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Energy Management Subcommittee

SCTE STANDARD

SCTE 216 2020

Adaptive Power System Interface Specification (APSIS™)

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1. Introduction

1.1. Executive Summary

The Adaptive Systems Interface Specification (APSIS™) is a method by which cable broadband providers can address and control energy management from an end to end perspective. The 2020 release contains updated references, reorganizes some content, and recognizes YANG data modeling as another device level protocol opportunity. The general idea behind APSIS is that power consumption should be reflective of demand. Figure 1identifies the components of the network and systems architecture being addressed by APSIS.

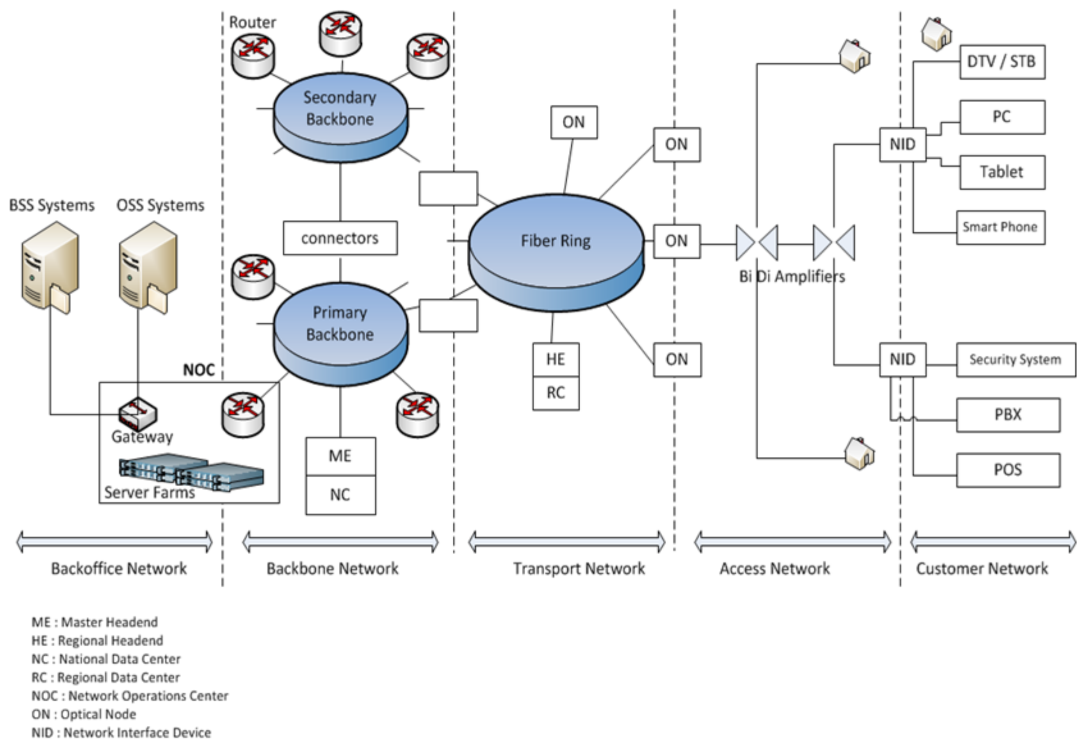

Figure 1 - Network Architecture

The cable network architecture described here provides context to segment devices into logical categories for the purpose of understanding software interfaces and interaction between components. The cable network is generally implemented in a hub-spoke topology, where network segments become more regionalized and numerous as we travel from left to right in the diagram. Network segments include:

The Back Office Network includes Business Support Systems (BSS) used to run operations including billing, customer relationship management, trouble management, and new customer acquisition and Operational Support Systems (OSS) which include inventory, provisioning, configuration, performance and fault management. Adaptive Power Applications will typically be implemented within this logical network segment.

The Backbone Network is comprised of content access and distribution systems, data centers, and other enterprise wide service delivery functions.

The Transport Network provides video, voice, and data service to local markets and includes head-end and hub facilities.

The Access Network serves the 'last mile' connecting the cable network to individual homes and businesses.

The Customer Network demarcation point is at a single point of interface to a home or business or at a device or devices within a home or business at which the service termination point resides. Examples of such demarcation points are Set Top Boxes (STBs), Cable Modems (CMs), embedded Multimedia Terminal Adapters (eMTAs), Media Gateways (MGs), Private Branch Exchange (PBXs), Point of Sale (POS) or any other similar Network Interface Devices (NIDs). Requirements pertaining to equipment residing in the Customer Network are not within the scope of this document.

1.2. Scope

This document is part of the work being done in SCTE's Standards Energy Management Subcommittee (EMS). The Adaptive Power System Interface Specification (APSIS) working group under the EMS is responsible for the creation and updates of this document. The document was developed for the benefit of the cable industry and includes contributions by cable operators, vendors and industry support organizations. While the initial intent of this document is to support the cable industry, the process, methodology and results of this effort may be applicable to other telecommunications networks.

Today's cable systems include broadband telecommunications infrastructure, including high-speed data services, digital telephony and other applications, and multi-channel video program distribution systems composed of highly specialized television distribution technology. This document specifies software interfaces to cable systems enabling a broad set of energy monitoring and management applications. Interfaces may be defined at the level of individual devices, collections of devices including an entire facility, and networks spanning multiple facilities.

Applications that influence service delivery in order to attenuate energy consumption are called adaptive power applications. The set of device and system level interfaces that support such applications are Adaptive Power System Interfaces.

The focus of this specification is to define interfaces within the domain of cable service delivery networks, including the cable 'plant', data centers, digital voice platforms, wireless platforms, and other communications and distribution electronics. An abstract information model is provided that defines a hierarchical structure for representing power related data and controls. The information model can be expressed in any number of specific protocols suitable for a specific environments Where the encoding format of information differs among protocols, the semantic definition is consistent. Interfaces will be defined for some number of device-level protocols, such as SNMP, YANG, or others. These interfaces are intended to complement definitions provided elsewhere that could allow a cable operator to obtain comprehensive visibility and control over their entire operations, including:

- The owned business enterprise networks (e.g., internal business networks, LANs, etc.)
- Operator facilities (e.g., HVAC, lighting, etc.)
- Interfaces to third parties (e.g., energy suppliers, other providers, demand-response managers, etc.)
- Interfaces to operator owned Customer Premises Equipment (CPE) (e.g., cable modem, set-top box, eMTA, etc.)
- Interfaces to energy consuming equipment owned by and located at a customer's and consumer's location (e.g., LCD TV, Wi-Fi Router, etc.)

Consumer Premise Equipment (CPE) are devices that deliver services within a customer's home or place of business and do not draw power from the service provider. APSIS does not directly address requirements of such equipment. However, a truly end-to-end energy management framework considers the impact of these devices on the service provider energy systems; for example, service provider applications on CPE can work in concert with logic within the network to optimize energy utilization within the network. Interface definitions between CPE and components within the service provider network may prove valuable in the future, although none are planned at this time.

The intent of this document is to identify the appropriate energy related data necessary to measure and manage energy consumption and define protocols used for the data exchange. This specification is intended to enhance business continuity and disaster recovery by optimizing the performance, availability, and reliability of cable networks, optimize expenditure on energy, and improve the Mean Time Between Failures (MTBF) and extend the useful life of components and equipment.

1.3. Benefits

Cable network operators continue to add customers to their broadband telecommunications networks and provide more services and data over those networks. These factors increase demand for power, and forecasts for utility power availability and cost show that energy management will become an important element in cost-effectively delivering services. Service provider goals addressed by energy management include higher customer satisfaction, more cost-efficient operations, lower energy costs, and rapid product deployment.

The supporting SCTE 245: Use Cases for Adaptive Power Using APSIS can be downloaded at the SCTE website.

1.4. Intended Audience

Cable broadband provider network engineers, power managers, cable provider network equipment manufactures and procurement mangers.

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

None at the time of 2020 publication.

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

- [EMAN YANG] Energy Management YANG model, https://www.scte.org/download-scteisbe-standards/

2.2. Standards from Other Organizations

- [IETF-EMAN-IM] Energy Management Framework, RFC 7326 https://datatracker.ietf.org/doc/draft-ietf-eman-framework/?include_text=1

- [IETF-EMAN-Object-MIB] Energy Object Context MIB, RFC 7461 http://datatracker.ietf.org/doc/draft-ietf-eman-energy-aware-mib/

- [IETF-EMAN-Power-MIB] Power, Energy Monitoring and Control MIB, RFC 7460 http://datatracker.ietf.org/doc/draft-ietf-eman-energy-monitoring-mib/

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 245 2018: Use Cases for Adaptive Power Using APSIS™ https://scte-cms-resource-storage.s3.amazonaws.com/Standards/SCTE%20245%202018.pdf

- SCTE 237 2017 Implementation Steps for Adaptive Power Systems Interface Specification (APSIS™) https://scte-cms-resource-storage.s3.amazonaws.com/Standards/ANSI_SCTE%20237%202017.pdf

3.2. Standards from Other Organizations

- [GR-3160-CORE] GR-3160-CORE, Generic Requirements for Telecommunications Data Center Equipment and Spaces http://telecom-info.telcordia.com/site-cgi/ido/docs.cgi?ID=SEARCH&DOCUMENT=GR-3160

- [GR-2930, NEBS] Telcordia GR-2930, NEBS: Raised Floor Generic Requirements for Network and Data Centers http://telecom-info.telcordia.com/site-cgi/ido/docs.cgi?ID=SEARCH&DOCUMENT=GR-2930&

- [TIA-942] TIA-942 Telecommunications Infrastructure Standard for Data Centers https://global.ihs.com/doc_detail.cfm?&item_s_key=00414811&item_key_date=860905&input_doc_number=tia%20942&input_doc_title=

- [ITU M.3010] ITU-T M.3010 Principles for a telecommunications management network http://www.itu.int/rec/T-REC-M.3010

- [IETF-EMAN] Energy Management Framework draft-ietf-eman-framework-16, https://datatracker.ietf.org/doc/draft-ietf-eman-framework/?include_text=1

3.3. Published Materials

- No informative references are applicable.

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

APSIS	Adaptive Power System Interface Specification	An end-to-end energy management standard and specification for cable telecommunications networks and associated interfaces.
API	Application Programming Interface	A programmatic interface used by business logic applications.
BSS	Business Support Systems	Systems that telecommunications providers use to run the operations of their business from a customer's perspective. Typical support systems include product management, order management, revenue assurance and management as well as customer management.
CAPWAP	Control and Provisioning of Wireless Access Networks	Standard, interoperable networking protocol that enables a central wireless LAN Access Controller (AC) to manage a collection of Wireless Termination Points (WTPs), more commonly known as Wireless Access Points.
CCAP	Converged Cable Access Platform	An access-side networking element or set of elements that combines the functionality of a CMTS with that of an Edge QAM, providing high-density services to cable subscribers.

CDN	Content Delivery Network	A system of computers on the Internet that delivers content transparently to end users
CM	Cable Modem	A modulator-demodulator at subscriber locations intended for use in conveying data communications on a cable television system.
CMTS	Cable Modem Termination System	An access-side networking element or set of elements that includes one or more MAC Domains and one or more Network System Interfaces. This unit is located at the cable television system Headend or distribution hub and provides data connectivity between a DOCSIS Radio Frequency Interface and a wide-area network.
COS	Classification of Service	Classification of network traffic within network equipment based on packet inspection
CPE	Customer Premises Equipment	Any piece of equipment that is owned or provided by the cable telecommunications operator and is located in a customer's home or business.
DACS	Digital Access Control Systems	A piece of circuit-switched network equipment used to control access to content in telecommunications networks
DHCP	Dynamic Host Configuration Protocol	Standardized network protocol used on Internet Protocol (IP) networks for dynamically distributing network configuration parameters, such as IP addresses for interfaces and services.
DNCS	Digital Network Control System	A piece of circuit-switched network equipment used to control access to content in telecommunications networks
DOCSIS	Data Over Cable Service Interface Specification	An international telecommunications standard that permits the addition of high-bandwidth data transfer to an existing cable TV (CATV) system.
DPI	Digital Program Insertion	Allows cable headends and broadcast affiliates to insert locally generated commercials and short programs into remotely distributed regional programs before they are delivered to home viewers
DTA	Digital Terminal (or Transport) Adapter	Digital television adapter (DTA), or digital-to-analog converter [set-top box], or commonly known as a converter box, is a television tuner that receives a digital television (DTV) transmission, and converts the digital signal into an analog signal that can be received and displayed on an analog television set.
DVR	Digital Video Recorder	Device or application software that records television programming in a digital format to a disk drive, USB flash drive, SD memory card, SSD or other local or networked mass storage device.

EMS	Element Management System	An element based system interface for monitoring and control of features and functions of a network.
EMS (SMS)	Energy Management Subcommittee	SCTE subcommittee tasked with the development of standards and operational practices impacting cable operator energy consumption.
eMTA	Embedded multimedia terminal adapter	Embedded Multimedia Terminal Adapter, a combination cable modem and telephone adapter
EPON	Ethernet Passive Optical Network	The use of a passive optical network is a common example of fiber to the home relying on less amplifiers commonly found in a coax plant and an arrangement for delivery of data over fiber to multiple (e.g. 32) customers sharing a common network data interface of 1Gbps or 10Gbps..
GigE/DWDM	Gigabit Ethernet	GigE = term describing various technologies for transmitting Ethernet frames at a rate of a gigabit per second (DWDM) = Dense wavelength division multiplexing of a variety of optical signals
GW	Gateway	A network node equipped for interfacing with another network that uses different protocols or on a different segment of the network
HBS	Home Security/automation Base Station	Central controlling device that enables manipulation of all the connected devices such as lights, thermostats, locks etc.
HDTV	High Definition Television	A physical device and service that provides a resolution and quality of picture that is substantially higher than that of standard definition televisions.
HFC	Hybrid Fiber Coax	A broadband bidirectional shared-media transmission system using optical fiber trunks between the headend and the fiber nodes, and coaxial cable distribution from the fiber nodes to the customer locations.
HTTP	Hyper Text Transfer Protocol	An application protocol for distributed, collaborative, hypermedia information systems
HTTPS	HTTP Secure	HTTP over secure socket layer (typically port 443)
HUB	Cable critical facility	Hub is a concept in network science which refers to a node with a multiple number of links ("heavily linked")
IETF	Internet Engineering Task Force	A body responsible for, among other things, developing standards used in the Internet.

IPDR	Internet Protocol Detail Record	Provides information about Internet Protocol (IP)-based service usage and other activities that can be used by Operational Support Systems (OSS) and Business Support Systems (BSS).
IPTV	Internet Protocol television	A system through which television services are delivered using the Internet protocol suite over a packet-switched network.
IRD	Integrated Receive/Decoder	Integrated receiver/decoder (IRD) is an electronic device used to pick up a radio-frequency signal and convert digital information transmitted in it.
IRTs	Integrated Receiver Transcoders	Provides MPEG-4 HD to MPEG-2 HD transcoding in a compact rack based unit.
IXPs	Internet Exchange Provider	An Internet exchange point (IX or IXP) is a physical infrastructure through which Internet service providers (ISPs) and Content Delivery Networks (CDNs) exchange Internet traffic between their networks (autonomous systems).[1
L2TP	Layer 2 Tunneling Protocol	L2TP is a tunneling protocol used to support virtual private networks (VPNs) or as part of the delivery of services by ISPs.
LDAP	Lightweight Directory Access Protocol	Lightweight Directory Access Protocol (LDAP) is an open, vendor-neutral, industry standard application protocol for accessing and maintaining distributed directory information services over an Internet Protocol (IP) network
LTRP	Laser Transmitter/Receiver Pair	The optical equipment located in the headend or hub serving the HFC access network comprised of a laser transmitter and receiver.
LWAPP	Lightweight access point protocol	Lightweight Access Point Protocol or LWAPP is the name of a protocol that can control multiple Wi-Fi wireless access points at once. It looks like there *may* be a mix-up on this line: LVI is not another name for LWAPP
MPEG	Moving Picture Experts Group	Coding of moving pictures and associated audio for digital storage media.
MTBF	Mean Time Between Failures	A measure that predicts the time between inherent failures of a system, equipment and/or component during its operational lifetime. Typically this is measured by the average time between failures.

MUX	Multiplexer	MUX, an abbreviation for multiplexer in circuit design or Mux, another name for Multiplex (TV)
NETCONF	Network Configuration Protocol	Network management protocol developed and standardized by the IETF. It was developed in the NETCONF working group and published in December 2006 as RFC 4741 and later revised in June 2011 and published as RFC 6241. The NETCONF protocol specification is an Internet Standards Track document. NETCONF provides mechanisms to install, manipulate, and delete the configuration of network devices. Its operations are realized on top of a simple Remote Procedure Call (RPC) layer. The NETCONF protocol uses an Extensible Markup Language (XML) based data encoding for the configuration data as well as the protocol messages. The protocol messages are exchanged on top of a secure transport protocol.
NIOS	Network Interface of Operator Supplied CPE	The customer side (northbound interface) demarcation point on the access network. In general, this is the connection point between the network cable (coaxial, Ethernet, etc.) and the CPE (set top box, cable modem, eMTA, etc.). The other demarcation point of the access network is the laser transmitter/receiver pair in the hub or Headend.
NMS	Network Management Systems	A combination of hardware and software used in conjunction to monitor and administer broadband telecommunications networks. Typical a NMS will interface with multiple Element Management Systems (EMS) that are focused on individual network elements or groups of related elements.
NOC	Network Operations Centers	A centralized location where the management and control of broadband telecommunications networks is exercised. NOCs can be centralized national centers or regionally focused points.
OSI	Open Systems Interconnect	OSI Model is a conceptual model that characterizes and standardizes the communication functions of a telecommunication or computing system without regard of their underlying internal structure and technology
OSS	Operations Support Systems	Typically network systems used by telecommunications providers to aid in the operation of networks including systems for inventory management, provisioning, configuration, performance and fault management.

OTT	Over The Top	Typically referred to as on-line delivery of audio and video without an Internet service provider being involved in the distribution, management or control of the content itself.
PBX	Public Branch eXchange	A telephone exchange for a business or office that makes connections from internal telephones of a private organization with the public switched telephone network.
POS	Point of Sale	A terminal composed of hardware and software that is used as an electronic cash register and serves as the device that records and transacts a sale.
PSTN	Public switched telephone network	Aggregate of the world's circuit-switched telephone networks that are operated by national, regional, or local telephony operators, providing infrastructure and services for public telecommunication.
QAM	Quadrature Amplitude Modulation	The format by which digital cable channels are encoded and transmitted via cable television providers.
RESTCONF	RESTful Configuration	An http RESTful API representation of a YANG model to serve as a functional equivalent of a NETCONF interface
SAN	Storage Area Network	A dedicated network that provides access to consolidated, block level data storage.
SCTE	Society of Cable Telecommunications Engineers	The technical and applied science leader for the cable telecommunications industry focused on providing technical solutions, programs and benefits for every level professional in the industry.
SDEM	Software Defined Energy Management	An element based management system with the expressed purpose of controlling the features and functions of network elements to monitor and control energy consumption, heat dissipation or other states.
SMS	Sustainability Management Subcommittee	The legacy subcommittee within the SCTE standards program that was responsible for identifying standards and best practices for reducing power consumption and costs, increasing operating efficiency and minimizing disposal effects of outdated equipment. Replaced by Energy Management Subcommittee in 2014.
SNMP	Simple Network Management Protocol	A network management protocol of the IETF.
STB	Set-top box	An information appliance device that generally contains a TV-tuner input and displays output connections to a television set and an external source of signal, turning the source signal into content in a form that can then be displayed on the television screen or other display device.

TBEC	Transaction Based Energy Control	A systems based dynamic model to reduce energy consumption on and through elements provisioned throughout a telecommunications network that is correlated to predicted or real-time traffic demand.
TFTP	Trivial file transfer protocol	A simple, lock-step, File Transfer Protocol which allows a Client (computing) to get from or put a file onto a remote Host (network).
VLANS	Virtual Local Area Network	A single layer-2 network partitioned to create multiple distinct broadcast domains, which are mutually isolated so that packets can only pass between them via one or more routers. A VLAN has the same attributes as a physical local area network (LAN), but it allows for end stations to be grouped together more easily even if they are not on the same network switch
VOD	Video on Demand	Systems which allow users to select and watch/listen to video or audio content when they choose to, rather than having to watch at a specific broadcast time. IPTV technology is often used to bring video on demand to televisions and personal computers.
VPN	Virtual Private Network	Virtual private network extends a private network across a public network, such as the Internet. It enables a computer or network-enabled device to send and receive data across shared or public networks as if it were directly connected to the private network, while benefiting from the functionality, security and management policies of the private network.
WAPs	Wireless access point(s)	Wireless access point, a device that allows wireless devices to connect to a wired network.
YANG	Yet Another Net Generation	A data modeling language used to describe network entities, their capabilities, and properties.

5.2. Definitions

Access Network	The last portion of the network wherein telecommunications signals are transmitted to customers to provide broadband services. Typically the maximum distance of the access network is 15 miles.
Backbone	The portion of a cable network infrastructure that interconnects multiple portions of the network and networks in various locations. The backbone also connects facilities where the subtending networks exist.
Data Center	Facilities that house telecommunications, computer and storage systems in support of the broadband telecommunications network.
Edge QAM	A headend or hub device that receives packets of digital video or data. It re-packetizes the video or data into an MPEG transport stream and

	digitally modulates the digital transport stream onto a downstream RF carrier using quadrature amplitude modulation (QAM).
Energy management:	The coordination of processes and technologies implemented to reduce or optimize energy end-use, operate efficiently, ensure the availability and quality of energy, and identify environmentally responsible, cost effective, efficient and sustainable energy sources with an emphasis on maximizing facility and/or system output.
Headend	A facility for receiving voice, video, data and other telecommunications signals for processing and distribution over the network. Typically these facilities distribute signals out to end customers or smaller hubs. A smaller, more regionally focused facility providing similar functions as a Master Headend but serving smaller populations of customers and network locations.
Master Headend	A master facility for receiving voice, video, data and other telecommunications signals for processing and distribution over the network. Typically these facilities are centrally located in a region and distribute signals out to smaller Headends.
National Distribution Centers	Locations in a broadband telecommunications network where centralized content and service origination occurs for the purpose of distributing and making such content available to customers throughout the network.
Transport Network	A portion of the broadband telecommunications network that connects a backbone to the access network. Multiple facilities *may* reside on the transport network.
Wi-Fi	A data communications technology (based on IEEE 802.11 standards) that allows an electronic device to exchange data wirelessly over a computer network, today usually over a broadband high-speed Internet connection.
YANG	A data modeling language for the NETCONF network configuration protocol

6. Energy Management Network Topology (Informative)

This section describes the components within each segment of the cable system described in section 1.1. The purpose of this section is to provide an inventory of the devices typically found in each network segment to provide context for device manufacturers and service operators. The devices identified here do not represent a comprehensive definition of the specific components within any given cable network segment. Many devices found in a cable system are generally computing devices that support energy management protocols defined elsewhere, such as [GR-3160-CORE], [GR-2930, NEBS], [TIA-942]. Other devices are more cable specific and are subject to APSIS defined protocols.

6.1. Back-office Network

The cable back-office is composed of generic computing systems and is included in our discussion to provide context as the locus for APSIS applications that interface with components within other segments of the system.

6.2. Backbone Network

This section will describe the backbone network including the devices, existing and needed measurement information, interfaces and associated requirements as well as control and communications capabilities.

The demarcation points of the backbone network are the northbound and southbound interfaces of the router interfaces (GigE/DWDM) that connect the backbone network to different facilities, networks and Interexchange Points (IXPs).

6.2.1. National Distribution & Data Centers

From an energy management perspective National Distribution Centers are similar to a general purpose data center in many ways. Yet, unlike traditional data centers they contain cable specific equipment such as purpose-build video processing systems. Also, cable specific systems such as satellite earth stations, located outside the physical building, require unique energy management.

A traditional data center is a purpose-build facility design to house any number of servers and associated networking equipment. The facilities are comprised of numerous seven foot racks of equipment laid out in rows. The dominant equipment in the racks are general purpose servers comprised of integrated compute, storage and I/O resources. A range of networking equipment and video-specific equipment are also collocated in the data center.

6.2.1.1. Server & Storage Equipment

1) Servers
   a) Rack mount computing devices consisting of CPU, Memory, Internal Storage and I/O
2) Storage Area Networks
   a) A storage area network (SAN) is a dedicated network that provides access to consolidated, block level data storage. SANs are primarily used to enhance storage devices, such as disk arrays, tape libraries, and optical jukeboxes, accessible to servers so that the devices appear like locally attached devices to the operating system. A SAN typically has its own network of storage devices that are generally not accessible through the local area network by other device.

6.2.1.2. Network Equipment

3) Ethernet Switches
   a) An Ethernet switch is a multi-port network bridge that processes and forwards data at the data link layer (layer 2) of the OSI model.
4) IP Routers
   a) Layer 3 IP Routers forward IP Packets among the internal network of the data center to the outside network for voice, video and data communications.
5) Load Balancers
   a) Load balancing is a computer networking method for distributing workloads across multiple computing resources, such as computers, a computer cluster, network links, central processing units or disk drives. Load balancing aims to optimize resource use, maximize throughput, minimize response time, and avoid overload of any one of the resources. Using multiple components with load balancing instead of a single component may increase reliability through redundancy.
6) Appliances (e.g., DPI, Firewalls, VPN Gateways, et al)
   a) A network appliance is a separate and discrete hardware device with integrated software (firmware), specifically designed to provide a specific computing resource. These devices became known as "appliances".

   b) Examples include: DPI (Deep Packet Inspection), Security (e.g., Firewall), Session Border Controllers

6.2.1.3. Video Specific Equipment

7) Video on Demand (VOD) servers
   a) Servers, as described above, focused on storing very large amounts of video titles as associated trick files.
8) Video ingest devices
   a) These devices accept input from video sources and store them in the appropriate format for delivery.
9) Content Deliver Network (CDN) caches
   a) CDNs, in general, distribute video assets, typically the most popular, closer to the edge of the network or closer to the consumers. The cache sub-system of a CDN is comprised of a large storage system.
10) Video Transcoding systems
   a) These devices, often specialized hardware and software systems, ingest video in one format and transcode it to one or more alternative formats for distribution to multiple devices. (E.g., MPEG2 to MPEG4)
11) IRDs (Integrated Receive/Decoder)
   a) The IRD used for the reception of contribution feeds that are intended for re-broadcasting. The IRD is the interface between a receiving satellite dish and the broadcasting facility video/audio infrastructure.
12) Ad Insertion Systems
   a) These systems allow an MPEG (Moving Picture Experts Group) transport stream to be spliced into a currently flowing MPEG transport stream seamlessly and with little or no artifacts. The controlling signaling used to initiate an MPEG is referred to as an SCTE35 message. The communication API between MPEG splicers and Content Delivery Servers or Ad Insertion Servers is referred to as SCTE30 messages.

Due to the business-critical nature of data centers these facilities are designed for high-availability ranging from 99.67% to 99.995%. To ensure continuous operation, these facilities often include power back up systems such as redundant grid connections, local power generators (e.g. diesel) and extensive batteries arrays. The latter of which imposes significant environment challenges particularly in disposal.

6.2.1.4. 6.2.1.4.Data Center Energy Management

Energy management of data centers has been identified as a major concern for cable operators. The density of equipment demands extensive and complex cooling systems. These systems consume approximately 33% of electricity of the data center. To address this there are numerous industry initiatives focused on energy efficiency in the data center. Examples of emerging techniques for energy management within data centers include:

- “Hot” and “cool” aisles with row-by-row cooling,
- Changing to high efficiency AC (240V) or high voltage DC and
- Fresh air cooling are examples of solutions being discussed

6.3. Transport Network

This section describes the transport network segment of the cable system, including headend and hub facilities.

Figure 2 illustrates the structure of the transport network.

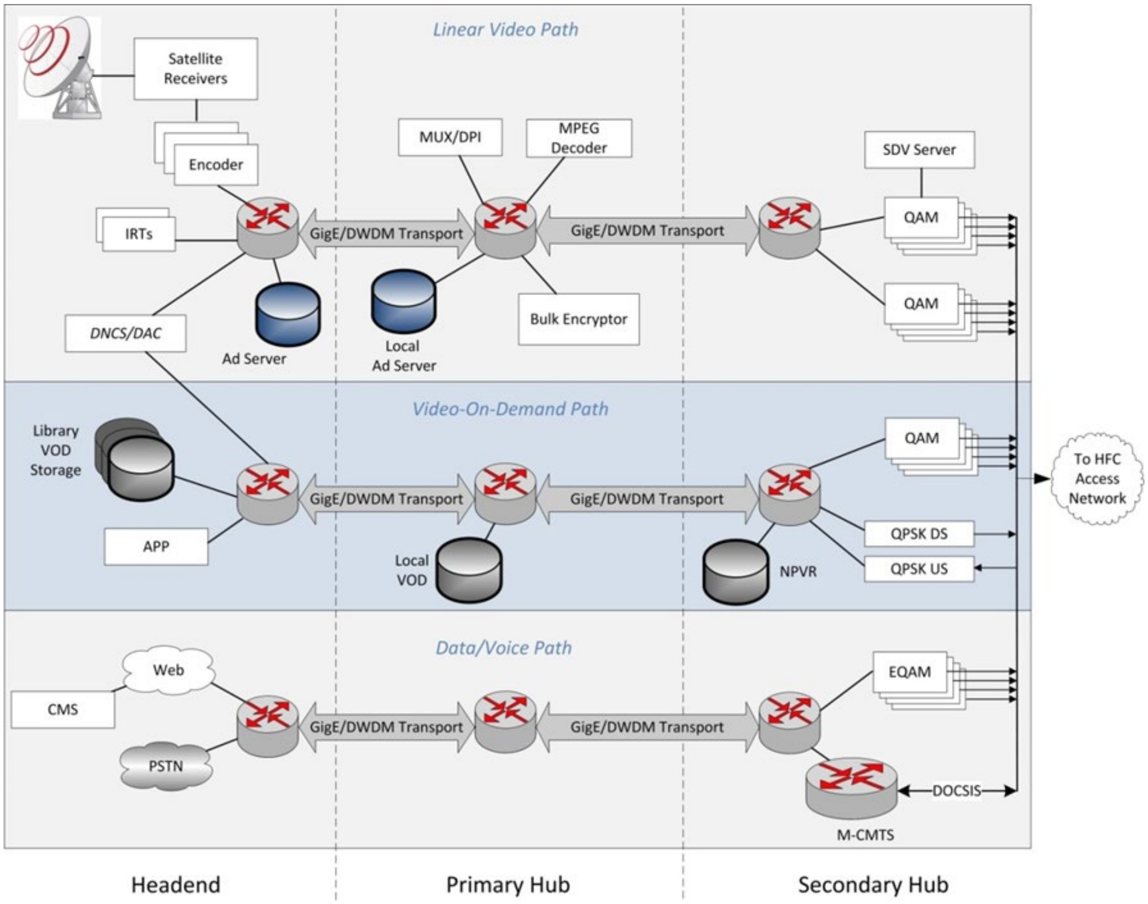

Figure 2 - Transport Network Headend and Hubs

There are multiple configurations and definitions for headends and hubs and these facilities can serve multiple purposes. This document will refer to three typical configurations of headends or hubs. These configurations can be visualized starting from the HFC network at the LRP in a secondary hub up through a transport network to the primary hub and on to the headend.

The secondary hub has demarcation points of the LRP which provides connectivity to the HFC network and the northbound router interface (GigE/DWDM) that connects the secondary hub to the transport network. Demarcation points for the primary hub are the southbound router interface (GigE/DWDM) of the transport network that connects to secondary hubs and the northbound router interface (GigE/DWDM) that connects the primary hub to the transport network to connect to the headend. The demarcation points of the headend are the southbound router interface (GigE/DWDM) connecting to the transport network towards the primary hub and numerous interfaces on the northbound side. Interfaces included are and not limited to: satellite receivers, public switched telephone network (PSTN) gateways, customer services equipment such as VOD servers, DNCS, Internet and advertising servers, etc.

The cable transport network segment typically includes the following device types:

- Satellite Receivers: Generally there is a single set of satellite receivers for a market or region. Some cable companies are moving more toward a terrestrial distribution over a fiber backbone.
- Encoders: Encoders take the information that comes off of the satellite and puts it into a compressed format (MPEG) for distribution over the local transport.
- IRTs: Integrated Receiver Transcoders have the ability to encode and decode, for example MPEG 4 HD to MPEG 2 HD video.
- Ad servers: The Ad servers are video servers that contain commercials that will be inserted into television programs.
- DNCS/DACS: The Digital Network Control System and Digital Access Control System are aspects of the cable headend that manage the customer authentication and flow of information to and from the set top box.
- MPEG Decoders: Hub equipment that decodes the video stream coming from the headend to allow for manipulation of the video stream including but not limited to ad insertion.
- MUX/DPI: Multiplexor/Digital Program Inserter device pulls ads from the ad insertion database and seamlessly inserts them into the video flow coming from the headend.
- Analog Modulators: Devices for putting analog signals on a carrier frequency.
- QAM Modulators: Devices used to provide a modulation scheme that transmits data by changing the amplitude of two carrier waves. The two carrier wave signals are out of phase with each other by 90 degrees on the cable wire.
- Bulk Encryptions: Process of encrypting large numbers of circuits at once after content has been multiplexed.
- Library VOD Storage: VOD storage in the master headend, this may be the source of the video content or may be a caching server for video from a main data center.
- Local VOD Storage: VOD Storage located at the hub site; this is a caching server that stores video files to mitigate network congestion.
- SDV Server: Device responsible for switched digital video broadcasting to the scriber over the cable medium. Switched video sends the digital video in a more efficient manner so that additional uses may be made of the freed up bandwidth. The scheme applies to digital video distribution both on typical cable TV systems using QAM channels, or on IPTV systems. Users of analog video transmitted on the cable are unaffected.
- Edge QAM: Device located in a hub vs. headend or datacenter that is used to provide modulation scheme that transmits data by changing the amplitude of two carrier waves. The two carrier wave signals are out of phase with each other by 90 degrees on the cable wire.
- CCAP: Converged Cable Access Platform (not illustrated). As cable systems evolve, data, linear, and on-demand video may all be delivered over a single device. CCAP will be responsible for increased QAM channel density, lower power requirements and reduced headend footprints on a consolidated piece of cable hardware.
- DAA: Distributed access architecture (not illustrated) enables the evolution of cable networks by decentralizing and virtualizing headend and network functions. DAA replaces analog fiber with IP connections (digital fiber) and creates a software-defined network that supports: Node evolution with remote PHY and remote MAC-PHY.
- GAP: Generic Access Platform (not illustrated) is a modular and configurable node.

6.4. Access Network

This section describes the Access Network.

The Access Network is illustrated in Figure 1– Network Architecture.

In the access network the demarcation points are the Network Interface of Operator Supplied customer premises equipment (NIOS) and the Laser / Receiver Pair (LRP) in the hub or headend. The NIOS interface is the physical interface of any operator supplied CPE or customer supplied CPE that is used to access services from the operator and the cable connecting to the CPE. Examples of CPE include but are not limited to:

- set top box (STB), digit video recorders (DVR)
- digital transport adapters (DTA)
- cable modems (CM)
- embedded multimedia terminal adapters (eMTA)
- home gateways (GW)
- home security/automation base stations (HBS)

Examples of the cable interfacing to the CPE include, but are not limited to: coaxial cable, category 5 cable, Wi-Fi transmitter and category 3 cable. The Laser Transmitter/Receiver Pair (LTRP) interface is the southbound interface in the access network that is found in the headend or hub. It comprises of the laser transmitter/receiver pair to provide optical transmission and receipt of communications signals to and from end users through the access network. This is the last piece of equipment the signals transit through in the headend or hub.

The cable Access Network segment typically includes the following device types:

- Upstream and Downstream Lasers: These systems drive the signal over the fiber portion of the hybrid fiber coax network.
- Fiber Node: The fiber node is the device that performs the optical to RF conversion and vice versa in the access portion of the network.
- Amplifier: Active and passive amplifiers drive the signals on the coaxial portion of the hybrid fiber coax network.
- Power Supplies: Devices that supply power to the hybrid fiber coax network and specifically provide power to the active elements in the network.
- There are three possible adaptive modes in which the access network may operate. All three areas focused on the fiber portion of the hybrid fiber coax network.

(i) Reverse/Automated Node Split: In many cable systems there have been a series of node splits such that many fiber portions connect to their respective coax cable runs at the same node location. Due to the built-in multiplexing functionality of the upstream and downstream laser systems an automated combining of signals to different coax runs should be able to be accomplished at times of low data or low “on demand” video usage. In this case a multi laser system may be able to shut down multiple lasers to save power. It is anticipated that this shut down would occur during the middle of the night. Since laser systems are not aware of the load there must be information coming from the data (CMTS), video (DACS/DNCS) or combined (CCAP) systems that can measure the load on the systems.

(ii) Burst Mode: Amplifiers in the node, that drive the upstream and downstream lasers are currently assumed to operate in a steady state. Depending on the traffic load, especially upstream traffic may justify putting the amps and lasers in a burst mode so they are only pulling appreciable power when there is an active signal. It is believed that the amps themselves would sense the burst and react appropriately.

(iii) Reduction in Bandwidth: Many cable systems have expanded the active bandwidth of the cable plant, up to 750 MHz.; to drive signal in the higher frequency portion of the spectrum requires higher bias current. If the load of a downstream is reduced at off peak hours then the biased current can be reduced. As with the first solution it is expected that information from the CMTS, DACS/DNCS, or CCAP would be needed to inform that systems of the reduced offered load. If is anticipated that during brownouts, this system could be used to offer “critical” channel on diminished cable system.

6.5. Customer Network

As indicated in section 1.1, the customer network is not in scope for this document.

7. Wireless Network Overview

Figure 3 illustrates a high-level reference architecture for a wireless network. Note that the access network is on the left and the back office is on the right, as opposed to our reference diagram for the service provider network in Figure 1.

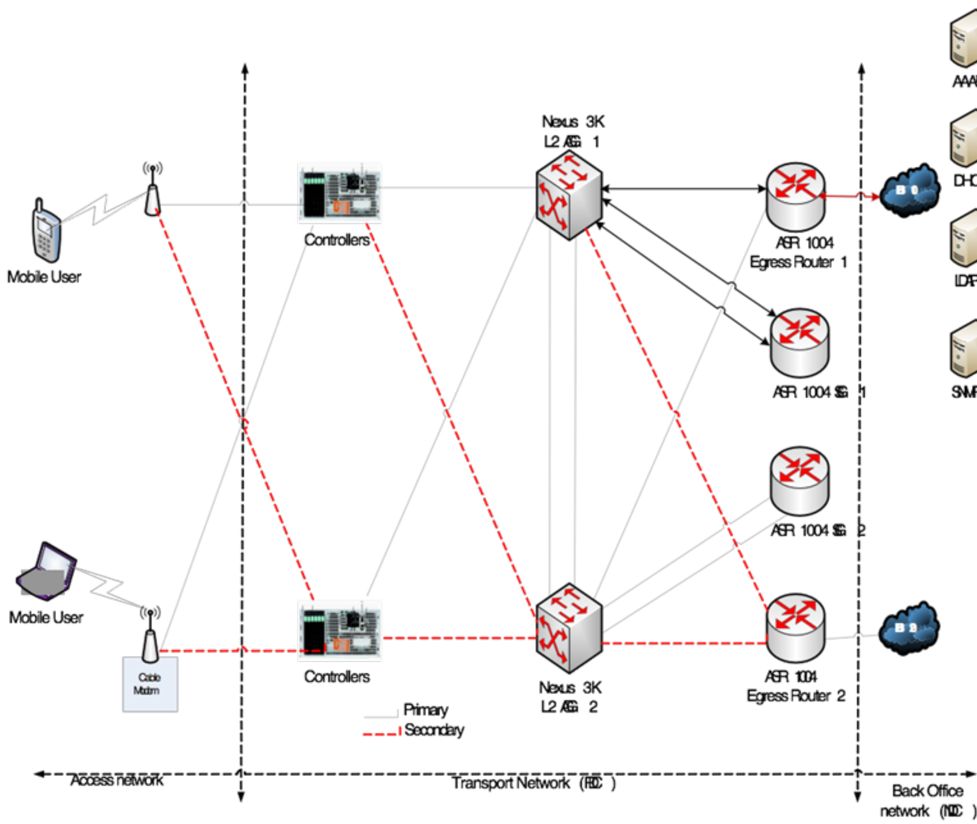

Figure 3 - Wireless Network Architecture

The Wi-Fi network architecture consists of several elements as seen in the above figure.

All the elements in the regional & national data centers have two units for the same network element (Switch, ISG, AAA) one serving as primary and the other as secondary. The secondary units don't carry any user traffic until there is a failure on the primary network elements. The amount of power consumed on secondary elements and failures in data centers in wireless architecture can be saved by introducing new power savings techniques.

Below is the description of few elements in Wi-Fi Architecture:

- Access network: This generally consists of Wireless Access Points (WAPs) and underlying backhaul transport (DOCSIS, Ethernet, and EPON). The access network provides the end user connectivity for wireless subscribers using 802.11 a/b/g/n/ac standards. Any failure in the access network will cause the clients to be disassociated from the network.

- WAP: Wireless access point is a device that allows wireless connections when connected to a router/L3 switch over a wired network The 802.11 standard protocols allows the wireless clients to connect to the access point over the air and the transport of the traffic is passed through a tunnel formed between the WAP and controllers. Tunnel types that are commonly used in today's Wi-Fi architecture are CAPWAP, LWAPP, L2TP and others.
- Cable Modem (CM): The wireless access point connects to the cable modem using either embedded or external versions. The cable modem acts as a layer 2 bridge and receives IP connectivity from CMTS after successful registration. During the initial boot up stage configuration files are pushed to the CM from CMTS for various parameters like bandwidth, COS, IP connectivity & provisional codes. Any failure in the cable modem will cause the access point to be disassociated from the network.
- Failures in the access network will prevent client authentication, which in turn will prevent access to network resources. Power saving techniques will be relatively complex as each vendor supports different protocols for transport.
- Regional data Center: Generally consists of aggregation switches, controllers & routers. Serves as a back bone to the network to provide IP connectivity to the clients, session management & policy enforcement. Controllers are used to manage all the access points within the same network. Access points establish a tunnel (via vendor proprietary protocol) with the controller and get provisioned before going online. Due to varying tunnel implementation procedures between vendors, proper designs need to be considered to pass the traffic from the access point controller to the upstream aggregation network.
- The Wi-Fi aggregation module forwards user traffic between various parts of the access network and the transport network. VLANS are created on the aggregation switches to reduce the broadcast domains and to minimize security issues.
- Policy enforcement routers: The functionality of this module is to check whether the user traffic is authenticated and authorized to use specific network services. User credentials and the MAC address of the end user are used as part of authentication process. Subsequent authentication methods are possible by using external radius servers (AAA) or an external portal page. These devices support all the routing capabilities within the network and with specific licenses can also provide Network Address Translation (NAT) to Wi-Fi clients to saves public address space. Traffic counts of the clients, bytes transmitted, bytes received, IP address changes, connection duration and changes in service type can be monitored when the user is connected to the network.
- Failures in the regional data center result in client connectivity issues leaving users unable to browse the internet.
- National Data Center: Generally consists of Radius Servers, LDAP, DHCP, TFTP & SNMP manager. All the clients are authenticated and authorized using the radius servers. The function of these servers is to perform Authentication, Authorization and Accounting (AAA). The AAA server generally receives access request from a NAS client with specific AVPes (username, password, calling- station ID and called – station ID etc.). If all the attributes sent by the NAS client are acceptable, AAA sends an access – accept message that includes service types for the users.
- Lightweight Directory Access Protocol (LDAP): - LDAP is a directory that creates and stores subscriber information. AAA acts as a proxy to verify the credential validation of the subscribers using LDAP.
- Dynamic Host Configuration Protocol (DHCP) server: DHCP servers are used to provide IP dynamically to all the cable modem and wireless clients associated with the WAP.
- Trivial File Transfer Protocol (TFTP) server: WAPs obtain TFTP server information from the CM DHCP offer message. WAPs connect to the TFTP server for script update or configuration changes.

- Simple Network Management Protocol (SNMP) manager: The function of this machine is to gather all the information from the SNMP agents using OIDS regarding the CPU/memory utilization, link up/down and power failure issues.
- Any failure in the NDC will cause the client to be in an unauthenticated state and disallowed from using Wi-Fi services.

7.1. Reference Power Levels for Wireless Network and System Architecture

7.1.1. Power Specifications

Table 1 - Power specification of typical access points

Model	AC Power	DC Power	Power Draw
Outdoor	40 - 90 V AC	40-50 V DC	10W standby mode 60W (with Heater and PoE output Enabled 25W (with Heater and PoE output Disabled)
Indoor	110 -240 V AC	Power over Ethernet and 12V DC	12.95W (PoE), 12W-15 W (12V DC)

Table 2 - Power specifications of typical access point controllers

Model	AC Power /Current	DC Power/Current	Power Supplies
Controllers	50/60 HZ,100 - 127VAC/ Max Current 8.9A 200-240VAC /Max Current 4.5A	48-60VDC/Max Current 20.5A	Dual, Hot swappable DC (or) AC Power Supplies

Table 3 - Power specification of a switch

Model	Specification	300W AC	300W DC
Switch	Input Current	4A at 100V	8A @ -40.5 to -75VDC
	2A at 240V	8A at -48 to -60V	-
	Output Current	25A at 12 VDC	25A @ 12 VDC

Table 4 - Power specification of a policy server/intelligent serving gateway (ISG)

Model	AC Power /Current	DC Power/Current	Power Supplies
Policy Routers	Worldwide ranging AC (85 to 264V; 120 or 240V; 60 or 50 Hz nominal)/960W	Worldwide ranging DC (-40.5 to -72: -48V nominal)/1020W Maximum out 760W	Dual power supply supported. Either AC (or) DC

Table 5 - ETE network elements in Wi-Fi architecture

Network Element	Access Network/Quantity	RDC/Quantity	NDC/Quantity	Priority	Adaptive Power Management	Power Measurement		
						Full Load	50% Load	No Load
Access Point Vendors -Vendor A -Vendor B -Vendor C	*y*/based on locations (few thousand's)	*x*	*x*	one	*x*	-Indoor Access points 12-15W -Outdoor Access points 25-30W	TBD	TBD
Wireless Controllers -Vendor A -Vendor B -Vendor C (LNS)	*x*	*y*/2 per each vendor	*x*	five	*x*	100-125W	TBD	TBD
Aggregration Switches -Vendor A	*x*	*y*/2 per each Core (Primary & Secondary)	*x*	six	*x*	199-455W	TBD	TBD
Policy Servers -ASR 1K	*x*	*y*/6 per each Core	*x*	seven	*x*	950-1050W	TBD	TBD
Radius Servers -ALU 8950	*x*	*x*	*y*/2 per each NDC	eight	*x*	750-800W	TBD	TBD
Mail Directories	*x*	*x*	*y*	eleven	*x*	TBD	TBD	TBD
Enterprise Service Directories	*x*	*x*	*y*	ten	*x*	TBD	TBD	TBD
DHCP Servers	*x*	*x*	*y*	three	*x*	TBD	TBD	TBD
TFTP Servers	*x*	*x*	*y*	four	*x*	TBD	TBD	TBD
Portal Servers	*x*	*x*	*y*/NetNearU Hosted	nine	*x*	TBD	TBD	TBD
Back Bone	*x*	*x*	*y*	two	*x*	TBD	TBD	TBD

Note: *x* = Non-Supported; *y* = Supported

Table 5 represents various network elements in an end to end Wi-Fi architecture. 90% of the existing elements in today's architecture do not support adaptive power management techniques. Some access point manufacturers support a feature in the wireless LAN controllers that disables the radios of the access points during off peak hours to save the power consumption thereby reducing power requirements and operating expenses.

The number of access points in an access network will be based on the population density and existing customers in those areas. 60-70% of the power consumed in a wi-fi architecture is due to the access points. An average 7 to 15W power consumption can be saved in an access point when both the radios are turned off during off peak hours. Table 6 below depicts an average estimate of the power saved using adaptive power management in access points.

Table 6 - Power saved by using APSIS

Number of Access points	Power consumed when both radios are on	Power consumed when both radios are off	estimated savings in power requirements
500 (indoor)	7500 W	3500 W	4000 W
500 (Outdoor)	15000 W	10000 W	5000 W
5000 (Indoor)	75000 W	35000 W	40000 W
5000 (outdoor)	150000 W	100000 W	50000 W

Note:

- Power consumed for an indoor unit when both radios are turned on is estimated at 15 W
- Power consumed for an indoor unit when both radios are turned off is estimated at 7 W
- Power consumed for an outdoor unit when both radios are turned on is estimated at 30 W
- Power consumed for an outdoor unit when both radios are turned off is estimated at 20 W

8. Communications Protocol & Control

The focus of this section will be on element and systems communications as described below.

8.1. Communications Reference Architecture

Figure 4 illustrates the APSIS Communications Reference Architecture

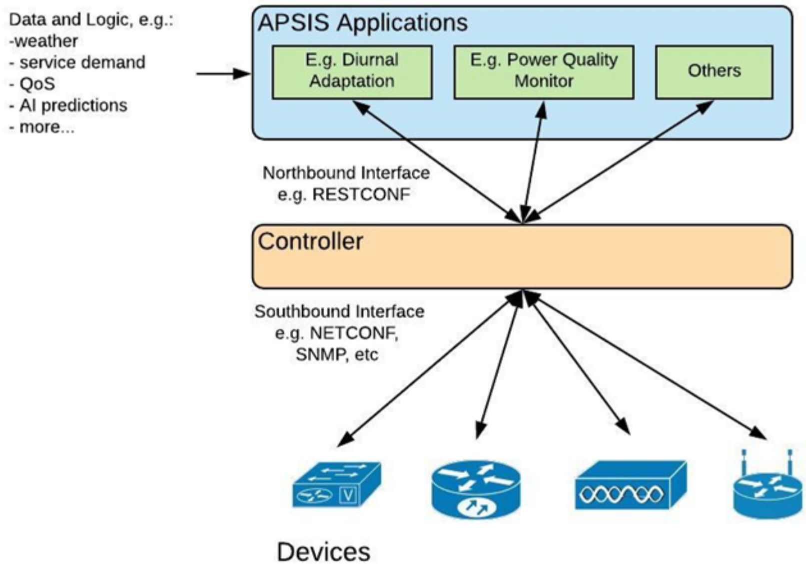

Figure 4 - APSIS Communications Reference Architecture

The APSIS communications reference architecture is derived from a more generalized Telecommunications Management Network as described in [ITU-T M.3010]. It is composed of devices that inhabit the network element domain, a data communication network, and any number of APSIS applications. The network element layer is composed of physical devices and represents all of the devices residing within the cable network reference architecture described in Sections 1.2.1 and 6. The communications layer may be composed of any number of data transport protocols, e.g. HTTP, IPDR, SNMP, NETCONF, etc. APSIS applications interface with network elements over the communications layer. APSIS applications interface with an individual or groups of network elements or sections of a network and implement service provider policies.

Typically, a 'controller' function handles the device-level protocol interactions and presents data or application programming interfaces (APIs) to applications, thus relieving applications of duplicating often complex logic.

8.1.1. Information Model

A logical definition of data entities and their associations forms a part of this specification. The information model serves to describe devices and systems in a protocol agnostic manner, such that a multitude of encodings can be transformed into a single logical representation. Any given device that conforms to this specification shall support one or more defined protocol, such as SNMP or other. Each of these protocols will define a unique binary encoding of the Information Model.

The APSIS information model is defined by the IETF as described in [IETF-EMAN-IM]

8.1.2. APSIS Protocols

· SNMP: Implementers of the APSIS specification that support the SNMP protocol shall comply with the definitions provided by the IETF as described in [IETF-EMAN-Object-MIB] and [IETF-EMAN-Power-MIB]

APSIS device level protocols currently under consideration include:

- IPDR Internet Protocol Detail Record: This high-performance interface is widely utilized in the cable industry, predominantly as a communications mechanism with CMTSs. This interface will be an option for monitoring-only of devices. A future version of the SCTE APSIS document, or an extension may provide a definition of an IPDR Service Definition that conforms to the information model.
- TR-069: This protocol is commonly used by consumer devices but is also relevant for the cable plant. A future version of the SCTE APSIS document, or an extension may provide a definition of a profile that conforms to the Information Model. See [TR-069]
- NETCONF Network Configuration Protocol: This protocol is becoming increasing relevant in the cable plant. NETCONF interfaces utilize the YANG (Yet Another Next Generation) data modeling language. While the NETCONF protocol supports device level, session-based communications, a corresponding RESTCONF API can also be generated from a YANG model, offering a more common http RESTful API to applications. Figure 4 illustrates a general case which when applied to NETCONF this scenario the Southbound NETCONF interface can be reflected in a functionally equivalent Northbound RESTCONF interface. See [RFC 6241], [YANG], [EMAN YANG].

9. Conclusion

As networks become more virtualized, cable operators are able to reap the benefits of adaptive power, SCTE 216 provides that framework and in turn, enable energy cost avoidance as well as potentially deferring equipment failure by keeping onboard electronics optimized for service delivery. Cable broadband providers can not only retrieve data but to also take system level actions resulting in dynamic and adaptive power savings. SCTE-216 helps the operating bottom line AND help reduce carbon footprint wherever possible as energy use and carbon are closely related. In summary, this document along with the informative APSIS references mentioned in section 3 provide a solid framework for cable operators to significantly address in a systematic way, the possibility of excess energy use across cable broadband networks.