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Energy Management (EMAN) Applicability Statement

Abstract

The objective of Energy Management (EMAN) is to provide an energy management framework for networked devices. This document presents the applicability of the EMAN information model in a variety of scenarios with cases and target devices. These use cases are useful for identifying requirements for the framework and MIBs. Further, we describe the relationship of the EMAN framework to other relevant energy monitoring standards and architectures.

Status of This Memo

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1. Introduction

The focus of the Energy Management (EMAN) framework is energy monitoring and management of energy objects [RFC7326]. The scope of devices considered are network equipment and their components, and devices connected directly or indirectly to the network. The EMAN framework enables monitoring of heterogeneous devices to report their energy consumption and, if permissible, control. There are multiple scenarios where this is desirable, particularly considering the increased importance of limiting consumption of finite energy resources and reducing operational expenses.

The EMAN framework [RFC7326] describes how energy information can be retrieved from IP-enabled devices using Simple Network Management Protocol (SNMP), specifically, Management Information Base (MIB) modules for SNMP.

This document describes typical applications of the EMAN framework as well as its opportunities and limitations. It also reviews other standards that are similar in part to EMAN but address different domains, describing how those other standards relate to the EMAN framework.

The rest of the document is organized as follows. Section 2 contains a list of use cases or network scenarios that EMAN addresses. Section 3 contains an abstraction of the use case scenarios to distinct patterns. Section 4 deals with other standards related and applicable to EMAN.

1.1. Energy Management Overview

EMAN addresses the electrical energy consumed by devices connected to a network. A first step to increase the energy efficiency in networks and the devices attached to the network is to enable energy objects to report their energy usage over time. The EMAN framework addresses this problem with an information model for electrical equipment: energy object identification, energy object context, power measurement, and power characteristics.

The EMAN framework defines SNMP MIB modules based on the information model. By implementing these SNMP MIB modules, an energy object can report its energy consumption according to the information model. Based on the information model, the MIB documents specify SNMP MIB modules, but it is equally possible to use other mechanisms such as YANG module, Network Conference Protocol (NETCONF), etc.

In that context, it is important to distinguish energy objects that can only report their own energy usage from devices that can also collect and aggregate energy usage of other energy objects.

1.2. EMAN Document Overview

The EMAN work consists of the following Standard Track and Informational documents in the area of energy management.

Applicability Statement (this document)

Requirements [RFC6988]: This document presents requirements of energy management and the scope of the devices considered.

Framework [RFC7326]: This document defines a framework for providing energy management for devices within or connected to communication networks and lists the definitions for the common terms used in these documents.

Energy Object Context MIB [RFC7461]: This document defines a MIB module that characterizes a device's identity, context, and relationships to other entities.

Monitoring and Control MIB [RFC7460]: This document defines a MIB module for monitoring the power and energy consumption of a device.

The MIB module contains an optional module for metrics associated with power characteristics.

Battery MIB [RFC7577]: This document defines a MIB module for monitoring characteristics of an internal battery.

1.3. Energy Measurement

It is increasingly common for today's smart devices to measure and report their own energy consumption. Intelligent power strips and some Power over Ethernet (PoE) switches can meter consumption of connected devices. However, when managed and reported through proprietary means, this information is difficult to view at the enterprise level.

The primary goal of the EMAN information model is to enable reporting and management within a standard framework that is applicable to a wide variety of end devices, meters, and proxies. This enables a management system to know who's consuming what, when, and how by leveraging existing networks across various equipment in a unified and consistent manner.

Because energy objects may both consume energy and provide energy to other devices, there are three types of energy measurement: energy input to a device, energy supplied to other devices, and net (resultant) energy consumed (the difference between energy input and supplied).

1.4. Energy Management

The EMAN framework provides mechanisms for energy control in addition to passive monitoring. There are many cases where active energy control of devices is desirable, for example, during low device utilization or peak electrical price periods.

Energy control can be as simple as controlling on/off states. In many cases, however, energy control requires understanding the energy object context. For instance, during non-business hours in a commercial building, some phones must remain available in case of emergency, and office cooling is not usually turned off completely, but the comfort level is reduced.

Energy object control therefore requires flexibility and support for different policies and mechanisms: from centralized management by an energy management system to autonomous control by individual devices and alignment with dynamic demand-response mechanisms.

The power states specified in the EMAN framework can be used in demand-response scenarios. In response to time-of-day fluctuation of energy costs or grid power shortages, network devices can respond and reduce their energy consumption.

1.5. EMAN Framework Application

A Network Management System (NMS) is an entity that requests information from compatible devices, typically using the SNMP protocol. An NMS may implement many network management functions, such as security or identity management. An NMS that deals exclusively with energy is called an Energy Management System (EnMS). It may be limited to monitoring energy use, or it may also implement control functions. An EnMS collects energy information for devices in the network.

Energy management can be implemented by extending existing SNMP support with EMAN-specific MIBs. SNMP provides an industry-proven and well-known mechanism to discover, secure, measure, and control SNMP-enabled end devices. The EMAN framework provides an information and data model to unify access to a large range of devices.

2. Scenarios and Target Devices

This section presents energy management scenarios that the EMAN framework should solve. Each scenario lists target devices for which the energy management framework can be applied, how the reported-on devices are powered, and how the reporting or control is accomplished. While there is some overlap between some of the use cases, the use cases illustrate network scenarios that the EMAN framework supports.

2.1. Network Infrastructure Energy Objects

This scenario covers the key use case of network devices and their components. For a device aware of one or more components, our information model supports monitoring and control at the component level. Typically, the chassis draws power from one or more sources and feeds its internal components. It is highly desirable to have monitoring available for individual components, such as line cards, processors, disk drives, and peripherals such as USB devices.

As an illustrative example, consider a switch with the following grouping of subentities for which energy management could be useful.

- o Physical view: chassis (or stack), line cards, and service modules of the switch.

- o Component view: CPU, Application-Specific Integrated Circuits (ASICs), fans, power supply, ports (single port and port groups), storage, and memory.

The ENTITY-MIB [RFC6933] provides a containment model for uniquely identifying the physical subcomponents of network devices. The containment information identifies whether one Energy Object belongs to another Energy Object (e.g., a line-card Energy Object contained in a chassis Energy Object). The mapping table, entPhysicalContainsTable, has an index, entPhysicalChildIndex, and the table, entPhysicalTable, has a MIB object, entPhysicalContainedIn, that points to the containing entity.

The essential properties of this use case are:

- o Target devices: network devices such as routers and switches, as well as their components.

- o How powered: typically by a Power Distribution Unit (PDU) on a rack or from a wall outlet. The components of a device are powered by the device chassis.

- o Reporting: Direct power measurement can be performed at a device level. Components can report their power consumption directly, or the chassis/device can report on behalf of some components.

2.2. Devices Powered and Connected by a Network Device

This scenario covers Power Sourcing Equipment (PSE) devices. A PSE device (e.g., a PoE switch) provides power to a Powered Device (PD) (e.g., a desktop phone) over a medium such as USB or Ethernet [RFC3621]. For each port, the PSE can control the power supply (switching it on and off) and usually meter actual power provided. PDs obtain network connectivity as well as power over a single connection so the PSE can determine which device is associated with each port.

PoE ports on a switch are commonly connected to devices such as IP phones, wireless access points, and IP cameras. The switch needs power for its internal use and to supply power to PoE ports. Monitoring the power consumption of the switch (supplying device) and the power consumption of the PoE endpoints (consuming devices) is a simple use case of this scenario.

This scenario illustrates the relationships between entities. The PoE IP phone is powered by the switch. If there are many IP phones connected to the same switch, the power consumption of all the IP phones can be aggregated by the switch.

The essential properties of this use case are:

Target devices: Power over Ethernet devices such as IP phones, wireless access points, and IP cameras.

How powered: PoE devices are connected to the switch port that supplies power to those devices.

Reporting: PoE device power consumption is measured and reported by the switch (PSE) that supplies power. In addition, some edge devices can support the EMAN framework.

This use case can be divided into two subcases:

a) The endpoint device supports the EMAN framework, in which case this device is an EMAN Energy Object by itself with its own Universally Unique Identifier (UUID). The device is responsible for its own power reporting and control. See the related scenario "Devices Connected to a Network" below.

b) The endpoint device does not have EMAN capabilities, and the power measurement may not be able to be performed independently and is therefore only performed by the supplying device. This scenario is similar to the "Mid-level Manager" below.

In subcase (a), note that two power usage reporting mechanisms for the same device are available: one performed by the PD itself and one performed by the PSE. Device-specific implementations will dictate which one to use.

2.3. Devices Connected to a Network

This use case covers the metering relationship between an energy object and the parent energy object to which it is connected, while receiving power from a different source.

An example is a PC that has a network connection to a switch but draws power from a wall outlet. In this case, the PC can report power usage by itself, ideally through the EMAN framework.

The wall outlet to which the PC is plugged in can be unmetered or metered, for example, by a Smart PDU.

a) If metered, the PC has a powered-by relationship to the Smart PDU, and the Smart PDU acts as a "mid-level manager".

b) If unmetered, or operating on batteries, the PC will report its own energy usage as any other Energy Object to the switch, and the switch may possibly provide aggregation.

These two cases are not mutually exclusive.

In terms of relationships between entities, the PC has a powered-by relationship to the PDU, and if the power consumption of the PC is metered by the PDU, then there is a metered-by relation between the PC and the PDU.

The essential properties of this use case are:

- o Target devices: energy objects that have a network connection but receive power supply from another source.

- o How powered: endpoint devices (e.g., PCs) receive power supply from the wall outlet (unmetered), a PDU (metered), or can be powered autonomously (batteries).

- o Reporting: The power consumption can be reported via the EMAN framework
  - by the device directly,
  - by the switch with information provided to it by the device, or
  - by the PDU from which the device obtains its power.

2.4. Power Meters

Some electrical devices are not equipped with instrumentation to measure their own power and accumulated energy consumption. External meters can be used to measure the power consumption of such electrical devices as well as collections of devices.

Three types of external metering are relevant to EMAN: PDUs, standalone meters, and utility meters. External meters can measure consumption of a single device or a set of devices.

Power Distribution Units (PDUs) can have built-in meters for each socket and can measure the power supplied to each device in an equipment rack. PDUs typically have remote management capabilities that can report and possibly control the power supply of each outlet.

Standalone meters can be placed anywhere in a power distribution tree and may measure all or part of the total. Utility meters monitor and report accumulated power consumption of the entire building. There can be submeters to measure the power consumption of a portion of the building.

The essential properties of this use case are:

- o Target devices: PDUs and meters.
- o How powered: from traditional mains power but supplied through a PDU or meter (where "mains power" is the standard AC power drawn from the wall outlet).
- o Reporting: PDUs report power consumption of downstream devices, usually a single device per outlet. Meters may report for one or more devices and may require knowledge of the topology to associate meters with metered devices.

Meters have metered-by relationships with devices and may have aggregation relationships between the meters and the devices for which power consumption is accumulated and reported by the meter.

2.5. Mid-level Managers

This use case covers aggregation of energy management data at "mid-level managers" that can provide energy management functions for themselves and associated devices.

A switch can provide energy management functions for all devices connected to its ports whether or not these devices are powered by the switch or whether the switch provides immediate network connectivity to the devices. Such a switch is a mid-level manager, offering aggregation of power consumption data for other devices. Devices report their EMAN data to the switch and the switch aggregates the data for further reporting.

The essential properties of this use case:

- o Target devices: devices that can perform aggregation; commonly a switch or a proxy.
- o How powered: mid-level managers are commonly powered by a PDU or from a wall outlet but can be powered by any method.
- o Reporting: The mid-level manager aggregates the energy data and reports that data to an EnMS or higher mid-level manager.

2.6. Non-residential Building System Gateways

This use case describes energy management of non-residential buildings. Building Management Systems (BMS) have been in place for many years using legacy protocols not based on IP. In these buildings, a gateway can provide a proxy function between IP networks and legacy building automation protocols. The gateway provides an interface between the EMAN framework and relevant building management protocols.

Due to the potential energy savings, energy management of buildings has received significant attention. There are gateway network elements to manage the multiple components of a building energy management system such as Heating, Ventilation, and Air Conditioning (HVAC), lighting, electrical, fire and emergency systems, elevators, etc. The gateway device uses legacy building protocols to communicate with those devices, collects their energy usage, and reports the results.

The gateway performs protocol conversion and communicates via RS-232/RS-485 interfaces, Ethernet interfaces, and protocols specific to building management such as BACnet (a protocol for building automation and control networks) [BACnet], Modbus [MODBUS], or ZigBee [ZIGBEE].

The essential properties of this use case are:

- o Target devices: building energy management devices -- HVAC systems, lighting, electrical, and fire and emergency systems.

- o How powered: any method.

- o Reporting: The gateway collects energy consumption of non-IP systems and communicates the data via the EMAN framework.

2.7. Home Energy Gateways

This use case describes the scenario of energy management of a home. The home energy gateway is another example of a proxy that interfaces with electrical appliances and other devices in a home. This gateway can monitor and manage electrical equipment (e.g., refrigerator, heating/cooling, or washing machine) using one of the many protocols that are being developed for residential devices.

Beyond simply metering, it's possible to implement energy saving policies based on time of day, occupancy, or energy pricing from the utility grid. The EMAN information model can be applied to the energy management of a home.

The essential properties of this use case are:

- o Target devices: home energy gateway and smart meters in a home.

- o How powered: any method.

- Reporting: The home energy gateway can collect power consumption of device in a home and possibly report the meter reading to the utility.

2.8. Data Center Devices

This use case describes energy management of a data center. Energy efficiency of data centers has become a fundamental challenge of data center operation, as data centers are big energy consumers and have an expensive infrastructure. The equipment generates heat, and heat needs to be evacuated through an HVAC system.

A typical data center network consists of a hierarchy of electrical energy objects. At the bottom of the network hierarchy are servers mounted on a rack; these are connected to top-of-the-rack switches, which in turn are connected to aggregation switches and then to core switches. Power consumption of all network elements, servers, and storage devices in the data center should be measured. Energy management can be implemented on different aggregation levels, i.e., at the network level, the Power Distribution Unit (PDU) level, and/or the server level.

Beyond the network devices, storage devices, and servers, data centers contain Uninterruptable Power Systems (UPSs) to provide back-up power for the facility in the event of a power outage. A UPS can provide backup power for many devices in a data center for a finite period of time. Energy monitoring of energy storage capacity is vital from a data center network operations point of view. Presently, the UPS MIB can be useful in monitoring the battery capacity, the input load to the UPS, and the output load from the UPS. Currently, there is no link between the UPS MIB and the ENTITY MIB.

In addition to monitoring the power consumption of a data center, additional power characteristics should be monitored. Some of these are dynamic variations in the input power supply from the grid, referred to as power quality metrics. It can also be useful to monitor how efficiently the devices utilize power.

Nameplate capacity of the data center can be estimated from the nameplate ratings (which indicate the maximum possible power draw) of IT equipment at a site.

The essential properties of this use case are:

- o Target devices: IT devices in a data center, such as network equipment, servers, and storage devices, as well as power and cooling infrastructure.

- o How powered: any method, but commonly by one or more PDUs.

- o Reporting: Devices may report on their own behalf or for other connected devices as described in other use cases.

2.9. Energy Storage Devices

Energy storage devices can have two different roles: one type whose primary function is to provide power to another device (e.g., a UPS) and one type with a different primary function but that has energy storage as a component (e.g., a notebook). This use case covers both.

The energy storage can be a conventional battery or any other means to store electricity, such as a hydrogen cell.

An internal battery can be a back-up or an alternative source of power to mains power. As batteries have a finite capacity and lifetime, means for reporting the actual charge, age, and state of a battery are required. An internal battery can be viewed as a component of a device and can be contained within the device from an ENTITY-MIB perspective.

Battery systems are often used in remote locations such as mobile telecom towers. For continuous operation, it is important to monitor the remaining battery life and raise an alarm when this falls below a threshold.

The essential properties of this use case are:

- o Target devices: devices that have an internal battery or external storage.

- o How powered: from batteries or other storage devices.

- o Reporting: The device reports on its power delivered and state.

2.10. Industrial Automation Networks

Energy consumption statistics in the industrial sector are staggering. The industrial sector alone consumes about half of the world's total delivered energy and is a significant user of electricity. Thus, the need for optimization of energy usage in this sector is natural.

Industrial facilities consume energy in process loads and non-process loads.

The essential properties of this use case are:

- o Target devices: devices used in an industrial sector.

- o How powered: any method.

- o Reporting: The Common Industrial Protocol (CIP) is commonly used for reporting energy for these devices.

2.11. Printers

This use case describes the scenario of energy monitoring and management of printers. Printers in this use case stand in for all imaging equipment, including Multi-function Devices (MFDs), scanners, fax machines, and mailing machines.

Energy use of printers has been a long-standing industry concern, and sophisticated power management is common. Printers often use a variety of low-power modes, particularly for managing energy-intensive thermo-mechanical components. Printers also have long made extensive use of SNMP for end-user system interaction and for management generally, with cross-vendor management systems able to manage fleets of printers in enterprises. Power consumption during active modes can vary widely, with high peak usage levels.

Printers can expose detailed power state information, distinct from operational state information, with some printers reporting transition states between stable long-term states. Many also support active setting of power states and policies, such as delay times, when inactivity automatically transitions the device to a lower power mode. Other features include reporting on components, counters for state transitions, typical power levels by state, scheduling, and events/alarms.

Some large printers also have a "Digital Front End", which is a computer that performs functions on behalf of the physical imaging system. These typically have their own presence on the network and are sometimes separately powered.

There are some unique characteristics of printers from the point of view energy management. While the printer is not in use, there are timer-based low power states, which consume little power. On the other hand, while the printer is printing or copying, the cylinder is heated so that power consumption is quite high but only for a short period of time. Given this work load, periodic polling of power levels alone would not suffice.

The essential properties of this use case are:

- o Target devices: all imaging equipment.
- o How powered: typically, AC from a wall outlet.
- o Reporting: The devices report for themselves.

2.12. Demand Response

The theme of demand response from a utility grid spans across several use cases. In some situations, in response to time-of-day fluctuation of energy costs or sudden energy shortages due power outages, it may be important to respond and reduce the energy consumption of the network.

From the EMAN use case perspective, the demand-response scenario can apply to a data center, building, or home. Real-time energy monitoring is usually a prerequisite so that during a potential energy shortfall the EnMS can provide an active response. The EnMS could shut down selected devices that are considered lower priority or uniformly reduce the power supplied to a class of devices. For multisite data centers, it may be possible to formulate policies such as the follow-the-sun type of approach by scheduling the mobility of Virtual Machines (VMs) across data centers in different geographical locations.

The essential properties of this use case are:

- o Target devices: any device.
- o How powered: traditional mains AC power.
- o Reporting: Devices report in real time.

- Control: demand response based upon policy or priority.

3. Use Case Patterns

The use cases presented above can be abstracted to the following broad patterns for energy objects.

3.1. Metering

- Energy objects that have the capability for internal metering

- Energy objects that are metered by an external device

3.2. Metering and Control

- Energy objects that do not supply power but can perform power metering for other devices

- Energy objects that do not supply power but can perform both metering and control for other devices

3.3. Power Supply, Metering, and Control

- Energy objects that supply power for other devices but do not perform power metering for those devices

- Energy objects that supply power for other devices and also perform power metering

- Energy objects that supply power for other devices and also perform power metering and control for other devices

3.4. Multiple Power Sources

- Energy objects that have multiple power sources, with metering and control performed by the same power source

- Energy objects that have multiple power sources supplying power to the device with metering performed by one or more sources and control performed by another source

4. Relationship of EMAN to Other Standards

The EMAN framework is tied to other standards and efforts that address energy monitoring and control. EMAN leverages existing standards when possible, and it helps enable adjacent technologies such as Smart Grid.

The standards most relevant and applicable to EMAN are listed below with a brief description of their objectives, the current state, and how that standard relates to EMAN.

4.1. Data Model and Reporting

4.1.1. IEC - CIM

The International Electrotechnical Commission (IEC) has developed a broad set of standards for power management. Among these, the most applicable to EMAN is IEC 61850, a standard for the design of electric utility automation. The abstract data model defined in 61850 is built upon and extends the Common Information Model (CIM). The complete 61850 CIM model includes over a hundred object classes and is widely used by utilities worldwide.

This set of standards were originally conceived to automate control of a substation (a facility that transfers electricity from the transmission to the distribution system). However, the extensive data model has been widely used in other domains, including Energy Management Systems (EnMS).

IEC TC57 WG19 is an ongoing working group with the objective to harmonize the CIM data model and 61850 standards.

Several concepts from IEC Standards have been reused in the EMAN documents. In particular, AC Power Quality measurements have been reused from IEC 61850-7-4. The concept of Accuracy Classes for measurement of power and energy has been adapted from ANSI C12.20 and IEC standards 62053-21 and 62053-22.

4.1.2. DMTF

The Distributed Management Task Force (DMTF) has defined a Power State Management profile [DMTF-DSP1027] for managing computer systems using the DMTF's Common Information Model (CIM). These specifications provide physical, logical, and virtual system management requirements for power-state control services. The DMTF standard does not include energy monitoring.

The Power State Management profile is used to describe and manage the Power State of computer systems. This includes controlling the Power State of an entity for entering sleep mode, awakening, and rebooting. The EMAN framework references the DMTF Power Profile and Power State Set.

4.1.2.1. Common Information Model Profiles

The DMTF uses CIM-based 'Profiles' to represent and manage power utilization and configuration of managed elements (note that this is not the 61850 CIM). Key profiles for energy management are 'Power Supply' (DSP 1015), 'Power State' (DSP 1027), and 'Power Utilization Management' (DSP 1085). These profiles define many features for the monitoring and configuration of a Power Managed Element's static and dynamic power saving modes, power allocation limits, and power states.

Reduced power modes can be established as static or dynamic. Static modes are fixed policies that limit power use or utilization. Dynamic power saving modes rely upon internal feedback to control power consumption.

Power states are eight named operational and non-operational levels. These are On, Sleep-Light, Sleep-Deep, Hibernate, Off-Soft, and Off-Hard. Power change capabilities provide immediate, timed interval, and graceful transitions between on, off, and reset power states. Table 3 of the Power State Profile defines the correspondence between the Advanced Configuration and Power Interface [ACPI] and DMTF power state models, although it is not necessary for a managed element to support ACPI. Optionally, a TransitioningToPowerState property can represent power state transitions in progress.

4.1.2.2. DASH

DMTF Desktop and Mobile Architecture for System Hardware [DASH] addresses managing heterogeneous desktop and mobile systems (including power) via in-band and out-of-band communications. DASH uses the DMTF's Web Services for Management (WS-Management) and CIM data model to manage and control resources such as power, CPU, etc.

Both in-service and out-of-service systems can be managed with the DASH specification in a fully secured remote environment. Full power life-cycle management is possible using out-of-band management.

4.1.3. ODVA

The Open DeviceNet Vendors Association (ODVA) is an association for industrial automation companies that defines the Common Industrial Protocol (CIP). Within ODVA, there is a special interest group focused on energy and standardization and interoperability of energy-aware devices.

The ODVA is developing an energy management framework for the industrial sector. There are synergies and similar concepts between the ODVA and EMAN approaches to energy monitoring and management.

ODVA defines a three-part approach towards energy management: awareness of energy usage, energy efficiency, and the exchange of energy with a utility or others. Energy monitoring and management promote efficient consumption and enable automating actions that reduce energy consumption.

The foundation of the approach is the information and communication model for entities. An entity is a network-connected, energy-aware device that has the ability to either measure or derive its energy usage based on its native consumption or generation of energy, or report a nominal or static energy value.

4.1.4. Ecma SDC

The Ecma International standard on Smart Data Centre [Ecma-SDC] defines semantics for management of entities in a data center such as servers, storage, and network equipment. It covers energy as one of many functional resources or attributes of systems for monitoring and control. It only defines messages and properties and does not reference any specific protocol. Its goal is to enable interoperability of such protocols as SNMP, BACnet, and HTTP by ensuring a common semantic model across them. Four power states are defined, Off, Sleep, Idle, and Active. The standard does not include actual energy or power measurements.

When used with EMAN, the SDC standard will provide a thin abstraction on top of the more detailed data model available in EMAN.

4.1.5. PWG

The IEEE Industry Standards and Technology Organization (ISTO) Printer Working Group (PWG) defines open standards for printer-related protocols for the benefit of printer manufacturers and related software vendors. The Printer WG covers power monitoring and management of network printers and imaging systems in the PWG Power Management Model for Imaging Systems [PWG5106.4]. Clearly, these devices are within the scope of energy management since they receive power and are attached to the network. In addition, there is ample scope for power management since printers and imaging systems are not used that often.

The IEEE-ISTO Printer Working Group (PWG) defines SNMP MIB modules for printer management and, in particular, a "PWG Power Management Model for Imaging Systems v1.0" [PWG5106.4] and a companion SNMP binding in the "PWG Imaging System Power MIB v1.0" [PWG5106.5]. This PWG model and MIB are harmonized with the DMTF CIM Infrastructure [DMTF-DSP0004] and DMTF CIM Power State Management Profile [DMTF-DSP1027] for power states and alerts.

These MIB modules can be useful for monitoring the power and Power State of printers. The EMAN framework takes into account the standards defined in the Printer Working Group. The PWG may harmonize its MIBs with those from EMAN. The PWG covers many topics in greater detail than EMAN, including those specific to imaging equipment. The PWG also provides for vendor-specific extension states (beyond the standard DMTF CIM states).

The IETF Printer MIB [RFC3805] is on the Standards Track, but that MIB module does not address power management.

4.1.6. ASHRAE

In the U.S., there is an extensive effort to coordinate and develop standards related to the "Smart Grid". The Smart Grid Interoperability Panel, coordinated by the government's National Institute of Standards and Technology, identified the need for a building side information model (as a counterpart to utility models) and specified this in Priority Action Plan (PAP) 17. This was designated to be a joint effort by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the National Electrical Manufacturers Association (NEMA), both ANSI-approved Standards Development Organizations (SDOs). The result is to be an information model, not a protocol.

The ASHRAE effort [ASHRAE] addresses data used only within a building as well as data that may be shared with the grid, particularly as it relates to coordinating future demand levels with the needs of the grid. The model is intended to be applied to any building type, both residential and commercial. It is expected that existing protocols will be adapted to comply with the new information model, as would new protocols.

There are four basic types of entities in the model: generators, loads, meters, and energy managers. The metering part of the model overlaps to a large degree with the EMAN framework, though there are features unique to each. The load part speaks to control capabilities well beyond what EMAN covers. Details of generation and of the energy management function are outside of EMAN scope.

A public review draft of the ASHRAE standard was released in July 2012. There are no apparent major conflicts between the two approaches, but there are areas where some harmonization is possible.

4.1.7. ANSI/CEA

The Consumer Electronics Association (CEA) has approved ANSI/CEA-2047 [ANSICEA] as a standard data model for Energy Usage Information. The primary purpose is to enable home appliances and electronics to communicate energy usage information over a wide range of technologies with pluggable modules that contain the physical-layer electronics. The standard can be used by devices operating on any home network including Wi-Fi, Ethernet, ZigBee, Z-Wave, and Bluetooth. The Introduction to ANSI/CEA-2047 states that "this standard provides an information model for other groups to develop implementations specific to their network, protocol and needs." It covers device identification, current power level, cumulative energy consumption, and provides for reporting time-series data.

4.1.8. ZigBee

The ZigBee Smart Energy Profile 2.0 (SEP) effort [ZIGBEE] focuses on IP-based wireless communication to appliances and lighting. It is intended to enable internal building energy management and provide for bidirectional communication with the power grid.

ZigBee protocols are intended for use in embedded applications with low data rates and low power consumption. ZigBee defines a general-purpose, inexpensive, self-organizing mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, etc.

ZigBee is currently not an ANSI-recognized SDO.

The EMAN framework addresses the needs of IP-enabled networks through the usage of SNMP, while ZigBee provides for completely integrated and inexpensive mesh solutions.

4.2. Measurement

4.2.1. ANSI C12

The American National Standards Institute (ANSI) has defined a collection of power meter standards under ANSI C12. The primary standards include communication protocols (C12.18, 21 and 22), data and schema definitions (C12.19), and measurement accuracy (C12.20). European equivalent standards are provided by IEC 62053-22.

These very specific standards are oriented to the meter itself and are used by electricity distributors and producers.

The EMAN framework [RFC7326] references the Accuracy Classes specified in ANSI C12.20.

4.2.2. IEC 62301

IEC 62301, "Household electrical appliances - Measurement of standby power" [IEC62301], specifies a power-level measurement procedure. While nominally for appliances and low-power modes, its concepts apply to other device types and modes, and it is commonly referenced in test procedures for energy using products.

While the standard is intended for laboratory measurements of devices in controlled conditions, aspects of it are informative to those implementing measurement in products that ultimately report via EMAN.

4.3. Other

4.3.1. ISO

The International Organization for Standardization (ISO) [ISO] is developing an energy management standard, ISO 50001, to complement ISO 9001 for quality management and ISO 14001 for environmental management. The intent is to facilitate the creation of energy management programs for industrial, commercial, and other entities. The standard defines a process for energy management at an organizational level. It does not define the way in which devices report energy and consume energy.

ISO 50001 is based on the common elements found in all of ISO’s management system standards, assuring a high level of compatibility with ISO 9001 and ISO 14001. ISO 50001 benefits include:

- o Integrating energy efficiency into management practices and throughout the supply chain.

- Using energy management best practices and good energy management behaviors.

- Benchmarking, measuring, documenting, and reporting energy intensity improvements and their projected impact on reductions in greenhouse gas (GHG) emissions.

- Evaluating and prioritizing the implementation of new energy-efficient technologies.

ISO 50001 has been developed by ISO project committee ISO TC 242, Energy Management. EMAN is complementary to ISO 9001.

4.3.2. Energy Star

The U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) jointly sponsor the Energy Star program [ESTAR]. The program promotes the development of energy efficient products and practices.

To qualify as Energy Star, products must meet specific energy efficiency targets. The Energy Star program also provides planning tools and technical documentation to encourage more energy-efficient building design. Energy Star is a program; it is not a protocol or standard.

For businesses and data centers, Energy Star offers technical support to help companies establish energy conservation practices. Energy Star provides best practices for measuring current energy performance, goal setting, and tracking improvement. The Energy Star tools offered include a rating system for building performance and comparative benchmarks.

There is no immediate link between EMAN and Energy Star, one being a protocol and the other a set of recommendations to develop energy-efficient products. However, Energy Star could include EMAN standards in specifications for future products, either as required or rewarded with some benefit.

4.3.3. Smart Grid

The Smart Grid standards efforts underway in the United States are overseen by the U.S. National Institute of Standards and Technology [NIST]. NIST is responsible for coordinating a public-private partnership with key energy and consumer stakeholders in order to facilitate the development of Smart Grid standards. These activities are monitored and facilitated by the Smart Grid Interoperability Panel (SGIP). This group has working groups for specific topics including homes, commercial buildings, and industrial facilities as they relate to the grid. A stated goal of the group is to harmonize any new standard with the IEC CIM and IEC 61850.

When a working group detects a standard or technology gap, the team seeks approval from the SGIP for the creation of a Priority Action Plan (PAP), a private-public partnership to close the gap. PAP 17 is discussed in Section 4.1.6.

PAP 10 addresses "Standard Energy Usage Information". Smart Grid standards will provide distributed intelligence in the network and allow enhanced load shedding. For example, pricing signals will enable selective shutdown of non-critical activities during peak price periods. Actions can be effected through both centralized and distributed management controls.

There is an obvious functional link between Smart Grid and EMAN in the form of demand response even though the EMAN framework itself does not address any coordination with the grid. As EMAN enables control, it can be used by an EnMS to accomplish demand response through translation of a signal from an outside entity.

5. Limitations

EMAN addresses the needs of energy monitoring in terms of measurement and considers limited control capabilities of energy monitoring of networks.

EMAN does not create a new protocol stack, but rather defines a data and information model useful for measuring and reporting energy and other metrics over SNMP.

EMAN does not address questions regarding Smart Grid, electricity producers, and distributors.

6. Security Considerations

EMAN uses SNMP and thus has the functionality of SNMP's security capabilities. SNMPv3 [RFC3411] provides important security features such as confidentiality, integrity, and authentication.

Section 10 of [RFC7460] and Section 6 of [RFC7461] mention that power monitoring and management MIBs may have certain privacy implications. These privacy implications are beyond the scope of this document. There may be additional privacy considerations specific to each use case; this document has not attempted to analyze these.

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