

Energy Management Working Group
Internet Draft
Intended status: Informational
Expires: October 19, 2013

Brad Schoening
Independent Consultant
Mouli Chandramouli
Cisco Systems Inc.
Bruce Nordman
Lawrence Berkeley National Laboratory
April 19, 2013

Energy Management (EMAN) Applicability Statement
draft-ietf-eman-applicability-statement-03

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 to 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 and MIBs. Further, we describe the relationship of the EMAN framework to relevant other energy monitoring standards and architectures.

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Expires October 19, 2013

[Page 1]

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Table of Contents

1. Introduction	3
1.1. Energy Management Overview	4
1.2. EMAN Document Overview	4
1.3. Energy Measurement	5
1.4. Energy Management	5
1.5. EMAN Framework Application	6
2. Scenarios and Target Devices	7
2.1. Network Infrastructure Energy Objects	7
2.2. Devices Powered by and Connected to a Network Device ...	8
2.3. Devices Connected to a Network	9
2.4. Power Meters	10
2.5. Mid-level Managers	11
2.6. Non-residential Building System Gateways	11
2.7. Home Energy Gateways	12
2.8. Data Center Devices	13
2.9. Energy Storage Devices	14
2.10. Industrial Automation Networks	15
2.11. Printers	15
2.12. Off-Grid Devices	16
2.13. Demand Response	17
2.14. Power Capping	17
3. Use Case Patterns	18
3.1. Metering	18
3.2. Metering and Control	18
3.3. Power Supply, Metering and Control	18
3.4. Multiple Power Sources	18

Internet-Draft	EMAN Applicability Statement	April 2013
4.	Relationship of EMAN to other Standards	19
4.1.	Data Model and Reporting	19
4.1.1.	IEC - CIM	19
4.1.2.	DMTF	19
4.1.3.	ODVA	21
4.1.4.	Ecma SDC	21
4.1.5.	PWG	22
4.1.6.	ASHRAE	22
4.1.7.	ZigBee	23
4.2.	Measurement	23
4.2.1.	ANSI C12	24
4.2.2.	IEC 62301	24
4.3.	Other	24
4.3.1.	ISO	24
4.3.2.	Energy Star	25
4.3.3.	Smart Grid	25
5.	Limitations	26
6.	Security Considerations	26
7.	IANA Considerations	27
8.	Acknowledgements	27
9.	References	27
9.1.	Normative References	27
9.2.	Informative References	27

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. It also reviews other standards that are similar in part to EMAN

but address different domains. This document describes how those other standards relate to the EMAN framework.

Expires October 19, 2013

[Page 3]

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 to EMAN 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 network equipment and 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 drafts define 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. While the MIB drafts contain MIB modules, the information model can be adapted to other mechanisms such as YANG modules, NETCONF etc.

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 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 use cases and scenarios for energy management. In addition, other relevant energy standards and architectures are discussed.

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

Internet-Draft EMAN Applicability Statement April 2013
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 identity, context and
relationships 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; and office cooling is usually not turned off totally, but the comfort level is reduced.

Energy object control requires flexibility and support for different policies 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 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 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.

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 illustrate network scenarios that the EMAN framework supports.

2.1. Network Infrastructure Energy Objects

This scenario covers network devices and their components. Power management of energy objects is 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 disk drives as well as peripherals such as 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 expresses if one Energy Object belongs to another Energy Object (e.g. a 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 and switches as well as their components.
- . 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.
- . 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 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 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 edge devices can support the EMAN framework.

This use case can be divided 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 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.

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 a different source.

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 acts 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.

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: end devices (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 energy objects able to measure or report the power consumption of external electrical devices, not natively connected to the network.

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) usually 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 and so may measure the total of groups of 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: PDUs report 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 are commonly powered by a PDU or from a wall outlet but 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. 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 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 [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 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.

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 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 through 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 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 facility 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, for data center energy management, in addition to monitoring the energy usage of IT equipment, 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, it can be useful to monitor how efficiently the devices utilize power.

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 which have 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 so be contained within the device from an ENTITY-MIB perspective.

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 this falls 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 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 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

Internet-Draft EMAN Applicability Statement April 2013
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 needs to be 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:

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

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 local energy sources.

Reporting: devices report their power usage, but only occasionally.

2.13. 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 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 EnMS could formulate a suitable response. The EnMS could shut down selected devices that are considered lower priority 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-sun 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, and it 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

Internet-Draft EMAN Applicability Statement April 2013
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 are performed by the same power source
- energy objects that have multiple power sources supplying
power to the device and metering is performed by one source and
control is performed by another source

4. Relationship of EMAN to other Standards

The EMAN framework is tied to other standards and efforts that deal with energy. 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 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). However, 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.

Several concepts from IEC Standards have been reused in the EMAN 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) 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, re-awaking, 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 (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 many features for 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 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 (DSP0232) (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.

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 and standardization and interoperability of energy-aware devices.

The Open DeviceNet Vendors Association (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. 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 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.

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.

The IEEE-ISTO Printer Working Group [PWG5106.4] 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 these devices receive power and are attached to the network. In addition, there is ample scope of 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 [DSP0004] and DMTF CIM Power State Management Profile [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, as well as some that are specific to imaging equipment. The PWG also provides for vendor-specific extension states (beyond the standard DMTF CIM states).

The IETF Printer MIB RFC3805 [RFC3805] has been standardized, however, this 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 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 SDO's. The result is to be an information model, not a 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 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 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 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. 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 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 looks for completely integrated and inexpensive mesh solution.

4.2. Measurement

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 power meters.

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

The EMAN standard references ANSI C12 accuracy classes.

4.2.2. IEC 62301

IEC 62301, "Household electrical appliances Measurement of standby power", 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 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 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 and ISO 14001. ISO 50001 benefits include:

- 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. 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 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. 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

Internet-Draft EMAN Applicability Statement April 2013
grid standards. These 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. 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. Both centralized and distributed management controls are in scope.

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

This memo includes no request to IANA.

8. Acknowledgements

Firstly, the authors thank Emmanuel Tychon for taking the lead for this draft and his substantial contributions to it. The authors thank Jeff Wheeler, Benoit Claise, Juergen Quittek, Chris Verges, John Parello, and Matt Laherty, for their valuable contributions. The authors thank Georgios Karagiannis for use case involving energy neutral homes, Elwyn Davies for off-grid electricity systems, and Kerry Lynn for demand response.

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Brad Schoening
44 Rivers Edge Drive
Little Silver, NJ 07739
USA

Phone: +1 917 304 7190
Email: brad.schoening@verizon.net

Mouli Chandramouli
Cisco Systems, Inc.
Sarjapur Outer Ring Road
Bangalore 560103
India

Phone: +91 80 4429 2409
Email: moulchan@cisco.com

Bruce Nordman
Lawrence Berkeley National Laboratory
1 Cyclotron Road, 90-4000
Berkeley 94720-8136
USA

Phone: +1 510 486 7089
Email: bnordman@lbl.gov