQ message again.

Type	Length	Value
1	2	Minimum time (in seconds) before transmitting another EM-REQ message

4.10 OFDM Channel Descriptor

4.11 OCD message

An OFDM Channel Descriptor allows the CMTS to communicate the parameters of the Downstream OFDM channel to cable modems. OCD describes the downstream direction only. OCD is used for parameters that are common for all profiles and are static assignments.



4.11.1 OCD TLVs

Name	T	L	V
Discrete Fourier Transform size	0	1	The size of the DFT defining the OFDM transmission. 0 = 4096 subcarriers at 50 kHz spacing 1 = 8192 subcarriers at 25 kHz spacing 2 to 255 are reserved
Cyclic prefix	1	1	This is the length of the cyclic prefix. The sample number given is with reference to a sample rate of 204.8 M samples/s. 0 = 0.9375 µs with 192 samples 1 = 1.25 µs with 256 samples 2 = 2.5 µs with 512 samples 3 = 3.75 µs with 768 samples 4 = 5.0 µs with 1024 samples 5 to 255 are reserved
Roll-off	2	1	This parameter specifies the transmitter window roll-off value. 0 = 0 µs with 0 samples 1 = 0.3125 µs with 64 samples 2 = 0.625 µs with 128 samples 3 = 0.9375 µs with 192 samples 4 = 1.25 µs with 256 samples 5 to 255 are reserved

Name	T	L	V	
OFDM spectrum location	3	4	This is a 32-bit number that specifies the center frequency in Hz of the subcarrier 0 of the OFDM transmission. Value is a multiple of 25 kHz or 50 kHz, respectively, for subcarrier spacing of 25 kHz or 50 kHz. This is the frequency of subcarrier X(0) in the definition of the DFT. See section 3.2.1	
Time Interleaving Depth	4	1	This integer that defines the depth of time interleaving from 1 up to a maximum value of 32.	
Subcarrier Assignment Range/List	5	Range 5 List 5-255	byte 0, bits 7:6	00 = range, continuous 01 = range, skip by 1 10 = list 11 = reserved
			byte 0, bit 5	0 = specific value 1 = default value
			byte 0, bits 4:0	00, 02-15, 17-19, 21-31 = reserved 01 = continuous pilot 16 = excluded subcarriers 20 = PLC, 16-QAM

Name	T	L	V	
			bytes 2,1	Start subcarrier index (range mode), or first list entry (list mode).
			bytes 4,3	End subcarrier index (range mode), or second list entry (list mode)
			bytes 6,5 to bytes 254, 253	Subsequent list entries (list mode).

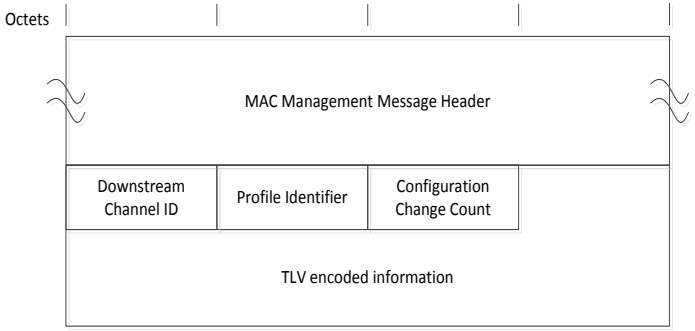
The role of subcarrier assignment is shared between the OCD and DPD message. The sub-carrier assignment TLV for OCD defines:.

- Exclusion of subcarriers
- Location of the PLC
- Continuous pilots

4.12 Downstream Profile Descriptor

4.12.1 DPD message

A Downstream Profile Descriptor allows the CMTS to communicate the parameters of Downstream Profiles to cable modems. There is one DPD message per profile. The DPD can be changed dynamically.



4.12.1.1 DPD TLVs : Subcarrier Assignment List/Range TLV

Type =5,

Length (1 byte)	**Value (Variable Length)**	
Range 5 List 5-255	byte 0, bits 7:6	00 = range, continuous 01 = range, skip by 1 10 = list 11 = reserved
	byte 0, bit 5	0 = specific value 1 = default value
	byte 0, bit 4	Reserved

Length (1 byte)	Value (Variable Length)		
	byte 0, bits 3:0	0 = zero bit loaded 1= reserved 2 = QPSK * 3 = reserved 4 = 16-QAM 5 = reserved 6 = 64-QAM 7 = 128-QAM	8 = 256-QAM 9 = 512-QAM 10 = 1024-QAM 11 = 2048-QAM 12 = 4096-QAM 13 = 8192-QAM 14 = 16384-QAM 15 = reserved
	bytes 2,1	Start subcarrier index (range mode), or first list entry (list mode).	
	bytes 4,3	End subcarrier index (range mode), or second list entry (list mode)	
	bytes 6,5 to bytes 254, 253	Subsequent list entries (list mode).	

- QPSK is for NCP profile only

4.12.1.2 DPD TLVs : Subcarrier Assignment Vector TLV

Type =6,

<table>
<tr><th>Length
(2 bytes)</th><th colspan="3">Value
(Variable Length)</th></tr>
<tr><td rowspan="3">2 +
ceiling
(N/2)</td><td>bytes 1,0</td><td colspan="2">bit 15: 0 => N is even
1 => N is odd. Ignore last 4 bits.

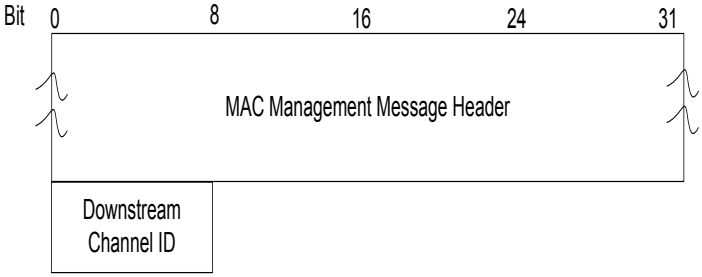
bits 14-13: reserved
bit 12-0: subcarrier start</td></tr>
<tr><td>bytes 2+</td><td colspan="2">bits 7-4: Zth subcarrier
bits 3-0: Z+1 subcarrier</td></tr>
<tr><td></td><td>0 = zero bit-loaded
1 = cont. pilot*
2 = QPSK **
3 = reserved
4 = 16-QAM
5 = reserved
6 = 64-QAM
7 = 128-QAM</td><td>8 = 256-QAM
9 = 512-QAM
10 = 1024-QAM
11 = 2048-QAM
12 = 4096-QAM
13 = 8192-QAM
14 = 16384-QAM
15 = reserved</td></tr>
</table>

* Continuous Pilots are assigned in the OCD and are not profile dependent. The “cont. pilot” setting in the DPD Subcarrier Assignment Vector TLV is merely a reminder of the continuous pilots assigned in the OCD.

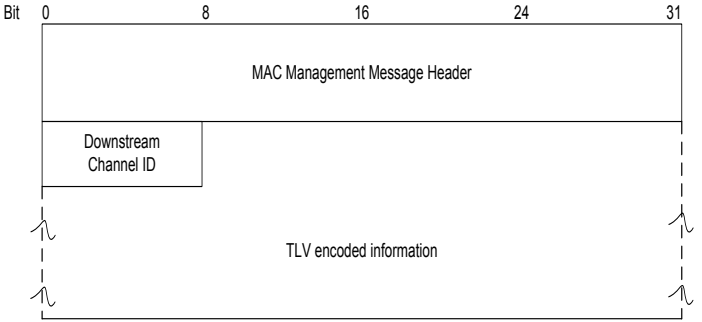
** QPSK is for NCP profile only

4.13 OFDM Downstream spectrum request

4.13.1 OFDM Downstream spectrum request message (ODS-REQ)



4.13.2 OFDM Downstream spectrum response message (ODS-RSP)



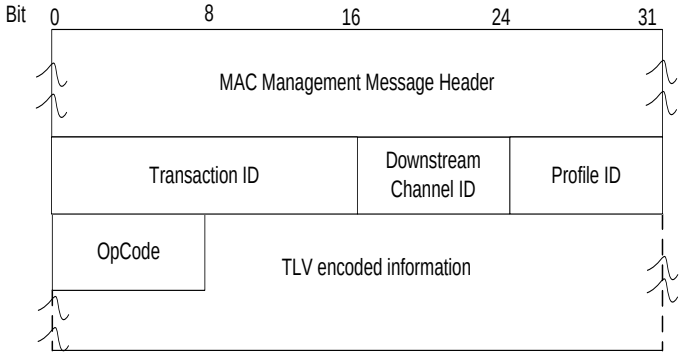
4.13.2.1 ODS-RSP TLVs

Name	**T**	**L**	**V**
ODS Response Vector	1	N + 8	
First Subcarrier-ID	1.1	2	ID of the subcarrier corresponding to the first value of the MER vector
RxMER per Subcarrier	1.2	N	Integer modulation error ratio measurements in 0.25dB steps (0xFF is 63.75dB). Values are encoded as a packed sequence of 8-bit values for N consecutive sub-carriers (N<= 7680) beginning with First Subcarrier-ID from TLV subtype 1.1.

4.14 OFDM downstream profile TEST

4.14.1 OFDM Downstream Profile Test Request OPT-REQ message

The OPT-REQ is used by the CMTS to cause a CM to test its ability to receive the specified downstream OFDM profile and then report the results.



Length (bytes)	Value
2	**Transaction ID**
1	**Downstream Channel ID**
1	**Profile ID** – the ID of the profile that is being tested
1	**OpCode:** 1 – Start 2 – Abort All other values reserved

4.14.1.1 OPT-REQ TLVs

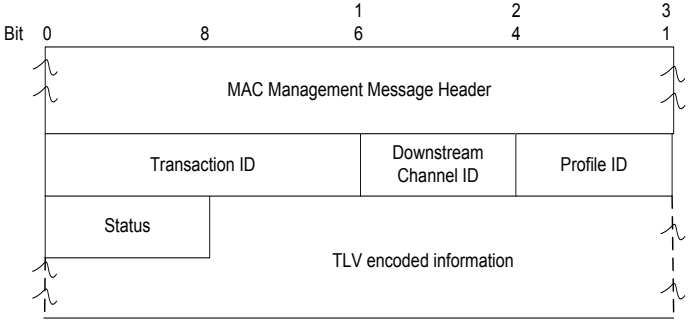
Name	Type (1 byte)	Length (1 byte)	Value
Requested Statistics	1	1	BITS encoding that commands the CM to include RxMER Margin Statistics in its OPT-RSP message. The specified RxMER Margin Statistics are requested when the bit is set to 1 and not requested when the bit is set to zero. Bit 0 – RxMER Statistics for Candidate Profile Bit 1 – RxMER Pass Fail for Candidate Profile Bit 2 – SNR Margin for Candidate Profile Bit 3 – Codeword Statistics for Candidate Profile Bit 4 – Codeword Pass Fail for Candidate Profile Bits 5 - 7: Reserved

Name	T	L	V
RxMER Target	2	3	The CMTS uses this two byte value to communicate the RxMER target for the modulation orders of the profile Byte 0 : Modulation order : 0 - 1 = reserved, 2 = QPSK, 3 = reserved , 4 = 16-QAM 5 = reserved, 6 = 64-QAM, 7 = 128-QAM, 8 = 256-QAM 9 = 512-QAM, 10 = 1024-QAM, 11 = 2048-QAM, = 4096-QAM 13 = 8192-QAM, 14 = 16384-QAM, 15-255 = reserved Byte 1: RxMER Target The required value for the profile RxMER (refer to OPT-RSP) in units of 0.25dB (0xFF is 63.75dB). This is the required RxMER value that the CM uses to calculate the SNR margin for the profile. Byte 2 : RxMER Margin The CM reports the number of subcarriers whose the measured RxMER is at least this value below the target RxMER for the bitloading of the given subcarrier in the OPT-RSP message. The value is in units of ¼ dB.

Name	T	L	V
Average SNR Target	3	1	The required value for average SNR Target (refer to OPT-RSP) in units of 0.25dB (0xFF is 63.75dB). This value is used in the determination of the SNR margin.
Max Duration	4	4	Maximum # of milliseconds before the CM MUST abort testing and attempt to send an OPT-RSP with an Incomplete Status.
Data Profile Testing Parameters	5		
Codeword Count (N_c)	5.1	4	Number of BCH codewords to be examined.
Maximum Uncorrectable Codeword Count (N_e)	5.2	4	Maximum number of codewords which are allowed to fail BCH decoding before the CM MUST abort the test and attempt to send an OPT-RSP with a Complete status.

Name	T	L	V
Codeword Tagging Enable	5.3	1	Indicates whether Codeword Tagging is in use for this test. Bit 0: Enable Codeword Tagging 0 – Codeword Tagging is disabled. (include all codewords , default) 1 – Codeword Tagging is enabled. (codewords for which “T” bit is set) Bits 7-1: Reserved
NCP Profile Testing Parameters	6		
Maximum NCP LDPC Unreliable Codeword Count	6.1	4	Maximum number of NCP codewords which are allowed to fail the NCP LDPC post-decoding syndrome check.
Maximum NCP CRC Failure Count	6.2	4	Maximum number of NCP codewords which are allowed to fail the NCP CRC check.

4.14.2 OFDM Profile Test Response (OPT-RSP) message



Length (bytes)	Value
2	**Transaction ID** – copied from received OPT-REQ message
1	**Downstream Channel ID** the channel for which the profile is being tested
1	**Profile ID** – the ID of the profile that is being tested
1	**Status:** 1 – Testing 2 – Profile Already Testing from Another Request 3 – No Free Profile Resource on CM 4 - Unknown Transaction ID 5 – Incomplete 6 – Complete All other values reserved

4.14.2.1 OPT-RSP TLVs

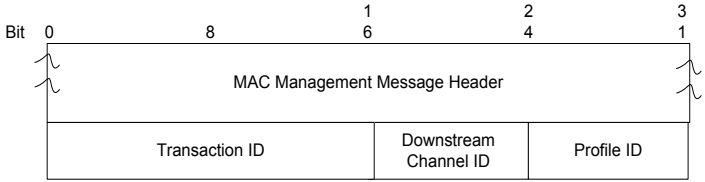
Name	Type (1 byte)	Length (2 byte)	Value
RxMER and SNR Margin Data	1		
RxMER per Subcarrier	1.1	N	Integer modulation error ratio measurements in 0.25dB steps (0xFF is 63.75dB). These are encoded as a packed sequence of 8-bit values for N consecutive sub-carriers (N ≤ 7680) from lowest active subcarrier to the highest active subcarrier, including all the subcarriers in between.
Pass/Fail for RxMER per Subcarrier	1.2	N	Pass Fail indication for each subcarrier's RxMER (1 bit for each subcarrier). A value of 1 indicates that the measured MER ≥ target value in the OPT-REQ A value of 0 indicates that the measured MER < target value in the OPT-REQ These are encoded as a sequence of 1-bit values for N consecutive subcarriers (N ≤ 7680) from lowest active subcarrier to the highest active subcarrier, including all the subcarriers in between.

Name	T	L	V
Number of subcarriers whose RxMER is RxMER Margin below the RxMER Target	1.3	2	The number of subcarriers (≤ 7680) whose RxMER is ≥ the RxMER Margin below the RxMER target for the bitloading of the given subcarrier
SNR Margin	1.4	1	The SNR margin of the candidate data profile (signed integer), in units of 0.25dB
Data Profile Codeword Data	2		
Codeword Count	2.1	4	Unsigned integer count of codewords that were examined during testing. If Codeword Tagging is disabled, this count includes all codewords received on the profile in question for the duration of the test. If Codeword Tagging is enabled, this count includes codewords received on the profile in question for the duration of the test for which the "T" bit was set in the NCP pointing to the codeword.

Name	T	L	V
Corrected Codeword Count	2.2	4	Unsigned integer count of codewords that failed pre-decoding LDPC syndrome check and passed BCH decoding. If Codeword Tagging is disabled, this count includes all codewords received on the profile in question for the duration of the test. If Codeword Tagging is enabled, this count includes codewords received on the profile in question for the duration of the test for which the “T” bit was set in the NCP pointing to the codeword.
Uncorrectable Codeword Count	2.3	4	Unsigned integer count of codewords that failed LDPC post-decoding syndrome check. If Codeword Tagging is disabled, this count includes all codewords received on the profile in question for the duration of the test. If Codeword Tagging is enabled, this count includes codewords received on the profile in question for the duration of the test for which the “T” bit was set in the NCP pointing to the codeword.

Name	T	L	V
NCP Codeword Data	3		
NCP Codeword Count	3.1	4	Unsigned integer count of NCP codewords that were examined during testing.
Unreliable NCP Codeword Count	3.2	4	Unsigned integer count of NCP codewords that failed LDPC post-decoding syndrome check.
NCP CRC Failure Count	3.3	4	Unsigned integer count of NCP codewords that failed the NCP CRC check.

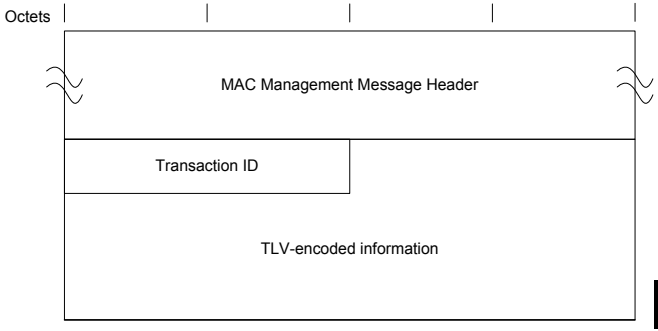
4.14.3 OFDM Profile Test Acknowledge (OPT-ACK) message



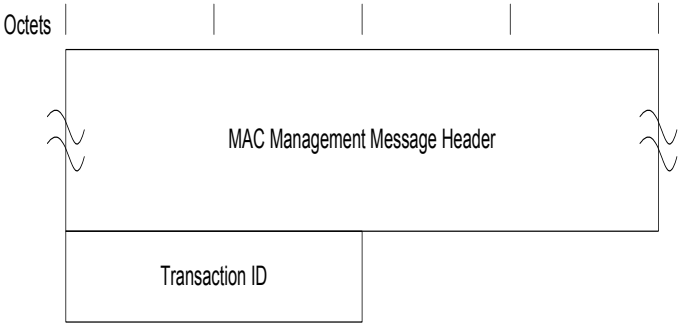
Length (bytes)	Value
2	**Transaction ID** – copied from received OPT-REQ message
1	**Downstream Channel ID** the channel for which the profile is being tested
1	**Profile ID** – the ID of the profile that is being tested

4.15 DOCSIS Time Protocol

4.15.1 DTP-REQ, DTP-RSP, DTP-Info message



4.15.2 DTP-ACK message



4.15.3 DTP TLVs

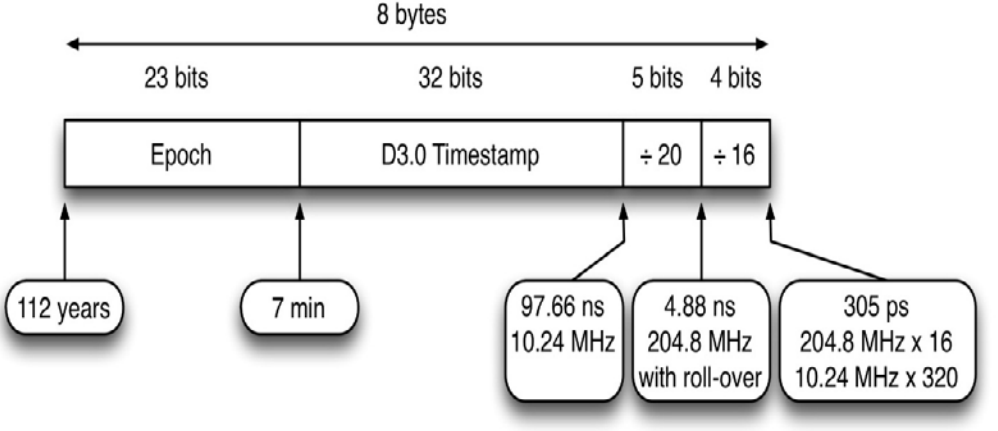
T	L	V
77	N	DOCSIS Time Protocol Encodings
77.1	4	Clock ID
CMTS Timing Parameters, 24-bit unsigned values, (nanoseconds)		
77.2	4	t-cmts-ds-i
77.3	4	t-cmts-ds-o
77.4	4	t-cmts-ds-p
77.5	4	t-cmts-us-o
77.6	4	t-cmts-us-p
HFC Timing Parameters, 24-bit unsigned values, (nanoseconds)		
77.7	4	t-hfc-ds-o
77.8	4	t-hfc-ds-p
77.9	4	t-hfc-us-o
77.10	4	t-hfc-us-p
CM Timing Parameters, 24-bit unsigned values, (nanoseconds)		
77.11	4	t-cm-ds-o
77.12	4	t-cm-ds-p

77.13	4	t-cm-us-o
77.14	4	t-cm-us-p
77.15	4	t-cm-ds-i
CMTS Timing Override Parameters, 24-bit unsigned values, (nanoseconds)		
77.16	4	t-cm-ds-o
77.17	4	t-cm-ds-p
77.18	4	t-cm-us-o
77.19	4	t-cm-us-p
77.20	4	t-cm-ds-i
77.21	4	True Ranging Offset.
77.22	4	Timing Adjustment.
77.23	1	DTP Error Code

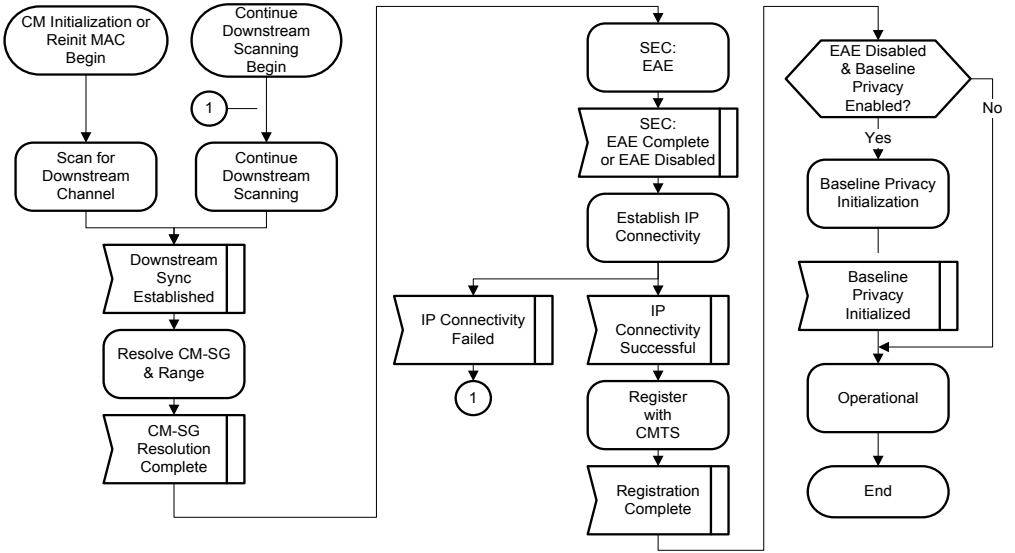
4.16 Extended Timestamp

DOCSIS 3.1 introduces an eight-byte extended timestamp. The value of the timestamp is referenced to the end of the PLC preamble.

The DOCSIS Extended Timestamp is now an absolute timestamp rather than a relative timestamp, and it has a higher degree of precision



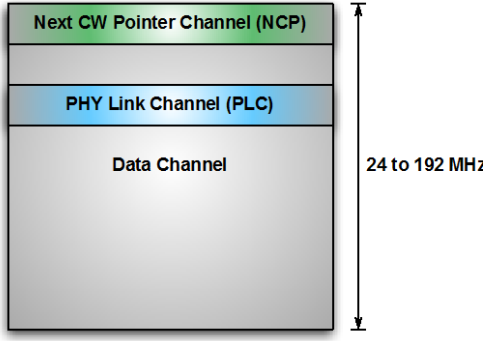
4.17 Cable Modem Initialization overview



PHY Link Channel

5

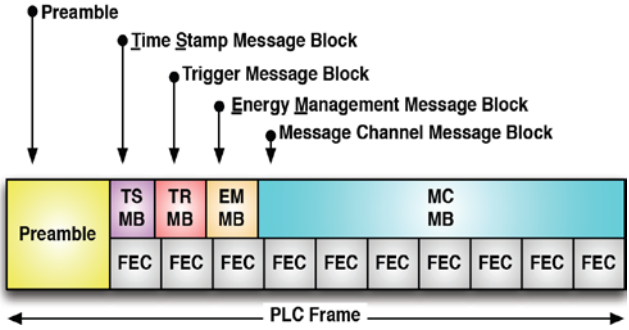
5 PHY Link Channel (PLC)



The PHY Link Channel (PLC) is located in the downstream convergence layer. It is used for several tasks:

-Timestamp
-Energy management
-Message channel for bringing new CMs on line.
-Trigger message for synchronizing an event between the CMTS and CM.

5.1 PLC Structure

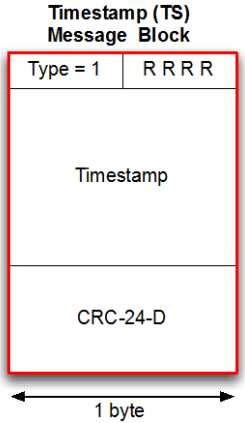


5.2 PLC Frame Length (including Preamble)

FFT Size	Symbol Time	PLC Frame				Data Capacity		Frame Time (ms) based upon Cyclic Prefix (us)				
		Sub carriers	FEC Blocks	Raw Bytes	Payload Bytes	Min	Max	0.9375 µs	1.25 µs	2.5 µs	3.75 µs	5.0 µs
4K	20 µs	8	10	480	360	0.9	1.1	2.68	2.72	2.88	3.04	3.20
8K	40 µs	16	20	960	720	1.0	1.1	5.24	5.28	5.44	5.60	5.76

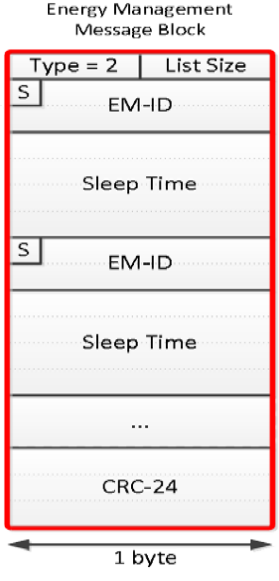
5.3 PLC Message Blocks

5.3.1 Timestamp Message Block



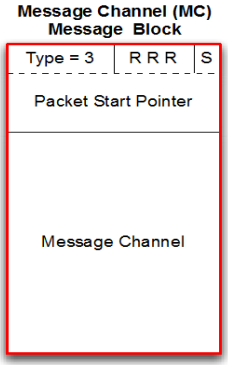
Field	Size	Value	Description
Type	4 bits	1	Timestamp MB
R	4 bits	0	Reserved
Timestamp	8 bytes		Extended Timestamp
CRC	3 bytes		CRC-24-D CRC field is computed over the entire message block except the CRC field itself, and included in the defined format to allow validation of the integrity Message Block Type and Message Body Size

5.3.2 Energy Management Message Block



Field	Size	Value	Description
Type	4 bits	2	Energy Management MB Type
List Size	4 bits		The number of EMMs in the block. Note that a value of zero signifies a Message Block with 16 EMMs.
S	1 bit	0 – Resume multistate operation 1 – Suspend multistate operation	Suspend Request. This field allows the CMTS to instruct CMs to suspend multi-sub-state DLS operation and remain in DLS-2 sub-state.
EM-ID	15 bits		Energy Management Identifier,
Sleep Time	32 bits		This is the timestamp value reference to the beginning of the preamble for the PLC frame that the CM would wake up and start receiving on the PLC. Note that the 4 byte value in the EMM corresponds to the DOCSIS 3.0 Timestamp.
CRC	3 bytes		CRC-24-D CRC field is computed over the entire message block except the CRC field itself, and included in the defined format to allow validation of the integrity Message Block Type and Message Body Size.

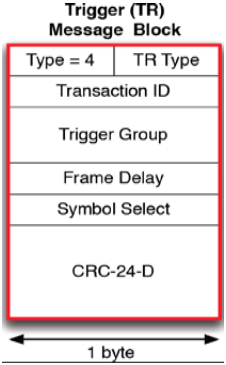
5.3.3 Message Channel Message Block



Field	Size	Value	Description
Type	4 bits	3	Message Channel MB
R	3 bits	0	Reserved
S	1 bit	0 1	Packet Start Pointer field is not present Packet Start Pointer field is present
Packet Start Pointer	2 bytes		Byte offset to the start of the first part of a new message. A value of 0x00 indicates the next byte is the beginning of a new packet.
Message Channel	Variable		Contains MMM segment or a 0xFF fill pattern

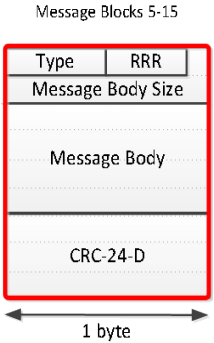
Note, that the minimum length of the MC MB is one byte when the MC MB includes no Message Channel field.

5.3.4 Trigger Message Block



Field	Size	Value	Description
Message Block Type	4 bits	4	Trigger MB
Trigger Type	4 bits	1	Identifies type of action to perform
Transaction ID	1 byte		Increments on each TR MB sent
Trigger Group	2 bytes		Group for unicast, multicast and broadcast triggers
Frame Delay	1 byte	2 to 31	How many frames to wait before performing action
Symbol Select	1 byte	0 to 127	Which symbol in PLC frame to perform action upon
CRC	3 bytes		CRC-24-D CRC field is computed over the entire message block except the CRC field itself, and included in the defined format to allow validation of the integrity Message Block Type and Message Body Size.

5.3.5 Future Use Message Blocks



Field	Size	Value	Description
Message Block Type	4 bits	5-15	
RRR	3 bits	N/A	Reserved field. The use of this field is specific to message block type and subject to future definition.
Message Body Size	9 bits		The length of the Message Body field specified in octets. The total length of a Message Block type 5-15 is Message Body Size plus 5 octets.
Message Body	0-511		The use of this field is specific to message block type and subject to future definition.
CRC	3 bytes		CRC-24-D. CRC field is computed over the entire message block except the CRC field itself, and included in the defined format to allow validation of the integrity Message Block Type and Message Body Size.

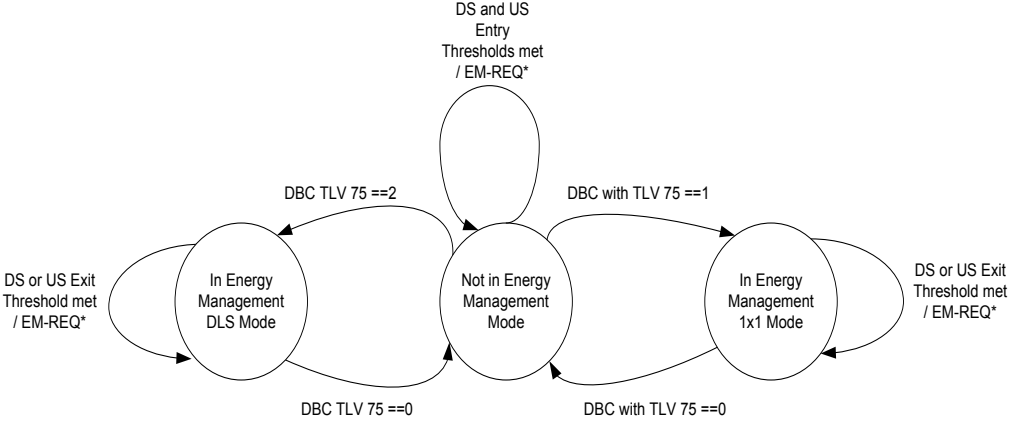
MAC Parameters and TLVs

6

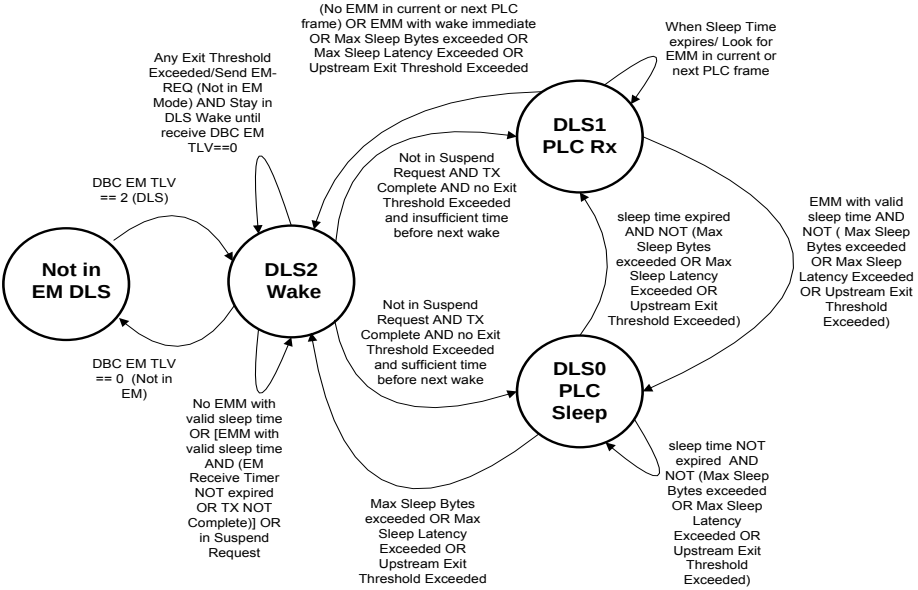
6 MAC Parameters and TLVs

6.1 Energy Management

6.1.1 EM SDL



6.1.2 DLS Substate for CM



6.2 CM-STATUS Event Codes

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
0	Reserved		
1	Secondary Channel MDD timeout	Lost MDD Timer expiry of a secondary channel advertised as active in the primary channel MDD.	Receipt of MDD; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ.
2	QAM/FEC lock failure	Loss of QAM or FEC lock on one of the downstream channels advertised as active in the primary channel MDD.	Re-establishment of QAM/FEC lock; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ.
3	Sequence out-of-range	Receipt of a packet with an out-of-range sequence number for a particular DSID.	Receipt of a packet with an in-range sequence number; OR change in the Sequence Change Count.

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
4	Secondary Channel MDD Recovery	Receipt of an MDD on a Secondary channel advertised as active in the most recent primary channel MDD.	MDD timeout event on the channel; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ.
5	QAM/FEC Lock Recovery	Successful QAM/FEC lock on a channel advertised as active in the most recent primary channel MDD.	Loss of QAM/FEC lock; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ.
6	T4 timeout	Expiration of the T4 timeout on the CM.	Receipt of maintenance opportunity (initial maintenance or station maintenance); OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Transmit Channel Set via DBC-REQ.

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
7	T3 retries exceeded	The number of T3 retries as specified in Annex B is exceeded.	Receipt of RNG-RSP message ; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Transmit Channel Set via DBC-REQ.
8	Successful ranging after T3 retries exceeded	Successful ranging on a channel for which T3 retries exceeded event had been reported.	The number of T3 retries as specified in Annex B is exceeded; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Transmit Channel Set via DBC-REQ.
9	CM operating on battery backup	CM detects loss of A/C Power for more than 5 seconds and the CM is operating on battery backup.	CM detects the presence of A/C Power and has returned from backup battery to operating on A/C power.

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
10	CM returned to A/C power	CM detects the presence of A/C Power for more than 5 seconds and has returned from backup battery to operating on A/C power.	CM detects loss of A/C Power and the CM is operating on battery backup.
11	MAC Removal Event	The CM has determined that one or more MAC addresses need to be removed due to a specific CMCI port transition. (ifOperStatus transitions from 'UP' to 'DOWN')	The CM has determined that specific CMCI port is operational (ifOperStatus = 'UP'). Note: Because this event is set to "off" by the link state transitioning to UP, it is possible that no CM-STATUS message will be sent due to the "Maximum Event Holdoff Timer". In order to ensure that a CM-STATUS message is sent, the "Maximum Event Holdoff Timer" for this event should be set to 20 msec.
12-15	Reserved for future use		

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
16	DS OFDM profile failure	Loss of FEC lock on one of the assigned downstream OFDM profiles of a channel	Re-establishment of FEC lock for that OFDM profile; OR removal of the channel from the active channel list in the primary channel MDD; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ
17	Primary Downstream Change	Loss of Primary Downstream followed by successful acquisition of a backup primary downstream channel as the new primary downstream channel	N/A
18	DPD Mismatch	The CM detect the mismatch between the LSB of DPD change count and NCP odd/even bit	Reacquire the DPD or NCP and re-establish the sync; OR Removal of the channel from the CM’s Receive Channel Set via DBC-REQ

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
19	Invalid DPD	The CM receives a DPD and detect that some parameter is invalid or not able to support by the CM.	New Valid DPD received for the same profile OR Removal of the channel from the CM's Receive Channel Set via DBC-REQ.
20	NCP profile failure	Loss of FEC lock on NCP	Re-establishment of FEC lock for NCP; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ
21	Loss of FEC Lock on PLC	Loss of FEC Lock on PLC	Re-establish the OFDM FEC lock on PLC for this channel OR removal of the channel from the CM's Receive Channel Set via DBC-REQ
22	NCP profile recovery	FEC recovery on NCP profile	Loss of FEC lock for NCP channel; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
23	FEC recovery on PLC channel	FEC recovery on PLC channel	Loss of FEC lock on PLC channel ; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ
24	FEC recovery on OFDM profile	FEC recovery on OFDM profile	Loss of FEC lock on this OFDM profile; OR removal of the channel from the CM's Receive Channel Set via DBC-REQ
25	OFDMA Profile failure	CM not able to support certain profile because the profile is out of modem capability when it get a UCD containing profile definition changes.	OFDMA profile removed from the assigned profile list for the CM; OR removal of the channel from the CM's Transmit Channel Set via DBC-REQ.
26	MAP Storage overflow indicator	The MAPs received by the CM contain more information elements than the CM can support.	N/A

Event Type Code	Event Condition	Status Report Events	
		Trigger Event to "on"	Reset Event to "off"
27	MAP Storage almost full indicator	The CM's internal MAP storage capacity is filling up.	N/A
28-255	Reserved for future use		

6.3 Well-known Addresses

Well-known IPv6 MAC Addresses	Well-known IPv6 Addresses	Description
33-33-00-01-00-02	FF02::1:2	All DHCP relay agents and servers
33-33-00-01-00-03	FF05::1:3	All DHCP servers
33-33-FF-xx-xx-xx	FF02:0:0:0:0:1:FFxx:xxxx	Link-local scope solicited node multicast address
33-33-00-00-00-02	FF02::2	Link-local scope all routers multicast address
33-33-00-00-00-01	FF02::1	Link-local scope all nodes multicast address

6.4 Parameters and Constants

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	Sync Interval	Nominal time between transmission of SYNC messages			200 msec
CMTS	UCD Interval	Time between transmission of UCD messages			2 sec
CMTS	Max MAP Pending	The number of minislots that a CMTS is allowed to map into the future			4096 minislot times for TDMA and S-CDMA upstream channels; the equivalent of 20 milliseconds for OFDMA upstream channels
CMTS	Ranging Interval	Time between transmission of broadcast Initial Maintenance opportunities			2 sec

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM	Lost Sync Interval	Time since last received SYNC message before synchronization is considered lost			600 msec
CM	Contention Ranging Retries	Number of Retries on Ranging Requests sent in broadcast maintenance opportunities	16		
CM, CMTS	Invited Ranging Retries	Number of Retries on Ranging Requests sent in unicast maintenance opportunities	16		
CM	Request Retries	Number of retries on bandwidth allocation requests	16		
CM CMTS	Registration Request/ Response Retries	Number of retries on Registration Requests/Responses	3		
CM	Data Retries	Number of retries on immediate data transmission	16		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	CM MAP processing time	Time provided between arrival of the last bit of a MAP at a CM and effectiveness of that MAP and "Relative Processing Delays"	(600 + M/5.12) µsec for operation in MTC mode for S-CDMA and TDMA channels. (600 + [(symbol duration + cyclic prefix duration) *(K+1)]) µsec for OFDMA channels. K is the number of symbols per OFDMA frame. (200 + M/5.12) µsec for operation not in MTC mode		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	CM Ranging Response processing time	Minimum time allowed for a CM following receipt of a ranging response before it is expected to transmit a ranging request in a unicast opportunity	1 msec		
CMTS	CM Configuration	The maximum time allowed for a CM, following receipt of a configuration file, to send a Registration Request to a CMTS.	30 sec		
CM	T1	Wait for UCD timeout			5 * UCD interval maximum value
CM	T2	Wait for broadcast ranging timeout			5 * ranging interval
CM	T3	Wait for ranging response	200 msec		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM	T4	Wait for unicast ranging opportunity. If the pending-till-complete field was used earlier by this modem, then the value of that field must be added to this interval. The T4 multiplier may be set in the RNG-RSP message.	30 sec (T4 Multiplier of 1)	30 sec	300 sec (T4 Multiplier of 10)
CMTS	T5	Wait for Upstream Channel Change response			2 sec
CM CMTS	T6	Wait for REG-RSP, REG-RSP-MP, or REG-ACK		3 sec	
CM CMTS	Minislot size for 1.x channels.	Size of minislot for upstream transmission. For channels that support DOCSIS 1.x CMs.	32 modulation intervals		
CM CMTS	Minislot size for DOCSIS 2.0 Only Channels.	Size of minislot for upstream transmission. For channels that do not support DOCSIS 1.x CMs.	16 symbols		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM CMTS	Timebase Tick	System timing unit	6.25 µsec		
CM CMTS	DSx Request Retries	Number of Timeout Retries on DSA/DSC/DSD Requests	3		
CM CMTS	DSx Response Retries	Number of Timeout Retries on DSA/DSC/DSD Responses	3		
CM CMTS	T7	Wait for DSA/DSC/DSD Response timeout			1 sec
CM CMTS	T8	Wait for DSA/DSC Acknowledge timeout			300 msec
CM	TFTP Backoff Start	Initial value for TFTP backoff	1sec		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM	TFTP Backoff End	Last value for TFTP backoff	16 sec		
CM	TFTP Request Retries	Number of retries on TFTP request	4		
CM	TFTP Download Retries	Number of retries on entire TFTP downloads	3		
CM	TFTP Wait	The wait between TFTP retry sequences	3 min		
CMTS	T9	Registration Timeout, the time allowed between the CMTS sending a RNG-RSP (success) to a CM, and receiving a REG-REQ or REG-REQ-MP from that same CM.	15 min	15 min	
CM CMTS	T10	Wait for Transaction End timeout	3 sec		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	T11	Wait for a DCC Response on the old channel			300 ms
CM	T12	Wait for a DCC Acknowledge			300 ms
CMTS	T13	Maximum holding time for QoS resources for DCC on the old channel			1 sec
CM	T14	Minimum time after a DSx reject-temp-DCC and the next retry of DSx command	2 sec		
CMTS	T15	Maximum holding time for QoS resources for DCC on the new channel	2 sec		35 sec
CM	T16	Maximum length of time CM remains in test mode after receiving TST-REQ message.			30 min.
CM	T17	Maximum Time that CM MUST inhibit transmissions on a channel in response to its Ranging Class ID matching a bit value in the Ranging Hold-Off Priority Field.	300 sec		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	DCC-REQ Retries	Number of retries on Dynamic Channel Change Request	3		
CM	DCC-RSP Retries	Number of retries on Dynamic Channel Change Response	3		
CM	Lost DCI-REQ interval	Time from sending DCI-REQ and not receiving a DCI-RSP			2 sec
CM	DCI-REQ retry	Number of retries of DCI-REQ before rebooting			16
CM	DCI Backoff start	Initial value for DCI backoff	1 sec		
CM	DCI Backoff end	Last value for DCI backoff	16 sec		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	CM UCD processing time	Time between the transmission of the last bit of a UCD with a new Change Count and the transmission time of the first bit of the first MAP using the new UCD.	1.5 ms * The number of TDMA and S-CDMA upstream channels modified simultaneously + 2.0 ms * The number of OFDMA channels modified simultaneously.		
CMTS	DBC-REQ Retries	Maximum number of times the CMTS will retransmit a DBC-REQ while awaiting the DBC-RSP from the CM	6		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM	DBC-REQ Timeout	The amount of time that the CM waits to receive all fragments of the DBC-REQ message.	1 second		
CM	DBC-RSP Retries	Maximum number of times the CM will retransmit a DBC-RSP while awaiting the DBC-ACK from the CMTS	6		
CM	DBC-ACK timeout	The amount of time that the CM waits for DBC-ACK after sending DBC-RSP	300 ms		
CM	DBC DS Acquisition timeout	The amount of time that the CM is to continue trying to acquire downstream channels added to the RCS in a DBC-REQ message.	1 second		
CMTS	Sequence Hold timeout	The time that the CMTS waits before changing the Sequence Change Count for a resequencing DSID	1 second		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM	DSID filter count	The total number of DSID filters	32		
CM	DSID resequencing context count	The number of DSIDs for re-sequencing	16		
CMTS	CMTS Skew Limit	Maximum interval between CMTS start of transmission of out-of-order sequenced packets on different Downstream Channels		3 msecs	5 msecs
CM	DSID Resequencing Wait Time	Per-DSID value for the minimum interval a CM delays forwarding of a higher-numbered sequenced packet while awaiting the arrival of a lower-numbered sequenced packet.		8 msec	13 msec
CMTS	MDD Interval	Time between MDD messages on a given channel			2 sec

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CM	Lost MDD timeout	Time to wait for a MDD before declaring MDD loss	3 * Maximum MDD Interval		
CM	Initializing channel timeout CM	This field defines the maximum total time that the CM can spend performing initial ranging on the upstream channels described in the TCC of a REG-RSP, REG-RSP-MP, or a DBC-REQ.		60sec	
CMTS	Initializing channel timeout CMTS	This field defines the maximum total time that the CMTS waits for a REG-ACK after sending a REG-RSP-MP or waiting for a DBC-RSP after sending a DBC-REQ before retransmitting the REG-RSP-MP or DBC-REQ.		Initializing Channel Timeout CM + 3 Seconds	
CM	T18	This timer is started when the CM receives the first Registration Response and controls the amount of time the CM waits to possibly receive a duplicate REG-RSP-MP if the REG-ACK is lost.		Initializing Channel Timeout CM + 6 Seconds	

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	Profile Advance Time	The time between the release of a next-active profile and the toggling of the odd/even bit in the NCP message block.	500 ms		
CMTS	OCD/DPD PLC Interval	DPD and OCD interval on the PLC		200 ms	250 ms
CMTS	OCD/DPD Profile A Interval	DPD and OCD interval on OFDM Profile A		500 ms	600 ms
CM	OCD/DPD PLC Timeout	DPD and OCD interval on the PLC that CM uses for timeout purposes	5*CMTS OCD/DPD PLC Interval maximum value		
CM	OCD/DPD Profile A Timeout	DPD and OCD interval on OFDM Profile A that CM uses for timeout purposes	5*CMTS OCD/DPD Profile A Interval maximum value		

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS	OPT-RSP Timer	The maximum time between sending an OPT-REQ and receiving an OPT-RSP with the same transaction ID for the same DS channel and profile ID;			800 ms
CMTS	OPT Test Timer	Maximum time between sending an OPT-REQ and receiving the OPT-RSP with a Status of either Complete or Incomplete			3 seconds
CM	OPT-ACK Timer	Maximum time between sending OPT-RSP with a Status of Complete or Incomplete and receiving an OPT-ACK;			800 ms
CM	OPT retry count	Maximum attempts to retransmit a message			3
CM	T-OFSM	OFDMA wait for first station maintenance opportunity timer			10 seconds

System	Name	Parameter Description	Minimum Value	Default Value	Maximum Value
CMTS CM	DTP Calibration Interval	The time interval between successive DTP calibration message sequences per CMTS-CM pair.	10 seconds		Depends upon the DTP Algorithm.
CMTS CM	DTP Retry Count	Maximum attempts to retransmit a message			3

6.5 Top Level TLV Encodings

Type	Description	Length	Cfg File	REG	DSx	DBC	DTP
0	Pad	-	x				
1	Downstream Frequency	4	x	x			
2	Upstream Channel ID	1	x	x			
3	Network Access Control Object	1	x	x			
4	DOCSIS 1.0 Class of Service	n	x	x			
5	Modem Capabilities	n		x			
6	CM Message Integrity Check (MIC)	16	x	x			
7	CMTS Message Integrity Check (MIC)	16	x	x			
8	Vendor ID Encoding	3		x			
9	SW Upgrade Filename	n	x				
10	SNMP Write Access Control	n	x				
11	SNMP MIB Object	n	x				

Type	Description	Length	Cfg File	REG	DSx	DBC	DTP
12	Modem IP Address	4		x			
13	Service(s) Not Available Response	3		x			
14	CPE Ethernet MAC Address	6	x				
15	Telephone Settings Option (deprecated)						
17	Baseline Privacy	n	x	x			
18	Max Number of CPEs	1	x	x			
19	TFTP Server Timestamp	4	x	x			
20	TFTP Server Provisioned Modem IPv4 Address	4	x	x			
21	SW Upgrade IPv4 TFTP Server	4	x				
22	Upstream Packet Classification	n	x	x	x		
23	Downstream Packet Classification	n	x	x	x		
24	Upstream Service Flow	n	x	x	x		
25	Downstream Service Flow	n	x	x	x	x	
26	Payload Header Suppression	n	x	x	x	x	

Type	Description	Length	Cfg File	REG	DSx	DBC	DTP
27	HMAC-Digest	20			x	x	
28	Maximum Number of Classifiers	2	x	x			
29	Privacy Enable	1	x	x			
30	Authorization Block	n			x		
31	Key Sequence Number	1			x	x	
32	Manufacturer Code Verification Certificate	n	x				
33	Co-Signer Code Verification Certificate	n	x				
34	SNMPv3 Kickstart Value	n	x				
35	Subscriber Mgmt Control	3	x	x			
36	Subscriber Mgmt CPE IPv4 List	n	x	x			
37	Subscriber Mgmt Filter Groups	8	x	x			
38	SNMPv3 Notification Receiver	n	x				
39	Enable 2.0 Mode	1	x	x			
40	Enable Test Modes	1	x	x			

Type	Description	Length	Cfg File	REG	DSx	DBC	DTP
41	Downstream Channel List	n	x	x			
42	Static Multicast MAC Address	6	x				
43	DOCSIS Extension Field	n	x	x			
44	Vendor Specific Capabilities	n		x			
45	Downstream Unencrypted Traffic (DUT) Filtering	n	x	x			
46	Transmit Channel Configuration (TCC)	n		x		x	
47	Service Flow SID Cluster Assignment	n		x	x	x	
48	Receive Channel Profile	n		x			
49	Receive Channel Configuration	n		x		x	
50	DSID Encodings	n		x		x	
51	Security Association Encoding	n		x		x	
52	Initializing Channel Timeout	2		x		x	
53	SNMPv1v2c Coexistence	n	x				
54	SNMPv3 Access View	n	x				

Type	Description	Length	Cfg File	REG	DSx	DBC	DTP
55	SNMP CPE Access Control	1	x				
56	Channel Assignment	n	x	x			
57	CM Initialization Reason	1		x			
58	SW Upgrade IPv6 TFTP Server	16	x				
59	TFTP Server Provisioned Modem IPv6 Address	16	x	x			
60	Upstream Drop Packet Classification	n	x	x	x		
61	Subscriber Mgmt CPE IPv6 Prefix List	n	x	x			
62	Upstream Drop Classifier Group ID	n	x	x			
63	Subscriber Mgmt Control Max CPE IPv6 Addresses	n	x	x			
64	CMTS Static Multicast Session Encoding	n	x				
65	L2VPN MAC Aging Encoding	n	x				
66	Management Event Control Encoding	n	x				
67	Subscriber Mgmt CPE IPv6 List	n	x	x			
68	Default Upstream Target Buffer Configuration	2	x				

Type	Description	Length	Cfg File	REG	DSx	DBC	DTP
69	MAC Address Learning Control	1	x				
70	Upstream Aggregate Service Flow	n	x				
71	Downstream Aggregate Service Flow	n	x				
72	Metro Ethernet Service Profile	n	x				
73	Network Timing Profile	n	x				
74	Energy Management Parameter Encoding	n	x	x			
75	Energy Management Mode Indicator	1				x	
76	CM Upstream AQM disable	1	x				
77	DOCSIS Time Protocol Encodings	n					x
78	Energy Management Identifier List for CM	n		x		x	
79	UNI Control Encoding	n	x				
80	Energy Management – DOCSIS Light Sleep Encodings	n				x	
201-231	eSAFE Configuration	n	x				
255	End-of-Data	-	x				

Acronyms

7 Abbreviations, Acronyms, and Namespaces

The specifications use the following abbreviations.

µs	Microsecond
ANSI	American National Standards Institute
APM	Alternate Provisioning Mode
AQM	Active Queue Management
AQP	ASF QoS
ARP	Address Resolution Protocol
ASCII	American Standard Code for Information Interchange
ASF	Aggregate Service Flow
ASM	Any Source Multicast
ASN.1	Abstract Syntax Notation 1
A-TDMA	Advanced Time Division Multiple Access
ATM	Asynchronous Transfer Mode
AWGN	Additive White Gaussian Noise
BC	Boundary Clock
BCH	Bose, Ray-Chaudhuri, Hocquenghem [codes]
BER	1) Bit Error Ratio; 2) Bit Error Rate
BGP	Border Gateway Protocol
BPI	Baseline Privacy Interface
BPI+	Baseline Privacy Interface Plus
BPKM	Baseline Privacy Key Management
BPSK	Binary Phase Shift Keying
BW	Bandwidth
CableLabs	Cable Television Laboratories, Inc.
CBR	Constant Bit Rate

CCF	Continuous Concatenation and Fragmentation
CCITT	International Telegraph and Telephone Consultative Committee (see also ITU-T)
CEA	Consumer Electronics Association
ceil	ceiling
CENELEC	European Committee for Electrotechnical Standardization
CER	Codeword Error Ratio
CIN	Converged Interconnect Network
CL	1) Convergence Layer; 2) CableLabs
CM	Cable Modem
CMCI	Cable Modem to Customer Premises Equipment Interface
CMIM	Cable Modem Interface Mask
CM-SG	Cable Modem Service Group
CMTS	Cable Modem Termination System
CNR	Carrier to Noise Ratio
CP	1) Cyclic Prefix; 2) Complementary Pilot
CPE	Customer Premises Equipment
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CS	Cyclic Suffix
CSO	Composite Second Order
CTB	Composite Triple Beat
CVC	Code Verification Certificate
CW	1) Continuous Wave; 2) Codeword
DA	Destination Address
DAD	Duplicate Address Detection
dB	Decibel
DBC	Dynamic Bonding Change

dBc	Decibel Carrier
DBG	Downstream Bonding Group
dBmV	Decibel Millivolt
dBr	Decibel Reference
DC	Downstream Channel
DCC	Dynamic Channel Change
DCI	Device Class Identifier
DCID	Downstream Channel Identifier
DCS	Downstream Channel Set
DEPI	Downstream External-PHY Interface
DER	Distinguished Encoding Rules
DES	Data Encryption Standard
DFT	Discrete Fourier Transform
DHCP	Dynamic Host Configuration Protocol
DHCPv4	IPv4 version of the Dynamic Host Configuration Protocol
DIX	Digital Intel Xerox
DLS	DOCSIS Light Sleep
DMAC	Destination Media Access Control address
DMPI	DOCSIS MAC-PHY Interface
DOCSIS	Data-Over-Cable Service Interface Specifications
DOCSIS 1.x	Data-Over-Cable Service Interface Specifications version 1.0 or 1.1
DOCSIS 2.0	Data-Over-Cable Service Interface Specifications version 2.0
DOCSIS 3.0	Data-Over-Cable Service Interface Specifications version 3.0
DOCSIS 3.1	Data-Over-Cable Service Interface Specifications version 3.1
DPD	Downstream Profile Descriptor
DPM	Dual-stack Provisioning Mode

DPV	DOCSIS Path Verify
DRFI	Downstream Radio Frequency Interface
DRW	Dynamic Range Window
DS	Downstream
DSCP	Differentiated Services Code Point
DS-EH/DS EHDR	Downstream Service Extended Header
DSG	DOCSIS Set-top Gateway
DSID	Downstream Service Identifier
DS-SG	Downstream Service Group
DTI	DOCSIS Time Interface
DTP	DOCSIS Time Protocol
DUID	DHCP Unique Identifier
DUT	Downstream Unencrypted Traffic
DVB	Digital Video Broadcasting [Project]
DVB-C2	"Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital transmission system for cable systems (DVB-C2)"
EAE	Early Authentication and Encryption
eCM	Embedded Cable Modem
eDOCSIS	Embedded Data-Over-Cable Service Interface Specifications
EEE	Energy Efficient Ethernet
EH	Extended Header
EHDR	Extended MAC Header
EM	Energy Management
EM MB	Energy Management Message Block
EMC	Electromagnetic Compatibility
EM-ID	Energy Management Identifier

EMM	Energy Management Message
eMTA	Embedded Multimedia Terminal Adapter
EN	European Standard (*Européen Norme*)
ePS	Embedded Portal Services
EQAM	Edge QAM
ERMI	Edge Resource Manager Interface
eRouter	Embedded Router
eSAFE	Embedded Service/Application Functional Entity
ETSI	European Telecommunications Standards Institute
EUI-64	64-bit Extended Unique Identifier
FC	Frame Control
FCC	Federal Communications Commission
FCRC	Fragment Cyclic Redundancy Check
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FHCS	Fragment Header Checksum
FIPS	Federal Information Processing Standard
FIR	Finite Impulse Response
FN	Fiber Node
FR	Fine Ranging
FT	1) Foot; 2) Feet
FTP	File Transfer Protocol
FTTH	Fiber to the Home
GARP	Generic Attribute Registration Protocol

GB	[Chinese] National Standard (*guobiao*)
GB/T	[Chinese] Recommended National Standard (*guobiao tuijian*)
GCR	Group Classifier Rule
GF	Galois Field
GHz	Gigahertz
GMAC	Group Media Access Control
GQC	Group QoS Configuration
GSF	Group Service Flow
GT	Guard Time
HCS	Header Check Sequence
HFC	Hybrid Fiber-Coaxial
HMAC	Keyed-Hash Message Authentication Code
HQoS	Hierarchical QoS
HRC	Harmonic Related Carriers
Hz	Hertz
I	In-phase
IA_PD	Identity Association for Prefix Delegation
IATC	Interface Aggregate Traffic Class
ICI	Inter-carrier Interference
ICMP	Internet Control Message Protocol
ICMPv4	IPv4 version of the Internet Control Message Protocol
ICMPv6	IPv6 version of the Internet Control Message Protocol
I-CMTS	Integrated Cable Modem Termination System
I-CMTS	Integrated Cable Modem Termination System
ID	Identifier
IDFT	Inverse Discrete Fourier Transform

IE	Information Element
IEC	International Electrotechnical Commission
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IETF	Internet Engineering Task Force
IFFT	Inverse Fast Fourier Transform
IGMP	Internet Group Management Protocol
IGP	Interior Gateway Protocol
IP	Internet Protocol
IPDR	Internet Protocol Detail Record
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IR	Initial Ranging
IRC	Incremental Related Carriers
IRT	Initial Retransmission Time
ISF	Individual Service Flow
ISI	Inter-symbol Interference
ISO	International Standards Organization
ITU	International Telecommunications Union
ITU-T	ITU Telecommunication Standardization Sector
IUC	Interval Usage Code
kb	Kilobit
kbps	Kilobits per second
kHz	Kilohertz
L2	Layer 2

L2PDU	Layer 2 Protocol Data Unit
L2VPN	Layer 2 Virtual Private Network
LAN	Local Area Network
LBG	Load Balancing Group
LDCP	Low Density Parity Check
LFSR	Linear Feedback Shift Register
LLC	Logical Link Control
LLR	Log-Likelihood Ratio
Log	Logarithm
LSB	Least Significant Bit
LTE	Long Term Evolution
M/N	Relationship of integer numbers M,N that represents the ratio of the downstream symbol clock rate to the DOCSIS master clock rate
MAC	Media Access Control
MB	Message Block
Mbps	Megabits per second
MC	Message Channel
MC MB	Message Channel Message Block
M-CMTS	Modular Cable Modem Termination System
M-CVC	Manufacturer's Code Verification Certificate
MD	Media Access Control Domain
MD-CM-SG	Media Access Control Domain Cable Modem Service Group
MDD	MAC Domain Descriptor
MD-DS-SG	Media Access Control Domain Downstream Service Group
MD-DS-SG-ID	Media Access Control Domain Downstream Service Group Identifier
MDF	Multicast DSID Forwarding
MD-US-SG	Media Access Control Domain Upstream Service Group

MD-US-SG-ID	Media Access Control Domain Upstream Service Group Identifier
MER	Modulation Error Ratio
MHz	Megahertz
MIB	Management Information Base
MIC	Message Integrity Check
MLD	Multicast Listener Discovery
MMM	MAC Management Message
MPEG	Moving Picture Experts Group
MRC	Maximum Retransmission Count
MRD	Maximum Retransmission Duration
MRT	Maximum Retransmission Time
ms	Millisecond
MSAP	Media Access Control Service Access Point
MSB	Most Significant Bit
MSC	Maximum Scheduled Codes
MSM	Maximum Scheduled Minislots
MSO	Multiple Systems Operator
Msym/s	Megasymbols per second
MTA	Multimedia Terminal Adapter
MTC	Multiple Transmit Channel [mode]
MTU	Maximum Transmit Unit
MULPI	MAC and Upper Layer Protocols Interface
NACO	Network Access Control Object
NCP	Next Codeword Pointer
ND	Neighbor Discovery
NDIS	Network Driver Interface Specification

NIC	Network Interface Card
NMS	Network Management System
ns	Nanosecond
NSI	Network-Side Interface
NTSC	National Television System Committee
OC	Ordinary Clock
OCD	OFDM Channel Descriptor
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplexing with Multiple Access
OID	Object Identifier
ONU	Optical Network Unit
OOB	Out-of-Band
OSI	Open Systems Interconnection
OSSI	Operations System Support Interface
OUDP	OFDMA Upstream Data Profile
OUI	Organizationally Unique Identifier
P	Pilot
PAPR	Peak-to-Average Power Ratio
PDU	Protocol Data Unit
PER	Packet Error Rate
PHS	Payload Header Suppression
PHY	Physical Layer
PID	Packet Identifier
PIM	Protocol Independent Multicast
pk-pk	Peak-to-Peak
Pkt	Packet

PLC	PHY Link Channel
PMD	Physical Media Dependent sublayer
PN	Pseudorandom Number
PNM	Proactive Network Maintenance
PoE	Power over Ethernet
ppm	Parts per Million
PRBS	Pseudo-Random Binary Sequence
Pre-eq	Pre-equalization
ps	picosecond
PSD	Power Spectral Density
Ptr	Pointer
PUSI	Payload Unit Start Indicator
Q	Quadrature
QAM	Quadrature Amplitude Modulation
QC-LDPC	Quasi-Cyclic Low-Density Parity Check
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RA	Router Advertisement
RC	Raised Cosine
RCC	Receive Channel Configuration
RCID	Receive Channel Identifier
RCP	Receive Channel Profile
RCP-ID	Receive Channel Profile Identifier
RCS	Receive Channel Set
REQ	Request
RF	Radio Frequency

RFC	Request For Comments
RFI	Radio Frequency Interface
RFoG	Radio Frequency Over Glass
RM	Receive Module
RMS	Root Mean Square
RP	Roll-off Period
RS	Router Solicitation
R-S	Reed-Solomon
RSA	Rivest, Shamir, Adleman
RSVP	Resource Reservation Protocol
RTP	Real-time Transport Protocol
RX	1) Receive; 2) Receiver
s	second
SA	Source Address
SA	Security Association
SAC	Selectable Active Codes
SAC	Standardization Administration of the People's Republic of China
SAID	Security Association Identifier
SAV	Source Address Verification
SC	SID_Cluster
S-CDMA	Synchronous Code Division Multiple Access
SCN	Signal-to-Composite Noise [ratio]
SC-QAM	Single-Carrier QAM
SCTE	Society of Cable Telecommunications Engineers
SDL	Specification and Description Language
SEC	Security

SF	Service Flow
SFID	Service Flow Identifier
SG	Service Group
SHA	Secure Hash Algorithm
SID	Service Identifier
SLAAC	Stateless Address Autoconfiguration
SM	Station Maintenance
SNAP	Subnetwork Access Protocol
SNMP	Simple Network Management Protocol
SNR	Signal-to-Noise Ratio
SPI	Serial Peripheral Interface
SSM	Source Specific Multicast
STB	Set-top Box
TCC	Transmit Channel Configuration
TCM	Trellis coded modulation
TCP	Transmission Control Protocol
TCS	Transmit Channel Set
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TEI	TDM Emulation Interface
TEK	Traffic Encryption Key
TFTP	Trivial File Transfer Protocol
TLV	Type/Length/Value
ToD	Time of Day
TOS	Type of Service
TR MB	Trigger Message Block

TRO	True Ranging Offset
TS	Time Stamp
TS MB	Timestamp Message Block
TV	Television
TWTT	Two-Way Time Transfer
TX	1) Transmit; 2) Transmitter
UBG	Upstream Bonding Group
UCD	Upstream Channel Descriptor
UCID	Upstream Channel Identifier
UDC	Upstream Drop Classifier
UDP	User Datagram Protocol
UGHB	Under-Grant Hold Bandwidth
UGHU	Under-Grant Hold Number of Users
UGS	Unsolicited Grant Service
UID	Unique Identifier
UNI	Unidirectional
URL	Uniform Resource Locator
US	Upstream
US-SG	Upstream Service Group
UTC	Coordinated Universal Time
VLAN	Virtual Local Area Network
VoIP	Voice over IP
XOR	Exclusive Or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