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Energy Management (EMAN) Applicability Statement
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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 framework for a variety of scenarios. This document lists use cases and target devices that can potentially implement the EMAN framework and associated SNMP MIB modules. These use cases are useful for identifying requirements for the framework. Further, we describe the relationship of the EMAN framework to relevant other energy monitoring standards and architectures.

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1. Introduction

The focus of the Energy Management (EMAN) framework is energy monitoring and management of energy objects [EMAN-DEF]. The scope of devices considered are network equipment and its components, and devices connected directly or indirectly to the network. The EMAN framework enables monitoring (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 [EMAN-FRAMEWORK] describes how energy information can be retrieved from IP-enabled devices using Simple Network Management Protocol (SNMP), specifically, Management Information Base (MIBs) for SNMP.

This document describes typical applications of the EMAN framework, as well as its opportunities and limitations. Other

standards that are similar to EMAN but address different domains are described. This document contains references to those other standards and describes how they 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 shall address. Section 3 contains an abstraction of the use case scenarios to distinct patterns. Section 4 deals with the standards related to EMAN and applicable to EMAN.

1.1. Energy Management Overview

While energy is available in many forms, EMAN addresses only the electrical energy consumed by devices connected to a network. First, a brief introduction to the definitions of Energy and Power are presented.

Energy is the capacity to perform work. Electrical energy is typically expressed in kilowatt-hour units (kWh) or other multiples of watt-hours (WH). One kilowatt-hour is the electrical energy used by a device drawing 1 kilowatt for one hour. Power is the rate of electrical energy flow. In other words, power = energy / time. Power is often measured in watts. A utility bill is usually based on electrical energy use measured in kWh.

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

The EMAN WG framework defines SNMP MIB modules based on the information model. By implementing the SNMP MIB modules, any energy object can report its energy consumption according to the information model. 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.

Target devices and scenarios considered for Energy Management are presented in Section 2 with detailed examples.

1.2. EMAN WG Document Overview

The EMAN working group charter called for producing a series of Internet standard drafts in the area of energy management. The following drafts were created by the working group.

Applicability Statement [EMAN-AS] this document presents the use cases and scenarios for energy management. In addition, other relevant energy standards and architectures are listed.

Requirements [EMAN-REQ] this document presents the requirements of energy management and the scope of the devices considered.

Framework [EMAN-FRAMEWORK] This document defines a framework for providing Energy Management for devices within or connected to communication networks.

Energy-Aware MIB [EMAN-AWARE-MIB] This document proposes a MIB module that characterizes a device's identity, context and the relationship to other entities.

Monitoring MIB [EMAN-MONITORING-MIB] 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 [EMAN-BATTERY-MIB] This document contains a MIB module for monitoring characteristics of an internal battery.

Energy Management Terminology [EMAN-DEF] This document lists the definitions for the common terms used in the Energy Management Working Group.

1.3. Energy Measurement

More and more devices are able to measure and report their own energy consumption. Smart 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 minimally useful at the enterprise level.

The primary goal of the EMAN MIBs 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 at any time by leveraging existing networks, across various equipment, in a unified and consistent manner.

Given that an energy object can consume energy and/or 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 provided).

1.4. Energy Management

Beyond energy monitoring, the EMAN framework provides mechanisms for energy control.

There are many cases where reducing energy consumption of devices is desirable, such as when the device utilization is low or when the electricity is expensive or in short supply.

In some cases, energy control requires considering the energy object context. For instance, in a building during non-business hours: usually not all phones would be turned off to keep some phones available in case of emergency; office cooling is usually not turned off totally, but the comfort level is reduced.

Energy object control requires flexibility and support for different polices and mechanisms: from centralized management with a network management station, to autonomous management by individual devices, and alignment with dynamic demand-response mechanisms.

The EMAN framework can be used as a tool for the demand/response scenario where in response to time-of-day fluctuation of energy costs or possible energy shortages, it is possible to respond and reduce the energy consumption for the network devices, effectively changing its power state.

1.5. EMAN Framework Application

A Network Management System (NMS) is the entity that requests information from compatible devices using SNMP protocol. An NMS implements many network management functions, e.g. security management, or identity management. An NMS that deals exclusively with energy is called EnMS,Energy Management System. It may be limited to monitoring energy use, or it may also implement control functions. In a typical application of the

EMAN framework, management software collects energy information for devices in the network.

Energy management can be implemented by extending existing SNMP support to the 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.

The scope of the target devices and the network scenarios considered for energy management are listed in Section 2.

2. Scenarios and Target Devices

In this section a selection of scenarios for energy management are presented. The fundamental objective of the use cases is to list important network scenarios that the EMAN framework should solve. These use cases then drive the requirements for the EMAN framework.

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 is accomplished. While there is some overlap between some of the use cases, the use cases serve as illustrative network scenarios EMAN framework supports.

2.1. Network Infrastructure Energy Objects

This scenario covers network devices and their components. Power management of energy objects is considered as a fundamental requirement of energy management of networks.

It can be important to monitor the energy consumption and possibly manage the power state of these devices at a granularity level finer than just the entire device. For these devices, the chassis draws power from one or more sources and feeds all its internal components. It is highly desirable to have monitoring available for individual components, such as line cards, processors, and hard drives as well as peripherals like USB devices.

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

- physical view: chassis (or stack), line cards, service modules of the switch.
- component view: CPU, ASICs, fans, power supply, ports (single port and port groups), storage and memory.

The ENTITY-MIB provides the containment tree framework, for uniquely identifying the physical sub-components of network devices. A component can be an Energy Object and the ENTITY-MIB containment tree shall express if that Energy Object belongs to another Energy Object (e.g. line-card Energy Object contained in a chassis Energy Object. The table entPhysicalContainsTable which has the index of entPhysicalChildIndex and the MIB object entPhysicalContainedIn which points to the containing entity.

The essential properties of this use case are:

- Target devices: network devices such as routers, switches and their components.
- How powered: typically by a PDU on a rack or from a wall outlet. The components of a device are powered by the device chassis.
- Reporting: direct power measurement can be performed at a device level. Components can report their power consumption directly or the chassis/device that can report on behalf of some components.

2.2. Devices Powered by and Connected to a Network Device

This scenario covers Power over Ethernet (PoE) devices. A PoE Power Sourcing Equipment (PSE) device [RFC3621] (e.g. a PoE switch) provides power to a Powered Device (PD) (e.g. a desktop phone). For each port, the PSE can control the power supply (switching it on and off) and 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 end-points (consuming devices) is a simple use case of this scenario.

It is also possible to illustrate the relationships between entities. The PoE IP phone is powered by the switch. If there are many IP phones connected to the same switch and the power

consumption of all the IP phones can be aggregated by the switch. In that case, the switch performs the aggregation function for other entities.

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 which supplies power to those devices.
- . Reporting: PoE device power consumption is measured and reported by the switch (PSE) which supplies power. In addition, some devices can have support for the EMAN framework.

This use case can be subdivided into two sub cases:

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

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

In the sub case (a) note that two power usage reporting 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 if the most accurate.

It is also possible to illustrate the relationships between entities. The PoE IP phone is powered by the switch. If there are many IP phones connected to the same switch and the power consumption of all the IP phones can be aggregated by the switch. In that case, the switch performs the aggregation function for other entities.

2.3. Devices Connected to a Network

The use case covers the metering relationship between an energy object and the parent energy object it is connected to, while receiving power from an external source such as a power brick.

An example is a PC which 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 the PC is plugged in can be metered for example by a Smart PDU, or unmetered.

a) If metered, the PC has a powered-by relationship to the Smart PDU, and the Smart PDU will act as a "Mid-Level Manager"

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

Note that a) and b) 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:

. Target devices: Energy objects that have a network connection, but receive power supply from another source.
. How powered: Children (e.g.: PCs)receive power supply from the wall outlet (unmetered), or a PDU (metered). That can also be powered autonomously (batteries).
. Reporting: Devices can measure and report the power consumption directly via the EMAN framework, or, communicate it to the network device (switch) and the switch can report the device's power consumption via the EMAN framework.

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.

This use case covers the proxy relationship of energy objects able to measure or report the power consumption of external electrical devices, not natively connected to the network. Examples of such metering devices are smart PDUs and smart meters.

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 Unit (PDUs) have inbuilt meters for each socket and so can measure the power supplied to each device in an equipment rack. The PDUs have remote management functionality which can measure and possibly control the power supply of each outlet.

Standalone meters can be placed anywhere in a power distribution tree are allocated to specific devices.
Utility meters monitor and report accumulated power consumption of the entire building. There can be sub-meters to measure the power consumption of a portion of the building.

The essential properties of this use case are:

- Target devices: PDUs and meters.
- How powered: From traditional mains power but as passed through a PDU or meter.
- Reporting: The PDUs reports power consumption of downstream devices, usually a single device per outlet.

The meters can have a metering relationship and possibly aggregation relationship 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 as well as 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:

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

2.6. Gateways to Building Systems

This use case describes energy management of 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 relationship between IP and legacy building automation protocols. The gateway can provide 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 [ASHRAE], MODBUS [MODBUS], or Zigbee [ZIGBEE].

The essential properties of this use case are:

. Target devices: Building energy management devices - HVAC systems, lighting, electrical, fire and emergency systems.
. How powered: Any method.
. 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 to the electrical appliances and other devices in a home. This gateway can monitor and manage electrical equipment (refrigerator, heating/cooling, washing machine etc.) using one of the many protocols that are being developed for the home area network products.

In its simplest form, metering can be performed at home. Beyond the metering, it is also possible to implement energy saving policies based on energy pricing from the utility grid. The EMAN information model can be applied to the protocols under consideration for energy management of a home.

The essential properties of this use case are:

- Target devices: Home energy gateway and smart meters in a home.
- How powered: Any method.
- Reporting: Home energy gateway can collect power consumption of device in a home and possibly report the metering reading to the utility.

Beyond the canonical setting of a home drawing power from the utility, it is also possible to envision an energy neutral situation wherein the buildings/homes that can produce and consume energy with reduced or zero net importing energy from the utility grid. There are many energy production technologies such as solar panels, wind turbines, or micro generators. This use case illustrates the concept of covers self-contained energy generation and consumption and possibly the aggregation of the energy use of homes.

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 datacenters are big energy consumers and have expensive infrastructure. The equipment generates heat, and heat needs to be evacuated though a 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 network storage devices in the data center should be measured. Energy management can be implemented on different aggregation levels, at the network level, Power Distribution Unit (PDU) level, and server level.

Beyond the network devices, storage devices and servers, data centers contain UPSs to provide back-up power for the network, storage devices in the event 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 such energy storage devices 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.

Thus from a Data center energy management point of view, in addition, to monitoring the energy usage of network devices, it is also important to monitor the remaining capacity of the UPS.

In addition to monitoring the power consumption of a data center, additional power characteristic metrics should be monitored. Some of these are dynamic variations in the input power supply from the grid referred to as power characteristics is one metric. Secondly, how the devices utilize the power in terms of efficiency can be useful to monitor these metrics.

Lastly, the nameplate power consumption (the worst case possible power draw) of all devices will make it possible to know an aggregate of the potential worst-case power usage and compare it to the budgeted power in the data center.

The essential properties of this use case are:

- Target devices: All IT devices in a data center, such as network equipment, servers, and storage devices, as well as power and cooling infrastructure.
- How powered: Any method but commonly by one or more PDUs.
- Reporting: Devices may report on their own behalf, or for other connected devices as described in other use cases.

2.9. Energy Storage Devices

There are two types of devices with energy storage: those whose primary function is to provide power to another device (e.g. a UPS), and those with a different primary function, but have an energy storage as a component as an alternate internal power source (e.g. a notebook). This use case covers both types of products.

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 thus could have the containment relationship from an ENTITY-MIB perspective to the device that contains the battery

Battery systems are used in mobile telecom towers including for use in remote locations. It is important to monitor the remaining battery life and raise an alarm when the battery life is below a threshold.

The essential properties of this use case are:

- Target devices: Devices that have an internal battery
- How powered: From internal batteries or mains power
- Reporting: The device reports on its internal battery

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 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 in non-process loads.

The essential properties of this use case are:

- Target devices: Devices used in industrial automation
- How powered: Any method.

. Reporting: Currently, CIP protocol is currently 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, also including multi-function devices (MFDs), copiers, scanners, fax machines, and mailing machines.

Energy use of printers has been an industry concern for several decades, and they usually have sophisticated power management with 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, and cross-vendor management systems manage fleets of printers in enterprises. Power consumption during active modes can vary widely, with high peak 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 setting of policies such as delay times when no activity will cause automatic transition 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 very little power. On the other hand, while the printer is printing or copying the cylinder needs to be heated so that power consumption is quite high but only for a short period of time (duration of the print job). Given this work load, periodic polling of power levels alone would not suffice.

The essential properties of this use case are:

. Target devices: All imaging equipment.
. How powered: Typically AC from a wall outlet.
. Reporting: Devices report for themselves by implementing [EMAN-MONITORING-MIB].

2.12. Off-Grid Devices

This use case concerns self-contained devices that use energy but are not connected to an infrastructure power delivery grid. These devices typically scavenge energy from environmental sources such as solar energy or wind power. The device generally contains a closely coupled combination of

. power scavenging or generation component(s)
. power storage component(s) (e.g., battery)
. power consuming component(s)

With scavenged power, the energy input is often dependent on the random variations of the weather. These devices therefore require energy management both for internal control and remote reporting of their state. In order to optimize the performance of these devices and minimize the costs of the generation and storage components, it is desirable to vary the activity level, and, hopefully, the energy requirements of the consuming components in order to make best use of the available stored and instantaneously generated energy. With appropriate energy management, the overall device can be optimized to deliver an appropriate level of service without over provisioning the generation and storage components.

In many cases these devices are expected to operate autonomously, as continuous communications for the purposes of remote control is either impossible or would result in excessive power consumption. Non continuous polling requires the ability to store and access later the information collected while the communication was not possible.

The essential properties of this use case are:

Target Devices: Remote network devices (mobile network) that consume and produce energy
How Powered: Can be battery powered or using natural energy sources
Reporting: Devices report their power usage but only occasionally.

2.13. Demand/Response

Demand/Response from the utility or grid is a common theme that spans across some of the 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 EMAN use case perspective, the demand/response scenario can apply to a Data Center or a Building or a residential home. As a first step, it may be important to monitor the energy consumption in real-time of a Data center, building or home which is already discussed in the previous use cases. Then based on the potential energy shortfall, the Energy Management System (EMS) could formulate a suitable response, i.e., the EMS could shut down some selected devices that may be considered discretionary or uniformly reduce the power supplied to all devices. For multi-site data centers it may be possible to formulate policies such as follow-the-moon type of approach, by scheduling the mobility of VMs across Data centers in different geographical locations.

2.14. Power Capping

Power capping is a technique to limit the total power consumption of a server. This technique can be useful for power limited data centers. Based on workload measurements, the server can choose the optimal power state of the server in terms of performance and power consumption. When the server operates at less than the power supply capacity, it runs at full speed. When the server power would be greater than the power supply capacity, it runs at a slower speed so that its power consumption matches the available power supply capacity. This gives vendors the option to use smaller, cost-effective power supplies that allow real world workloads to run at nominal themselves.

3. Use Case Patterns

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

3.1. Metering

-energy objects which have capability for internal metering
- energy objects which are metered by an external device

3.2. Metering and Control

- energy objects that do not supply power, but can perform only 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 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 and metering and control is performed by one source

- energy objects that have multiple power sources and metering is performed by one source and control another source

4. Relationship of EMAN to other Standards

EMAN as a framework is tied to other standards and efforts that deal with energy. Existing standards are leveraged when possible. EMAN 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 Electro-technical 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 was originally conceived to automate control of a substation (facilities which transfer electricity from the transmission to the distribution system). While the original domain of 61850 is substation automation, the extensive data model has been widely used in other domains, including Energy Management Systems (EMS).

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

Concepts from IEC Standards have been reused in the EMAN WG drafts. In particular, AC Power Quality measurements have been reused from IEC 61850-7-4. The concept of Accuracy Classes for measure 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)[DMTF] has standardized management solutions for managing servers and PCs, including power-state configuration and management of elements in a heterogeneous environment. These specifications provide physical, logical and virtual system management requirements for power-state control.

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 (Common Information Model) '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 monitoring and configuration of a Power Managed Element's static and dynamic power saving modes, power allocation limits and power states, among other features.

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 ACPI and DMTF power state models, although it is not necessary for a managed element to support ACPI. Optionally, a TransitingToPowerState property can represent power state transitions in progress.

4.1.2.2. DASH

DMTF DASH [DASH] (Desktop And Mobile Architecture for System Hardware) addresses managing heterogeneous desktop and mobile systems (including power) via in-band and out-of-band communications. DASH provides management and control of managed elements like power, CPU, etc. using the DMTF's WS-Management web services and CIM data model.

Both in service and out-of-service systems can be managed with the DASH specification in a fully secured remote environment. Full power lifecycle 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 and defines the Common Industrial Protocol (CIP). Within ODVA, there is a special interest group focused on energy.

The Open DeviceNet Vendors Association (ODVA) is developing an energy management framework for the industrial sector. There are synergies between the ODVA and EMAN approaches to energy management.

There are many similar concepts between the ODVA and EMAN frameworks towards monitoring and management of energy aware devices. In particular, one of the concepts being considered different energy meters based on if the device consumes electricity or produces electricity or a passive device.

ODVA defines a three-part approach towards energy management: awareness of energy usage, consuming energy more efficiently, and exchanging energy with the 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 committee on Smart Data Centre (TC38-TG2 SDC [Ecma-SDC]) is in the process of defining 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 in kWor kWh.

The 14th draft of SDC process was published in March 2011 and the development of the standard is still underway. 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. IEEE-ISTO Printer Working Group (PWG)

The IEEE-ISTO Printer Working Group (PWG) defines SNMP MIB modules for printer management and has recently defined 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 [DSP0004] and DMTF CIM Power State Management Profile [DSP1027] for power states and alerts.

The PWG would like its MIBs to be harmonized as closely as possible with those from EMAN. The PWG covers many topics in greater detail than EMAN, as well as some that are specific to imaging equipment. The PWG also provides for vendor-specific extension states (i.e., beyond the standard DMTF CIM states.)

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 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and National Electrical Manufacturers Association (NEMA), both ANSI approved SDO's. The result is to be an information model, not a device level monitoring protocol.

The ASHRAE effort 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 any new protocols.

There are four basic types of entities in the model: generators, loads, meters, and energy managers.

The metering part of this model overlaps with the EMAN framework to a large degree, 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 is expected soon, and at that point detailed comparison of the two models can be made. There are no apparent major conflicts between the two approaches, but there are likely areas where some harmonization is possible, and regardless, a description of the correspondences would be helpful to create.

4.1.7. ZigBee

The Zigbee Smart Energy 2.0 effort[ZIGBEE] focuses on wireless communication to appliances and lighting. Zigbee 1.x is not based on IP, whereas Zigbee 2.0 is supposed to interoperate with IP. It is intended to enable building energy management and enable direct load control by utilities.

ZigBee protocols are intended for use in embedded applications requiring 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 looks for completely integrated and inexpensive mesh solution.

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.ANSI C12.20 defines accuracy classes for watt-hour meters.

All of these standards are oriented toward the meter itself, and are therefore very specific and used by electricity distributors and producers.

The EMAN standard references ANSI C12 accuracy classes.

4.2.2. IEC62301

IEC 62301, "Household electrical appliances Measurement of standby power", [IEC62301] specifies a power level measurement procedure. While nominally for appliances and low-power modes, many aspects of it 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, many aspects of it are informative to those implementing measurement in products that ultimately report via EMAN.

4.3. Other

4.3.1. ISO

The ISO [ISO] is developing an energy management standard, ISO 50001, to complement ISO 9001 for quality management, and ISO 14001 for environment management. The intent of the framework 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 organization 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 (quality management) and ISO 14001 (environmental management). ISO 50001 benefits includes:

- o Integrating energy efficiency into management practices and throughout the supply chain
- o Energy management best practices and good energy management behaviors
- o benchmarking, measuring, documenting, and reporting energy intensity improvements and their projected impact on reductions in greenhouse gas (GHG) emissions
- o Evaluating and prioritizing the implementation of new energy-efficient technologies

ISO 50001 has been developed by ISO project committee ISO/PC 242, Energy management. EMAN is complementary to ISO 9001.

4.3.2. EnergyStar

The US Environmental Protection Agency (EPA) and US 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 EnergyStar, 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. SmartGrid

The Smart Grid standards efforts underway in the United States are overseen by the US 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. The NIST smart grid standards activities are monitored and facilitated by the SGIP (Smart Grid Interoperability Panel). 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. There are currently 17 PAPs. 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-load pricing periods. These actions can be effected through both centralized and distributed management controls.

There is an obvious functional link between SmartGrid and EMAN in the form of demand response, even if the EMAN framework does not take any specific step toward SmartGrid communication. As EMAN framework enables control, it can be used to realize power savings in the demand response through translation of a signal from an outside entity.

5. Limitations

EMAN Framework 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.

The EMAN framework does not address questions regarding SmartGrid, electricity producers, and distributors even if there is obvious link between them.

6. Security Considerations

EMAN shall use SNMP protocol for energy management and thus has the functionality of SNMP's security capabilities. SNMPv3 [RFC3411] provides important security features such as confidentiality, integrity, and authentication.

7. IANA Considerations

This memo includes no request to IANA.

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9. Open Issues

OPEN ISSUE 1: Relevant IEC standards for application for EMAN Applicability Statement document can provide guidance on the issue of what is appropriate standard used by EMAN

IEC 61850-7-4 has been extensively used in EMAN WG documents. The other IEC documents referred for possible use are IEC 61000-4-30, IEC 62053-21 and IEC 62301.

There is feedback that IEC 61850-7-4 applies only to sub-stations ?

OPEN ISSUE 2: Should review ASHRAE SPC 201P standard when it is released for public review

. Need to review ASHRAE information model and the use cases and how it relates to EMAN

OPEN ISSUE 3: Review ALL requirements to ensure that they can be traced to a use case

. Missing is an use case for power characteristics

OPEN ISSUE 4: Should the Applicability Statement cover concepts that are only developed to implement the requirements in the framework, or only cover concepts that already are well-defined?

If the latter, this would suggest not including "energy object" (instead refer to devices and components), and not include "parent/child" (instead refer generically to relationships).

OPEN ISSUE 5: Should the terminology document be referenced, since it will disappear once the definitions are put into each relevant draft?

OPEN ISSUE 6: Should use cases be included if they do not add any requirements and so are redundant with previous use cases?

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