SCTE · ISBE

STANDARDS

Energy Management Subcommittee

SCTE STANDARD

SCTE 232 2019

Key Performance Metrics: Energy Efficiency & Functional Density of CMTS, CCAP, and Time Server Equipment

NOTICE

The Society of Cable Telecommunications Engineers (SCTE) / International Society of Broadband Experts (ISBE) Standards and Operational Practices (hereafter called "documents") are intended to serve the public interest by providing specifications, test methods and procedures that promote uniformity of product, interchangeability, best practices and ultimately the long-term reliability of broadband communications facilities. These documents shall not in any way preclude any member or non-member of SCTE•ISBE from manufacturing or selling products not conforming to such documents, nor shall the existence of such standards preclude their voluntary use by those other than SCTE•ISBE members.

SCTE•ISBE assumes no obligations or liability whatsoever to any party who may adopt the documents. Such adopting party assumes all risks associated with adoption of these documents, and accepts full responsibility for any damage and/or claims arising from the adoption of such documents.

Attention is called to the possibility that implementation of this document may require the use of subject matter covered by patent rights. By publication of this document, no position is taken with respect to the existence or validity of any patent rights in connection therewith. SCTE•ISBE shall not be responsible for identifying patents for which a license may be required or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Patent holders who believe that they hold patents which are essential to the implementation of this document have been requested to provide information about those patents and any related licensing terms and conditions. Any such declarations made before or after publication of this document are available on the SCTE•ISBE web site at http://www.scte.org.

All Rights Reserved

© Society of Cable Telecommunications Engineers, Inc. 2019
140 Philips Road
Exton, PA 19341

Table of Contents

Title **Page Number**

List of Figures

1. Introduction

1.1. Executive Summary

This document is the second of multiple parts in a series that provides the cable operator with a standard reference to determine how well a piece of rack or shelf equipment performs in terms of minimizing the power required to do its particular job. In addition, this standard provides the means to quantify the amount of useful work the equipment provides per physical space. This part of the series focuses on the CMTS, CCAP, and other related cable operator critical facility equipment.

1.2. Scope

Cable operator networks are large expansive networks that involve hundreds if not thousands of miles of coaxial or fiber cable powered by power supplies in the outside plant and connecting customers to critical infrastructure facilities such as hubs, headends, data centers, regional, and national distribution datacenters. In these facilities is a vast array of equipment responsible for the production and support of the cable operator's products and services such as voice, video, data, home automation and security, and Wi-Fi. The importance of powering all of these devices in the critical facilities is ever increasing as the customer expectation is for 100% availability due to the critical nature of the services being provided to business and residential customers. This document defines how to use a standard methodology to measure the density of hardware to meet the needs of optimizing critical space, as well as measuring energy consumption for the various network element classes. This part of the series focuses on the CMTS, CCAP, and other related cable operator critical facility equipment.

1.2.1. Applicability to Critical Facilities

The energy efficiency and functional density metrics in this document apply to critical facilities used by cable operators. Critical facilities are defined in section 5.2.

1.2.2. Hardware Service Feature Density Metrics

This standard defines the method to calibrate product density, in terms of service features per amount of space utilized.

1.2.3. Energy Consumption Metrics

This standard defines the method to calibrate energy consumption based on service features such as Watts per Downstream Channel, Watts per Service Group, or similar for cable headend, hub, and cable subscriber access equipment.

1.2.4. Applicable Equipment

The energy efficiency and functional density metrics in this standard apply to all indoor equipment used in critical facilities that functions as one or more of the following:

- "Legacy" (i.e. pre-CCAP) CMTS broadband routing equipment - in particular, the Integrated Cable Modem Termination System (I-CMTS)
- Converged Cable Access Platform (CCAP) – including Integrated CCAP (I-CCAP) and Distributed CCAP Architecture (DCA) equipment
- PTP and NTP Time Servers

1.2.5. Non-Applicable Equipment

The energy efficiency and functional density metrics in this standard do NOT apply to the following equipment classes.

- Customer Premises Equipment (CPE)
- Outdoor Plant and associated powering equipment except for DCA modules that will be included in the energy efficiency metrics
- Facilities equipment covered by SCTE 184, such as
  - Generators and line-power back-up systems
  - Building HVAC control and monitoring equipment
  - Logistical and physical support such as lighting, fire alarming, and security systems, etc.

1.3. Benefits

This standard defines energy and functional density specific performance metrics based on service features that are inherent to the type of equipment. Standard metrics such as watts/QAM Channel and watts/Service Group for cable access equipment are identified. This standard will contribute to improve the overall energy footprint by enabling engineering driven decisions that reduce energy consumption at the source of power consumption.

1.4. Intended Audience

Cable operator headend and hub engineers, procurement teams, and operations staff.

1.5. Areas for Further Investigation or to be Added in Future Versions

Given the current CableLabs project: Flexible MAC Architecture (FMA) System Specification, CM-SP-FMA-SYS-I01, there could be minor revision to this publication. Addressing use of name plate data.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- [ANSI/SCTE 210 2015] *Performance Metrics for Energy Efficiency & Functional Density of Cable Data Generation, Storage, Routing, and Transport Equipment*, http://www.scte.org/SCTEDocs/Standards/SCTE%20210%202015.pdf

- [SCTE_General_Test_Procedures] *ANSI/SCTE 231 2019, General Test Procedures for Evaluation of Energy Consumption Metrics and in Support of Functional Density Metrics*

2.2. Standards from Other Organizations

- [ATIS-0600015.2018] *Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting – General Requirements*, May 2018.

- [ATIS-0600015.03.2009] *Energy Efficiency for Telecommunications Equipment: Methodology for Measurement and Reporting for Router and Ethernet Switch Products*, July 2009.
- [DOCSIS DRFI] *Downstream Radio Frequency Interface Specification*, CM-SP-DRFI-I14-131120, November 20, 2013, Cable Television Laboratories, Inc., https://www.cablelabs.com/specification/downstream-rf-interface-specification/
- [DOCSIS PHYv3.1] *DOCSIS 3.1, Physical Layer Specification*, CM-SP-PHYv3.1-I16-190121, December 10, 2015, Cable Television Laboratories, Inc., https://www.cablelabs.com/specification/physical-layer-specification/
- [DOCSIS PHYv4.0] Data-Over-Cable Service Interface Specifications DOCSIS® 4.0, CM-SP-PHYv4.0-I01-190815 August 15, 2019 https://www.cablelabs.com/specification/docsis 4-0 physical-layer-specification/
- [DOCSIS PHYv3.0] *DOCSIS 3.0, Physical Layer Specification*, CM-SP-PHYv3.0-I13-170111, December 7, 2017, Cable Television Laboratories, Inc., https://www.cablelabs.com/specification/docsis-3-0-physical-layer-interface-specification/
- [R-PHY] Data-Over-Cable Service Interface Specifications DCA - MHAv2 Remote PHY Specification, CM-SP-R-PHY-I10-180509, May 9, 2018, Cable Television Laboratories, Inc. https://www.cablelabs.com/specification/CM-SP-R-PHY-I10-180509.pdf
- [EN 300 429] *ETSI EN 300 429 V1.2.1: Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems*, April 1998.
- [ITU-T J.83-B] *Annex B to ITU-T Rec. J.83 (12/2007), Digital multi-program systems for television sound and data services for cable distribution*.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- [ANSI/SCTE 226 2016] *Cable Facility Classification Definitions and Criteria,* https://www.scte.org/SCTEDocs/Standards/ANSI_SCTE%20226%202015.pdf.

3.2. Standards from Other Organizations

- [DOCSIS MULPIv3.0] *Media Access Control and Upper Layer Protocols Interface Specification,* CM-SPMULPIv3.0-I26-150305, March 5, 2015, Cable Television Laboratories, Inc., *http://www.cablelabs.com/specification/docsis-3-0-mac-and-upper-layer-protocols-interface-specification/*
- [DOCSIS 3.1 MAC] DOCSIS 3.1 MAC and Upper Layer Protocols Interface Specification CM-SP-MULPIv3.1-I18-190422, April 22 2019, Cable Television Laboratories, Inc., https://specification-search.cablelabs.com/CM-SP-MULPIv3.1
- [DOCSIS DEPI] *Downstream External PHY Interface Specification,* CM-SP-DEPI-I08-100611, June 11, 2010, *http://www.cablelabs.com/specification/downstream-external-phy-interface-specification/*

- [DCA-Remote MACPHY] *Remote MAC-PHY Technical Report,* CM-TR-R-MACPHY-V01-150730, July 30, 2015, Cable Television Laboratories, Inc., *https://specification-search.cablelabs.com/remote-mac-phy-technical-report*
- [DOCSIS 4.0 MAC] *DOCSIS 4.0 MAC and Upper Layer Protocols Interface Specification,* CM-SP-MULPIv4.0-I01-190815, August 15, 2019, Cable Television Laboratories, Inc., *https://cablelabs.com/CM-SP-MULPIv4.0*

3.3. Published Materials

- [DOCSIS CCAP] Converged Cable Access Platform Architecture Technical Report, CM-TR-CCAP-V03-120511, May 11, 2012, *http://www.cablelabs.com/specification/ccap-architecture-technical-report/?v=3*
- [DOCSIS MHA] *Data-Over-Cable Service Interface Specifications Modular Headend Architecture - EQAM Architectural Overview Technical Report,* December 9, 2008, *http://www.cablelabs.com/wp-content/uploads/specdocs/CM-TR-MHA-V02-081209.pdf*
- [European Broadband CoC] *European Commission Joint Research Centre: Code of Conduct on Energy Consumption of Broadband Equipment,* Version 7.0, 2019, http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/files/documents/ICT_CoC/cocv5-broadband_final.pdf

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

Abbreviation	Description
A-TDMA	Advanced Time Division Multiple Access

 © SCTE•ISBE

CCAP	Converged Cable Access Platform
CMTS	Cable Modem Termination System
DAA	Distributed Access Architecture
DCA	Distributed CCAP Architecture
DEPI	Downstream External PHY Interface
DOCSIS	Data Over Cable Service Interface Specifications
DPoE	DOCSIS Provisioning of EPON
DS	downstream
DTI	DOCSIS timing interface
EPON	Ethernet Passive Optical Network
EQAM (edge-QAM)	edge quadrature amplitude modulator
FDX	DOCSIS 3.1 Full Duplex
FEC	forward error correction
GBPS	Gigabits Per Second
GPS	Global Positioning System
HE	headend
I-CCAP	Integrated CCAP
I-CMTS	Integrated Cable Modem Termination System
IP	Internet Protocol
KPM	key performance metric
NC	narrowcast
NSI	Network Side Interface
NTP	Network Time Protocol
M-CMTS	Modular Cable Modem Termination System
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PIC	physical interface card
PTP	Precision Time Protocol
QAM	Quadrature Amplitude Modulation or Quadrature Amplitude Modulator
RF	radio frequency
RPD	Remote-PHY Device
RMD	Remote MAC-PHY Device
SC-QAM	Single Carrier Quadrature Amplitude Modulation or Single Carrier Quadrature Amplitude Modulator
SDV	switched digital video
US	upstream
VoD	video on demand

5.2. Definitions

Term	Definition
Critical facility	The network, facility, and/or building responsible for the reliable delivery of information services.
Key Performance Metric	A standard of measurement for the efficiency of use of energy or rack and space/volume for cable equipment in critical facilities

Channel Utilization	The amount of data traffic passing through a downstream or upstream QAM channel on a sustained basis expressed as a percentage of the channel's maximum theoretical throughput.

6. "Legacy" CMTS and Related Equipment

6.1. Description of Equipment

6.1.1. *Introduction*

The following subsections briefly describe Cable Modem Termination System (CMTS), and Time Server equipment, all of which operate in a cable television headend or distribution hub. Note that CMTS products are considered to be "legacy" equipment and are not expected to be widely used in new deployments. Later generation Converged Cable Access Platform (CCAP) equipment (which also supports CMTS functionality) is covered in section 8.

A CMTS is fully defined by the CableLabs DOCSIS set of specifications. In short, a CMTS forwards (at layer 2 or layer 3) data packets between a wide area network via its network-side interfaces and customer premise equipment via its DOCSIS RF interface ports. There are two types of CMTSs (Integrated CMTS and Modular CMTS) as described below.

For more information please see the following informative references:
- CMTS – [DOCSIS MULPIv3.0]
- DOCSIS RF Interfaces – [DOCSIS DRFI] and [DOCSIS PHYv3.0]

6.1.2. *Integrated CMTS (I-CMTS)*

With an I-CMTS, the downstream (DS) RF interfaces, upstream (US) RF interfaces, network-side interfaces and associated control plane and data plane processing entities all reside on a single CMTS network element.

6.1.3. *Modular CMTS (M-CMTS)*

With an M-CMTS, the interfaces and associated control plane and data plane processing entities are distributed among multiple network elements. The first of these network elements, called an M-CMTS core, is comprised of the upstream RF interfaces and the network-side interfaces. All upstream and network-side control plane and data plane processing for those interfaces is also handled by the M-CMTS core. Downstream MAC-layer processing is also performed on the M-CMTS core.

A separate network element, the edge-QAM, contains the M-CMTS downstream RF interface ports as well as network-side interfaces. The M-CMTS core transmits downstream data content and control to the edge-QAM across the converged interconnect network (CIN) via the DOCSIS-defined DEPI interface (which is a form of an IP tunnel). The edge-QAM then performs the downstream physical-layer processing necessary to modulate and transmit the data content of the downstream channel onto downstream RF port(s) toward the CM and CPE devices on the HFC network.

A third component, the DOCSIS Timing Interface (DTI) server provides a common sense of timing and frequency to the other M-CMTS components via the DOCSIS Timing Interface (DTI). See Figure 1.

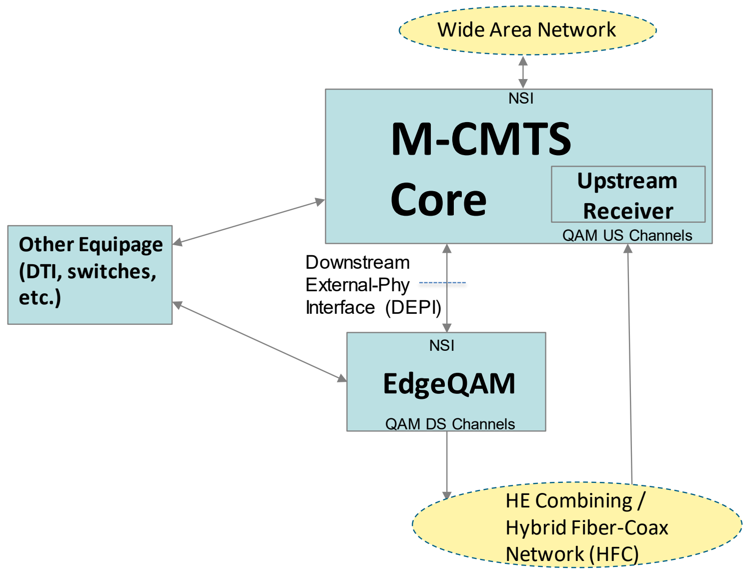

Figure 1 – M-CMTS Reference

For more information on the M-CMTS, see the following informative references:

- [DOCSIS MULPIv3.0]
- [DOCSIS DEPI]
- [DOCSIS MHA]

6.1.4. DOCSIS Timing Interface (DTI) Server

As noted in section 6.1.3, the DTI server provides a common sense of timing and frequency to M-CMTS components via the DOCSIS Timing Interface (DTI). DOCSIS timing server equipment is considered inherently energy efficient, and is not expected to be widely deployed by cable operators in the near future. Therefore energy and functional density metrics for this legacy equipment type are not included in this specification.

6.2. Energy Metrics for Legacy CMTS and Related Equipment

6.2.1. Introduction

The following sections specify the metrics to be used for determining the power consumption for entities associated with the corresponding equipment type.

Power consumption metrics have been defined for the I-CMTS equipment type. **It has been determined that M-CMTS equipment is not planned to be widely deployed by MSOs in the future. Therefore, this document does not include M-CMTS energy metrics and functional density metrics.**

Note that an edge-QAM device can be a component of an M-CMTS system as well as in a “video edge-QAM” application (in conjunction with a video server). Specific metrics for the video edge-QAM context will be defined in a future standard focusing on video-related equipment.

Note: Systems can be configured in multiple ways to provide varying services and the intent here is to define metrics that can be used generically for multiple equipment configurations, multiple generations of equipment for a particular vendor and also across multiple vendors. There is a need to keep the metrics simple for making fair comparisons yet comprehensive enough to be applied across the various configurations and use-cases.

6.2.2. I-CMTS Power Consumption Metrics

6.2.2.1. I-CMTS Power Consumption per Downstream Channel

I-CMTS power consumption per downstream channel ***shall*** be determined with the following metric:

$$\frac{I\text{-}CMTS\ Total\ Chassis\ Power\ (Watts)}{Maximum\ Number\ of\ DS\ channels\ supported\ by\ the\ chassis}$$

I-CMTS Total Chassis Power ***shall*** represent the total power consumption (in watts) of the I-CMTS chassis as determined by measurements at the power entry point just outside the chassis.

Maximum Number of DS channels supported by the chassis ***shall*** represent the highest number of DOCSIS downstream channels that can be supported in the chassis with the following constraints. The configuration for I-CMTS ***shall*** allow for the following two cases:

a. A ratio of one downstream RF port to two corresponding upstream RF ports.
b. A ratio of one downstream RF port to one corresponding upstream RF port.

The metric above ***shall*** be evaluated for both above cases if supported by the particular I-CMTS product. If the I-CMTS product does not support both cases then the metric ***shall*** be evaluated for either case a. or case b.

The applicable test procedures for evaluating the above metric are covered in sections 10.1, 10.2, 10.3, 10.4, 10.6 and their subsections.

6.2.2.2. I-CMTS Power Consumption per Upstream Channel

I-CMTS power consumption per upstream channel ***shall*** be determined with the following metric:

$$\frac{I\text{-}CMTS\ Total\ Chassis\ Power\ (Watts)}{Maximum\ Number\ of\ US\ channels\ supported\ by\ the\ chassis}$$

I-CMTS Total Chassis Power ***shall*** represent the total power consumption (in watts) of the I-CMTS chassis as determined by measurements at the power entry point just outside the chassis.

Maximum Number of US channels supported by the chassis ***shall*** represent the highest number of DOCSIS upstream channels that can be supported in the chassis with the following constraints. The configuration for I-CMTS ***shall*** allow for the following two cases:

a. A ratio of one downstream RF port to two corresponding upstream RF ports.
b. A ratio of one downstream RF port to one corresponding upstream RF port.

The metric above ***shall*** be evaluated for both cases a. and b. if supported by the particular I-CMTS product. If the I-CMTS product does not support both cases then the metric ***shall*** be evaluated for either case a. or case b.
The applicable test procedures for evaluating the above metric are covered in sections 10.1, 10.2, 10.3, 10.4, 10.6, and their subsections.

6.2.3. DOCSIS Timing Interface (DTI) Server Power Consumption Metrics

The (legacy) DTI server equipment is considered inherently energy efficient and is not expected to be widely deployed by cable operators in the near future. Therefore, power consumption metrics for this equipment type are not included in this specification.

6.3. Functional Density Metrics for Legacy CMTS, Edge-QAM, and Related Equipment

6.3.1. I-CMTS Functional Density Metrics

The I-CMTS Downstream Functional Density ***shall*** be determined with the following metric:

- *Maximum Number of Downstream channels per I-CMTS rack unit*

The above metric ***shall*** be evaluated by dividing *Maximum Number of DS channels supported by the chassis* (as specified in section 6.2.2.1) by the total number of chassis rack units.

The I-CMTS Upstream Functional Density ***shall*** be determined with the following metric:

- *Maximum Number of Upstream channels per I-CMTS rack unit*

The above metric ***shall*** be evaluated by dividing *Maximum Number of US channels supported by the chassis* (as specified in section 6.2.2.2) by the total number of chassis rack units.

6.3.2. DOCSIS Timing Interface (DTI) Server Functional Density Metrics

The (legacy) DTI server equipment is not expected to be widely deployed by cable operators in the near future. Therefore, functional density metrics for this equipment type are not included in this specification.

7. PTP and NTP Time Server Equipment

7.1. PTP and NTP Time Server Equipment Description

The following subsections cover equipment that provides high precision timing / frequency reference and synchronization to other equipment (clients) running in the network. This equipment typically communicates via protocol packets and can reside in the network multiple router hops from the client equipment. A direct connection to client equipment is not required.

Timing servers provide one or more timing functions such as the following. This standard will be limited in scope to time servers that provide either PTP or NTP support as well as time servers that provide both PTP and NTP support. PTP and NTP are the predominant timing functions being deployed during the lifetime of this document.

- Precision Time Protocol (PTP) Grandmaster clock (based on IEEE 1588)
- Network Time Protocol (NTP) server (based on Stratum 1, 2, or 3)

With this class of timing equipment, accuracy is of utmost importance and GPS support is typically the norm.

 © SCTE•ISBE

7.2. PTP and NTP Time Server Equipment Power Consumption Metrics

The metrics defined in the subsections below are to be applied to equipment providing either (or both) PTP or NTP timing functionality.

The applicable test procedures for evaluating the metrics for PTP and NTP time server equipment are covered in sections 10.1, 10.2, 10.4, 10.7, and their subsections.

7.2.1. PTP Time Server Power Consumption per Client

For equipment that provides PTP timing functionality, the power consumption per client ***shall*** be determined with the following metric:

$$\frac{\textit{Time Server Total Chassis Power (Watts)}}{\textit{Maximum Number of Timing Server Clients supported by the chassis}}$$

Time Server Total Chassis Power ***shall*** represent the total power consumption (in watts) of the time server chassis as determined by measurements at the power entry point just outside the chassis.

Maximum Number of Timing Server Clients supported by the chassis ***shall*** represent the highest number of PTP clients that the server can support simultaneously.

7.2.2. NTP Time Server Power Consumption per NTP Transactions per Second

For equipment that provides NTP timing functionality, the power consumption per NTP Transactions per Second ***shall*** be determined with the following metric:

$$\frac{\textit{Time Server Total Chassis Power (Watts)}}{\textit{Maximum Number of NTP Transactions per Second supported by the chassis}}$$

Time Server Total Chassis Power ***shall*** represent the total power consumption (in watts) of the time server chassis as determined by measurements at the power entry point just outside the chassis.

Maximum Number of NTP Transactions per Second supported by the chassis ***shall*** represent the highest number of request messages from clients that the server can respond to.

7.3. PTP and NTP Time Server Equipment Functional Density Metrics

The PTP Time Server Functional Density ***shall*** be determined with the following metric:

- *Maximum Number of PTP Clients per timing server rack unit*

The above metric ***shall*** be evaluated by dividing the *Maximum Number of PTP Clients supported by the chassis* by the total number of chassis rack units.

The NTP Time Server Functional Density ***shall*** be determined with the following metric:

- *Maximum Number of NTP Transactions per Second per timing server rack unit*

The above metric ***shall*** be evaluated by dividing the *Maximum Number of NTP Transactions per second supported by the chassis* by the total number of chassis rack units.

8. CCAP Equipment

8.1. CCAP Equipment Description

8.1.1. Integrated CCAP (I-CCAP) Equipment Description

The Converged Cable Access Platform (CCAP) provides the layer 2 and layer 3 data forwarding services of a traditional CMTS and the video processing and modulation functions of an edge-QAM into a single platform. A CCAP can also support Ethernet Passive Optical Network (EPON) functionality, providing DOCSIS Provisioning of EPON (DPoE) services through access-side PON interfaces. The CCAP supports video services in the downstream and DOCSIS services in the downstream and upstream directions.

The CCAP is a full RF spectrum device, allowing 160 6-MHz QAM channels (or 120 8-MHz QAM channels) to be placed on the downstream for video and DOCSIS 3.0 services. In addition, the CCAP supports DOCSIS 3.1, allowing wider OFDM channels to be placed within the downstream spectrum to 1218 MHz. In the upstream, both DOCSIS 3.0 and 3.1 channels (OFDMA channels) are supported. DOCSIS 3.0 supports 42, 65 and 85 MHz upstream splits while DOCSIS 3.1 supports those plus a 204 MHz split.

Note – Some extended spectrum plans are being considered for the future that go beyond 1218 downstream and 204 MHz upstream. Those are out of scope and not considered in this revision.

Most current CCAP installations are located in the headend in a single chassis and are referred to as Integrated CCAP (I-CCAP). The platform is designed to be ultra-dense, meaning that the number of downstream RF interfaces in a CCAP is much greater than the number supplied on traditional headend equipment. The platform has a mid-plane architecture with active, replaceable line cards for data processing connected across the mid plane to passive physical interface cards (PICs) with RF interfaces. This allows line card redundancy and failover, as well as allowing line cards to be replaced without disconnecting cables from the RF interfaces on the PICs.

The combination of video and data processing, as well as the RF density of the CCAP, reduces the amount of equipment needed in the headend (CMTS, edge-QAM, and combining network).

Two useful entities are commonly used to characterize the essence of a CCAP. The first is the concept of a composite Service Group (SG). A composite SG, for the purpose of this document, is defined as a subset of an I-CCAP chassis consisting of a single downstream service group (DSSG) and one or more associated upstream service group (USSG). For a I-CCAP chassis, each DSSG and USSG have a corresponding RF port. Multiple composite SGs are supported by a I-CCAP chassis with each composite SG typically serving about 500 to 1500 homes, although this is shrinking over time with fiber deep HFC networks.

The second useful entity associated with a CCAP system is the aspect of its data throughput, typically expressed in Gbps. This stems from the fact that a CCAP is fundamentally a routing platform and can support a variable number of DOCSIS channels per SG. Since a CCAP implementation may not have symmetrical downstream/upstream throughput capabilities, total CCAP throughput is often expressed as the sum of separate “downstream throughput” and “upstream throughputs”.

Generations of CCAP equipment that include Ethernet Passive Optical Network (EPON) interfaces are also out of scope for this document.

8.1.2. Distributed CCAP Architecture (DCA) Equipment Description

There has been recent strong interest in Distributed CCAP Architectures (DCA) where some or all of the CCAP functionality is pushed to a remote location including the outside plant in the field.

A key differentiation between DCA and I-CCAP is that the DCA optical transport is digital rather than analog. The digital optical link essentially makes the connection between the headend and the remote location (e.g. fiber node) a Layer 2/3 packet-based connection. In an HFC plant with a digital optical link, the link utilizes a baseband network transmission technology such as Ethernet, EPON (Ethernet over Passive Optical Networks), GPON (Gigabit Passive Optical Network), or any layer 2 technology that would support a fiber-based PHY layer.

The first distributed system defined by CableLabs is the Remote PHY (R-PHY) system that consists of a R-PHY device (RPD) located either in a node or shelf product; and a CCAP core chassis or server located in the headend or data center. The RPD performs the DOCSIS PHY layer processing while the CCAP core handles the DOCSIS MAC and upper layer CCAP protocols. The RPD plus all CCAP core components are functionally equivalent to an I-CCAP. Some additional Ethernet aggregation switching may also be needed in a DCA system and MUST be included in the energy metric measurements.

The CableLabs Flexible MAC Architecture (FMA) working group is in the process of defining several other variants of DCA including interfaces for various Remote MAC-PHY (R-MACPHY) systems. Much new product development is happening in this area. The first DCA system specified by the FMA working group is one that consists of a R-MACPHY device (RMD) located either in a node or shelf product; along with some core functions located in the headend or data center. The RMD performs the DOCSIS MAC and PHY layer processing. Additional processing may still be necessary in the headend or data center to provide full CCAP functionality. This may include routers, ethernet switches, MAC manager and a video processing core. These collectively will be referred to as RMD core components and all MUST be included in the energy metric measurements.

DCA device definitions:

- **RPD** – A Remote PHY device (RPD) is a DCA module capable of DOCSIS PHY layer processing. It is typically located in the outside plant fiber node or a shelf in a cabinet or other remote location. An RPD module supports a single or sometimes several composite SGs as defined above.
- **CCAP Core** – A CCAP Core is the part of a Remote PHY DCA system located in the headend or data center that performs all of the MAC and upper layer CCAP processing. It may be a dedicated chassis similar to I-CCAP devices or may be a virtual core running on a COTS server. The CCAP Core may be disaggregated across multiple entities (e.g. DOCSIS core, Video core, Ethernet switching/aggregation, and Control/Management element). All functions and features of the combined CCAP Core entities + RPD are equivalent to the I-CCAP discussed above. The energy metrics MUST include all CCAP Core elements necessary to implement the same function as I-CCAP.
- **RMD** – A Remote MAC-PHY device (RMD) is a DCA module capable of DOCSIS MAC and PHY layer processing. It is typically located in the outside plant fiber node or a shelf in a cabinet or other remote location. An RMD module supports a single or sometimes several composite SGs as defined above.
- **RMD Core** – The RMD Core components may include: router, ethernet aggregation switches, MAC manager and video core processing engine. All functions and features of the combined

RMD Core entities + RMD are equivalent to the I-CCAP discussed above. The energy metrics MUST include all RMD Core elements necessary to implement the same function as I-CCAP.

Note that for the RPD and RMD node products, there may not be a one to one mapping between DSSG/USSG and RF legs on the node. For example, a 1x1 RPD/RMD module supports a single composite SG with a single DSSG and a single USSG while a 1x2 RPD/RMD module supports a single composite SG with a single DSSG and two USSG. Either of these DCA modules may be put into a node with four RF legs. Note that the node will also contain sufficient RF combining and splitting to map the DSSG and USSG to the appropriate RF legs. Another example might be a 2x2 or 2x4 RPD/RMD that contains two composite service groups with 1:1 or 1:2 DS:US ratios respectively but maps to 4 RF legs in the node.

Also note that the CCAP Core and RMD core components connect via Ethernet and hence do not have any RF ports. That is why this metric applies to power per composite SG in the core which consists of one DSSG and its one or more associated USSG rather than per RF port.

DOCSIS has continued to evolve and now DOCSIS 4.0 includes support for DOCSIS Full Duplex (FDX) operation. DOCSIS FDX is intended for a Node+0 distributed system (i.e. RPD, RMD) and allows the upstream and downstream frequencies to overlap from 108 MHz up to 684 MHz. The FDX systems are substantially different then legacy DOCSIS 3.0/3.1 systems and will have their own separate scenarios defined for measuring power metrics.

8.2. CCAP Equipment Energy Metrics

The two metrics specified in the below subsections are to be used to evaluate the power consumption characteristics of CCAP equipment, both I-CCAP and DCA equipment. It is important to note that evaluation and consideration of both metrics is required in order to ensure a comprehensive understanding of these characteristics.

Note that the metric specified in section 8.2.2 (Power Consumption per Throughput) is also applied to legacy I-CMTS equipment for comparing the power consumption of that equipment with that of CCAP equipment. See section 9.

8.2.1. CCAP Power Consumption per Service Group

For chassis-based equipment, the CCAP power consumption per service group ***shall*** be determined with the following metric:

$$\frac{\textit{CCAP Total Chassis Power (Watts)}}{\textit{Maximum Number of Composite Service roups supported by the chassis}}$$

CCAP Total Chassis Power (Watts) ***shall*** represent the total power consumption (in watts) of the CCAP chassis as determined by measurements at the power entry point just outside the chassis.

Maximum Number of Composite Service Groups supported by the chassis ***shall*** represent the highest number of composite Service Groups that can be supported in the chassis with the following constraints. The configuration for CCAP ***shall*** allow for the following cases:

a. A Composite service group with a 1:2 ratio consisting of a **single** downstream service group (DSSG) and **two** corresponding upstream service groups (USSG).

b. A Composite service group with a 1:1 ratio consisting of a **single** DSSG and a **single** corresponding USSG.

The metric above shall be evaluated for both cases a and b for chassis-based equipment.

The applicable test procedures for evaluating the above metric are covered in sections 10.1, 10.2, 10.3, 10.4, 10.8, and their subsections.

The power consumption per service group for node-based DCA equipment ***shall*** be determined with the following metric:

$$\frac{\text{Total DCA Module Delta Power (Watts)}}{\text{Maximum Number of Composite Service roups supported by the module}}$$

Total DCA Module Delta Power (Watts) ***shall*** represent the total incremental power consumption (in watts) of the node when operating in digital DCA mode compared to the node operating in traditional analog mode. The node power shall be determined by measurements at the power entry point just outside the node housing. The Total DCA Module Delta Power shall be the Total DCA Node Power minus the Total Analog Node Power.

DCA modules located in fiber nodes (e.g. RPD, RMD) are typically available in a single configuration (e.g. 1x1, 1x2, or 2x2). The node in analog mode shall be configured with the same segmentation as the DCA module configuration (i.e. 1x1, 1x2 or 2x2 to match DCA module).

This specification is not trying to define metrics to measure node power as that can vary tremendously from node type to node type depending on number of active RF legs and various HFC plant requirements. Rather, this specification is trying to capture the contribution to outside plant power usage from a distributed digital architecture.

8.2.2. CCAP Power Consumption per Throughput

The power consumption per throughput for chassis-based CCAP equipment ***shall*** be determined with the following metric:

$$\frac{Total\ Chassis\ Power\ (Watts)}{Maximum\ Downstream\ Throughput\ (Gbps) + Maximum\ Upstream\ Throughput\ (Gbps)}$$

Total Chassis Power ***shall*** represent the total power consumption in Watts of the equipment chassis as determined by measurements at the power entry point just outside the chassis.

Maximum Downstream Throughput ***shall*** represent the maximum downstream payload[1] throughput (i.e. rate of data traffic) supported by the chassis in Gbps as determined by measurements at the egress (cable-side) interfaces with the following conditions. The maximum downstream throughput ***shall*** be supported with a downstream packet loss not to exceed 0.01% (i.e. approximating non-blocking operation). If the packet loss exceeds the above limit then the downstream throughput ***shall*** be decreased until the limit is met.

 © SCTE•ISBE

Maximum Upstream Throughput ***shall*** represent the maximum upstream payload[1] throughput (i.e. rate of data traffic) supported by the chassis in Gbps as determined by measurements at the egress (network-side) interfaces with the following conditions. The maximum upstream throughput ***shall*** be supported with an upstream packet loss not to exceed 0.01% (i.e. approximating non-blocking operation). If the packet loss exceeds the above limit then the upstream throughput ***shall*** be decreased until the limit is met.

The applicable test procedures for evaluating the above metric for a CCAP system are covered in sections 10.1, 10.2, 10.5, 10.8, and their subsections. The applicable test procedures for evaluating the above metric for a legacy I-CMTS system are covered in sections 10.1, 10.2, 10.5, 10.6, and their subsections.

The power consumption per throughput for node-based DCA equipment ***shall*** be determined with the following metric:

$$\frac{Total\ DCA\ Module\ Delta\ Power\ (Watts)}{Maximum\ Downstream\ Throughput\ (Gbps) + Maximum\ Upstream\ Throughput\ (Gbps)}$$

Total DCA Module Delta Power ***shall*** represent the total incremental power consumption in Watts of the DCA module inside the node as described above in section 8.2.1.

Maximum Downstream Throughput is the same as defined above.

Maximum Upstream Throughput is the same as defined above.

[1]Payload throughput as defined in this standard includes DOCSIS overhead bits (e.g. FEC, Preamble) but does *not* include Ethernet and IP header bits.

8.3. Rack mounted CCAP Equipment Functional Density Metrics

The CCAP Service Group Functional Density for rack-mounted CCAP equipment ***shall*** be determined with the following metric:

- *Maximum Number of Composite Service Groups per CCAP rack unit*

The above metric ***shall*** be evaluated by dividing the maximum number of composite service groups supported by the CCAP chassis by the total number of chassis rack units. The maximum number of composite service groups per CCAP chassis unit ***shall*** be determined as specified in section 8.2.1.

The CCAP Throughput Functional Density ***shall*** be determined with the following metric:

- *Maximum Throughput per CCAP rack unit*

The above metric ***shall*** be evaluated by dividing the maximum throughput (in Gbps) supported by the CCAP chassis by the total number of chassis rack units. The maximum throughput per CCAP chassis unit ***shall*** be determined using the guidance provided in sections 8.2.2 and 10.5.

9. Legacy I-CMTS versus CCAP Equipment

The intent of the below metric is to provide a means for comparing the power consumption of legacy I-CMTS equipment with that of CCAP equipment.

9.1. Power Consumption per Throughput

The power consumption per throughput for legacy I-CMTS or CCAP equipment ***shall*** be determined with the metric specified in section 8.2.2.

10. Test Procedures

10.1. General Requirements and Methodology

The general requirements and methodology specified in [SCTE_General_Test_Procedures] for measuring power consumption ***shall*** be applied to the testing of all equipment types. That document includes requirements for aspects such as environmental, measurement equipment calibration, equipment stabilization, and general power measurement guidelines.

10.2. General Equipment Configuration

The following general equipment configuration (adapted from [ATIS-0600015.03.2009] – section 6.2) ***shall*** be applied to the testing of all equipment types:

- All testing ***shall*** be performed on a fully-loaded chassis or node, as defined by the referenced application.
- All ports ***shall*** be in an active state and passing or ready to pass traffic.
- System software ***shall*** be properly configured prior to the test and all the necessary hardware components installed. Hardware and software ***shall*** be representative of a production unit.
- There is no EUT configuration change allowed any time beyond preparation phase. This includes (but not limited to) external configuration commands, scripts executing configuration commands on EUT during testing, etc.

Configuration ***shall*** include redundancy if supported by the particular EUT.

For any configuration or functionality that is not supported by the EUT, the equipment vendor ***shall*** provide a reasonable substitution and the particular substitution details ***shall*** be recorded along with the test results.

10.2.1. Packet Length Distribution for I-CMTS and CCAP

The following distribution of packet lengths ***shall*** be applied to the testing of I-CMTS and CCAP equipment.

10.2.1.1. Downstream Packet Length

Packet Length (bytes)	Percentage of Total Traffic (%)
64	10
220	5
1000	5
1514	80

10.2.1.2. Upstream Packet Length

The following table ***shall*** be used for all SC-QAM channels and for any OFDMA channels that are below 108 MHz.

Packet Length (bytes)	Percentage of Total Traffic (%)
64	50
70	25
200	15
1483	10

All OFDMA channels that are greater than 108 MHz, including FDX channels, ***shall*** use the same packet length distribution as the downstream channels.

10.3. General Measurement Procedure – 70% Utilization

The 70% Utilization procedure ***shall*** consist of the following steps.

1. Pre-conditions:
    a. Prior to the actual test, the EUT ***shall*** be exposed to the environmental conditions defined in [SCTE_General_Test_Procedures].
2. Configuration and Stabilization:
    a. Prior to testing, the EUT ***shall*** be powered and configured according to the requirements and loading defined in the test procedures section for the particular equipment type as listed below.
        i. I-CMTS equipment – Section 10.6
        ii. CCAP equipment – Section 10.8
    b. Traffic generators are used to simulate traffic and collect the performance-related results according to the test conditions for the equipment type under test. Generators ***shall*** be configured for the specified traffic mix and traffic profile. Traffic generation ***shall*** be configured such that all configured cable-side downstream and upstream channels (CCAP and I-CMTS only) of the EUT are utilized at **70% ± 0.5%**. The configured network-side interfaces ***shall*** support the cable-side utilization of 70% with a packet loss not to exceed 0.01% (i.e. approximating non-blocking operation). If the network-side drop rate exceeds 0.01% then additional network-side resources ***shall*** be installed to increase the capacity.
    c. Allow the equipment to stabilize in this mode for 15 minutes.
3. Measure and record the chassis power consumption for a period of 15 minutes. The measurement ***shall*** be in Watts as determined with a Power Meter at the power entry point just outside the chassis. If the power varies over the 15 minute measurement time interval, an average of the measurement ***shall*** be calculated.
4. Evaluate the appropriate equipment power consumption metric (see list below) and record the results.
    a. I-CMTS equipment – Section 6.2.2

    b. CCAP equipment – Section 8.2.1
5. Repeat steps 2 – 4 for each applicable configuration scenario defined in the test configuration section for the equipment type under test.

10.4. General Measurement Procedure – Idle Test

The purpose of this procedure is to evaluate the power consumption metrics while the system is not passing traffic. The Idle test procedure ***shall*** consist of the following steps.

1. Pre-conditions:
    a. Prior to the actual test, the EUT ***shall*** be exposed to the environmental conditions outlined in [SCTE_General_Test_Procedures].
2. Configuration and Stabilization:
    a. Prior to testing, the EUT ***shall*** be powered and configured according to the requirements and loading defined in the test procedures sections for the particular equipment type. In particular, the EUT ***shall*** still be *capable* of performing its normal functions (e.g. passing traffic, registering cable modems, etc.) across its full set of resources.
        i. I-CMTS equipment – Section 10.6
        ii. PTP and NTP Time Server equipment – Section 10.7
        iii. CCAP equipment – Section 10.8
    b. The traffic generators ***shall*** be configured as follows:
        i. For I-CMTS and CCAP equipment: Configure the traffic generators such that all configured upstream channels, downstream channels, and network-side interfaces of the EUT are utilized at **0%** with a tolerance of **0.1%**.
        ii. For PTP and NTP Time Server equipment: Configure the traffic generators such that no PTP or NTP client operations are taking place.
    c. Allow the equipment to stabilize in this mode for 15 minutes.
3. Measure and record the chassis power consumption for a period of 15 minutes. The measurement ***shall*** be in Watts as determined with a Power Meter at the power entry point just outside the chassis. If the power varies over the 15 minute measurement time interval, an average of the measurement ***shall*** be calculated.
4. Evaluate the appropriate equipment power consumption metric (see list below) and record the results.
    a. I-CMTS equipment – Section 6.2.2
    b. PTP and NTP Time Server equipment – Section 7.2.1
    c. CCAP equipment – Section 8.2.1
5. Repeat steps 2 – 4 for each applicable configuration scenario defined in the test configuration section for the equipment type under test.

10.5. General Measurement Procedure – Power Per Throughput

The Power per Throughput measurement procedure ***shall*** consist of the following steps.

1. Pre-conditions:
    a. Prior to the actual test, the EUT ***shall*** be exposed to the environmental conditions defined in [SCTE_General_Test_Procedures].
2. Configuration and Stabilization:
    a. Prior to testing, the EUT ***shall*** be powered and configured according to the requirements and loading defined in the test procedures section for the particular equipment type as listed below.

        i. I-CMTS equipment – Section 10.6
        ii. CCAP equipment – Section 10.8
    b. Traffic generators are used to simulate traffic and collect the performance-related results according to the test conditions for the equipment type under test. Generators ***shall*** be configured for the specified traffic mix and traffic profile. The traffic rate ***shall*** be configured such that the measured downstream and upstream EUT payload[1] throughputs achieve their highest possible sustained values with no more than the maximum packet drop rate specified in section 8.2.2.
        i. The downstream payload throughput ***shall*** be measured at the (cable-side) egress interfaces. This effectively measures the rate of traffic that the EUT forwards to cable-side clients.
        ii. The upstream payload throughput ***shall*** be measured at the (network-side) egress interfaces. This effectively measures the rate of traffic from cable-side clients that is forwarded by the EUT.
    c. Allow the equipment to stabilize in this mode for 15 minutes.
3. Measure and record the chassis or node power consumption for a period of 15 minutes. The measurement ***shall*** be in Watts as determined with a Power Meter at the power entry point just outside the chassis. If the power varies over the 15 minute measurement time interval, an average of the measurement ***shall*** be calculated.
4. Evaluate the appropriate equipment power consumption metric (see list below) and record the results.
    a. I-CMTS equipment (for comparison with CCAP) – Section 9.1
    b. CCAP equipment – Section 8.2.2
5. Repeat steps 2 – 4 for each applicable configuration scenario defined in the test configuration section for the equipment type under test.

[1]Payload throughput as defined in this standard includes DOCSIS overhead bits (e.g. FEC, Preamble) but does *not* include Ethernet and IP header bits.

10.6. Power Consumption Test Procedures for I-CMTS Equipment

The I-CMTS chassis ***shall*** be at the maximum line card and common equipment configuration with all active RF ports enabled.

The I-CMTS power consumption metric ***shall*** be evaluated for the North American and European configurations shown below for both scenarios A and B if supported by the particular I-CMTS product. If the I-CMTS product does not support both scenarios then the metric ***shall*** be evaluated for either scenario A or scenario B for both the North American and European configurations.

10.6.1. North American I-CMTS Configuration

	Scenario A **1:2 DS:US RF Port Ratio**	**Scenario B** **1:1 DS:US RF Port Ratio**
DS Spectrum	54 - 1002 MHz	54 - 1002 MHz
DS D3.0 SC-QAM channels per RF port	**Maximum supported equipage per port**	**Maximum supported equipage per port**
US Spectrum	5 – 42 MHz	5 - 42 MHz
US D3.0 SC-QAM Channels per RF Port	**Maximum supported equipage per port**	**Maximum supported equipage per port**

The following channel configuration ***shall*** be applied for North American I-CMTS equipment:

Downstream:
- Configure the supported maximum number of DOCSIS 3.0 SC-QAM downstream channels per RF port. All DOCSIS SC-QAM downstream channels ***shall*** be Annex B 256-QAM (modulation order), 6 MHz channel width, configured per [ITU-T J.83-B], running at the maximum [DOCSIS DRFI]-specified power level.

Upstream:
- Configure the supported maximum number of DOCSIS 3.0 SC-QAM upstream channels per RF port. All DOCSIS SC-QAM upstream channels ***shall*** be configured as A-TDMA (channel-type), 64-QAM (modulation order), 6.4 MHz (channel width).

10.6.2. European I-CMTS Configuration

	Scenario A **1:2 DS:US RF Port Ratio**	**Scenario B** **1:1 DS:US RF Port Ratio**
DS Spectrum	108 - 1002 MHz	108 - 1002 MHz
DS D3.0 SC-QAM channels per RF port	**Maximum supported equipage per port**	**Maximum supported equipage per port**
US Spectrum	5 – 65 MHz	5 - 65 MHz
US D3.0 SC-QAM Channels per RF Port	**Maximum supported equipage per port**	**Maximum supported equipage per port**

 © SCTE•ISBE

The following channel configuration ***shall*** be applied for European I-CMTS equipment:

Downstream:

- Configure the supported maximum number of DOCSIS 3.0 SC-QAM downstream channels per RF port. All DOCSIS SC-QAM downstream channels ***shall*** be Annex A 256-QAM (modulation order), 8 MHz channel width, configured per [EN 300 429], running at the maximum [DOCSIS DRFI]-specified power level.

Upstream:

- Configure the supported maximum number of DOCSIS 3.0 SC-QAM upstream channels per RF port. All DOCSIS SC-QAM upstream channels ***shall*** be configured as A-TDMA (channel-type), 64-QAM (modulation order), 6.4 MHz channel width.

10.6.3. I-CMTS Traffic Distribution

The I-CMTS North American and European test configurations per channel type ***shall*** consist of the following traffic mixtures.

- Downstream D3.0 SC-QAM channels: 100% unicast[1] HSD
- Upstream D3.0 SC-QAM channels: 100% unicast HSD

[1]Some downstream packet replication such as IP multicast is permitted in order to fully utilize the downstream capacity of cable-side channels for the power per throughput measurement (see sections 9 and 10.5).

The I-CMTS North American and European test configuration ***shall*** provide for the downstream and upstream packet length distribution specified in section 10.2.1.

10.6.4. Additional I-CMTS configuration:

The following additional configurations apply to both the North American and European test configurations.

- Static routing configuration *should* be used for the population of routing tables. Dynamic routing protocols *may* be utilized.

10.7. Power Consumption Test Procedures for PTP and NTP Time Server Equipment

10.7.1. Time Server Equipment Supporting PTP Only

The following test procedures ***shall*** be applied to the testing of time server equipment that provides PTP timing functionality but not NTP functionality.

1. Configure the EUT for operation as a Precision Time Protocol (PTP) Grandmaster clock (based on IEEE 1588).
2. Appropriate test generator equipment ***shall*** be configured and connected to the EUT such that the maximum number of PTP clients supported by the EUT can be simultaneously served.
3. Perform power measurements to evaluate the metric defined in section 7.2.1 and record the results.

 © SCTE•ISBE

10.7.2. Time Server Equipment Supporting NTP Only

The following test procedures ***shall*** be applied to the testing of time server equipment that provides NTP timing functionality but not PTP functionality.

1. Configure the EUT for operation as a Network Time Protocol (NTP) server (based on Stratum 1, 2, or 3).
2. Appropriate test generator equipment ***shall*** be configured and connected to the EUT such that the maximum number of NTP transactions supported by the EUT can be simultaneously served.
3. Perform power measurements to evaluate the metric defined in section 0 and record the results.

10.7.3. Time Server Equipment Supporting Both PTP and NTP

The following test procedures ***shall*** be applied to the testing of time server equipment that provides both PTP as well as NTP timing functionality.

1. Configure the EUT to its maximum scaling capabilities for operation as a Precision Time Protocol (PTP) Grandmaster clock (based on IEEE 1588) while disabling / minimizing functionality providing NTP timing operations.
2. Appropriate test generator equipment ***shall*** be configured and connected to the EUT such that the maximum number of PTP clients supported by the EUT can be simultaneously served.
3. Evaluate the metric defined in section 7.2.1 and record the results.
4. Configure the EUT to its maximum scaling capabilities for operation as a Network Time Protocol (NTP) server (based on Stratum 1, 2, or 3) while disabling / minimizing functionality providing PTP timing operations.
5. Appropriate test generator equipment ***shall*** be configured and connected to the EUT such that the maximum number of NTP transactions supported by the EUT can be simultaneously served.
6. Allow the EUT and test equipment to stabilize for 15 minutes.
7. Perform power measurements to evaluate the metric defined in section 0 and record the results.

10.8. Power Consumption Test Procedures for CCAP Equipment

10.8.1. CCAP Configuration

The chassis or module ***shall*** be at the maximum line card and common equipment configuration with all active ports enabled (e.g. RF, Ethernet ports) to the extent such that only the maximum number of composite service groups are configured and enabled. Extra downstream or upstream RF ports (and other related equipage) that are not part of a composite service group ***shall*** not be configured and enabled.

The applicable test configuration scenario(s) from the tables in sections 10.8.1.1 and 10.8.1.1 ***shall*** be determined based on the product generation definition date as specified in [SCTE_General_Test_Procedures] - section 6.7.1.

The following tables have been modified from the previous revision of this document such that the North American and European configurations both use the same downstream configurations. The only difference in the downstream being whether the narrowcast QAM, broadcast QAM and DOCSIS 3.0 SC-QAM are configured for Annex B (6-MHz N.A.) or Annex A (8-MHz Euro). The number of DOCSIS 3.0 upstream channels and DOCSIS 3.1 OFDMA non-overlapping spectrum varies depending on whether it is North American (42 MHz), Euro (65 MHz), Mid-split (85 MHz) or High-split (204 MHz) systems.

10.8.1.1. N.A./Euro CCAP Test Configurations with 1st Gen D3.1 modems

	Scenario A (860 MHz)	Scenario B (1002 MHz)	Scenario C (1218/85 MHz)	Scenario D (1218/204 MHz)
DS Spectrum	108 - 860 MHz	108 - 1002 MHz	108 - 1218 MHz	258 - 1218 MHz
DS NarrowCast Video SC-QAM chan per DSSG	**8 Annex A or 12 Annex B**	**12 Annex A or 16 Annex B**	**6 Annex A or 8 Annex B**	**6 Annex A or 8 Annex B**
DS Broadcast Video SC-QAMs chan per DSSG	**20 Annex A or 24 Annex B**	**20 Annex A or 24 Annex B**	**20 Annex A or 16 Annex B**	**20 Annex A or 16 Annex B**
DS D3.0 SC-QAM chan per DSSG	**12 Annex A or 16 Annex B**	**16 Annex A or 24 Annex B**	**16 Annex A or 24 Annex B**	**16 Annex A or 24 Annex B**
DS D3.1 OFDM chan per DSSG	**One 96 MHz** D3.1 OFDM channel	**One** 192 **MHz** D3.1 OFDM channel	**Two** 192 **MHz** D3.1 OFDM channels	**Two** 192 **MHz** D3.1 OFDM channels
DS:US ratios	**1:1 & 1:2 ratios**	**1:1 & 1:2 ratios**	**1:1 & 1:2 ratios**	**1:1 & 1:2 ratios**
US Spectrum	N.A.: 5 – 42 MHz Euro: 5 – 65 MHz	Mid-split: 5 – 85 MHz	Mid-split: 5 – 85 MHz	High-split: 12 – 204 MHz
US D3.0 SC-QAM chan per USSG	N.A.: **Three 6.4 MHz** Euro: **Six 6.4 MHz**	**Eight 6.4 MHz**	**Eight 6.4 MHz**	**Eight 6.4 MHz**
US D3.1 OFDMA chan per USSG	N.A.: **12 MHz** OFDMA Euro: **16 MHz** OFDMA	**One 24 MHz** OFDMA	**One 24 MHz** OFDMA	**One 44 MHz + one 96 MHz** OFDMA

Each scenario applies to both a 1:1 DS:US ratio and 1:2 DS:US ratio. Note – this table is from CMTS perspective. It may take a combination of different types of CPE devices to fully load the system.

While the previous table showed a progression of scenarios using existing DOCSIS 3.1 cable modem technology (i.e. downstream support for up to 24 3.0 SC-QAM + 2x192 MHz OFDM), the following table defines some upcoming scenarios based on next generation cable modem technologies operating in an All-IP environment (i.e. DOCSIS only). Scenarios E & F increase the DOCSIS 3.1 OFDM channels to 4x192 MHz while Scenarios G & H introduce DOCSIS 4.0 Full-Duplex (FDX) devices.

10.8.1.1. CCAP Test Configurations with Next Gen D3.1 modems

	Scenario E (1218/85 MHz)	**Scenario F** (1218/204 MHz)	**Scenario G** (FDX = 108-300 MHz)	**Scenario H** (FDX = 108-684 MHz)
DS Spectrum	108 - 1218 MHz	258 - 1218 MHz	DS Only: 300 - 1218 MHz FDX[a]: 108 – 300 MHz	DS Only: 684 - 1218 MHz FDX[a]: 108 – 684 MHz
DS NarrowCast Video SC-QAM chan per DSSG	**No NC QAM**	**No NC QAM**	**No NC QAM**	**No NC QAM**
DS Broadcast Video SC-QAM chan per DSSG	**No BC QAM**	**No BC QAM**	**No BC QAM**	**No BC QAM**
DS 3.0 SC-QAM chan per DSSG	**16 Annex A or 16 Annex B**	**16 Annex A or 16 Annex B**	**16 Annex A or 16 Annex B**	**16 Annex A or 16 Annex B**
DS D3.1 OFDM chan per DSSG	**Four 192 MHz** D3.1 OFDM channel	**Four 192 MHz** D3.1 OFDM channel	DS Only: **One 192 MHz** D3.1 OFDM channels	DS Only: **One 192 MHz** D3.1 OFDM channels
DS FDX OFDM chan per DSSG	–	–	FDX[a]: **Two 96 MHz OFDM** FDX channels	FDX[a]: **Three 192 MHz OFDM** FDX channels
DS:US ratios	**1:1 & 1:2 ratios**	**1:1 & 1:2 ratios**	**1:1 & 1:2 ratios**	**1:1 & 1:2 ratios**
US Spectrum	Mid-split: 5 – 85 MHz	High-split: 12 – 204 MHz	Mid-split: 5 – 85 MHz FDX: 108 – 300 MHz	Mid-split: 5 – 85 MHz FDX: 108 – 684 MHz
US 3.0 SC-QAM chan per USSG	**Four 6.4 MHz**	**Four 6.4 MHz**	**Four 6.4 MHz**	**Four 6.4 MHz**
US D3.1 OFDMA chan per USSG	Mid-split: **One 52 MHz OFDMA**	High -split: **one 70 MHz + one 96 MHz OFDMA**	Mid-split: **one 52 MHz OFDMA**	Mid-split: **one 52 MHz OFDMA**
US FDX OFDMA chan per USSG[a]	–	–	FDX[a]: **Two 96 MHz** OFDMA FDX channels	FDX[a]: **Six 96 MHz** OFDMA FDX channels
[a] FDX spectrum that overlaps in US and DS				

Note – this table is from CMTS perspective. It may take a combination of different types of CPE devices to fully load the system.

The following channel configuration ***shall*** be applied for all CCAP equipment:

Downstream:

- Configure the bandwidth for each DOCSIS 3.1 downstream OFDM Channels per DSSG as specified in the table above.
  - All DOCSIS 3.1 downstream OFDM Channels ***shall*** be 4096-QAM (modulation order) running at the maximum [DOCSIS PHYv3.1]-specified power level.
- Configure the supported maximum number of SC-QAM downstream channels per DSSG with the number of channel types as listed in the table above.

- All North American SC-QAM downstream channels ***shall*** be Annex B 256-QAM (modulation order), 6 MHz (channel-width), configured per [ITU-T J.83-B], running at the maximum [DOCSIS DRFI]-specified power level.
- All Euro SC-QAM downstream channels ***shall*** be Annex A 256-QAM (modulation order), 8 MHz (channel-width), configured per [EN 300 429], running at the maximum [DOCSIS DRFI]-specified power level.

Upstream:

- Configure the bandwidth for each DOCSIS 3.1 upstream OFDMA Channels per USSG as specified in the table above.
  - All DOCSIS 3.1 upstream OFDMA Channels ***shall*** be 1024-QAM (modulation order).
- Configure the supported maximum number of DOCSIS 3.0 SC-QAM upstream channels per USSG. All DOCSIS SC-QAM upstream channels ***shall*** be configured as A-TDMA (channel-type); 64-QAM (modulation order); 6.4 MHz (channel-width).
  - SC-QAM upstream channels with no overlap with an OFDMA channel may be utilized up to 100%.
  - OFDMA upstream spectrum with no overlap with SC-QAM channels may be utilized up to 100%.
  - For upstream SC-QAM and OFDMA channels that overlap in spectrum due to time-division multiplexing, the following channel utilizations ***shall*** apply:
    - Scenarios A: Up to 70% utilization for SC-QAM channels and up to 30% utilization for OFDMA channels.
    - Scenario B-H: Up to 50% utilization for SC-QAM channels and up to 50% utilization of OFDMA channels.

The following channel configuration ***shall*** be applied for FDX CCAP equipment:

Downstream FDX channels:

- Configure the bandwidth for each FDX downstream OFDM Channels per DSSG as specified in the table above.
  - All FDX downstream OFDM Channels ***shall*** be 4096-QAM (modulation order) running at the maximum [DOCSIS PHYv3.1]-specified power level.
  - The following channel utilizations ***shall*** apply to DS FDX channels: 80%

Upstream FDX channels:

- Configure the bandwidth for each FDX upstream OFDMA Channels per USSG as specified in the table above.
  - All FDX upstream OFDMA Channels ***shall*** be 1024-QAM (modulation order).
  - The following channel utilizations ***shall*** apply to US FDX channels: 20%

10.8.1.2. CCAP Traffic Distribution

The CCAP test configuration per channel type ***shall*** consist of the following traffic mixtures:

- Downstream Narrowcast Video SC-QAM channels: SDV or VoD.
- Downstream Broadcast Video SC-QAM channels: 100% video program content
- Downstream D3.0 SC-QAM channels: 100% unicast[1] HSD
- Downstream D3.1 OFDM channels: 100% unicast[1] HSD traffic

- Upstream D3.0 SC-QAM channels: 100% unicast HSD traffic
- Upstream D3.1 OFDMA channels: 100% unicast HSD traffic

[1]Some downstream packet replication such as IP multicast is permitted in order to fully utilize the downstream capacity of cable-side channels for the power per throughput measurement (section 10.5).

The CCAP test configuration ***shall*** provide for the downstream and upstream packet length distribution specified in section 10.2.1.

10.8.1.3. Additional CCAP configuration:

Static routing configuration *should* be used for the population of routing tables. Dynamic routing protocols *may* be utilized.

10.9. Functional Density Test Procedures

Guidance on the evaluation of the functional density metric(s) for a given equipment type can be found in the corresponding section that defines the metric(s).

10.10. Recording of Results

Results ***shall*** be documented in accordance with [SCTE_General_Test_Procedures].

If the chassis supports redundancy, equipment vendors ***shall*** submit a user-doc level description of their support for redundancy. Fail-over times may optionally be provided, however the description should give a sense for how long a redundant card will take to become fully operational. For example, are all cable modems served by the redundant card required to re-register?

See section 10.2. If it was necessary for the vendor to provide a substitution for configuration or functionality that is not supported by the EUT, the equipment vendor ***shall*** document the particular substitution details.

Additional functionality implemented in the EUT which may not have been exercised during the specified tests (for example, functionality included for future-proofing) *should* be itemized by the vendor.