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STANDARDS

Energy Management Subcommittee

AMERICAN NATIONAL STANDARD

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Energy Metrics for Cable Operator Access Networks

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1. Introduction

1.1. Executive Summary

This document enables cable operators to measure how effective changes in the access network (AN) service impacts energy consumption from both a high-level and functional operations perspective. It enables operators to gauge individual progress, as well as measure progress against the cable industry, without ambiguity. This document also serves as a reliable compass by focusing operator resources on areas of the network with the greatest opportunity and prioritizing energy efficiency spend during budget cycles.

1.2. Scope

This document contains metrics for measuring the energy efficiency of access networks (ANs) that are utilized to transport information between a service provider and a plurality of users. For the purposes of this document, the AN includes all active and passive equipment between the headend or hub, referred herein as the "hub," and the demarcation point at the user premises. This document does not include any equipment inside the hub, nor does it include any customer premises equipment (CPE).

The metrics defined in this document are designed to capture the overall energy efficiency of the network and are not designed to evaluate the energy efficiency of individual components within the network.

The metrics defined in this document may be calculated for the entire operator network as a whole or across individual segments of the network. Additionally, the metrics may be calculated over various time spans, ranging from hours to days or weeks. The period over which calculations are performed should be clearly noted along with the results.

1.3. Benefits

This document can be used to influence, measure and communicate the progress of energy efficiency improvements in the AN. It enables operators to predict and evaluate the energy efficiency and monetary impact of new equipment being considered for deployment. When used in conjunction with SCTE 212, SCTE 211 allows operators to translate operational energy management successes into financial results.

1.4. Intended Audience

Cable operator: outside plant engineering, metrics teams, access network engineers, and access network managers; or others responsible for measuring energy performance.

This document also provides energy efficiency guidance to equipment manufacturers.

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

None at this time of release.

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

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

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

- SCTE 205 2014, Outside Plant Power Recommended Preventive Maintenance Procedure

3.2. Standards from Other Organizations

- ETSI TR 105 174-6 V0.0.10 (2015-03), CABLE; Broadband Deployment and Energy Management; Part 6: Cable Access Networks
- ETSI ES 205 200-2-4 V0.0.12 (2015-06), CABLE; Energy management; Global KPIs; Operational infrastructures; Part 2: Specific requirements; Sub-part 4: Cable Access Networks

3.3. Published Materials

- Brooks, Paul; Outside Plant Powering Efficiency; November, 2011 Cable-Tec Expo, Atlanta GA

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

AC	alternating current
AN	access network
AP	access point
BC	broadcast
bps	bits per second
ch	channel
CMTS	cable modem termination system
CPE	customer premises equipment
DC	direct current
DPS	device power supply
DS	downstream
EMS	[SCTE] Energy Management Subcommittee
EPCB	energy per consumed bit
ETSI	European Telecommunications Standards Institute
FEC	forward error correction
HD	high definition
HFC	hybrid fiber-coax
Hz	hertz
KPI	key performance indicator
kW	kilowatt
kWh	kilowatt-hour
LPS	line power supply
Mbps	megabits per second

RF	radio frequency
s	second
SCTE	Society of Cable Telecommunications Engineers
SD	standard definition
SDV	switched digital video
SI	International System of Units (Le Système International d' Unités)
TB	terabyte
UHD	ultra high definition
US	upstream
V	volt
VOD	video on demand

5.2. Definitions

access network	Utilized to transport information between a service provider and a plurality of users. Includes all active and passive equipment between the headend or hub and the demarcation point at the user premises.
downstream	Information flowing from the hub to the user
outside plant	Outside plant refers to all of the physical cabling and supporting passives (including cables, connectors, taps, cabinets, poles) and actives (including fiber nodes, remote PHY devices, remote MAC-PHY devices, amplifiers, line extenders) located between a demarcation point in a head-end or hub facility and a demarcation point in a customer premises.
upstream	Information flowing from the user to the hub

6. Overview and Methodology

6.1. Access Network Powering Methods

A typical hybrid fiber-coax (HFC) network powering diagram is shown in Figure 1. The AN contains devices such as nodes, amplifiers and Wi-Fi access points (APs) that require electrical power to operate. The electrical power is provided to the AN by line power supplies (LPSs), which convert electrical power from the power grid to a quasi-square wave 60 volt (V) or 90 V alternating current (AC) voltage to power the AN equipment. The current from the LPS is conducted by the passive and active equipment in the AN across distances that can range from several feet to several miles. Because of the resistance of the conductors in the AN, there is a voltage drop and power dissipation in the conductors as the current traverses the path to the active components that utilize the power to produce useful work.

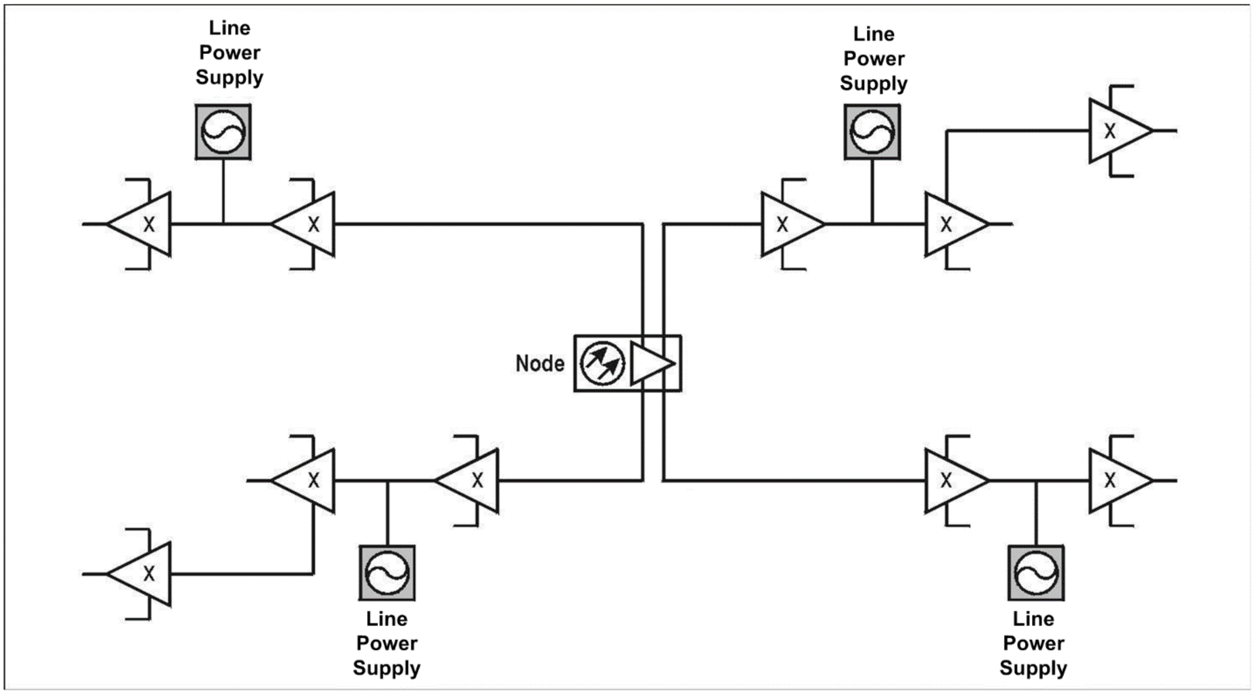

Figure 1 - Typical HFC Powering

Each active device in the AN contains a power supply to convert the AC voltage into useful direct current (DC) voltages for use inside the active device. To avoid confusion with the LPS, these power supplies inside the devices will be called the device power supply (DPS).

Electrical power is consumed in the LPS as heat because of inefficiencies, in the cable and other passive conductors as heat because of resistance, in the DPS as heat because of inefficiencies and in the actives devices as heat because of inefficiencies and to produce useful work.

6.2. Useful Work

The purpose of the AN is to carry information between the hub and the user. In general, this information consists of video, voice and data. For most of the history of television, the video content was carried as analog modulated radio frequency (RF) signals. However, most of the video in the AN today is carried as digitally modulated signals that contain the video information. All of the voice and data in the network is also carried as digitally modulated signals. Thus, all the "useful work" produced by the AN will be characterized in this document as the carriage of digitally modulated signals (representing digital bits) between the hub and user in both directions. If the AN contains any analog video, that carriage will be characterized by an equivalent amount of digital bits.

7. Requirements and Metrics

7.1. Consumed Bit

A consumed bit ***shall*** be defined as follows:

- In the downstream (DS), a consumed bit is a bit of information that is used by at least one user or device connected to the AN.
    - All data or telephony bits delivered to a user or device are defined as consumed.

  - All video on demand (VOD) or switched digital video (SDV) bits are defined as consumed.
  - Broadcast (BC) video bits are only defined as consumed if at least one CPE device connected to the AN is either displaying or recording the video bits. See Section 7.5 for the definition of a consumed broadcast channel.
- In the upstream (US), all bits are defined as consumed.
- Data overhead bits such as bits used in packet headers are considered to be consumed bits, because they are part of the information that is delivered to the user or device.
- Forward error correction (FEC) bits or other bits added to the data stream which are used to enable transmission across the access network ***shall not*** be considered to be consumed since the information is not delivered to the end user or device.

7.2. Consumed Bitrate

The consumed bitrate ***shall*** be defined as the rate of consumed bits per second (bps).

7.3. Energy Per Consumed Bit

Energy per consumed bit (EPCB) ***shall*** be defined as the total energy into the AN divided by the number of consumed bits. In the International System of Units (SI) derived unit joule, this would be expressed as joules/bit. However, in order to use units that are more meaningful to cable operators, the EPCB ***shall*** be reported in the units of kilowatt-hours per terabyte, expressed as kWh/TB, where:

- 1 kWh = 3,600,000 joules
- 1 byte = 8 bits
- 1 kWh/TB = 0.45E-6 joules/bit = 0.45 microjoules/bit

EPCB will be the fundamental metric to measure the efficiency of the AN. It relates the total amount of energy fed into the AN to the useful work done by the AN, which is the delivery of bits that are used (consumed).

It is beneficial to measure the EPCB at different locations in the AN like customer premise, outside plant or hub/headend to help determine areas of improvement. This will help determine energy shift as architecture changes. In addition, tracking kWh independent of the TB can provide value to compare month to month change and same geo locations.

7.4. Equivalent Analog Video Bitrate

For the purposes of computing EPCB, any analog video channel being carried by the AN ***shall*** be defined to have an equivalent bitrate of 3 megabits per second (Mbps). This equivalent analog video bit rate ***shall*** only be used in the EPCB calculation if the analog video channel is being consumed by at least one user connected to the AN.

7.5. Consumed Broadcast Channels

In order to calculate the number of broadcast channels that can be considered consumed, the average number of broadcast channels in use ***shall*** be calculated from available statistics from the video CPE devices. This average ***shall*** be representative of the number of broadcast channels being consumed across the times being used for the energy measurement. For instance, if the reported value is meant to represent the average EPCB of the network, the calculated number of consumed broadcast channels must be an average of all times of the day and week.

The calculation of consumed broadcast channels ***shall*** be performed for each type of broadcast video service. For the purposes of this calculation, the types of broadcast video services ***shall*** be partitioned by average bit rate. The most likely types are standard definition (SD) digital channels, high definition (HD) digital channels and analog video channels. However, other types such as UHD (ultra high definition) may be used if applicable. The bit rate of analog channels ***shall*** be determined as defined in Section 7.4.

For each type of broadcast service, determine the average number of viewed channels across the measurement time period and calculate the bytes transmitted during that time period as:

Bytes consumed = bit rate * # of viewed channels * 1/8 bit/byte * time in seconds

The number of bytes transmitted for each type of broadcast service ***shall*** then be added together to obtain the total bytes transmitted for all broadcast services.

8. Sample Calculation

8.1. Assumptions:

- Measurement period = 1 week
- HFC network power = 2700 watts
- SD bit rate = 3 Mbps
- HD bit rate = 12 Mbps
- Analog video broadcast channels viewed = 9
- SD average broadcast channels viewed = 22
- HD average broadcast channels viewed = 45
- HD VOD and SDV average channels viewed = 25

8.2. Energy Calculation:

- Total Power = 2.7 kW * 24 * 7 = 453.6 kWh

8.3. Consumed Bytes Calculation

- SD BC bytes consumed = 3E6 bps * 22 ch * 1/8 bit/byte * 604800 seconds
  = 5.0E12 bytes = 5.0 TB
- HD BC bytes consumed = 12E6 bps * 45 ch * 1/8 bit/byte * 604800 seconds
  = 40.8E12 bytes = 40.8 TB
- Analog BC bytes consumed = 3E6 bps * 9 ch * 1/8 bit/byte * 604800 seconds
  = 2.0E12 bytes = 2.0 TB
- HD VOD bytes consumed = 12E6 bps * 25 ch * 1/8 bit/byte * 604800 seconds
  = 22.7E12 bytes = 22.7 TB
- Cable modem termination system (CMTS) DS (measured) = 14.4 TB
- CMTS US (measured) = 1.5 TB
- Total terabytes consumed = 5.0 + 40.8 + 2.0 + 22.7 + 14.4 + 1.5 = 86.4 TB

8.4. Energy Efficiency Calculation:

- EPCB = 453.6 / 86.4 = 5.25 kWh/TB

9. Implications

This section will discuss some of the implications of the requirements and metrics defined by this standard and are informative only.

The AN has a capacity that is greater than the rate of consumed bits, however, that excess capacity serves no purpose when it is not being used. This excess capacity could be RF spectrum that has no carriers or it can be unused streams within a digital multiplex. Regardless of the form, if the bits either do not exist or are not being used, they are not counted.

Wi-Fi access points attached to the AN consume power but also provide bits to users. Those bits are counted as consumed bits. Thus, the addition of APs to the AN does not penalize the EPCB.

The EPCB can be improved in many ways. Some possible methods are:

- Higher efficiency LPS
- Lower resistive loss between the LPS and DPS
- Higher efficiency DPS
- Full utilization of RF spectrum in both the DS and US
- Maximization of the spectral efficiency of the RF carriers (maximization of bits per second per hertz)

10. Summary

The outside plant plays a vital role in the access network, by connecting the service provider to the customers. For most types of access networks, power is required to service this geographically diverse population of customers. By defining the performance of the network based on a watts-per-bit ratio a benchmark of energy consumption versus information delivered is established. Future measurements may be compared to this benchmark of access network performance and used to evaluate the impact of network changes over time.