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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 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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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

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

The rest of the document is organized as follows. Section 2 contains a list of use cases or network scenarios that EMAN addresses. Section 3 contains an abstraction of the use case scenarios to distinct patterns. Section 4 deals with other standards related 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 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 electrical equipment: energy object identification, energy object context, power measurement and power characteristics.

The EMAN framework defines SNMP MIB modules based on the information model. By implementing 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 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.

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

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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.

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

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 end-points (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 and powered by a switch, then 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.

These two cases are not mutually exclusive.

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

The essential properties of this use case are:

- . 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

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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 IP
and a variety of non-IP protocols and technologies, including
RS-232/RS-485 interfaces, Ethernet interfaces, and protocols
specific to building management such as BACNET [ASHRAE], MODBUS
[MODBUS], and 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.

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

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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. However, it is important to note that EMAN is independent of whether building energy is sourced from the grid, on-site, or local storage.

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 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

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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.

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 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 any building type including a Data center. Monitoring energy consumption in real-time, as discussed in previous use cases. Then based on the potential energy shortfall. The EnMS could respond by shutting 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 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

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

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.

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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 - Common Information Model

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 IEC 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.

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.

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 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.

4.1.5. PWG

The IEEE-ISTO Printer Working Group (PWG) defines open standards for printer related protocols, for the benefit of printer manufacturers and related software vendors. The Printer WG covers power monitoring and management of network printers and

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imaging systems in the PWG Power Management Model for Imaging Systems [IEEE-ISTO]. 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

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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.

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 supported by the ZigBee Alliance, a group of companies
which maintains and publishes the ZigBee standard.

The EMAN framework addresses the general purpose needs of IP-
networks through the usage of SNMP, while ZigBee defines a for
fully integrated and inexpensive mesh solution.

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 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.

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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 50001.

4.3.2. Energy Star

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

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

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

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

The Smart Grid standards efforts underway in the United States are overseen by the U.S. National Institute of Standards and Technology [NIST]. NIST is responsible for coordinating a public-private partnership with key energy and consumer stakeholders in order to facilitate the development of smart grid standards. These activities are monitored and facilitated by the 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.

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.

7. IANA Considerations

This memo includes no request to IANA.

8. Acknowledgements

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9. Open Issues

OPEN ISSUE 1: Should review ASHRAE SPC 201P standard information model and the use cases and how it relates to EMAN

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Definition of Managed Objects for Battery Monitoring
draft-ietf-eman-battery-mib-07

Abstract

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, it defines managed objects that provide information on the status of batteries in managed devices.

Status of this Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

Today, more and more managed devices contain batteries that supply them with power when disconnected from electrical power distribution grids. Common examples are nomadic and mobile devices, such as notebook computers, netbooks, and smart phones. The status of batteries in such a device, particularly the charging status is typically controlled by automatic functions that act locally on the device and manually by users of the device.

In addition to this, there is a need to monitor battery status of these devices by network management systems. This document defines a portion of the Management Information Base (MIB) that provides a means for monitoring batteries in or attached to managed devices. The Battery MIB module defined in Section 4 meets the requirements for monitoring the status of batteries specified in [I-D.ietf-eman-requirements].

The Battery MIB module provides for monitoring the battery status. According to the framework for energy management [I-D.ietf-eman-framework] it is an Energy Managed Object, and thus, MIB modules such as the Power and Energy Monitoring MIB [I-D.ietf-eman-energy-monitoring-mib] could in principle be implemented for batteries. The Battery MIB extends the more generic aspects of energy management by adding battery-specific information. Amongst other things, the Battery MIB enables the monitoring of:

- o the current charge of a battery,
- o the age of a battery (charging cycles),
- o the state of a battery (e.g. being re-charged),
- o last usage of a battery,
- o maximum energy provided by a battery (remaining and total capacity).

Further, means are provided for battery-powered devices to send notifications when the current battery charge has dropped below a certain threshold in order to inform the management system of needed replacement. The same applies to the age of a battery.

Many battery-driven devices have existing instrumentation for monitoring the battery status, because this is already needed for local control of the battery by the device. This reduces the effort for implementing the managed objects defined in this document. For many devices only additional software will be needed but no additional hardware instrumentation for battery monitoring.

Since there are a lot of devices in use that contain more than one battery, means for battery monitoring defined in this document

support addressing multiple batteries within a single device. Also, batteries today often come in packages that can include identification and might contain additional hardware and firmware. The former allows to trace a battery and allows continuous monitoring even if the battery is e.g. installed in another device. The firmware version is useful information as the battery behavior might be different for different firmware versions.

Not explicitly in scope of definitions in this document are very small backup batteries, such as for example, batteries used on PC motherboard to run the clock circuit and retain configuration memory while the system is turned off. Other means may be required for reporting on these batteries. However, the MIB module defined in Section 3.1 can be used for this purpose.

A traditional type of managed device containing batteries is an Uninterruptible Power Supply (UPS) system; these supply other devices with electrical energy when the main power supply fails. There is already a MIB module for managing UPS systems defined in RFC 1628 [RFC1628]. This module includes managed objects for monitoring the batteries contained in an UPS system. However, the information provided by these objects is limited and tailored the particular needs of UPS systems.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies MIB modules that are compliant to the SMIV2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

3. Design of the Battery MIB Module

3.1. MIB Module Structure

The Battery MIB module defined in this document defines objects for reporting information about batteries. All managed objects providing information of the status of a battery are contained in a single table called `batteryTable`. The `batteryTable` contains one conceptual row per battery.

If there is an implementation of the Entity MIB module [RFC4133] that identifies the batteries to be reported on by individual values for managed object `entPhysicalIndex`, then it is REQUIRED that these values are used as index values for the `batteryTable`.

The kind of entity in the `entPhysicalTable` of the Entity MIB module is indicated by the value of enumeration object `entPhysicalClass`. Since there is no value called 'battery' defined for this object, it is RECOMMENDED that for batteries the value of this object is chosen to be `powerSupply(6)`.

The `batteryTable` contains three groups of objects. The first group (OIDs ending with 2-11) provides information on static properties of the battery. The second group of objects (OIDs ending with 12-19) provides information on the current battery state, if it is charging or discharging, how much it is charged, its remaining capacity, the number of experienced charging cycles, etc.

```

batteryTable(1)
+--batteryEntry(1) [batteryIndex]
    +--- --- Integer32      batteryIndex(1)
    +--- r-n SnmpAdminString batteryIdentifier(2)
    +--- r-n SnmpAdminString batteryFirmwareVersion(3)
    +--- r-n Enumeration    batteryType(4)
    +--- r-n Unsigned32     batteryTechnology(5)
    +--- r-n Unsigned32     batteryDesignVoltage(6)
    +--- r-n Unsigned32     batteryNumberOfCells(7)
    +--- r-n Unsigned32     batteryDesignCapacity(8)
    +--- r-n Unsigned32     batteryMaxChargingCurrent(9)
    +--- r-n Unsigned32     batteryTrickleChargingCurrent(10)
    +--- r-n Unsigned32     batteryActualCapacity(11)
    +--- r-n Unsigned32     batteryChargingCycleCount(12)
    +--- r-n DateAndTime    batteryLastChargingCycleTime(13)
    +--- r-n Enumeration    batteryChargingOperState(14)
    +--- rwn Enumeration    batteryChargingAdminState(15)
    +--- r-n Unsigned32     batteryActualCharge(16)
    +--- r-n Unsigned32     batteryActualVoltage(17)
    +--- r-n Integer32      batteryActualCurrent(18)
    +--- r-n Integer32      batteryTemperature(19)
    +--- rwn Unsigned32     batteryAlarmLowCharge(20)
    +--- rwn Unsigned32     batteryAlarmLowVoltage(21)
    +--- rwn Unsigned32     batteryAlarmLowCapacity(22)
    +--- rwn Unsigned32     batteryAlarmHighCycleCount(23)
    +--- rwn Integer32      batteryAlarmHighTemperature(24)
    +--- rwn Integer32      batteryAlarmLowTemperature(25)

```

The third group of objects in this table (OIDs ending with 20-25) indicates thresholds which can be used to raise an alarm if a property of the battery exceeds one of them. Raising an alarm may include sending a notification.

The Battery MIB defines four notifications. One indicating a low battery charging state, one indicating an aged battery that may need to be replaced and two dealing with battery temperature. The temperature-related notifications are either indicating the battery temperature to have risen above or fallen below a predefined value.

3.2. Battery Technologies

Static information in the batteryTable includes battery type and technology. The battery type distinguishes primary (not rechargeable) batteries from rechargeable (secondary) batteries and capacitors. The battery technology describes the actual technology of a battery, which typically is a chemical technology.

Since battery technologies are subject of intensive research and

widely used technologies are often replaced by successor technologies within a few years, the list of battery technologies was not chosen as a fixed list. Instead, IANA has created a registry for battery technologies at <http://www.iana.org/assignments/eman> where numbers are assigned to battery technologies (TBD).

The table below shows battery technologies known today that are in commercial use with the numbers assigned to them by IANA. New entries can be added to the IANA registry if new technologies are developed or if missing technologies are identified. Note that there exists a huge number of battery types that are not listed in the IANA registry. Many of them are experimental or cannot be used in an economically useful way. New entries should be added to the IANA registry only if the respective technologies are in commercial use and relevant to standardized battery monitoring over the Internet.

battery technology	assigned number
Unknown	1
Other	2
Zinc-carbon	3
Zinc chloride	4
Nickel oxyhydroxide	5
Lithium-copper oxide	6
Lithium-iron disulfide	7
Lithium-manganese dioxide	8
Zinc-air	9
Silver oxide	10
Alkaline	11
Lead acid	12
Nickel-cadmium	13
Nickel-metal hydride	14
Nickel-zinc	15
Lithium-ion	16
Lithium polymer	17
Double layer capacitor	18

3.3. Charging Cycles

The lifetime of a battery can be approximated using the measure of charging cycles. A commonly used definition of a charging cycle is the amount of discharge equal to the design (or nominal) capacity of the battery [SBS]. This means that a single charging cycle may include several steps of partial charging and discharging until the amount of discharging has reached the design capacity of the battery.

After that the next charging cycle immediately starts.

4. Definitions

BATTERY-MIB DEFINITIONS ::= BEGIN

IMPORTS

```
MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,
mib-2, Integer32, Unsigned32
    FROM SNMPv2-SMI -- RFC2578
SnmpAdminString
    FROM SNMP-FRAMEWORK-MIB -- RFC3411
DateAndTime
    FROM SNMPv2-TC -- RFC2579
MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP
    FROM SNMPv2-CONF; -- RFC2580
```

batteryMIB MODULE-IDENTITY

```
LAST-UPDATED "201106261200Z" -- 26 june 2010
ORGANIZATION "IETF EMAN Working Group"
CONTACT-INFO
    "General Discussion: eman@ietf.org
    To Subscribe: http://www.ietf.org/mailman/listinfo/eman
    Archive: http://www.ietf.org/mail-archive/web/eman
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```

DESCRIPTION

"This MIB module defines a set of objects for monitoring batteries of networked devices and of their components.

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(<http://trustee.ietf.org/license-info>).

This version of this MIB module is part of RFC yyyy; see the RFC itself for full legal notices."

-- replace yyyy with actual RFC number & remove this notice

-- Revision history

REVISION "201106261200Z" -- 26 June 2010

DESCRIPTION

"Initial version, published as RFC yyyy."

-- replace yyyy with actual RFC number & remove this notice

::= { mib-2 zzz }

-- zzz to be assigned by IANA.

--*****

-- Top Level Structure of the MIB module

--*****

batteryNotifications OBJECT IDENTIFIER ::= { batteryMIB 0 }

batteryObjects OBJECT IDENTIFIER ::= { batteryMIB 1 }

batteryConformance OBJECT IDENTIFIER ::= { batteryMIB 2 }

-- 1. Object Definitions

-- 1.1. Battery Table

batteryTable OBJECT-TYPE

SYNTAX SEQUENCE OF BatteryEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table provides information on batteries.

It contains one conceptual row per battery."

::= { batteryObjects 1 }

batteryEntry OBJECT-TYPE

SYNTAX BatteryEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry providing information on a battery."

INDEX { batteryIndex }

::= { batteryTable 1 }

```
BatteryEntry ::=
    SEQUENCE {
        batteryIndex                Integer32,
        batteryIdentifier            SnmpAdminString,
        batteryFirmwareVersion      SnmpAdminString,
        batteryType                 INTEGER,
        batteryTechnology           Unsigned32,
        batteryDesignVoltage       Unsigned32,
        batteryNumberOfCells       Unsigned32,
        batteryDesignCapacity      Unsigned32,
        batteryMaxChargingCurrent   Unsigned32,
        batteryTrickleChargingCurrent Unsigned32,
        batteryActualCapacity      Unsigned32,
        batteryChargingCycleCount  Unsigned32,
        batteryLastChargingCycleTime DateAndTime,
        batteryChargingOperState    INTEGER,
        batteryChargingAdminState   INTEGER,
        batteryActualCharge         Unsigned64,
        batteryActualVoltage       Unsigned32,
        batteryActualCurrent       Integer32,
        batteryTemperature         Integer32,
        batteryAlarmLowCharge      Unsigned32,
        batteryAlarmLowVoltage     Unsigned32,
        batteryAlarmLowCapacity    Unsigned32,
        batteryAlarmHighCycleCount Unsigned32,
        batteryAlarmHighTemperature Integer32,
        batteryAlarmLowTemperature Integer32
    }
```

```
batteryIndex OBJECT-TYPE
    SYNTAX      Integer32 (1..2147483647)
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This object identifies a battery for which status is
        reported. Index values MUST be locally unique.

        If there is an instance of the entPhysicalTable (defined in
        the ENTITY-MIB module, see RFC 4133) with an individual
        entry for each battery, then it is REQUIRED that values of
        batteryIndex match the corresponding values of
        entPhysicalIndex for the batteries. Otherwise, index values
        may be chosen arbitrarily."
    ::= { batteryEntry 1 }
```

```
batteryIdentifier OBJECT-TYPE
    SYNTAX      SnmpAdminString
    MAX-ACCESS  read-only
```

STATUS current
DESCRIPTION

"This object contains an identifier for the battery.

Many manufacturers deliver not pure batteries but battery packages including additional hardware and firmware. Typically, these modules include an identifier that can be retrieved by a device at which a battery has been installed. The identifier is useful when batteries are removed and re-installed at the same or other devices. Then the device or the network management system can trace batteries and achieve continuity of battery monitoring.

If the battery identifier cannot be represented using the ISO/IEC IS 10646-1 character set, then a hexadecimal encoding of a binary representation of the battery identifier must be used.

The value of this object must be an empty string if there is no battery identifier or if the battery identifier is unknown."

::= { batteryEntry 2 }

batteryFirmwareVersion OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the version number of the firmware that is included in a battery module.

Many manufacturers deliver not pure batteries but battery packages including additional hardware and firmware.

Since the behavior of the battery may change with the firmware, it may be useful to retrieve the firmware version number.

The value of this object must be an empty string if there is no firmware or if the version number of the firmware is unknown."

::= { batteryEntry 3 }

batteryType OBJECT-TYPE

SYNTAX INTEGER {
 unknown(1),
 other(2),
 primary(3),

```
        rechargeable(4),
        capacitor(5)
    }
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This object indicates the type of battery.
    It distinguishes between primary (not rechargeable)
    batteries, rechargeable (secondary) batteries and capacitors
    which are not really batteries but often used in the same
    way as a battery.

    The value other(2) can be used if the battery type is known
    but none of the ones above. Value unknown(1) is to be used
    if the type of battery cannot be determined."
 ::= { batteryEntry 4 }
```

batteryTechnology OBJECT-TYPE

```
SYNTAX Unsigned32
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This object indicates the technology used by the battery.
    Numbers identifying battery types are registered at IANA.
    A current list of assignments can be found at
    <http://www.iana.org/assignments/eman>.

    Value 0 (unknown) MUST be used if the type of battery
    cannot be determined.

    Value 1 (other) can be used if the battery type is known
    but not one of the types already registered at IANA."
 ::= { batteryEntry 5 }
```

batteryDesignVoltage OBJECT-TYPE

```
SYNTAX Unsigned32
UNITS "millivolt"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This object provides the design (or nominal) voltage of the
    battery in units of millivolt (mV).

    Note that the design voltage is a constant value and
    typically different from the actual voltage of the battery.

    A value of 0 indicates that the design voltage is unknown."
 ::= { batteryEntry 6 }
```

batteryNumberOfCells OBJECT-TYPE

SYNTAX Unsigned32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the number of cells contained in the battery.

A value of 0 indicates that the number of cells is unknown."

::= { batteryEntry 7 }

batteryDesignCapacity OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere hours"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the design (or nominal) capacity of the battery in units of milliampere hours (mAh).

Note that the design capacity is a constant value and typically different from the actual capacity of the battery. Usually, this is a value provided by the manufacturer of the battery.

A value of 0 indicates that the design capacity is unknown."

::= { batteryEntry 8 }

batteryMaxChargingCurrent OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the maximal current to be used for charging the battery in units of milliampere (mA).

Note that the maximal charging current may not lead to optimal charge of the battery and that some batteries can only be charged with the maximal current for a limited amount of time.

A value of 0 indicates that the maximal charging current is unknown."

::= { batteryEntry 9 }

batteryTrickleChargingCurrent OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object provides the recommended current to be used for trickle charging the battery in units of milliampere (mA).

Typically, this is a value recommended by the manufacturer of the battery or by the manufacturer of the charging circuit.

A value of 0 indicates that the recommended trickle charging current is unknown."

::= { batteryEntry 10 }

batteryActualCapacity OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object provides the actual capacity of the battery in units of milliampere hours (mAh).

Typically, the actual capacity of a battery decreases with time and with usage of the battery. It is usually lower than the design capacity

Note that the actual capacity needs to be measured and is typically an estimate based on observed discharging and charging cycles of the battery.

A value of 'ffffffff'H indicates that the actual capacity cannot be determined."

::= { batteryEntry 11 }

batteryChargingCycleCount OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates the number of completed charging cycles that the battery underwent. In line with the Smart Battery Data Specification Revision 1.1, a charging cycle is defined as the process of discharging the battery by a total amount equal to the battery design capacity as given by object batteryDesignCapacity. A charging cycle

may include several steps of charging and discharging the battery until the discharging amount given by batteryDesignCapacity has been reached. As soon as a charging cycle has been completed the next one starts immediately independent of the battery's current charge at the end of the cycle.

For batteries of type primary(1) the value of this object is always 0.

A value of 'ffffffff'H indicates that the number of charging cycles cannot be determined."

::= { batteryEntry 12 }

batteryLastChargingCycleTime OBJECT-TYPE

SYNTAX DateAndTime

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The date and time of the last charging cycle. The value '0000000000000000'H is returned if the battery has not been charged yet or if the last charging time cannot be determined.

For batteries of type primary(1) the value of this object is always '0000000000000000'H."

::= { batteryEntry 13 }

batteryChargingOperState OBJECT-TYPE

SYNTAX INTEGER {
 unknown(1),
 charging(2),
 fastCharging(3),
 maintainingCharge(4),
 noCharging(5),
 discharging(6)
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current charging state of the battery.

Value unknown(1) indicates that the charging state of the battery cannot be determined.

Value charging(2) indicates that the battery is being

charged in a way that the charge of the battery increases.

Value fastCharging(3) indicated that the battery is being charged rapidly, i.e. faster than in the charging(2) state. If multiple fast charging states exist, all of these states are indicated by fastCharging(3).

Value maintainingCharge(4) indicates that the battery is being charged with a low current that compensates self-discharging. This includes trickle charging, float charging and other methods for maintaining the current charge of a battery.

Value noCharging(5) indicates that the battery is not being charged or discharged by electric current between the battery and electric circuits external to the battery. Note that the battery may still be subject to self-discharging.

Value discharging(6) indicates that the battery is being discharged and that the charge of the battery decreases."

::= { batteryEntry 14 }

batteryChargingAdminState OBJECT-TYPE

```
SYNTAX      INTEGER {
                charging(2),
                fastCharging(3),
                maintainingCharge(4),
                noCharging(5),
                discharging(6),
                notSet(7)
            }
```

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"The value of this object indicates the desired status of the charging state of the battery. The real state is indicated by object batteryChargingOperState. See the definition of object batteryChargingOperState for a description of the values.

When this object is initialized by an implementation of the BATTERY-MIB module, its value is set to notSet(7).

However, a SET request can only set this object to either charging(2), fastCharging(3), maintainingCharge(4), noCharging(5), or discharging(6). Attempts to set this object to notSet(7) will always fail with an

'inconsistentValue' error. In case multiple fast charging states exist, the battery logic can choose an appropriate fast charging state - preferably the fastest.

When the batteryChargingAdminState object is set, then the BATTERY-MIB implementation must try to set the battery to the indicated state. The result will be indicated by object batteryChargingOperState.

Due to operational conditions and limitations of the implementation of the BATTERY-MIB module, changing the battery status according to a set value of object batteryChargingAdminState may not be possible.

Setting the value of object batteryChargingAdminState may result in not changing the state of the battery to this value or even in setting the charging state to another value. For example, setting batteryChargingAdminState to value fastCharging(3) may have no effect when the battery logic is not allowing fast charging due to temperature constraints."

```
::= { batteryEntry 15 }
```

batteryActualCharge OBJECT-TYPE

SYNTAX Unsigned64
UNITS "milliampere hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object provides the actual charge of the battery in units of milliampere hours (mAh).

Note that the actual charge needs to be measured and is typically an estimate based on observed discharging and charging cycles of the battery.

A value of 'ffffffff'H indicates that the actual charge cannot be determined."

```
::= { batteryEntry 16 }
```

batteryActualVoltage OBJECT-TYPE

SYNTAX Unsigned32
UNITS "millivolt"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object provides the actual voltage of the battery

in units of millivolt (mV).

A value of 'ffffffff'H indicates that the actual voltage cannot be determined."

::= { batteryEntry 17 }

batteryActualCurrent OBJECT-TYPE

SYNTAX Integer32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the actual charging or discharging current of the battery in units of milliampere (mA).

Charging current is represented by positive values, discharging current is represented by negative values.

A value of '7ffffffff'H indicates that the actual current cannot be determined."

::= { batteryEntry 18 }

batteryTemperature OBJECT-TYPE

SYNTAX Integer32

UNITS "deci-degrees Celsius"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The ambient temperature at or near the battery.

A value of '7ffffffff'H indicates that the temperature cannot be determined."

::= { batteryEntry 19 }

batteryAlarmLowCharge OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere hours"

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object provides the lower threshold value for object batteryActualCharge. If the value of object batteryActualCharge falls below this threshold, a low battery alarm will be raised. The alarm procedure may include generating a batteryLowNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualCharge."

::= { batteryEntry 20 }

batteryAlarmLowVoltage OBJECT-TYPE

SYNTAX Unsigned32
UNITS "millivolt"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the lower threshold value for object batteryActualVoltage. If the value of object batteryActualVoltage falls below this threshold, a low battery alarm will be raised. The alarm procedure may include generating a batteryLowNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualVoltage."

::= { batteryEntry 21 }

batteryAlarmLowCapacity OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the lower threshold value for object batteryActualCapacity. If the value of object batteryActualCapacity falls below this threshold, a battery aging alarm will be raised. The alarm procedure may include generating a batteryAgingNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualCapacity."

::= { batteryEntry 22 }

batteryAlarmHighCycleCount OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the upper threshold value for object batteryChargingCycleCount. If the value of object batteryChargingCycleCount rises above this threshold, a battery aging alarm will be raised. The alarm procedure may include generating a batteryAgingNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryChargingCycleCount."

::= { batteryEntry 23 }

batteryAlarmHighTemperature OBJECT-TYPE

```

SYNTAX      Integer32
UNITS       "deci-degrees Celsius"
MAX-ACCESS  read-write
STATUS      current
DESCRIPTION
    "This object provides the upper threshold value for object
    batteryTemperature.  If the value of object
    batteryTemperature rises above this threshold, a battery
    high temperature alarm will be raised.  The alarm procedure
    may include generating a batteryHighTemperatNotification.

    A value of '7fffffff'H indicates that no alarm will be
    raised for any value of object batteryTemperature."
 ::= { batteryEntry 24 }

```

batteryAlarmLowTemperature OBJECT-TYPE

```

SYNTAX      Integer32
UNITS       "deci-degrees Celsius"
MAX-ACCESS  read-write
STATUS      current
DESCRIPTION
    "This object provides the lower threshold value for object
    batteryTemperature.  If the value of object
    batteryTemperature rises above this threshold, a battery
    low temperature alarm will be raised.  The alarm procedure
    may include generating a batteryLowTemperatNotification.

    A value of '7fffffff'H indicates that no alarm will be
    raised for any value of object batteryTemperature."
 ::= { batteryEntry 25 }

```

```

-----
-- 2. Notifications
-----

```

batteryLowNotification NOTIFICATION-TYPE

```

OBJECTS     {
    batteryActualCharge,
    batteryActualVoltage
}
STATUS      current
DESCRIPTION
    "This notification can be generated when the current charge
    (batteryActualCharge) or the current voltage
    (batteryActualVoltage) of the battery falls below a
    threshold defined by object batteryAlarmLowCharge or object
    batteryAlarmLowVoltage, respectively. The notification can

```

only be sent again when the current voltage or the current charge become higher than the respective thresholds through charging before falling below the thresholds again (to avoid fluctuations through e.g. temperature). The notification can also be sent again when a charging process is interrupted and either the battery charge (batteryActualCharge) or battery voltage (batteryActualVoltage) is still below either the value of the object batteryAlarmLowCharge or the value of object batteryAlarmLowVoltage."

```
::= { batteryNotifications 1 }
```

batteryAgingNotification NOTIFICATION-TYPE

```
OBJECTS      {
    batteryActualCapacity,
    batteryChargingCycleCount
}
STATUS       current
DESCRIPTION   "This notification can be generated when the actual
               capacity (batteryActualCapacity) falls below a threshold
               defined by object batteryAlarmLowCapacity
               or when the charging cycle count of the battery
               (batteryChargingCycleCount) exceeds the threshold defined
               by object batteryAlarmHighCycleCount."
::= { batteryNotifications 2 }
```

batteryHighTemperatNotification NOTIFICATION-TYPE

```
OBJECTS      {
    batteryTemperature
}
STATUS       current
DESCRIPTION   "This notification can be generated when the measured
               temperature (batteryTemperature) rises above a threshold
               defined by object batteryAlarmHighTemperature."
::= { batteryNotifications 3 }
```

batteryLowTemperatNotification NOTIFICATION-TYPE

```
OBJECTS      {
    batteryTemperature
}
STATUS       current
DESCRIPTION   "This notification can be generated when the measured
               temperature (batteryTemperature) falls below a threshold
               defined by object batteryAlarmLowTemperature."
::= { batteryNotifications 4 }
```

```
-----
-- 3. Conformance Information
-----

batteryCompliances OBJECT IDENTIFIER ::= { batteryConformance 1 }
batteryGroups       OBJECT IDENTIFIER ::= { batteryConformance 2 }

-----

-- 3.1. Compliance Statements
-----

batteryCompliance MODULE-COMPLIANCE
    STATUS          current
    DESCRIPTION
        "The compliance statement for implementations of the
        POWER-STATE-MIB module.

        A compliant implementation MUST implement the objects
        defined in the mandatory groups batteryDescriptionGroup
        and batteryStatusGroup."
    MODULE -- this module
        MANDATORY-GROUPS {
            batteryDescriptionGroup,
            batteryStatusGroup
        }

    GROUP    batteryAlarmThresholdsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryAlarmThresholdsGroup."

    GROUP    batteryNotificationsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryNotificationsGroup."

    GROUP    batteryAdminGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryAdminGroup."

    OBJECT batteryAlarmLowCharge
    MIN-ACCESS read-only
    DESCRIPTION
        "The agent is not required to support set
        operations to this object."

    OBJECT batteryAlarmLowVoltage
```

MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

OBJECT batteryAlarmLowCapacity
MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

OBJECT batteryAlarmHighCycleCount
MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

OBJECT batteryHighTemperatNotification
MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

::= { batteryCompliances 1 }

-- 3.2. MIB Grouping

batteryDescriptionGroup OBJECT-GROUP
OBJECTS {
batteryIdentifier,
batteryFirmwareVersion,
batteryType,
batteryTechnology,
batteryDesignVoltage,
batteryNumberOfCells,
batteryDesignCapacity,
batteryMaxChargingCurrent,
batteryTrickleChargingCurrent
}
STATUS current
DESCRIPTION
"A compliant implementation MUST implement the objects
contained in this group."
::= { batteryGroups 1 }

batteryStatusGroup OBJECT-GROUP

```
OBJECTS {
    batteryActualCapacity,
    batteryChargingCycleCount,
    batteryLastChargingCycleTime,
    batteryChargingOperState,
    batteryActualCharge,
    batteryActualVoltage,
    batteryActualCurrent,
    batteryTemperature
}
STATUS      current
DESCRIPTION
    "A compliant implementation MUST implement the objects
    contained in this group."
 ::= { batteryGroups 2 }

batteryAdminGroup OBJECT-GROUP
OBJECTS {
    batteryChargingAdminState
}
STATUS      current
DESCRIPTION
    "A compliant implementation does not have to implement the
    object contained in this group."
 ::= { batteryGroups 3 }

batteryAlarmThresholdsGroup OBJECT-GROUP
OBJECTS {
    batteryAlarmLowCharge,
    batteryAlarmLowVoltage,
    batteryAlarmLowCapacity,
    batteryAlarmHighCycleCount,
    batteryAlarmHighTemperature,
    batteryAlarmLowTemperature
}
STATUS      current
DESCRIPTION
    "A compliant implementation does not have to implement the
    objects contained in this group."
 ::= { batteryGroups 4 }

batteryNotificationsGroup NOTIFICATION-GROUP
NOTIFICATIONS {
    batteryLowNotification,
    batteryAgingNotification,
    batteryHighTemperatNotification,
    batteryLowTemperatNotification
}
```



```
STATUS      current
DESCRIPTION
    "A compliant implementation does not have to implement the
    notifications contained in this group."
 ::= { batteryGroups 5 }
END
```

5. Security Considerations

There are a number of management objects defined in this MIB module with a MAX-ACCESS clause of read-write. Such objects may be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations. These are the tables and objects and their sensitivity/vulnerability:

- o batteryChargingAdminState
Setting the battery charging state can be beneficial for an operator for various reasons such as charging batteries when the price of electricity is low. However, setting the charging state can e.g. be used by an attacker to discharge batteries of devices and thereby switching these devices off if they are powered solely by batteries. In particular, if the batteryAlarmLowCharge and batteryAlarmLowVoltage can also be set, this attack will go unnoticed (i.e. no notifications are sent).
- o batteryAlarmLowCharge and batteryAlarmLowVoltage
These objects set the threshold for an alarm to be raised when the battery charge or voltage falls below the corresponding one of them. An attacker setting one of these alarm values can switch off the alarm by setting it to the 'off' value 0 or modify the alarm behavior by setting it to any other value. The result may be loss of data if the battery runs empty without warning to a recipient expecting such a notification.
- o batteryAlarmLowCapacity and batteryAlarmHighCycleCount
These objects set the threshold for an alarm to be raised when the battery becomes older and less performant than required for stable operation. An attacker setting this alarm value can switch off the alarm by setting it to the 'off' value 0 or modify the alarm behavior by setting it to any other value. This may either lead to a costly replacement of a working battery or too old or too weak batteries are used. The consequence of the latter could e.g. be that a battery cannot provide power long enough between two scheduled charging actions causing the powered device to shut down and potentially loose data.

- o batteryAlarmHighTemperature and batteryAlarmLowTemperature
These objects set thresholds for an alarm to be raised when the battery rises above/falls below them. An attacker setting one of these alarm values can switch off these alarms by setting them to the 'off' value '7fffffff'H or modify the alarm behavior by setting them to any other value. The result may e.g. be an unnecessary shutdown of a device if batteryAlarmHighTemperature is set to too low or damage to the device by too high temperatures if switched off or set to too high values or by damage to the battery when it e.g. is being charged. Batteries can also be damaged e.g. in an attempt to charge them at too low temperatures.

Some of the readable objects in this MIB module (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control even GET and/or NOTIFY access to these objects and possibly to even encrypt the values of these objects when sending them over the network via SNMP. These are the tables and objects and their sensitivity/vulnerability:

All potentially sensible or vulnerable objects of this MIB modules are in the batteryTable. In general, there are no serious operational vulnerabilities foreseen in case of an unauthorized read access to this table. However, privacy issues need to be considered. It may be a trade secret of the operator

- o how many batteries are installed in a managed node (batteryIndex)
- o how old these batteries are (batteryActualCapacity and batteryChargingCycleCount)
- o when the next replacement cycle for batteries can be expected (batteryAlarmLowCapacity and batteryAlarmHighCycleCount)
- o what battery type and make are used with which firmware version (batteryIdentifier, batteryFirmwareVersion, batteryType, and batteryTechnology)

SNMP versions prior to SNMPv3 did not include adequate security. Even if the network itself is secure (for example by using IPsec), even then, there is no control as to who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in this MIB module.

It is RECOMMENDED that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

Further, deployment of SNMP versions prior to SNMPv3 is NOT RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to enable cryptographic security. It is then a customer/operator

responsibility to ensure that the SNMP entity giving access to an instance of this MIB module is properly configured to give access to the objects only to those principals (users) that have legitimate rights to GET or SET (change/create/delete) them.

6. IANA Considerations

6.1. SMI Object Identifier Registration

The Battery MIB module defined in this document uses the following IANA-assigned OBJECT IDENTIFIER value recorded in the SMI Numbers registry:

Descriptor	OBJECT IDENTIFIER value
-----	-----
batteryMIB	{ mib-2 xxx }

[NOTE for IANA: Please allocate an object identifier at <http://www.iana.org/assignments/smi-numbers> for object batteryMIB.]

6.2. Battery Technology Registration

Object batteryTechnology defined in Section 4 reports battery technologies. Eighteen values for battery technologies have initially been defined. They are listed in a table in Section 3.2.

For ensuring extensibility of this list, IANA has created a registry for battery technologies at <http://www.iana.org/assignments/eman> and filled it with the initial list given in Section 3.2.

New assignments of numbers for battery technologies will be administered by IANA through Expert Review ([RFC5226]). Experts must check for sufficient relevance of a battery technology to be added.

[NOTE for IANA: Please create a new registry under <http://www.iana.org/assignments/eman> for battery types. Please fill the registry with values from the table in Section 3.2]

7. Open Issues

7.1. Entity MIB augmentation

Alignment with Entity MIB version 4 is need as soon as it becomes stable.

7.2. Kind of entity

In section 3.1 we recommend to use a value of powerSupply(6) for object entPhysicalClass, if the entity is a battery. This sections needs to be updates once we have values for entPhysicalClass maintained by IANA. We should then register a new value "battery(xy)" at IANA and replace "powerSupply(6) in this section.

7.3. Voltage and temperature per cell?

For lithium-ion batteries it is common to measure voltage not just in total but also per cell. Also temperature per cell is sometimes of interest. Shall we support this? It would require a cell table.

7.4. Notifications for removable batteries

PCs and other devices offer battery replacement at runtime. We need to specify events for added a batteries and removed batteries (batteryAddedNotification, batteryAddedNotification). The energy management system should get informed about such events, because they either create a new entry in the battery table or they remove one from it.

7.5. Notification for battery charging state changes?

Do we need a notification for battery charging state changes?

7.6. Support for ACPI critical battery state?

The ACPI has a 'critical' battery state. This is when the battery is in a state that it cannot be used anymore and must be charged. We already have a batteryLowNotification. Would we also need a batteryCriticalNotification?

8. Acknowledgements

We would like to thank Steven Chew and Bill Mielke for their valuable input.

9. References

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Energy Object Context MIB
draft-ietf-eman-energy-aware-mib-07

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Abstract

This document defines a subset of a Management Information Base (MIB) for energy management of devices. The module addresses device identification, context information, and the relationships between reporting devices, remote devices, and monitoring devices.

Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

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1. Introduction

The EMAN standards provide a specification for Energy Management. This document defines a subset of a Management Information Base (MIB) for use with network management protocols for Energy monitoring of network devices and devices attached to the network and possibly extending to devices in the industrial automation setting with a network interface.

The focus of the MIB module specified in this document is on the identification of Energy Objects and reporting the context and relationships of Energy Objects as defined in [EMAN-FMWK]. The module addresses Energy Object Identification, Energy Object Context, and Energy Object Relationships.

1.1. Energy Management Document Overview

This document specifies the ENERGY-OBJECT-CONTEXT-MIB module. This document is based on the Energy Management Framework [EMAN-FMWK] and meets the requirements on identification of Energy Objects and their context and relationships as specified in the Energy Management requirements [EMAN-REQ].

A second MIB module required by the [EMAN-FMWK], the Power and Energy Monitoring MIB [EMAN-MON-MIB], monitors the Energy Objects for Power States, for the Power and Energy consumption. Power State monitoring includes: retrieving Power States, Power State properties, current Power State, Power State transitions, and Power State statistics. In addition, this MIB module provides the Power Characteristics properties of the Power and Energy, along with optional characteristics.

The applicability statement document [EMAN-AS] provides the list of use cases, and describes the common aspects of between existing Energy standards and the EMAN standard, and shows how the EMAN framework relates to other frameworks.

2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies MIB modules that are compliant with SMIv2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

3. Requirements and Use Cases

Firstly, to illustrate the importance of energy monitoring in networks and secondly to list some of the important areas to be addressed by the energy management Framework, several use cases and network scenarios are presented in the EMAN applicability statement document [EMAN-AS]. In addition, for each scenario, the target devices for energy management, and how those devices powered and metered are also presented. To address the network scenarios, requirements for power and energy monitoring for networking devices are specified in [EMAN-REQ]. Based on the requirements [EMAN-REQ], the [EMAN-FMWK] presents an solution approach.

Accordingly, the scope of the MIB module in this document is in accordance to the requirements specified in [EMAN-REQ] and [EMAN-FMWK].

4. Terminology

Please refer to [EMAN-FMWK] for the definitions of the following terminology used in this draft.

Device

Component

Energy Management System (EnMS)

ISO Energy Management System

Energy

Power

Demand

Power Characteristics

Electrical Equipment

Non-Electrical Equipment (Mechanical Equipment)

Energy Object

Electrical Energy Object

Non-Electrical Energy Object

Energy Monitoring

Energy Control

Provide Energy:

Receive Energy:

Power Interface

Power Inlet

Power Outlet

Energy Management Domain

Energy Object Identification

Energy Object Context

Energy Object Relationship

Aggregation Relationship

Power Source Relationship

Proxy Relationship

Energy Object Parent

Energy Object Child

Power State

Power State Set

Nameplate Power

5. Architecture Concepts Applied to the MIB Module

This section describes the basic concepts specified in the Energy Management Architecture [EMAN-FMWK], with specific information related to the MIB module specified in this document.

The Energy Object Context MIB module defined in this document defines MIB objects for identification of Energy Objects, and reporting context and relationship of an Energy Object. The managed objects are contained in two tables eoTable and eoProxyTable.

The first table eoTable focuses on the link to the other MIB modules, context of the Energy Object. The second table eoRelationTable specifies the relationships between Energy Objects. This is a simplified representation of relationship between Energy Objects. The third table eoProxyTable describes the proxy capabilities of a Energy Object Parent for a specific local Energy Object Child.

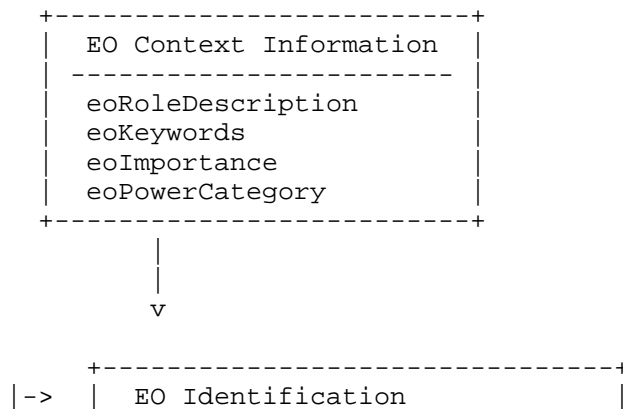
```
+-- eoTable(2)
|
|  +- eoEntry(1) [entPhysicalIndex]
|  |
|  |  +-- r-n PethPsePortIndexOrZero      eoEthPortIndex(1)
|  |  +-- r-n PethPsePortGroupIndexOrZero  eoEthPortGrpIndex(2)
|  |  +-- r-n LldpPortNumberOrZero         eoLldpPortNumber(3)
|  |  +-- rwn MacAddress                   eoMgmtMacAddress(4)
```

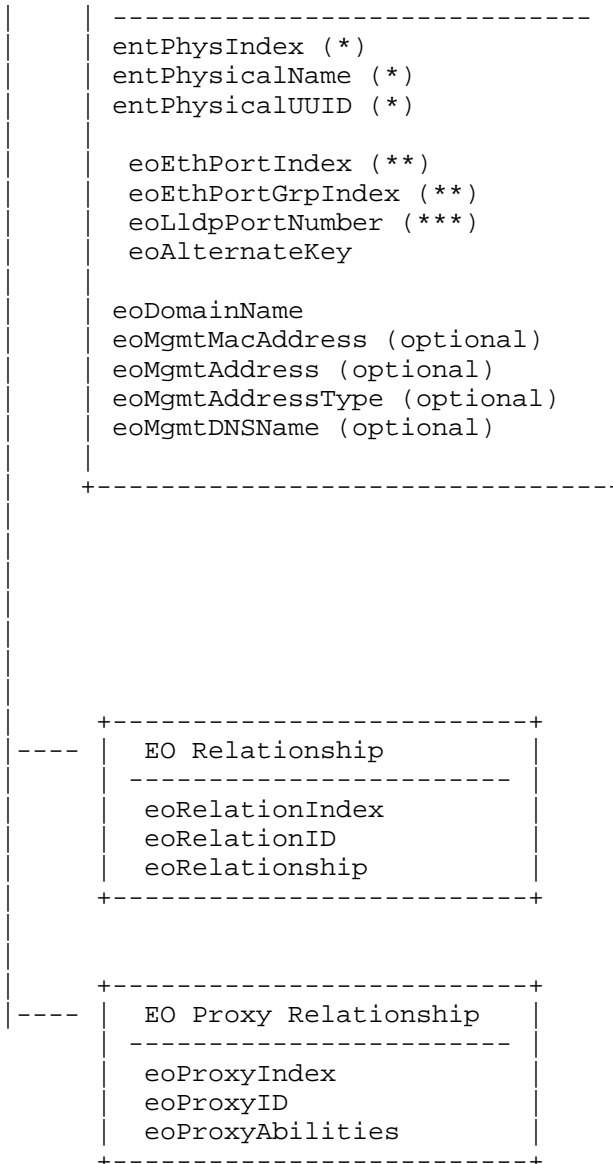
```

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|
|  +-- r-n eoMgmtAddressType          eoMgmtAddressType(5)
|  +-- r-n InetAddress                eoMgmtAddress(6)
|  +-- r-n SnmpAdminString            eoMgmtDNSName(7)
|  +-- rwn SnmpAdminString            eoDomainName(8)
|  +-- rwn SnmpAdminString            eoRoleDescription(9)
|  +-- rwn EnergyObjectKeywordList    eoKeywords(10)
|  +-- rwn Integer32                  eoImportance(11)
|  +-- r-n INTEGER                    eoPowerCategory(12)
|  +-- rwn SnmpAdminString            eoAlternateKey(13)
|
|  +- eoRelationTable
|  |
|  |  +- eoRelationEntry [entPhysicalIndex, eoRelationIndex]
|  |  |
|  |  |  +-- --n INTEGER              eoRelationIndex(1)
|  |  |  +-- --n OctetString          eoRelationID(2)
|  |  |  +-- rwn BITS                 eoRelationship(3)
|  |
|  +- eoProxyTable(3)
|  |
|  |  +- eoProxyEntry (1)[entPhysicalIndex , eoProxyIndex ]
|  |  |
|  |  |  +-- --n INTEGER              eoProxyIndex(1)
|  |  |  +-- --n OctetString          eoProxyID(2)
|  |  |  +-- r-n BITS                 eoProxyAbilities(3)

```

The following UML diagram illustrates the relationship of the MIB objects in the eoTable, eoRelationTable and eoProxyTable that describe the identity, context and relationship of an Energy Object.





- ```
(*) Compliance From the ENTITY MIB [EMAN-ENTITY]
(**) Link with the Power over Ethernet MIB [RFC3621]
(***) Link with LLDP MIBs [LLDP-MIB] [LLDP-MED-MIB]
```



As displayed in figure 1, the MIB objects can be classified in different logical grouping of MIB objects.

- 1) The Energy Object Identification. See Section 5.1 "Energy Object Identification". Devices and their sub-components are characterized by the power-related attributes of a physical entity present in the ENTITY MIB [EMAN-ENTITY].
- 2) The Context Information. See Section 5.2 "Energy Object Context"
- 3) The links to other MIB modules. See Section 5.3 "Links to other Identifiers"
- 4) The Energy Object Child Relationships specific information. See Section 5.4 "Child: Energy Objects Relationship."
- 5) The Energy Object Parent Relationships specific information. See Section 5.5 "Parent: Energy Objects Relationship."
- 6) The Energy Object Identity Persistence. See Section 5.6 "Energy Object Identity Persistence"

## 5.1 Energy Object Identification

Refer to the "Energy Object Information" section in [EMAN-FMWK] for background information about Energy Objects.

Every Energy Object MUST implement the unique index, entPhysicalIndex, entPhysicalName and entPhysicalUUID from the ENTITY MIB [EMAN-ENTITY]. Module Compliance of ENTITY-MIB with respect to entity4CRCompliance should be supported which require a limited number of objects supported (entPhysicalClass, entPhysicalName, entPhysicalUUID). entPhysicalIndex is used as index for the primary Energy Object information in the ENERGY-OBJECT-CONTEXT-MIB module.

Every Energy Object MUST have a printable name assigned to it. Energy Objects MUST implement the entPhysicalName object specified in the ENTITY-MIB, which must contain the Energy Object name.

For the ENERGY-OBJECT-CONTEXT-MIB compliance, every Energy Object instance MUST implement the entPhysicalUUID from the ENTITY MIB [EMAN-ENTITY ].

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As displayed in [RFC4122], the following is an example of the  
string representation of a UUID as a URN: urn:uuid:f81d4fae-  
7dec-11d0-a765-00a0c91e6bf6.

For example, to understand the relationship between Energy  
Object Components and Energy Objects, the ENTITY-MIB physical  
containment tree [EMAN-ENTITY ] MUST be implemented.  
A second example deals with one of the ENTITY-MIB extensions: if  
the Energy Object temperature is required, the managed objects  
from the ENTITY-SENSOR-MIB [RFC3433] should be supported.

When an Energy Object Parent acts as a Power Aggregator or a  
Power Proxy, the Energy Object Parent and its Energy Object  
Child/Children MUST be members of the same Energy Management  
Domain, specified by the eoDomainName MIB Object.

Each Energy Object MUST belong to a single Energy Management  
Domain or in other words, an Energy Object cannot belong to more  
than one Energy Management Domain. Refer to the "Energy  
Management Domain" section in [EMAN-FMWK] for background  
information. The eoDomainName, which is an element of the  
eoTable, is a read-write MIB object. The Energy Management  
Domain should map 1-1 with a metered or sub-metered portion of  
the network. The Energy Management Domain MUST be configured on  
the Energy Object Parent. The Energy Object Children MAY inherit  
the some of the domain parameters (possibly domain name, some of  
the context information such as role or keywords, importance)  
from the Energy Object Parent or the Energy Management Domain  
MAY be configured directly in an Energy Object Child.

## 5.2 Energy Object Context

Refer to the "Energy Object Context" section in [EMAN-FMWK] for  
background information.

An Energy Object must provide a value for eoImportance in the  
range of 1..100 to help differentiate the use or relative value  
of the device. The importance range is from 1 (least important)  
to 100 (most important). The default importance value is 1.

An Energy Object can provide a set of eoKeywords. These keywords  
are a list of tags that can be used for grouping and summary  
reporting within or between Energy Management Domains.

An Energy Object can be classified based on the physical properties of the Energy Object. That Energy Object can be classified as consuming power or supplying power to other devices or that Energy Object can perform both of those functions and finally, an Energy Object can be a passive meter.

Additionally, an Energy Object can provide an eoRoleDescription string that indicates the purpose the Energy Object serves in the network.

### 5.3 Links to Other Identifiers

While the entPhysicalIndex is the primary index for all MIB objects in the ENERGY-OBJECT-CONTEXT-MIB module, the Energy Management Systems (EnMS) must be able to make the link with the identifier(s) in other supported MIB modules.

If the Energy Object is a PoE port, and if the Power over Ethernet MIB [RFC3621] is supported by the Energy Object SNMP agent, then the Energy Object eoethPortIndex and eoethPortGrpIndex MUST contain the values of pethPsePortIndex and pethPsePortGroupIndex [RFC3621].

The Energy Object eoLldpPortNumber MUST contain the lldpLocPortNum from the LLDP MIB [LLDP-MIB], if the LLDP-MED MIB is supported on the Energy Object SNMP agent.

The intent behind the links to the other MIB module identifier(s) is to correlate the instances in the different MIB modules. This will allow the ENERGY-OBJECT-CONTEXT-MIB MIB module to reference other MIB modules in cases where the Power over Ethernet and the LLDP MIB modules are supported by the SNMP agent. Some use cases may not implement any of these two MIB modules for the Energy Objects. However, in situation where any of these two MIB modules are implemented, the EnMS must be able to correlate the instances in the different MIB modules.

The eoAlternateKey alternate key object specifies a manufacturer defined string that can be used to identify the Energy Object. Since EnMS may need to correlate objects across management systems, this alternate key is provided to facilitate such a link. This optional value is intended as a foreign key or alternate identifier for a manufacturer or EnMS to use to correlate the unique Energy Object Id in other systems or namespaces. If an alternate key is not available or is not applicable then the value is the zero-length string.

#### 5.4 Child: Energy Object Relationships

Refer to the "Energy Object Parent and Child" section in [EMAN-FMWK] for the definition and background information. In order to link the Energy Object Child and the Energy Object Parent, a separate table (eoRelationTable) has been introduced in this MIB module. The following relationships between Energy objects have been considered in the eoRelationTable.

Metering Relationship -> meteredBy , metering

Power Source Relationship -> poweredBy , powering

Aggregation Relationship -> aggregatedBy , aggregating

Proxy Relationship -> proxyBy , proxying

Each Energy object can have one or more Energy Object relationships with other Energy Objects. Depending on the direction of the relationship, an Energy Object can be considered as an Energy Object Parent or an Energy Object Child. The relationship between the Energy Objects is specified with an arbitrary index and the UUID of the remote Energy Object. The UUID MUST comply to the RFC 4122 specifications. It is important to note that it is possible that an Energy Object may not have an Energy Object relationship with other Energy Objects.

Proxy is a special relationship, and the Energy Object can designate another Energy Object that can have the proxy capabilities such as energy reporting, power state configurations, non physical wake capabilities (such as Wake-on-LAN)), or any combination of capabilities.

The eoProxyAbilities object is specific to the Proxy Relationship. This object describes the capabilities of the Energy Object Parent for the Energy Object Child represented by the entPhysicalIndex. The possible capabilities are: report, configuration, and/or wakeonlan. This object only applies to an Energy Object Child.

Since the communication between the Energy Object Parent and Energy Object Child may not be via SNMP (as defined in EMAN-

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FMWK), an Energy Object Child can have additional MIB objects  
that can be used for easier identification by the EnMS. The  
optional objects eoMgmtMacAddress, eoMgmtAddressType  
eoMgmtDNSName can be used to help identify the relationship  
between the child and other NMS objects. These objects can be  
used as an alternate key to help link the Energy Object with  
other keyed information that may be stored within the EnMS(s).

## 5.5 Parent: Energy Object Relationships

When the Energy Object is an Energy Object Parent, the  
relationship table specifies the relationships to every Energy  
Object children. The explicit relationship between the Energy  
Object parent and each Energy Object child can be powering,  
metering, proxying and aggregating.

## 5.6 Energy Object Identity Persistence

In some situations, the Energy Object identity information  
should be persistent even after a device reload. For example,  
in a static setup where a switch monitors a series of connected  
PoE phones, there is a clear benefit for the EnMS if the Energy  
Object Identification and all associated information persist, as  
it saves a network discovery. However, in other situations,  
such as a wireless access point monitoring the mobile user PCs,  
there is not much advantage to persist the Energy Object  
Information. The identity information of an Energy Object  
should be persisted and there is value in the writable MIB  
objects persisted.

## 6. MIB Definitions

```
-- *****
--
--
-- This MIB is used for describing the identity and the
-- context information of Energy Objects in network
--
--
-- *****
```

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ENERGY-OBJECT-CONTEXT-MIB DEFINITIONS ::= BEGIN

```
IMPORTS
 MODULE-IDENTITY,
 OBJECT-TYPE,
 mib-2,
 Integer32
 FROM SNMPv2-SMI
 TEXTUAL-CONVENTION, MacAddress, TruthValue
 FROM SNMPv2-TC
 MODULE-COMPLIANCE,
 OBJECT-GROUP
 FROM SNMPv2-CONF
 SnmpAdminString
 FROM SNMP-FRAMEWORK-MIB
 InetAddressType, InetAddress
 FROM INET-ADDRESS-MIB
 entPhysicalIndex
 FROM ENTITY-MIB
 UUIDorZero
 FROM UUID-TC-MIB;

energyAwareMIB MODULE-IDENTITY
 LAST-UPDATED "201210190000Z"
 ORGANIZATION "IETF EMAN Working Group"
 CONTACT-INFO
 "WG Charter:
 http://datatracker.ietf.org/wg/eman/charter/

 Mailing Lists:
 General Discussion: eman@ietf.org
 To Subscribe: https://www.ietf.org/mailman/listinfo/eman
 Archive: http://www.ietf.org/mail-archive/web/eman

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DESCRIPTION

"This MIB is used for describing the identity and the  
context information of Energy Objects"

REVISION

"201210190000Z"

DESCRIPTION

"Initial version, published as RFC XXXX."

::= { mib-2 xxxxx }

energyAwareMIBNotifs OBJECT IDENTIFIER

::= { energyAwareMIB 0 }

energyAwareMIBObjects OBJECT IDENTIFIER

::= { energyAwareMIB 2 }

energyAwareMIBConform OBJECT IDENTIFIER

::= { energyAwareMIB 3 }

-- Textual Conventions

PethPsePortIndexOrZero ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"This textual convention is an extension of the pethPsePortIndex convention, which defines a greater than zero value used to identify a power Ethernet PSE port. This extension permits the additional value of zero. The semantics of the value zero are object-specific and must, therefore, be defined as part of the description of any object that uses this syntax. Examples of the usage of this extension are situations where none or all physical entities need to be referenced."

SYNTAX Integer32 (0..2147483647)

PethPsePortGroupIndexOrZero ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"This textual convention is an extension of the pethPsePortGroupIndex convention from the Power Over Ethernet MIB [RFC3621], which defines a greater than zero value used to identify group containing the port to which a power Ethernet PSE is connected. This extension permits the additional value of zero. The semantics of the value zero are object-specific and must, therefore, be defined as part of the description of any object that uses this syntax. Examples of the usage of this extension are situations where none or all physical entities need to be referenced."

SYNTAX Integer32 (0..2147483647)

LldpPortNumberOrZero ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"This textual convention is an extension of the LldpPortNumber convention specified in the LLDP MIB, which defines a greater than zero value used to uniquely identify each port contained in the chassis (that is known to the LLDP agent) by a port number. This extension permits the additional value of zero. The semantics of the value zero are object-specific and must, therefore, be defined as part of the description of any object that uses this syntax. Examples of the usage of



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this extension are situations where none or all physical  
entities need to be referenced."  
SYNTAX Integer32(0..4096)

EnergyObjectKeywordList ::= TEXTUAL-CONVENTION  
STATUS                    current  
DESCRIPTION  
    "A list of keywords that can be used to group Energy  
    Objects for reporting or searching. If multiple keywords  
    are present, then this string will contain all the  
    keywords separated by the ',' character. All alphanumeric  
    characters and symbols (other than a comma), such as #,  
    (, \$, !, and &, are allowed. White spaces before and  
    after the commas are excluded, as well as within a  
    keyword itself.  
  
    For example, if an Energy Object were to be tagged with  
    the keyword values 'hospitality' and 'guest', then the  
    keyword list will be 'hospitality,guest'."  
SYNTAX OCTET STRING (SIZE (0..2048))

EnergyRelations ::= TEXTUAL-CONVENTION  
STATUS                    current  
DESCRIPTION  
    "This object specifies relationship between Energy  
    Objects. For example, poweredby relationship indicates,  
    Energy Object A is powered by Energy Object B. From the  
    point of view of Energy Object B, it is powering Energy  
    Object A. "  
SYNTAX                    BITS {  
                          none (0),                    --  
                          poweredby(1),              -- power relationship  
                          powering(2),  
                          meteredby(3),              -- meter relationship  
                          metering(4),  
                          proxyby(5),                -- proxy relationship  
                          proxying(6),  
                          aggregatedby(7), -- aggregation relationship

```
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 aggregating(8)
 }
```

-- Objects

```
eoTable OBJECT-TYPE
 SYNTAX SEQUENCE OF EoEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table lists Energy Objects."
 ::= { energyAwareMIBObjects 2 }
```

```
eoEntry OBJECT-TYPE
 SYNTAX EoEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "An entry describes the attributes of an Energy Object.
 Whenever a new Energy Object is added or an existing
 Energy Object is deleted, a row in the eoTable is added
 or deleted."

 INDEX {entPhysicalIndex }
 ::= { eoTable 1 }
```

```
EoEntry ::= SEQUENCE {
 eoEthPortIndex PethPsePortIndexOrZero,
 eoEthPortGrpIndex PethPsePortGroupIndexOrZero,
 eoLldpPortNumber LldpPortNumberOrZero,
 eoMgmtMacAddress MacAddress,
 eoMgmtAddressType InetAddressType,
 eoMgmtAddress InetAddress,
 eoMgmtDNSName SnmpAdminString,
 eoDomainName SnmpAdminString,
 eoRoleDescription SnmpAdminString,
 eoKeywords EnergyObjectKeywordList,
 eoImportance Integer32,
 eoPowerCategory INTEGER,
 eoAlternateKey SnmpAdminString
}
```

eoEthPortIndex OBJECT-TYPE  
SYNTAX PethPsePortIndexOrZero  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION  
"This variable uniquely identifies the power Ethernet  
port to which the attached device is connected [RFC3621].  
In addition, PoE MIB should be instantiated on the  
device. If such a power Ethernet port cannot be specified  
or is not known then the object is zero."  
 ::= { eoEntry 1 }

eoEthPortGrpIndex OBJECT-TYPE  
SYNTAX PethPsePortGroupIndexOrZero  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION  
"This variable uniquely identifies the group containing  
the port to which a power Ethernet PSE is connected  
[RFC3621]. In addition, PoE MIB should be instantiated on  
the device. If such a group cannot be specified or is not  
known then the object is zero."  
 ::= { eoEntry 2 }

eoLldpPortNumber OBJECT-TYPE  
SYNTAX LldpPortNumberOrZero  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION  
"This variable uniquely identifies the port component  
(contained in the local chassis with the LLDP agent) as  
defined by the lldpLocPortNum in the [LLDP-MIB] and  
[LLDP-MED-MIB]. In addition, LLDP MIB should be  
instantiated on the device If such a port number cannot  
be specified or is not known then the object is zero."  
 ::= { eoEntry 3 }

eoMgmtMacAddress OBJECT-TYPE  
SYNTAX MacAddress  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION  
"This object specifies a MAC address of the Energy  
Object. This object typically only applies to Energy  
Object Children. This object can be used as an alternate  
key to help link the Energy Object with other keyed  
information that may be stored within the EnMS(s). The

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    eoMgmtMacAddress MIB object SHOULD be implemented for  
    Energy Object Children, and MAY be implemented for Energy  
    Object Parents."  
::= { eoEntry 4 }

eoMgmtAddressType OBJECT-TYPE  
    SYNTAX            InetAddressType  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "This object specifies the eoMgmtAddress type, i.e. an  
        IPv4 address or an IPv6 address. This object MUST be  
        populated when eoMgmtAddress is populated. The  
        eoMgmtAddressType MIB object SHOULD be implemented for  
        Energy Object Children, and MAY be implemented for Energy  
        Object Parents."  
::= { eoEntry 5 }

eoMgmtAddress OBJECT-TYPE  
    SYNTAX            InetAddress  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "This object specifies the management address as an IPv4  
        address or IPv6 address of Energy Object. The IP address  
        type, i.e. IPv4 or IPv6, is determined by the  
        eoMgmtAddressType value. This object can be used as an  
        alternate key to help link the Energy Object with other  
        keyed information that may be stored within the EnMS(s).  
        The eoMgmtAddress MIB object SHOULD be implemented for  
        Energy Object Children, and MAY be implemented for Energy  
        Object Parents."  
::= { eoEntry 6 }

eoMgmtDNSName OBJECT-TYPE  
    SYNTAX            SnmpAdminString  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "This object specifies the DNS name of the eoMgmtAddress.  
        This object can be used as an alternate key to help link  
        the Energy Object with other keyed information that may  
        be stored within the EnMS(s). The eoMgmtDNSName MIB  
        objects SHOULD be implemented for Energy Object Children,  
        and MAY be implemented for Energy Object Parents."

eoDomainName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object specifies the name of an Energy Management Domain for the Energy Object. This object specifies a zero-length string value if no Energy Management Domain name is configured. The value of eoDomainName must remain constant at least from one re-initialization of the entity local management system to the next re-initialization."

::= { eoEntry 8 }

eoRoleDescription OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object specifies an administratively assigned name to indicate the purpose an Energy Object serves in the network.

For example, we can have a phone deployed to a lobby with eoRoleDescription as 'Lobby phone'.

This object specifies the value is the zero-length string value if no role description is configured.

The value of eoRoleDescription must remain constant at least from one re-initialization of the entity local management system to the next re-initialization. "

::= { eoEntry 9 }

eoKeywords OBJECT-TYPE

SYNTAX EnergyObjectKeywordList

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object specifies a list of keywords that can be used to group Energy Objects for reporting or searching. The value is the zero-length string if no keywords have been configured. If multiple keywords are present, then

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this string will contain all the keywords separated by  
the ',' character. For example, if an Energy Object were  
to be tagged with the keyword values 'hospitality' and  
'guest', then the keyword list will be  
'hospitality,guest'.

If write access is implemented and a value is written  
into the instance, the agent must retain the supplied  
value in the eoKeywords instance associated with  
the same physical entity for as long as that entity  
remains instantiated. This includes instantiations  
across all re-initializations/reboots of the local  
management agent. "  
::= { eoEntry 10        }

eoImportance OBJECT-TYPE

SYNTAX                Integer32 (1..100)

MAX-ACCESS            read-write

STATUS                current

DESCRIPTION

"This object specifies a ranking of how important the  
Energy Object is (on a scale of 1 to 100) compared with  
other Energy Objects in the same Energy Management  
Domain. The ranking should provide a business or  
operational context for the Energy Object as compared to  
other similar Energy Objects. This ranking could be used  
as input for policy-based network management.

Although network managers must establish their own  
ranking, the following is a broad recommendation:

90 to 100 Emergency response  
80 to 90 Executive or business critical  
70 to 79 General or Average  
60 to 69 Staff or support  
40 to 59 Public or guest  
1 to 39 Decorative or hospitality

The value of eoImportance must remain constant at least  
from one re-initialization of the entity local  
management system to the next re-initialization. "

DEFVAL                { 1 }

::= { eoEntry 11        }

eoPowerCategory OBJECT-TYPE

SYNTAX                INTEGER {  
                        consumer(0),

```

 producer(1),
 consumerproducer(2),
 meter(3)
 }
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION

```

"This object describes the Energy Object category, which indicates the expected behavior or physical property of the Energy Object, based on its design. An Energy Object can be a consumer(0), producer(1), or consumerproducer(2) or meter (3).

There are devices with a dual mode - consuming energy and producing of energy and those are identified as consumerproducer.

In some cases, a meter is required to measure the power consumption. In such a case, this meter Energy Object category is meter(3). "

```
 ::= { eoEntry 12 }
```

eoAlternateKey OBJECT-TYPE

```

 SYNTAX SnmpAdminString
 MAX-ACCESS read-write
 STATUS current
 DESCRIPTION

```

"This object specifies a manufacturer defined string that can be used to identify the Energy Object. Since Energy Management Systems (EnMS) and Network Management Systems (NMS) may need to correlate objects across management systems, this alternate key is provided to provide such a link. This optional value is intended as a foreign key or alternate identifier for a manufacturer or EnMS/NMS to use to correlate the unique Energy Object Id in other systems or namespaces. If an alternate key is not available or is not applicable then the value is the zero-length string.

The value of eoAlternateKey must remain constant at least from one re-initialization of the entity local management system to the next re-initialization. "

```
 ::= { eoEntry 13 }
```

eoRelationTable OBJECT-TYPE

```

 SYNTAX SEQUENCE OF EoRelationEntry
 MAX-ACCESS not-accessible

```

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                  STATUS                   current  
                  DESCRIPTION  
          "This table describes the relationships between Energy Objects."  
          ::= { energyAwareMIBObjects 3 }

eoRelationEntry OBJECT-TYPE  
     SYNTAX                   EoRelationEntry  
     MAX-ACCESS           not-accessible  
     STATUS                   current  
     DESCRIPTION  
     "An entry in this table describes the relationship between  
     Energy objects."  
     INDEX                   { entPhysicalIndex, eoRelationIndex }  
     ::= { eoRelationTable 1 }

EoRelationEntry ::= SEQUENCE {  
                                  eoRelationIndex       Integer32,  
                                  eoRelationID           UUIDorZero,  
                                  eoRelationship        EnergyRelations  
                                  }

eoRelationIndex       OBJECT-TYPE  
     SYNTAX                   Integer32 (0..2147483647)  
     MAX-ACCESS           not-accessible  
     STATUS                   current  
     DESCRIPTION  
     "This object is an arbitrary index to identify the Energy Object  
     related to another Energy Object"  
     ::= { eoRelationEntry 1 }

eoRelationID           OBJECT-TYPE  
     SYNTAX                   UUIDorZero  
     MAX-ACCESS           read-only  
     STATUS                   current  
     DESCRIPTION  
     "This object specifies the Universally Unique Identifier (UUID)  
     of the peer (other) Energy Object. The UUID must comply to the  
     RFC 4122 specifications. "  
     ::= { eoRelationEntry 2 }

eoRelationship        OBJECT-TYPE  
     SYNTAX                   EnergyRelations  
     MAX-ACCESS           read-write  
     STATUS                   current



DESCRIPTION

"This object describes the relations between Energy objects. For each Energy object, the relations between the other Energy objects are specified using the bitmap. If the Energy Object is a Parent and has no other relations, none(0) is specified."

::= { eoRelationEntry 3 }

eoProxyTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoProxyEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table describes the proxy capabilities of a Energy Object Parent for a specific local Energy Object Child. "

::= { energyAwareMIBObjects 4 }

eoProxyEntry OBJECT-TYPE

SYNTAX EoProxyEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry describes the attributes of an Energy Object. Whenever a new Energy Object is added or deleted, a row in the eoProxyTable is added or deleted."

INDEX { entPhysicalIndex, eoProxyIndex }

::= { eoProxyTable 1 }

EoProxyEntry ::= SEQUENCE {

eoProxyIndex Integer32,  
eoProxyID UUIDorZero,  
eoProxyAbilities BITS

}

eoProxyIndex OBJECT-TYPE

SYNTAX Integer32 (0..2147483647)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This object is an arbitrary index for an Energy Object."

::= { eoProxyEntry 1 }

eoProxyID OBJECT-TYPE

SYNTAX UUIDorZero

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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"This object describes the Universally Unique Identifier  
(UUID) of the Energy Object Parent.

The UUID must comply to the RFC 4122 specifications.

The object contains an URI and, therefore, the syntax of  
this object must conform to RFC 3986, section 2."

REFERENCE

"RFC 3986, Uniform Resource Identifiers (URI): Generic  
Syntax, section 2, August 1998.  
RFC 4122, Uniform Resource Identifier (UUID) URN  
Namespace, July 2005."

::= { eoProxyEntry 2 }

eoProxyAbilities OBJECT-TYPE

SYNTAX                BITS {  
                      none(0),  
                      report(1),  
                      configuration(2),  
                      wakeonlan(3)  
                      }

MAX-ACCESS            read-only

STATUS                current

DESCRIPTION

"This object describes the proxy capabilities of the  
Energy Object Parent for the local Energy Object Child  
specified in the EoRelationTable. none (0) is be used  
when the Energy Object Parent does not have any proxy  
abilities regarding the Energy Object Child. report(1)  
indicates that the Energy Object Parent reports the usage  
for the Energy Object Child.  
configuration(2) indicates that the Energy Object Parent  
can configure the Power Level for the Energy Object  
Child.  
wakeonlan(3) indicates that the Energy Object Parent can  
wake up the Energy Object Child (the mechanism is  
unspecified)."

::= { eoProxyEntry 3 }

-- Conformance

energyAwareMIBCompliances OBJECT IDENTIFIER

::= { energyAwareMIBObjects 5 }

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energyAwareMIBGroups    OBJECT IDENTIFIER  
     ::= { energyAwareMIBObjects 6    }

energyAwareMIBFullCompliance MODULE-COMPLIANCE

     STATUS                    current

     DESCRIPTION

         "When this MIB is implemented with support for  
         read-write, then such an implementation can  
         claim full compliance. Such devices can then  
         be both monitored and configured with this MIB."

     MODULE                    -- this module

     MANDATORY-GROUPS {  
         energyAwareMIBTableGroup,  
         energyAwareRelationTableGroup  
     }

GROUP           energyAwareOptionalMIBTableGroup

     DESCRIPTION

         "A compliant implementation does not have to  
         implement. Module Compliance of ENTITY-MIB  
         with respect to entity4CRCompliance should  
         be supported. "

GROUP           energyAwareProxyTableGroup

     DESCRIPTION "A compliant MIB implementation does  
     not have to implement. Module Compliance of  
     ENTITY-MIB with respect to entity4CRCompliance  
     should be supported. "

     ::= { energyAwareMIBCompliances 1 }

energyAwareMIBReadOnlyCompliance MODULE-COMPLIANCE

     STATUS                    current

     DESCRIPTION

         "When this MIB is implemented without support for  
         read-write (i.e. in read-only mode), then such an  
         implementation can claim read-only compliance.  
         Such a device can then be monitored but cannot be  
         Configured with this MIB.  
         Module Compliance of ENTITY-MIB with respect to

```

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 entity4CRCompliance should be supported."
MODULE -- this module

MANDATORY-GROUPS {
 energyAwareMIBTableGroup,
 energyAwareRelationTableGroup
 }

GROUP energyAwareOptionalMIBTableGroup
DESCRIPTION
 "A compliant implementation does not have to implement
 the managed objects in this GROUP.
 Module Compliance of ENTITY-MIB
 with respect to entity4CRCompliance should
 be supported. "

 ::= { energyAwareMIBCompliances 2 }

-- Units of Conformance

energyAwareMIBTableGroup OBJECT-GROUP
 OBJECTS
 {
 eoDomainName,
 eoRoleDescription,
 eoAlternateKey,
 eoKeywords,
 eoImportance,
 eoPowerCategory
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the objects
 related to the EnergyObject.
 Module Compliance of ENTITY-MIB
 with respect to entity4CRCompliance should
 be supported. "
 ::= { energyAwareMIBGroups 1 }

energyAwareOptionalMIBTableGroup OBJECT-GROUP
 OBJECTS
 {

```

```

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 eoEthPortIndex,
 eoEthPortGrpIndex,
 eoLldpPortNumber,
 eoMgmtMacAddress,
 eoMgmtAddressType,
 eoMgmtAddress,
 eoMgmtDNSName
 }
STATUS current
DESCRIPTION
 "This group contains the collection of all the objects
 related to the Energy Object."
 ::= { energyAwareMIBGroups 2 }

energyAwareRelationTableGroup OBJECT-GROUP
 OBJECTS
 {
 -- Note that object eoRelationIndex is not
 -- included since it is not-accessible

 eoRelationID,
 eoRelationship
 }
 STATUS current
DESCRIPTION
 "This group contains the collection of all objects
 specifying the relationship between Energy Objects."
 ::= { energyAwareMIBGroups 3 }

energyAwareProxyTableGroup OBJECT-GROUP
 OBJECTS
 {
 -- Note that object eoProxyIndex is not
 -- included since it is not-accessible

 eoProxyID,
 eoProxyAbilities
 }
 STATUS current
DESCRIPTION
 "This group contains the collection of all objects
 specifying the Proxy relationship."
 ::= { energyAwareMIBGroups 4 }

END

```

Some of the readable objects in these MIB modules (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control even GET and/or NOTIFY access to these objects and possibly to even encrypt the values of these objects when sending them over the network via SNMP.

There are a number of management objects defined in these MIB modules with a MAX-ACCESS clause of read-write and/or read-create. Such objects MAY be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations. The following are the tables and objects and their sensitivity/vulnerability:

- . Unauthorized changes to the eoDomainName, entPhysicalName, eoRoleDescription, eoKeywords, and/or eoImportance MAY disrupt power and energy collection, and therefore any predefined policies defined in the network.

SNMP versions prior to SNMPv3 did not include adequate security. Even if the network itself is secure (for example, by using IPsec), there is still no secure control over who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in these MIB modules.

It is RECOMMENDED that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

Further, deployment of SNMP versions prior to SNMPv3 is NOT RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to enable cryptographic security. It is then a customer/operator responsibility to ensure that the SNMP entity giving access to an instance of these MIB modules is properly configured to give access to the objects only to those principals (users) that have legitimate rights to GET or SET (change/create/delete) them.

## 8. IANA Considerations

The MIB module in this document uses the following IANA-assigned OBJECT IDENTIFIER values recorded in the SMI Numbers registry:

| Descriptor     | OBJECT IDENTIFIER value |
|----------------|-------------------------|
| -----          | -----                   |
| energyAwareMIB | { mib-2 xxx }           |

Additions to this MIB module are subject to Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested MIB objects for completeness and accuracy of the description. Requests for MIB objects that duplicate the functionality of existing objects SHOULD be declined. The smallest available OID SHOULD be assigned to a new MIB objects. The specification of new MIB objects SHOULD follow the structure specified in Section 6 and MUST be published using a well-established and persistent publication medium.

## 9. Acknowledgement

We would like to thank Juergen Quittek and Juergen Schoenwalder for their suggestions on the new design of EnergyRelationsTable which was a proposed solution for the open issue on the representation of Energy Object children as a UUIDlist.

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Power and Energy Monitoring MIB  
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## Abstract

This document defines a subset of the Management Information Base (MIB) for power and energy monitoring of devices.

## Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

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## 1. Introduction

This document defines a subset of the Management Information Base (MIB) for use in energy management of devices within or connected to communication networks. The MIB modules in this document are designed to provide a model for energy management, which includes monitoring for power state and energy consumption of networked elements. This MIB takes into account the Energy Management Framework [EMAN-FMWK], which in turn, is based on the Requirements for Energy Management [EMAN-REQ].

Energy management is applicable to devices in communication networks. Target devices for this specification include (but are not limited to): routers, switches, Power over Ethernet (PoE) endpoints, protocol gateways for building management systems, intelligent meters, home energy gateways, hosts and servers, sensor proxies, etc. Target devices and the use cases

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for Energy Management are discussed in Energy Management  
Applicability Statement [EMAN-AS].

Where applicable, device monitoring extends to the individual components of the device and to any attached dependent devices. For example: A device can contain components that are independent from a power-state point of view, such as line cards, processor cards, hard drives. A device can also have dependent attached devices, such as a switch with PoE endpoints or a power distribution unit with attached endpoints.

Devices and their sub-components may be characterized by the power-related attributes of a physical entity present in the ENTITY-MIB, even though the ENTITY-MIB compliance is not a requirement due to the variety and broad base of devices concerned with energy management.

## 2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies MIB modules that are compliant to SMIv2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

## 3. Use Cases

Requirements for power and energy monitoring for networking devices are specified in [EMAN-REQ]. The requirements in [EMAN-REQ] cover devices typically found in communications networks, such as switches, routers, and various connected endpoints. For a power monitoring architecture to be useful, it should also apply to facility meters, power distribution units, gateway proxies for commercial building control, home automation devices, and devices that interface with the utility and/or smart grid. Accordingly, the scope of the MIB modules in this document is broader than that specified in [EMAN-REQ]. Several use cases for Energy Management have been identified in the

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"Energy Management (EMAN) Applicability Statement" [EMAN-AS]. An  
illustrative example scenario is presented in Section 8.

#### 4. Terminology

Please refer to [EMAN-FMWK] for the definitions of the  
following terminology used in this draft.

Device

Component

Energy Management

Energy Management System (EnMS)

ISO Energy Management System

Energy

Power

Demand

Power Characteristics

Electrical Equipment

Non-Electrical Equipment (Mechanical Equipment)

Energy Object

Electrical Energy Object

Non-Electrical Energy Object

Energy Monitoring

Energy Control

Provide Energy:

Receive Energy:

Power Interface



Power Outlet

Energy Management Domain

Energy Object Identification

Energy Object Context

Energy Object Relationship

Aggregation Relationship

Metering Relationship

Power Source Relationship

Proxy Relationship

Energy Object Parent

Energy Object Child

Power State

Power State Set

Nameplate Power

## 5. Architecture Concepts Applied to the MIB Module

This section describes the concepts specified in the Energy Management Framework [EMAN-FMWK] that pertain to power usage, with specific information related to the MIB module specified in this document. This subsection maps to the section "Architecture High Level Concepts" in the Power Monitoring Architecture [EMAN-FMWK].

The Energy Monitoring MIB has 2 independent MIB modules. The first MIB module energyObjectMib is focused on measurement of power and energy. The second MIB module powerCharMIB is focused on Power Characteristics measurements.

The energyObjectMib MIB module consists of four tables. The first table eoPowerTable is indexed by entPhysicalIndex. The second table eoPowerStateTable indexed by entPhysicalIndex,

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 and eoPowerStateIndex. The eoEnergyParametersTable is indexed  
 by eoEnergyParametersIndex. The eoEnergyTable is indexed by  
 eoEnergyParametersIndex and eoEnergyCollectionStartTime.

```

eoMeterCapabilitiesTable(1)
|
+--- eoMeterCapabilitiesEntry(1) [entPhysicalIndex]
| |
| +---r-n BITS eoMeterCapability
|
|
eoPowerTable(1)
|
+---eoPowerEntry(1) [entPhysicalIndex]
| |
| +---r-n Integer32 eoPower(1)
| +-- r-n Integer32 eoPowerNamePlate(2)
| +-- r-n UnitMultiplier eoPowerUnitMultiplier(3)
| +-- r-n Integer32 eoPowerAccuracy(4)
| +-- r-n INTEGER eoMeasurementCaliber(5)
| +-- r-n INTEGER eoPowerCurrentType(6)
| +-- r-n INTEGER eoPowerOrigin(7)
| +-- rwn Integer32 eoPowerAdminState(8)
| +-- r-n Integer32 eoPowerOperState(9)
| +-- r-n OwnerString eoPowerStateEnterReason(10)
| |
| +---eoPowerStateTable(2)
| | +---eoPowerStateEntry(1)
| | | [entPhysicalIndex,
| | | eoPowerStateIndex]
| | |
| | +--- --n IANAPowerStateSet eoPowerStateIndex(1)
| | +-- r-n Integer32 eoPowerStateMaxPower (2)
| | +-- r-n UnitMultiplier
| | | eoPowerStatePowerUnitMultiplier (3)
| | +-- r-n TimeTicks eoPowerStateTotalTime(4)
| | +-- r-n Counter32 eoPowerStateEnterCount(5)
| |
| +---eoEnergyParametersTable(1)
| +---eoEnergyParametersEntry(1) [eoEnergyParametersIndex]
| |
| | +--- --n PhysicalIndex eoEnergyObjectIndex (1)
| | + r-n Integer32 eoEnergyParametersIndex (2)
| | +-- r-n TimeInterval

```

```

| eoEnergyParametersIntervalLength (3)
| +--- r-n Integer32
| eoEnergyParametersIntervalNumber (4)
| +--- r-n Integer32
| eoEnergyParametersIntervalMode (5)
| +--- r-n TimeInterval
| eoEnergyParametersIntervalWindow (6)
| +--- r-n Integer32
| eoEnergyParametersSampleRate (7)
| +--- r-n RowStatus eoEnergyParametersStatus (8)
|
+eoEnergyTable (1)
+----eoEnergyEntry(1) [eoEnergyParametersIndex,
eoEnergyCollectionStartTime]
|
| +--- r-n TimeTicks eoEnergyCollectionStartTime (1)
| +--- r-n Integer32 eoEnergyConsumed (2)
| +--- r-n Integer32 eoEnergyProduced (3)
| +--- r-n Integer32 eoEnergyNet (4)
| +--- r-n UnitMultiplier
| eoEnergyUnitMultiplier (5)
| +--- r-n Integer32 eoEnergyAccuracy(6)
| +--- r-n Integer32 eoEnergyMaxConsumed (7)
| +--- r-n Integer32 eoEnergyMaxProduced (8)
| +--- r-n TimeTicks
| eoEnergyDiscontinuityTime(9)
| +--- r-n RowStatus eoEnergyParametersStatus (10)

```

The powerCharacteristicsMIB consists of four tables.  
 eoACPwrCharacteristicsTable is indexed by entPhysicalIndex.  
 eoACPwrCharacteristicsPhaseTable is indexed by entPhysicalIndex  
 and eoPhaseIndex. eoACPwrCharacteristicsWyePhaseTable and  
 eoACPwrCharacteristicsDelPhaseTable are indexed by  
 entPhysicalIndex and eoPhaseIndex.

```

eoACPwrCharacteristicsTable (1)
|
+----eoACPwrCharacteristicsEntry (1) [entPhysicalIndex]
|
| +----r-n INTEGER eoACPwrCharacteristicsConfiguration
(1)
| +--- r-n Integer32 eoACPwrCharacteristicsAvgVoltage (2)
| +--- r-n Integer32 eoACPwrCharacteristicsAvgCurrent (3)
| +--- r-n Integer32 eoACPwrCharacteristicsFrequency (4)
| +--- r-n UnitMultiplier
| eoACPwrCharacteristicsPowerUnitMultiplier (5)

```

```

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| +--- r-n Integer32 eoACPwrCharacteristicsPowerAccuracy
(6) |
| +--- r-n Integer32
| eoACPwrCharacteristicsTotalActivePower (7)
| +--- r-n Integer32
| | eoACPwrCharacteristicsTotalReactivePower (8)
| +--- r-n Integer32
| eoACPwrCharacteristicsTotalApparentPower (9)
| +--- r-n Integer32
| eoACPwrCharacteristicsTotalPowerFactor(10)
| +--- r-n Integer32 eoACPwrCharacteristicsThdAmperes
(11) |
| +eoACPwrCharacteristicsPhaseTable (1)
| +---EoACPwrCharacteristicsPhaseEntry(1)[entPhysicalIndex,
| | | |
| | | | eoPhaseIndex]
| | | |
| | +--- r-n Integer32 eoPhaseIndex (1)
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsPhaseAvgCurrent (2)
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsPhaseActivePower (3)
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsPhaseReactivePower (4)
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsPhaseApparentPower (5)
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsPhasePowerFactor (6)
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsPhaseImpedance (7)
| |
| +eoACPwrCharacteristicsDelPhaseTable (1)
| +--- eoACPwrCharacteristicsDelPhaseEntry(1)
| | | |
| | | | [entPhysicalIndex,
| | | | | | |
| | | | | | | eoPhaseIndex]
| | | |
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage
(1) |
| | +--- r-n Integer32
| | | eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage
(2) |
| | +--- r-n Integer32 eoACPwrCharacteristicsDelThdCurrent
(3) |
| |
| +eoACPwrCharacteristicsWyePhaseTable (1)
| +--- eoACPwrCharacteristicsWyePhaseEntry (1)
| | | |
| | | | [entPhysicalIndex,
| | | | | | |
| | | | | | | eoPhaseIndex]

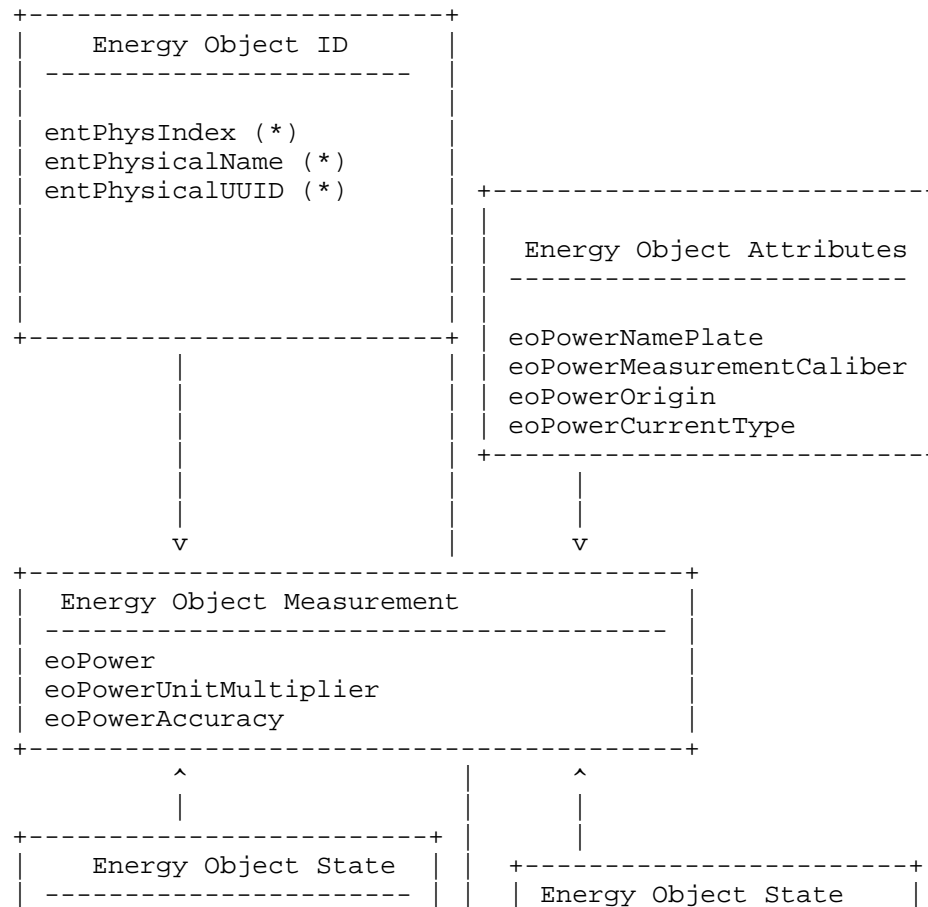
```

```

Internet-Draft <Power and Energy Monitoring MIB> October 2012
|
| +-- r-n Integer32
| | eoACPwrCharacteristicsWyePhaseToNeutralVoltage
(1)
|
| +-- r-n Integer32
| | eoACPwrCharacteristicsWyePhaseCurrent (2)
| +-- r-n Integer32
| | eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage
(3)
|
| .

```

A UML representation of the MIB objects in the two MIB modules are energyObjectMib and powerCharacteristicsMIB are presented.



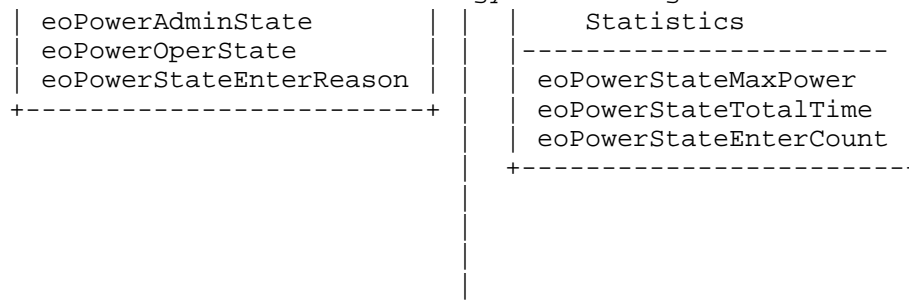
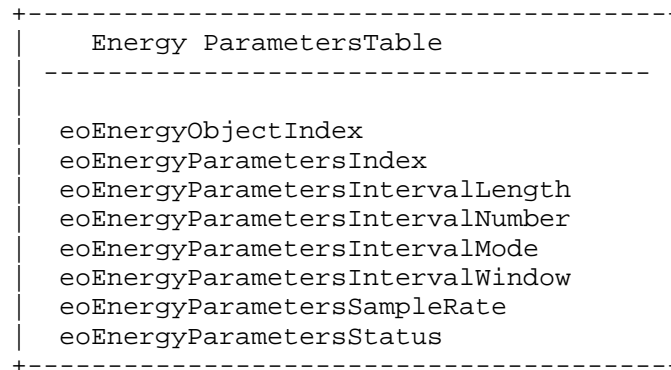


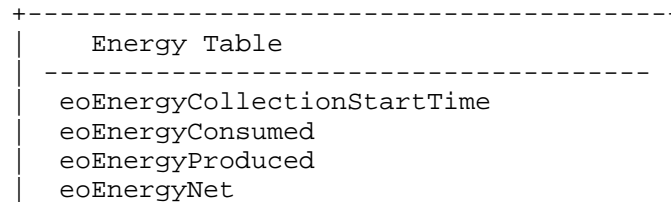
Figure 1:UML diagram for energyObjectMib

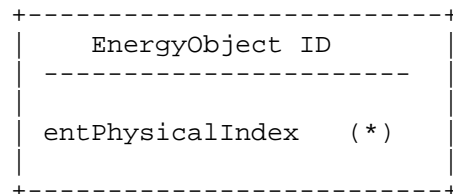
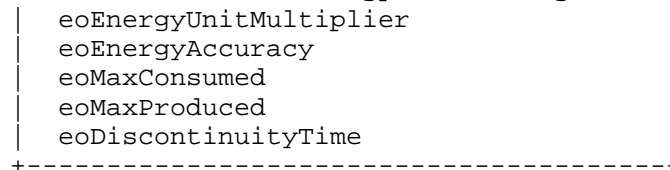
(\*)    Link with the ENTITY-MIB

V

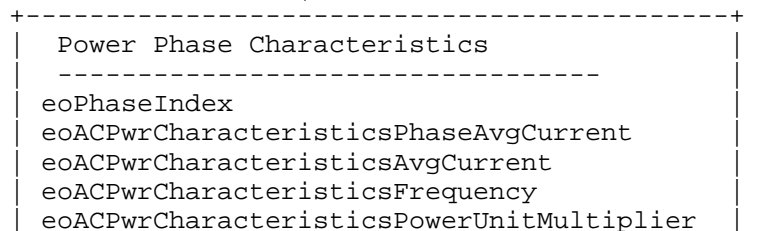
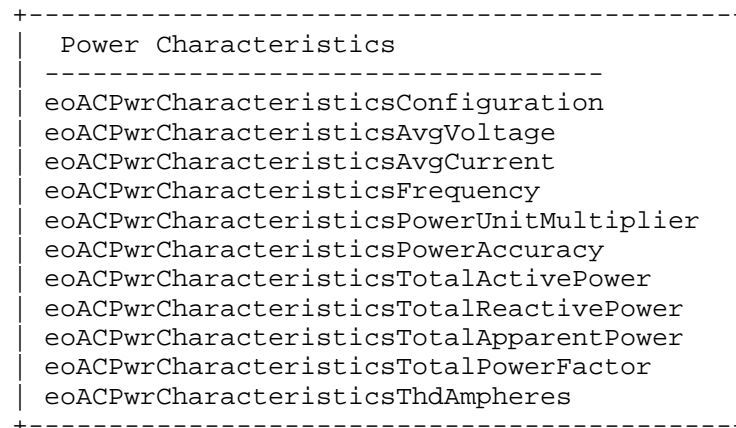


V





↓  
v



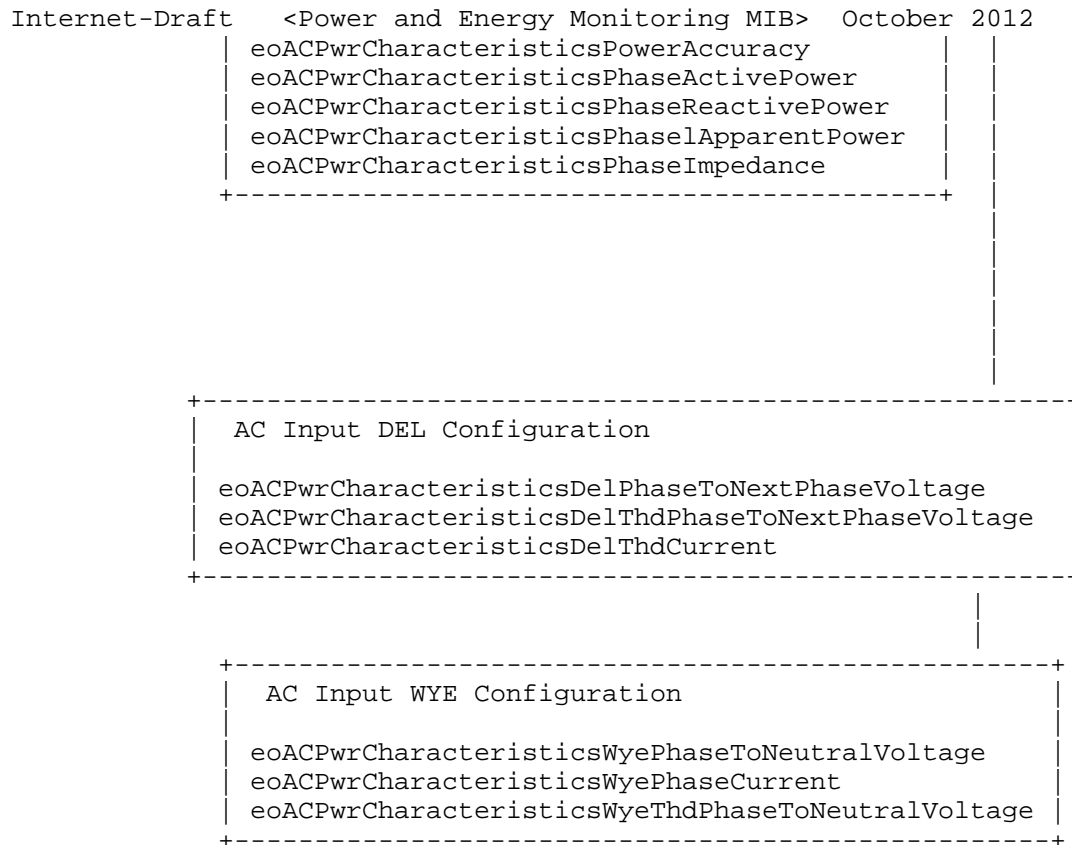


Figure 2: UML diagram for the powerCharacteristicsMIB

(\*) Link with the ENTITY-MIB

### 5.1. Energy Object Information

Refer to the "Energy Object Information" section in [EMAN-FMWK] for background information. An energy aware device is considered as an instance of a Energy Object as defined in the [EMAN-FMWK].



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The Energy Object identity information is specified in the MIB ENERGY-AWARE-MIB module [EMAN-AWARE-MIB] primary table, i.e. the eoTable. In this table, every Energy Object SHOULD have a printable name eoName, and MUST HAVE a unique Energy Object index entPhysicalUUID and entPhysicalIndex. The ENERGY-AWARE-MIB module returns the relationship (parent/child) between Energy Objects. There are several possible relationships between Parent and Child as defined in [EMAN-AWARE-MIB] such as MeteredBy, PoweredBy, AggregatedBy and ProxyedBy.

## 5.2. Power State

Refer to the "Power States" section in [EMAN-FMWK] for background information.

An Energy Object may have energy conservation modes called Power States. Between the ON and OFF states of a device, there can be several intermediate energy saving modes. Those energy saving modes are called as Power States.

Power States, which represent universal states of power management of an Energy Object, are specified by the eoPowerState MIB object. The actual Power State is specified by the eoPowerOperState MIB object, while the eoPowerAdminState MIB object specifies the Power State requested for the Energy Object. The difference between the values of eoPowerOperState and eoPowerAdminState can be attributed that the Energy Object is busy transitioning from eoPowerAdminState into the eoPowerOperState, at which point it will update the content of eoPowerOperState. In addition, the possible reason for change in Power State is reported in eoPowerStateEnterReason. Regarding eoPowerStateEnterReason, management stations and Energy Objects should support any format of the owner string dictated by the local policy of the organization. It is suggested that this name contain at least the reason for the transition change, and one or more of the following: IP address, management station name, network manager's name, location, or phone number.

The MIB objects eoPowerOperState, eoPowerAdminState, and eoPowerStateEnterReason are contained in the eoPowerTable MIB table.

The eoPowerStateTable table enumerates the maximum power usage in watts, for every single supported Power State of each Power State Set supported by the Energy Object. In addition,

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PowerStateTable provides additional statistics:  
eoPowerStateEnterCount, the number of times an entity has  
visited a particular Power State, and eoPowerStateTotalTime, the  
total time spent in a particular Power State of an Energy  
Object.

#### 5.2.1. Power State Set

There are several standards and implementations of Power State  
Sets. A Energy Object can support one or multiple Power State  
Set implementation(s) concurrently.

There are currently three Power State Sets advocated:

- unknown(0)
- IEEE1621(256) - [IEEE1621]
- DMTF(512) - [DMTF]
- EMAN(1024) - [EMAN-MONITORING-MIB]

The respective specific states related to each Power State Set  
are specified in the following sections. The guidelines for  
addition of new Power State Sets have been specified in the IANA  
Considerations Section.

#### 5.2.2. IEEE1621 Power State Set

The IEEE1621 Power State Set [IEEE1621] consists of 3  
rudimentary states : on, off or sleep.

- on(0) - The device is fully On and all features of the  
device are in working mode.
- off(1) - The device is mechanically switched off and does  
not consume energy.
- sleep(2) - The device is in a power saving mode, and some  
features may not be available immediately.

The Textual Convention IANAPowerStateSet provides the proposed  
numbering of the Power States within the IEEE1621 Power State  
Set.

#### 5.2.3. DMTF Power State Set

DMTF [DMTF] standards organization has defined a power profile  
standard based on the CIM (Common Information Model) model that  
consists of 15 power states ON (2), SleepLight (3), SleepDeep

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 (4), Off-Hard (5), Off-Soft (6), Hibernate(7), PowerCycle Off-Soft (8), PowerCycle Off-Hard (9), MasterBus reset (10), Diagnostic Interrupt (11), Off-Soft-Graceful (12), Off-Hard Graceful (13), MasterBus reset Graceful (14), Power-Cycle Off-Soft Graceful (15), PowerCycle-Hard Graceful (16). DMTF standard is targeted for hosts and computers. Details of the semantics of each Power State within the DMTF Power State Set can be obtained from the DMTF Power State Management Profile specification [DMTF].

DMTF power profile extends ACPI power states. The following table provides a mapping between DMTF and ACPI Power State Set:

| DMTF<br>Power State                | ACPI<br>Power State |
|------------------------------------|---------------------|
| Reserved(0)                        |                     |
| Reserved(1)                        |                     |
| ON (2)                             | G0-S0               |
| Sleep-Light (3)                    | G1-S1 G1-S2         |
| Sleep-Deep (4)                     | G1-S3               |
| Power Cycle (Off-Soft) (5)         | G2-S5               |
| Off-hard (6)                       | G3                  |
| Hibernate (Off-Soft) (7)           | G1-S4               |
| Off-Soft (8)                       | G2-S5               |
| Power Cycle (Off-Hard) (9)         | G3                  |
| Master Bus Reset (10)              | G2-S5               |
| Diagnostic Interrupt (11)          | G2-S5               |
| Off-Soft Graceful (12)             | G2-S5               |
| Off-Hard Graceful (13)             | G3                  |
| MasterBus Reset Graceful (14)      | G2-S5               |
| Power Cycle off-soft Graceful (15) | G2-S5               |

```

| Power Cycle off-hard Graceful (16)| G3 |

```

Figure 3: DMTF and ACPI Powe State Set Mapping

The Textual Convention IANAPowerStateSet contains the proposed numbering of the Power States within the DMTF Power State Set.

#### 5.2.4. EMAN Power State Set

The EMAN Power State Set represents an attempt for a uniform standard approach to model the different levels of power consumption of a device. The EMAN Power States are an expansion of the basic Power States as defined in IEEE1621 that also incorporate the Power States defined in ACPI and DMTF. Therefore, in addition to the non-operational states as defined in ACPI and DMTF standards, several intermediate operational states have been defined.

There are twelve Power States, that expand on IEEE1621 on, sleep and off. The expanded list of Power States are divided into six operational states, and six non-operational states. The lowest non-operational state is 1 and the highest is 6. Each non-operational state corresponds to an ACPI state [ACPI] corresponding to Global and System states between G3 (hard-off) and G1 (sleeping). For Each operational state represent a performance state, and may be mapped to ACPI states P0 (maximum performance power) through P5 (minimum performance and minimum power).

An Energy Object may have fewer Power States than twelve and would then map several policy states to the same power state. Energy Object with more than twelve states, would choose which twelve to represent as power policy states.

In each of the non-operational states (from mechoff(1) to ready(6)), the Power State preceding it is expected to have a lower power consumption and a longer delay in returning to an operational state:

IEEE1621 Power(off):

```

 mechoff(1) : An off state where no entity features are
 available. The entity is unavailable.
 No energy is being consumed and the power

```

softoff(2) : Similar to mechoff(1), but some components remain powered or receive trace power so that the entity can be awakened from its off state. In softoff(2), no context is saved and the device typically requires a complete boot when awakened. This corresponds to ACPI state G2.

IEEE1621 Power(sleep)

hibernate(3): No entity features are available. The entity may be awakened without requiring a complete boot, but the time for availability is longer than sleep(4). An example for state hibernate(3) is a save-to-disk state where DRAM context is not maintained. Typically, energy consumption is zero or close to zero. This corresponds to state G1, S4 in ACPI.

sleep(4) : No entity features are available, except for out-of-band management, for example wake-up mechanisms. The time for availability is longer than standby(5). An example for state sleep(4) is a save-to-RAM state, where DRAM context is maintained. Typically, energy consumption is close to zero. This corresponds to state G1, S3 in ACPI.

standby(5) : No entity features are available, except for out-of-band management, for example wake-up mechanisms. This mode is analogous to cold-standby. The time for availability is longer than ready(6). For example, the processor context is not maintained. Typically, energy consumption is close to zero. This corresponds to state G1, S2 in ACPI.

ready(6) : No entity features are available, except for out-of-band management, for example wake-up mechanisms. This mode is analogous to hot-standby. The entity can

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be quickly transitioned into an operational state. For example, processors are not executing, but processor context is maintained. This corresponds to state G1, S1 in ACPI.

IEEE1621 Power(on):

lowMinus(7) : Indicates some entity features may not be available and the entity has selected measures/options to provide less than low(8) usage. This corresponds to ACPI State G0. This includes operational states lowMinus(7) to full(12).

low(8) : Indicates some features may not be available and the entity has taken measures or selected options to provide less than mediumMinus(9) usage.

mediumMinus(9): Indicates all entity features are available but the entity has taken measures or selected options to provide less than medium(10) usage.

medium(10) : Indicates all entity features are available but the entity has taken measures or selected options to provide less than highMinus(11) usage.

highMinus(11): Indicates all entity features are available and power usage is less than high(12).

high(12) : Indicates all entity features are available and the entity is consuming the highest power.

The Textual Convention IANAPowerStateSet contains the proposed numbering of the Power States within the EMAN Power State Set.

### 5.3. Energy Object Usage Information

Refer to the "Energy Object Usage Measurement" section in [EMAN-FMWK] for background information.

For an Energy Object, power usage is reported using eoPower. The magnitude of measurement is based on the eoPowerUnitMultiplier MIB variable, based on the UnitMultiplier Textual Convention (TC). Power measurement magnitude should conform to the IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22] definition of unit multiplier for the SI (System International) units of measure. Measured values are represented in SI units obtained by BaseValue \* 10 raised to the power of the scale.

For example, if current power usage of an Energy Object is 3, it could be 3 W, 3 mW, 3 KW, or 3 MW, depending on the value of eoPowerUnitMultiplier. Note that other measurements throughout the two MIB modules in this document use the same mechanism, including eoPowerStatePowerUnitMultiplier, eoEnergyUnitMultiplier, and eoACPwrCharacteristicsPowerUnitMultiplier.

In addition to knowing the usage and magnitude, it is useful to know how a eoPower measurement was obtained. An NMS can use this to account for the accuracy and nature of the reading between different implementations. For this eoPowerOrigin describes whether the measurements were made at the device itself or from a remote source. The eoPowerMeasurementCaliber describes the method that was used to measure the power and can distinguish actual or estimated values. There may be devices in the network, which may not be able to measure or report power consumption. For those devices, the object eoPowerMeasurementCaliber shall report that measurement mechanism is "unavailable" and the eoPower measurement shall be "0".

The nameplate power rating of an Energy Object is specified in eoPowerNameplate MIB object.

#### 5.4. Optional Power Usage Characteristics

Refer to the "Optional Power Usage Characteristics" section in [EMAN-FMWK] for background information.

The optional powerCharacteristicsMIB MIB module can be implemented to further describe power usage characteristics measurement. The powerCharacteristicsMIB MIB module adheres closely to the IEC 61850 7-2 standard to describe AC measurements.

The powerCharacteristicsMIB MIB module contains a primary table, the eoACPwrCharacteristicsTable table, that defines power characteristics measurements for supported entPhysicalIndex entities, as a sparse extension of the eoPowerTable (with entPhysicalIndex as primary index). This eoACPwrCharacteristicsTable table contains such information as the configuration (single phase, DEL 3 phases, WYE 3 phases), voltage, frequency, power accuracy, total active/reactive power/apparent power, amperage, and voltage.

In case of 3-phase power, the eoACPwrCharacteristicsPhaseTable additional table is populated with Power Characteristics measurements per phase (so double indexed by the entPhysicalIndex and eoPhaseIndex). This table, which describes attributes common to both WYE and DEL configurations, contains the average current, active/reactive/apparent power, power factor, and impedance.

In case of 3-phase power with a DEL configuration, the eoACPwrCharacteristicsDelPhaseTable table describes the phase-to-phase power characteristics measurements, i.e., voltage and current.

In case of 3-phase power with a Wye configuration, the eoACPwrCharacteristicsWyePhaseTable table describes the phase-to-neutral power characteristics measurements, i.e., voltage and current.

#### 5.5. Optional Energy Measurement

Refer to the "Optional Energy and demand Measurement" section in [EMAN-FMWK] for the definition and terminology information.

It is relevant to measure energy when there are actual power measurements from an Energy Object, and not when the power measurement is assumed or predicted as specified in the description clause of the object eoPowerMeasurementCaliber.

Two tables are introduced to characterize energy measurement of an Energy Object: eoEnergyTable and eoEnergyParametersTable. Both energy and demand information can be represented via the eoEnergyTable. Energy information will be an accumulation with no interval. Demand information can be represented. The eoEnergyParametersTable consists of the parameters defining eoEnergyParametersIndex, an index of that specifies the setting for collection of energy measurements for an Energy Object, eoEnergyObjectIndex, linked to the entPhysicalIndex of the



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 Energy Object, the duration of measurement intervals in seconds,  
 (eoEnergyParametersIntervalLength), the number of successive  
 intervals to be stored in the eoEnergyTable,  
 (eoEnergyParametersIntervalNumber), the type of measurement  
 technique (eoEnergyParametersIntervalMode), and a sample rate  
 used to calculate the average (eoEnergyParametersSampleRate).  
 Judicious choice of the sampling rate will ensure accurate  
 measurement of energy while not imposing an excessive polling  
 burden.

There are three eoEnergyParametersIntervalMode types used for  
 energy measurement collection: period, sliding, and total. The  
 choices of the the three different modes of collection are based  
 on IEC standard 61850-7-4. Note that multiple  
 eoEnergyParametersIntervalMode types MAY be configured  
 simultaneously. It is important to note that for a given Energy  
 Object, multiple modes (periodic, total, sliding window) of  
 energy measurement collection can be configured with the use of  
 eoEnergyParametersIndex. However, simultaneous measurement in  
 multiple modes for a given Energy Object depends on the Energy  
 Object capability.

These three eoEnergyParametersIntervalMode types are illustrated  
 by the following three figures, for which:

- The horizontal axis represents the current time, with the  
 symbol <--- L ---> expressing the  
 eoEnergyParametersIntervalLength, and the  
 eoEnergyCollectionStartTime is represented by S1, S2, S3, S4,  
 ..., Sx where x is the value of  
 eoEnergyParametersIntervalNumber.
- The vertical axis represents the time interval of sampling and  
 the value of eoEnergyConsumed can be obtained at the end of the  
 sampling period. The symbol ===== denotes the duration of  
 the sampling period.

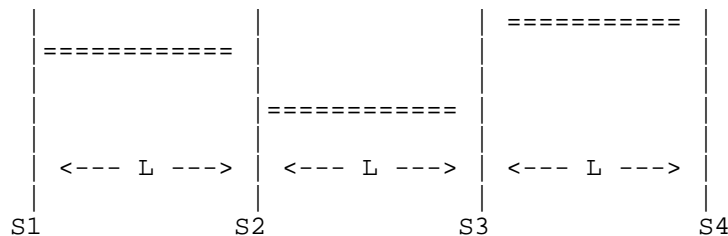


Figure 4 : Period eoEnergyParametersIntervalMode

A eoEnergyParametersIntervalMode type of 'period' specifies non-overlapping periodic measurements. Therefore, the next eoEnergyCollectionStartTime is equal to the previous eoEnergyCollectionStartTime plus eoEnergyParametersIntervalLength.  $S2=S1+L$ ;  $S3=S2+L$ , ...

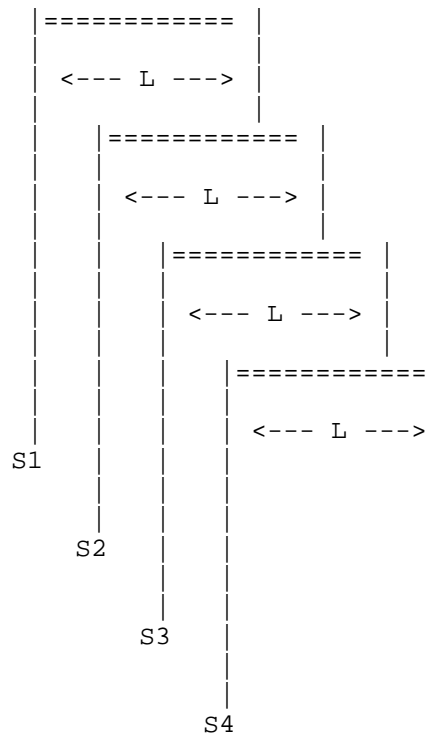
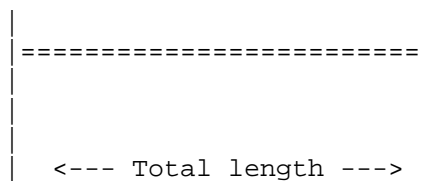


Figure 5 : Sliding eoEnergyParametersIntervalMode

A eoEnergyParametersIntervalMode type of 'sliding' specifies overlapping periodic measurements.





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denotes the start time of the energy measurement interval based on sysUpTime [RFC3418]. The value of eoEnergyConsumed is the measured energy consumption over the time interval specified (eoEnergyParametersIntervalLength) based on the Energy Object internal sampling rate (eoEnergyParametersSampleRate). While choosing the values for the eoEnergyParametersIntervalLength and eoEnergyParametersSampleRate, it is recommended to take into consideration either the network element resources adequate to process and store the sample values, and the mechanism used to calculate the eoEnergyConsumed. The units are derived from eoEnergyUnitMultiplier. For example, eoEnergyConsumed can be "100" with eoEnergyUnitMultiplier equal to 0, the measured energy consumption of the Energy Object is 100 watt-hours. The eoEnergyMaxConsumed is the maximum energy observed and that can be "150 watt-hours".

The eoEnergyTable has a buffer to retain a certain number of intervals, as defined by eoEnergyParametersIntervalNumber. If the default value of "10" is kept, then the eoEnergyTable contains 10 energy measurements, including the maximum.

Here is a brief explanation of how the maximum energy can be calculated. The first observed energy measurement value is taken to be the initial maximum. With each subsequent measurement, based on numerical comparison, maximum energy may be updated. The maximum value is retained as long as the measurements are taking place. Based on periodic polling of this table, an NMS could compute the maximum over a longer period, i.e. a month, 3 months, or a year.

## 5.6. Fault Management

[EMAN-REQ] specifies requirements about Power States such as "the current power state" , "the time of the last state change", "the total time spent in each state", "the number of transitions to each state" etc. Some of these requirements are fulfilled explicitly by MIB objects such as eoPowerOperState, eoPowerStateTotalTime and eoPowerStateEnterCount. Some of the other requirements are met via the SNMP NOTIFICATION mechanism. eoPowerStateChange SNMP notification which is generated when the value(s) of ,eoPowerStateIndex, eoPowerOperState, eoPowerAdminState have changed.

It is foreseen that most Energy Objects will require the implementation of the ENERGY-AWARE MIB [EMAN-AWARE-MIB] as a prerequisite for this MIB module. In such a case, eoPowerTable of the EMAN-MON-MIB is a sparse extension of the eoTable of ENERGY-AWARE-MIB. Every Energy Object MUST implement entPhysicalIndex, entPhysicalUUID and entPhysicalName from the ENTITY-MIB [EMAN-ENTITY]. As the primary index for the Energy Object, entPhysicalIndex is used.

The NMS must first poll the ENERGY-AWARE-MIB module [EMAN-AWARE-MIB], if available, in order to discover all the Energy Objects and the relationships between those (notion of Parent/Child). In the ENERGY-AWARE-MIB module tables, the Energy Objects are indexed by the entPhysicalIndex.

If an implementation of the ENERGY-AWARE-MIB module is available in the local SNMP context, for the same Energy Object, the entPhysicalIndex value (EMAN-AWARE-MIB) shall be used. The entPhysicalIndex characterizes the Energy Object in the energyObjectMib and the powerCharacteristicsMIB MIB modules (this document).

From there, the NMS must poll the eoPowerStateTable (specified in the energyObjectMib module in this document), which enumerates, amongst other things, the maximum power usage. As the entries in eoPowerStateTable table are indexed by the Energy Object ( entPhysicalIndex), by the Power State Set (eoPowerStateIndex), the maximum power usage is discovered per Energy Object, and the power usage per Power State of the Power State Set. In other words, polling the eoPowerStateTable allows the discovery of each Power State within every Power State Set supported by the Energy Object.

If the Energy Object is an Aggregator or a Proxy, the MIB module would be populated with the Energy Object Parent and Children information, which have their own Energy Object index value (entPhysicalIndex). However, the parent/child relationship must be discovered thanks to the ENERGY-AWARE-MIB module.

Finally, the NMS can monitor the power characteristics thanks to the powerCharacteristicsMIB MIB module, which reuses the entPhysicalIndex to index the Energy Object.

#### 7.1. Link with the ENTITY-MIB and the ENTITY-SENSOR MIB

RFC 4133 [RFC4133] defines the ENTITY-MIB module that lists the physical entities of a networking device (router, switch, etc.) and those physical entities indexed by entPhysicalIndex. From an energy-management standpoint, the physical entities that consume or produce energy are of interest.

RFC 3433 [RFC3433] defines the ENTITY-SENSOR MIB module that provides a standardized way of obtaining information (current value of the sensor, operational status of the sensor, and the data units precision) from sensors embedded in networking devices. Sensors are associated with each index of entPhysicalIndex of the ENTITY-MIB [RFC4133]. While the focus of the Power and Energy Monitoring MIB is on measurement of power usage of networking equipment indexed by the ENTITY-MIB, this MIB proposes a customized power scale for power measurement and different power state states of networking equipment, and functionality to configure the power state states.

When this MIB module is used to monitor the power usage of devices like routers and switches, the ENTITY-MIB and ENTITY-SENSOR MIB SHOULD be implemented. In such cases, the Energy Objects are modeled by the entPhysicalIndex through the entPhysicalEntity MIB object specified in the eoTable in the ENERGY-AWARE-MIB MIB module [EMAN-AWARE-MIB].

However, the ENTITY-SENSOR MIB [RFC3433] does not have the ANSI C12.x accuracy classes required for electricity (i.e., 1%, 2%, 0.5% accuracy classes). Indeed, entPhySensorPrecision [RFC3433] represents "The number of decimal places of precision in fixed-point sensor values returned by the associated entPhySensorValue object". The ANSI and IEC Standards are used for power measurement and these standards require that we use an accuracy class, not the scientific-number precision model specified in RFC3433. The eoPowerAccuracy MIB object models this accuracy. Note that eoPowerUnitMultiplier represents the scale factor per IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22], which is a more logical representation for power measurements (compared to entPhySensorScale), with the mantissa and the exponent values  $X * 10^Y$ .

Power measurements specifying the qualifier 'UNITS' for each measured value in watts are used in the LLDP-EXT-MED-MIB, POE

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[RFC3621], and UPS [RFC1628] MIBs. The same 'UNITS' qualifier  
is used for the power measurement values.

One cannot assume that the ENTITY-MIB and ENTITY-SENSOR MIB are implemented for all Energy Objects that need to be monitored. A typical example is a converged building gateway, monitoring several other devices in the building, doing the proxy between SNMP and a protocol like BACNET. Another example is the home energy controller. In such cases, the eoPhysicalEntity value contains the zero value, thanks to PhysicalIndexOrZero textual convention.

The eoPower is similar to entPhySensorValue [RFC3433] and the eoPowerUnitMultiplier is similar to entPhySensorScale.

## 7.2. Link with the ENTITY-STATE MIB

For each entity in the ENTITY-MIB [RFC4133], the ENTITY-STATE MIB [RFC4268] specifies the operational states (entStateOper: unknown, enabled, disabled, testing), the alarm (entStateAlarm: unknown, underRepair, critical, major, minor, warning, indeterminate) and the possible values of standby states (entStateStandby: unknown, hotStandby, coldStandby, providingService).

From a power monitoring point of view, in contrast to the entity operational states of entities, Power States are required, as proposed in the Power and Energy Monitoring MIB module. Those Power States can be mapped to the different operational states in the ENTITY-STATE MIB, if a formal mapping is required. For example, the entStateStandby "unknown", "hotStandby", "coldStandby", states could map to the Power State "unknown", "ready", "standby", respectively, while the entStateStandby "providingService" could map to any "low" to "high" Power State.

## 7.3. Link with the POWER-OVER-ETHERNET MIB

Power-over-Ethernet MIB [RFC3621] provides an energy monitoring and configuration framework for power over Ethernet devices. The RFC introduces a concept of a port group on a switch to define power monitoring and management policy and does not use the entPhysicalIndex as the index. Indeed, the pethMainPseConsumptionPower is indexed by the pethMainPseGroupIndex, which has no mapping with the entPhysicalIndex.

One cannot assume that the Power-over-Ethernet MIB is implemented for all Energy Objects that need to be monitored. A typical example is a converged building gateway, monitoring several other devices in the building, doing the proxy between SNMP and a protocol like BACNET. Another example is the home energy controller. In such cases, the `eoethPortIndex` and `eoethPortGrpIndex` values contain the zero value, thanks to new `PethPsePortIndexOrZero` and textual `PethPsePortGroupIndexOrZero` conventions.

However, if the Power-over-Ethernet MIB [RFC3621] is supported, the Energy Object `eoethPortIndex` and `eoethPortGrpIndex` contain the `pethPsePortIndex` and `pethPsePortGroupIndex`, respectively.

As a consequence, the `entPhysicalIndex` MIB object has been kept as the unique Energy Object index.

Note that, even though the Power-over-Ethernet MIB [RFC3621] was created after the ENTITY-SENSOR MIB [RFC3433], it does not reuse the precision notion from the ENTITY-SENSOR MIB, i.e. the `entPhySensorPrecision` MIB object.

#### 7.4. Link with the UPS MIB

To protect against unexpected power disruption, data centers and buildings make use of Uninterruptible Power Supplies (UPS). To protect critical assets, a UPS can be restricted to a particular subset or domain of the network. UPS usage typically lasts only for a finite period of time, until normal power supply is restored. Planning is required to decide on the capacity of the UPS based on output power and duration of probable power outage. To properly provision UPS power in a data center or building, it is important to first understand the total demand required to support all the entities in the site. This demand can be assessed and monitored via the Power and Energy Monitoring MIB.

UPS MIB [RFC1628] provides information on the state of the UPS network. Implementation of the UPS MIB is useful at the aggregate level of a data center or a building. The MIB module contains several groups of variables:

- `upsIdent`: Identifies the UPS entity (name, model, etc.).
- `upsBattery` group: Indicates the battery state (`upsbatteryStatus`, `upsEstimatedMinutesRemaining`, etc.)



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- upsInput group: Characterizes the input load to the UPS (number of input lines, voltage, current, etc.).
- upsOutput: Characterizes the output from the UPS (number of output lines, voltage, current, etc.)
- upsAlarms: Indicates the various alarm events.

The measurement of power in the UPS MIB is in Volts, Amperes and Watts. The units of power measurement are RMS volts and RMS Amperes. They are not based on the EntitySensorDataScale and EntitySensorDataPrecision of ENTITY-SENSOR-MIB.

Both the Power and Energy Monitoring MIB and the UPS MIB may be implemented on the same UPS SNMP agent, without conflict. In this case, the UPS device itself is the Energy Object Parent and any of the UPS meters or submeters are the Energy Object Children.

#### 7.5. Link with the LLDP and LLDP-MED MIBs

The LLDP Protocol is a Data Link Layer protocol used by network devices to advertise their identities, capabilities, and interconnections on a LAN network.

The Media Endpoint Discovery is an enhancement of LLDP, known as LLDP-MED. The LLDP-MED enhancements specifically address voice applications. LLDP-MED covers 6 basic areas: capability discovery, LAN speed and duplex discovery, network policy discovery, location identification discovery, inventory discovery, and power discovery.

Of particular interest to the current MIB module is the power discovery, which allows the endpoint device (such as a PoE phone) to convey power requirements to the switch. In power discovery, LLDP-MED has four Type Length Values (TLVs): power type, power source, power priority and power value. Respectively, those TLVs provide information related to the type of power (power sourcing entity versus powered device), how the device is powered (from the line, from a backup source, from external power source, etc.), the power priority (how important is it that this device has power?), and how much power the device needs.

The power priority specified in the LLDP-MED MIB [LLDP-MED-MIB] actually comes from the Power-over-Ethernet MIB [RFC3621]. If the Power-over-Ethernet MIB [RFC3621] is supported, the exact

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value from the pethPsePortPowerPriority [RFC3621] is copied over  
in the lldpXMedRemXPoEPDPowerPriority [LLDP-MED-MIB]; otherwise  
the value in lldpXMedRemXPoEPDPowerPriority is "unknown". From  
the Power and Energy Monitoring MIB, it is possible to identify  
the pethPsePortPowerPriority [RFC3621], thanks to the  
eoethPortIndex and eoethPortGrpIndex.

The lldpXMedLocXPoEPDPowerSource [LLDP-MED-MIB] is similar to  
eoPowerOrigin in indicating if the power for an attached device  
is local or from a remote device. If the LLDP-MED MIB is  
supported, the following mapping can be applied to the  
eoPowerOrigin: lldpXMedLocXPoEPDPowerSource fromPSE(2) and  
local(3) can be mapped to remote(2) and self(1), respectively.

## 8. Implementation Scenario

This section provides an illustrative example scenario for the  
implementation of the Energy Object, including Energy Object  
Parent and Energy Object Child relationships.

Example Scenario of a campus network: Switch with PoE Endpoints  
with further connected devices.

The campus network consists of switches that provide LAN  
connectivity. The switch with PoE ports is located in wiring  
closet. PoE IP phones are connected to the switch. The IP  
phones draw power from the PoE ports of the switch. In  
addition, a PC is daisy-chained from the IP phone for LAN  
connectivity.

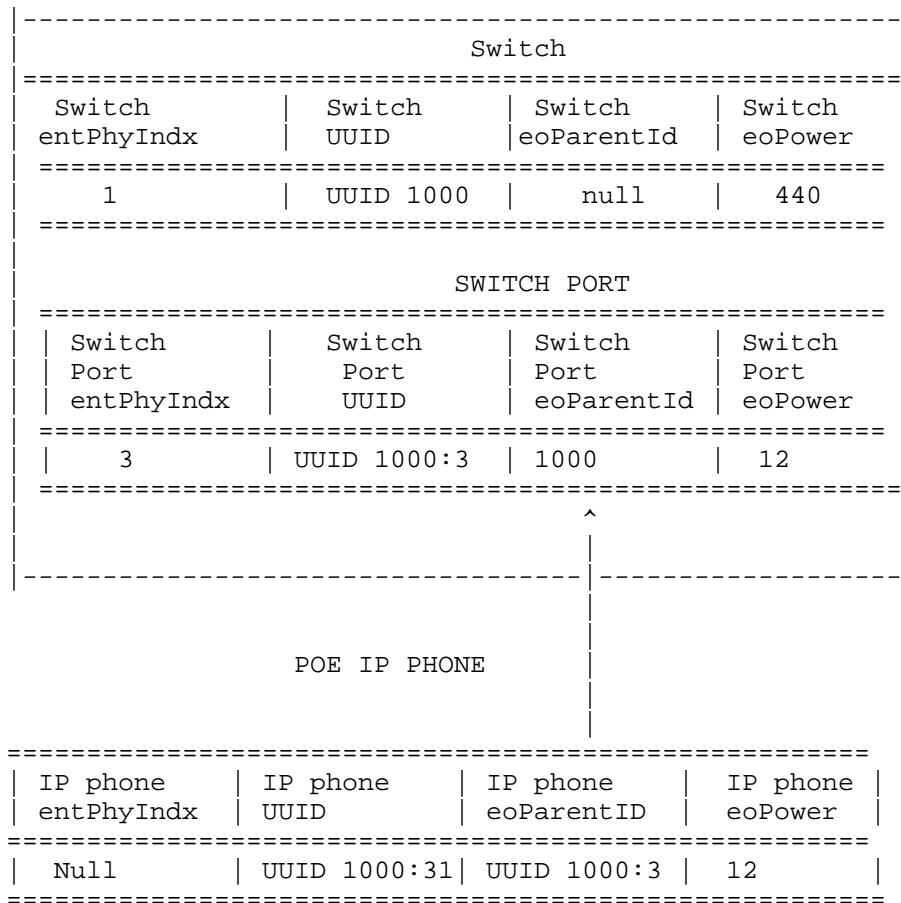
The IP phone consumes power from the PoE switch, while the PC  
consumes power from the wall outlet.

The switch has implementations of ENTITY-MIB [EMAN-ENTITY ] and  
ENERGY-AWARE MIB [EMAN-AWARE-MIB] while the PC does not have  
implementation of the ENTITY-MIB, but has an implementation of  
ENERGY-AWARE MIB [EMAN-AWARE-MIB]. The switch has the following  
attributes, entPhysicalIndex "1", and entPhysicalUUID "UUID  
1000". The power usage of the switch is "440 Watts". The  
switch does not have an Energy Object Parent.

The PoE switch port has the following attributes: The switch  
port has entPhysicalIndex "3", and entPhysicalUUID is "UUID  
1000:3". The power metered at the POE switch port is "12  
watts". In this example, the POE switch port has the switch as  
the Energy Object Parent, with its eoParentID of "1000".

The attributes of the PC are given below. The PC does not have an entPhysicalIndex, and the entPhysicalUUID is "UUID 1000:57 ". The PC has an Energy Object Parent, i.e. the switch port whose entPhysicalUUID is "UUID 1000:3". The power usage of the PC is "120 Watts" and is communicated to the switch port.

This example illustrates the important distinction between the Energy Object Children: The IP phone draws power from the switch, while the PC has LAN connectivity from the phone, but is powered from the wall outlet. However, the Energy Object Parent sends power control messages to both the Energy Object Children (IP phone and PC) and the Children react to those messages.



PC connected to switch via IP phone

| PC<br>entPhyIndx | PC<br>UUID   | PC<br>eoParentID | PC<br>eoPower |
|------------------|--------------|------------------|---------------|
| 7                | UUID 1000:57 | UUID 1000:3      | 120           |

Figure 1: Example scenario

## 9. Structure of the MIB

The primary MIB object in this MIB module is the `energyObjectMibObject`. The `eoPowerTable` table of `energyObjectMibObject` describes the power measurement attributes of an Energy Object entity. The notion of identity of the device in terms of uniquely identification of the Energy Object and its relationship to other entities in the network are addressed in [EMAN-AWARE-MIB].

Logically, this MIB module is a sparse extension of the [EMAN-AWARE-MIB] module. Thus the following requirements which are applied to [EMAN-AWARE-MIB] are also applicable. As a requirement for this MIB module, [EMAN-AWARE-MIB] should be implemented and as Module Compliance of ENTITY-MIB V4 [EMAN-ENTITY] with respect to `entity4CRCompliance` should be supported which requires 3 MIB objects (`entPhysicalIndex`, `entPhysicalName` and `entPhysicalUUID`) MUST be implemented.

`eoMeterCapabilitiesTable` is useful to enable applications to determine the capabilities supported by the local management agent. This table indicates the energy monitoring MIB groups that are supported by the local management system. By reading the value of this object, it is possible for applications to know which tables contain the information and are usable without walking through the table and querying every element which involves a trial-and-error process.

The power measurement of an Energy Object contains information describing its power usage (`eoPower`) and its current power state (`eoPowerOperState`). In addition to power usage, additional

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information describing the units of measurement  
(eoPowerAccuracy, eoPowerUnitMultiplier), how power usage  
measurement was obtained (eoPowerMeasurementCaliber), the  
source of power (eoPowerOrigin) and the type of power  
(eoPowerCurrentTtype) are described.

An Energy Object may contain an optional eoPowerCharacteristics  
table that describes the electrical characteristics associated  
with the current power state and usage.

An Energy Object may contain an optional eoEnergyTable to  
describe energy measurement information over time.

An Energy Object may also contain optional battery information  
associated with this entity.

## 10. MIB Definitions

```
-- *****
--
--
-- This MIB is used to monitor power usage of network
-- devices
--
-- *****

ENERGY-OBJECT-MIB DEFINITIONS ::= BEGIN

IMPORTS
 MODULE-IDENTITY,
 OBJECT-TYPE,
 NOTIFICATION-TYPE,
 mib-2,
 Integer32, Counter32, TimeTicks
 FROM SNMPv2-SMI
 TEXTUAL-CONVENTION, DisplayString, RowStatus, TimeInterval,
 TimeStamp
 FROM SNMPv2-TC
 MODULE-COMPLIANCE, NOTIFICATION-GROUP, OBJECT-GROUP
 FROM SNMPv2-CONF
 OwnerString
 FROM RMON-MIB
 entPhysicalIndex, PhysicalIndex
 FROM ENTITY-MIB;
```

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energyObjectMib MODULE-IDENTITY  
LAST-UPDATED "201210220000Z" -- 22 October 2012

ORGANIZATION "IETF EMAN Working Group"  
CONTACT-INFO

"WG charter:  
<http://datatracker.ietf.org/wg/eman/charter/>

Mailing Lists:

General Discussion: [eman@ietf.org](mailto:eman@ietf.org)

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Email: bclaise@cisco.com"

#### DESCRIPTION

"This MIB is used to monitor power and energy in devices.

This table sparse extension of the eoTable from the ENERGY-AWARE-MIB. As a requirement [EMAN-AWARE-MIB] should be implemented.

Module Compliance of ENTITY-MIB v4 with respect to entity4CRCompliance should be supported which requires implementation of 3 MIB objects (entPhysicalIndex, entPhysicalName and entPhysicalUUID)."

#### REVISION

"201210220000Z"            -- 22 October 2012

#### DESCRIPTION

"Initial version, published as RFC XXXX."

::= { mib-2 xxx }

energyObjectMibNotifs OBJECT IDENTIFIER  
::= { energyObjectMib 0 }

energyObjectMibObjects OBJECT IDENTIFIER  
::= { energyObjectMib 1 }

energyObjectMibConform OBJECT IDENTIFIER  
::= { energyObjectMib 2 }

IANAPowerStateSet ::= TEXTUAL-CONVENTION  
    STATUS   current  
    DESCRIPTION

"IANAPowerState is a textual convention that describes Power State Sets and Power State Set Values an Energy Object supports. IANA has created a registry of Power State supported by an Energy Object and IANA shall administer the list of Power State Sets and Power States.

The textual convention assumes that power states in a power state set are limited to 255 distinct values. For a Power State Set S, the named number with the value S \* 256 is allocated to indicate the power state set. For a Power State X in the Power State S, the named number with the value S \* 256 + X + 1 is allocated to represent the power state."

REFERENCE

"<http://www.iana.org/assignments/eman>  
RFC EDITOR NOTE: please change the previous URL if this is not the correct one after IANA assigned it."

SYNTAX           INTEGER {  
                  other(0),            -- indicates other set  
                  unknown(255),       -- unknown power state  
  
                  ieee1621(256), -- indicates IEEE1621 set  
                  ieee1621On(257),  
                  ieee1621Off(258),  
                  ieee1621Sleep(259),  
  
                  dmtf(512),    -- indicates DMTF set  
                  dmtfOn(513),  
                  dmtfSleepLight(514),  
                  dmtfSleepDeep(515),  
                  dmtfOffHard(516),  
                  dmtfOffSoft(517),  
                  dmtfHibernate(518),  
                  dmtfPowerOffSoft(519),  
                  dmtfPowerOffHard(520),  
                  dmtfMasterBusReset(521),  
                  dmtfDiagnosticInterrupt(522),  
                  dmtfOffSoftGraceful(523),



```
dmtfOffHardGraceful(524),
dmtfMasterBusResetGraceful(525),
dmtfPowerCycleOffSoftGraceful(526),
dmtfPowerCycleHardGraceful(527),

eman(1024), -- indicates EMAN set
emanmechoff(1025),
emansoftoff(1026),
emanhibernate(1027),
emansleep(1028),
emanstandby(1029),
emanready(1030),
emanlowMinus(1031),
emanlow(1032),
emanmediumMinus(1033),
emanmedium(1034),
emanhighMinus(1035),
emanhigh(1036)
}
```

UnitMultiplier ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The Unit Multiplier is an integer value that represents the IEEE 61850 Annex A units multiplier associated with the integer units used to measure the power or energy.

For example, when used with eoPowerUnitMultiplier, -3 represents 10<sup>-3</sup> or milliwatts."

REFERENCE

"The International System of Units (SI),  
National Institute of Standards and Technology,  
Spec. Publ. 330, August 1991."

SYNTAX INTEGER {

```
yocto(-24), -- 10^-24
zepto(-21), -- 10^-21
atto(-18), -- 10^-18
femto(-15), -- 10^-15
pico(-12), -- 10^-12
nano(-9), -- 10^-9
micro(-6), -- 10^-6
milli(-3), -- 10^-3
units(0), -- 10^0
kilo(3), -- 10^3
mega(6), -- 10^6
giga(9), -- 10^9
tera(12), -- 10^12
peta(15), -- 10^15
```

```

 exa(18), -- 10^18
 zetta(21), -- 10^21
 yotta(24) -- 10^24
 }

-- Objects

eoMeterCapabilitiesTable OBJECT-TYPE
 SYNTAX SEQUENCE OF EoMeterCapabilitiesEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table is useful for helping applications determine the
 monitoring capabilities supported by the local management
 agents. It is possible for applications to know which tables
 are usable without going through a trial-and-error process."
 ::= { energyObjectMibObjects 1 }

eoMeterCapabilitiesEntry OBJECT-TYPE
 SYNTAX EoMeterCapabilitiesEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "An entry describes the metering capability of an Energy
 Object."
 INDEX { entPhysicalIndex }
 ::= { eoMeterCapabilitiesTable 1 }

EoMeterCapabilitiesEntry ::= SEQUENCE {
 eoMeterCapability BITS
}

eoMeterCapability OBJECT-TYPE
 SYNTAX BITS {
 none(0),
 powermetering(1), -- power measurement
 energymetering(2), -- energy measurement
 powercharacteristics(3) -- power characteristics
 }
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "An indication of the Energy monitoring capabilities supported
 by this agent. This object use a BITS syntax and indicate the

```

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MIB groups supported by the probe. By reading the value of this  
object, it is possible to determine the MIB tables supported. "  
 ::= { eoMeterCapabilitiesEntry 1 }

eoPowerTable OBJECT-TYPE  
SYNTAX SEQUENCE OF EoPowerEntry  
MAX-ACCESS not-accessible  
STATUS current  
DESCRIPTION  
"This table lists Energy Objects."  
 ::= { energyObjectMibObjects 2 }

eoPowerEntry OBJECT-TYPE  
SYNTAX EoPowerEntry  
MAX-ACCESS not-accessible  
STATUS current  
DESCRIPTION  
"An entry describes the power usage of an Energy Object."  
  
INDEX { entPhysicalIndex }  
 ::= { eoPowerTable 1 }

EoPowerEntry ::= SEQUENCE {  
  
    eoPower Integer32,  
    eoPowerNameplate Integer32,  
    eoPowerUnitMultiplier UnitMultiplier,  
    eoPowerAccuracy Integer32,  
    eoPowerMeasurementCaliber INTEGER,  
    eoPowerCurrentType INTEGER,  
    eoPowerOrigin INTEGER,  
    eoPowerAdminState IANAPowerStateSet,  
    eoPowerOperState IANAPowerStateSet,  
    eoPowerStateEnterReason OwnerString  
}

eoPower OBJECT-TYPE  
SYNTAX Integer32  
UNITS "Watts"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"This object indicates the power measured for the Energy Object. For alternating current, this value is obtained as an average over fixed number of AC cycles. . This value is specified in SI units of watts with the magnitude of watts (milliwatts, kilowatts, etc.) indicated separately in eoPowerUnitMultiplier. The accuracy of the measurement is specified in eoPowerAccuracy. The direction of power flow is indicated by the sign on eoPower. If the Energy Object is consuming power, the eoPower value will be positive. If the Energy Object is producing power, the eoPower value will be negative.

The eoPower MUST be less than or equal to the maximum power that can be consumed at the power state specified by eoPowerState.

The eoPowerMeasurementCaliber object specifies how the usage value reported by eoPower was obtained. The eoPower value must report 0 if the eoPowerMeasurementCaliber is 'unavailable'. For devices that can not measure or report power, this option can be used."

::= { eoPowerEntry 1 }

eoPowerNameplate OBJECT-TYPE

SYNTAX Integer32

UNITS "Watts"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the rated maximum consumption for the fully populated Energy Object. The nameplate power requirements are the maximum power numbers and, in almost all cases, are well above the expected operational consumption. The eoPowerNameplate is widely used for power provisioning. This value is specified in either units of watts or voltage and current. The units are therefore SI watts or equivalent Volt-Amperes with the magnitude (milliwatts, kilowatts, etc.) indicated separately in eoPowerUnitMultiplier."

::= { eoPowerEntry 2 }

eoPowerUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The magnitude of watts for the usage value in eoPower  
and eoPowerNameplate."

::= { eoPowerEntry 3 }

eoPowerAccuracy OBJECT-TYPE

SYNTAX Integer32 (0..10000)

UNITS "hundredths of percent"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates a percentage value, in 100ths of a percent, representing the assumed accuracy of the usage reported by eoPower. For example: The value 1010 means the reported usage is accurate to +/- 10.1 percent. This value is zero if the accuracy is unknown or not applicable based upon the measurement method."

ANSI and IEC define the following accuracy classes for power measurement:

IEC 62053-22 60044-1 class 0.1, 0.2, 0.5, 1 3.

ANSI C12.20 class 0.2, 0.5"

::= { eoPowerEntry 4 }

eoPowerMeasurementCaliber OBJECT-TYPE

SYNTAX INTEGER {  
unavailable(1) ,  
unknown(2),  
actual(3) ,  
estimated(4),  
presumed(5)  
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object specifies how the usage value reported by eoPower was obtained:

- unavailable(1): Indicates that the usage is not available. In such a case, the eoPower value must be 0 for devices that can not measure or report power this option can be used.

- unknown(2): Indicates that the way the usage was determined is unknown. In some cases, entities report aggregate power on behalf of another device. In such cases it is not known whether the usage reported is actual(2), estimated(3) or presumed (4).

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- actual(3): Indicates that the reported usage was measured by the entity through some hardware or direct physical means. The usage data reported is not presumed (4) or estimated (3) but the real apparent current energy consumption rate.

- estimated(4): Indicates that the usage was not determined by physical measurement. The value is a derivation based upon the device type, state, and/or current utilization using some algorithm or heuristic. It is presumed that the entity's state and current configuration were used to compute the value.

- presumed(5): Indicates that the usage was not determined by physical measurement, algorithm or derivation. The usage was reported based upon external tables, specifications, and/or model information. For example, a PC Model X draws 200W, while a PC Model Y draws 210W"

::= { eoPowerEntry 5 }

eoPowerCurrentType OBJECT-TYPE

SYNTAX INTEGER {  
ac(1),  
dc(2),  
unknown(3)  
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates whether the eoUsage for the Energy Object reports alternative current AC(1), direct current DC(2), or that the current type is unknown(3)."

::= { eoPowerEntry 6 }

eoPowerOrigin OBJECT-TYPE

SYNTAX INTEGER {  
self (1),  
remote (2)  
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the source of power measurement and can be useful when modeling the power usage of attached devices. The power measurement can be performed by the entity itself or the power measurement of the

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entity can be reported by another trusted entity using a  
protocol extension. A value of self(1) indicates the  
measurement is performed by the entity, whereas remote(2)  
indicates that the measurement was performed by another  
entity."

::= { eoPowerEntry 7 }

eoPowerAdminState OBJECT-TYPE

SYNTAX IANAPowerStateSet

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object specifies the desired Power State and the  
Power State Set for the Energy Object. Note that  
other(0) is not a Power State Set and unknown(255) is  
not a Power State as such, but simply an indication that  
the Power State of the Energy Object is unknown.

Possible values of eoPowerAdminState within the Power  
State Set are registered at IANA.

A current list of assignments can be found at

<<http://www.iana.org/assignments/eman>>

RFC-EDITOR: please check the location after IANA"

::= { eoPowerEntry 8 }

eoPowerOperState OBJECT-TYPE

SYNTAX IANAPowerStateSet

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object specifies the current operational Power  
State and the Power State Set for the Energy Object.  
other(0) is not a Power State Set and unknown(255) is  
not a Power State as such, but simply an indication that  
the Power State of the Energy Object is unknown.

Possible values of eoPowerAdminState within the Power  
State Set are registered at IANA.

A current list of assignments can be found at

<<http://www.iana.org/assignments/eman>>

RFC-EDITOR: please check the location after IANA"

::= { eoPowerEntry 9 }

eoPowerStateEnterReason OBJECT-TYPE

SYNTAX OwnerString

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"This string object describes the reason for the eoPowerAdminState transition. Alternatively, this string may contain with the entity that configured this Energy Object to this Power State."

DEFVAL { "" }

::= { eoPowerEntry 10 }

eoPowerStateTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoPowerStateEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table enumerates the maximum power usage, in watts, for every single supported Power State of each Energy Object."

This table has an expansion-dependent relationship on the eoPowerTable, containing rows describing each Power State for the corresponding Energy Object. For every Energy Object in the eoPowerTable, there is a corresponding entry in this table."

::= { energyObjectMibObjects 3 }

eoPowerStateEntry OBJECT-TYPE

SYNTAX EoPowerStateEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"A eoPowerStateEntry extends a corresponding eoPowerEntry. This entry displays max usage values at every single possible Power State supported by the Energy Object."

For example, given the values of a Energy Object corresponding to a maximum usage of 11W at the state 1 (mechoff), 6 (ready), 8 (mediumMinus), 12 (High):

| State         | MaxUsage | Units |
|---------------|----------|-------|
| 1 (mechoff)   | 0        | W     |
| 2 (softoff)   | 0        | W     |
| 3 (hibernate) | 0        | W     |
| 4 (sleep)     | 0        | W     |
| 5 (standby)   | 0        | W     |
| 6 (ready)     | 8        | W     |
| 7 (lowMinus)  | 8        | W     |
| 8 (low)       | 11       | W     |



|                |    |   |
|----------------|----|---|
| 9 (medimMinus) | 11 | W |
| 10 (medium)    | 11 | W |
| 11 (highMinus) | 11 | W |
| 12 (high)      | 11 | W |

Furthermore, this table extends to return the total time in each Power State, along with the number of times a particular Power State was entered."

```

INDEX { entPhysicalIndex,
 eoPowerStateIndex
 }
 ::= { eoPowerStateTable 1 }

EoPowerStateEntry ::= SEQUENCE {
 eoPowerStateIndex IANAPowerStateSet,
 eoPowerStateMaxPower Integer32,
 eoPowerStatePowerUnitMultiplier UnitMultiplier,
 eoPowerStateTotalTime TimeTicks,
 eoPowerStateEnterCount Counter32
}

eoPowerStateIndex OBJECT-TYPE
 SYNTAX IANAPowerStateSet
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "
 This object specifies the index of the Power State of
 the Energy Object within a Power State Set. The
 semantics of the specific Power State can be obtained
 from the Power State Set definition."
 ::= { eoPowerStateEntry 1 }

eoPowerStateMaxPower OBJECT-TYPE
 SYNTAX Integer32
 UNITS "Watts"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This object indicates the maximum power for the Energy
 Object at the particular Power State. This value is
 specified in SI units of watts with the magnitude of the
 units (milliwatts, kilowatts, etc.) indicated separately
 in eoPowerStatePowerUnitMultiplier. If the maximum power
 is not known for a certain Power State, then the value is
 encoded as 0xFFFF."

```

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For Power States not enumerated, the value of  
eoPowerStateMaxPower might be interpolated by using the  
next highest supported Power State."

::= { eoPowerStateEntry 2 }

eoPowerStatePowerUnitMultiplier OBJECT-TYPE

SYNTAX           UnitMultiplier

MAX-ACCESS       read-only

STATUS           current

DESCRIPTION

"The magnitude of watts for the usage value in  
eoPowerStateMaxPower."

::= { eoPowerStateEntry 3 }

eoPowerStateTotalTime OBJECT-TYPE

SYNTAX           TimeTicks

MAX-ACCESS       read-only

STATUS           current

DESCRIPTION

"This object indicates the total time in hundreds  
of seconds that the Energy Object has been in this power  
state since the last reset, as specified in the  
sysUpTime."

::= { eoPowerStateEntry 4 }

eoPowerStateEnterCount OBJECT-TYPE

SYNTAX           Counter32

MAX-ACCESS       read-only

STATUS           current

DESCRIPTION

"This object indicates how often the Energy  
Object has  
entered this power state, since the last reset of the  
device as specified in the sysUpTime."

::= { eoPowerStateEntry 5 }

eoEnergyParametersTable OBJECT-TYPE

SYNTAX           SEQUENCE OF EoEnergyParametersEntry

MAX-ACCESS       not-accessible

STATUS           current

DESCRIPTION

"This table is used to configure the parameters for  
Energy measurement collection in the table  
eoEnergyTable. This table allows the configuration of  
different measurement settings on the same Energy

```
Object."
 ::= { energyObjectMibObjects 4 }

eoEnergyParametersEntry OBJECT-TYPE
 SYNTAX EoEnergyParametersEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "An entry controls an energy measurement in
 eoEnergyTable."
 INDEX { eoEnergyParametersIndex }
 ::= { eoEnergyParametersTable 1 }

EoEnergyParametersEntry ::= SEQUENCE {
 eoEnergyObjectIndex PhysicalIndex,
 eoEnergyParametersIndex Integer32,
 eoEnergyParametersIntervalLength TimeInterval,
 eoEnergyParametersIntervalNumber Integer32,
 eoEnergyParametersIntervalMode Integer32,
 eoEnergyParametersIntervalWindow TimeInterval,
 eoEnergyParametersSampleRate Integer32,
 eoEnergyParametersStatus RowStatus
}

eoEnergyObjectIndex OBJECT-TYPE
 SYNTAX PhysicalIndex
 MAX-ACCESS read-create
 STATUS current
 DESCRIPTION
 "The unique value, to identify the specific Energy Object
 on which the measurement is applied, the same index used
 in the eoPowerTable to identify the Energy Object."
 ::= { eoEnergyParametersEntry 1 }

eoEnergyParametersIndex OBJECT-TYPE
 SYNTAX Integer32 (0..2147483647)
 MAX-ACCESS read-create
 STATUS current
 DESCRIPTION
 "This object specifies the index of the Energy
 Parameters setting for collection of energy measurements
 for an Energy Object. An Energy Object can have multiple
 eoEnergyParametersIndex, depending on the capability of
 the Energy Object"
 ::= { eoEnergyParametersEntry 2 }

eoEnergyParametersIntervalLength OBJECT-TYPE
```

SYNTAX                    TimeInterval  
MAX-ACCESS                read-create  
STATUS                    current

DESCRIPTION

"This object indicates the length of time in hundredth of seconds over which to compute the average eoEnergyConsumed measurement in the eoEnergyTable table. The computation is based on the Energy Object's internal sampling rate of power consumed or produced by the Energy Object. The sampling rate is the rate at which the Energy Object can read the power usage and may differ based on device capabilities. The average energy consumption is then computed over the length of the interval."

DEFVAL { 90000 }  
::= { eoEnergyParametersEntry 3 }

eoEnergyParametersIntervalNumber OBJECT-TYPE

SYNTAX                    Integer32  
MAX-ACCESS                read-create  
STATUS                    current

DESCRIPTION

"The number of intervals maintained in the eoEnergyTable. Each interval is characterized by a specific eoEnergyCollectionStartTime, used as an index to the table eoEnergyTable. Whenever the maximum number of entries is reached, the measurement over the new interval replacesthe oldest measurement. There is one exception to this rule: when the eoEnergyMaxConsumed and/or eoEnergyMaxProduced are in (one of) the two oldest measurement(s), they are left untouched and the next oldest measurement is replaced."

DEFVAL { 10 }  
::= { eoEnergyParametersEntry 4 }

eoEnergyParametersIntervalMode OBJECT-TYPE

SYNTAX                    INTEGER {  
                          period(1),  
                          sliding(2),  
                          total(3)  
                          }

MAX-ACCESS                read-create  
STATUS                    current

DESCRIPTION

"A control object to define the mode of interval calculation for the computation of the average eoEnergyConsumed or eoEnergyProduced measurement in the eoEnergyTable table."

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A mode of period(1) specifies non-overlapping periodic measurements.

A mode of sliding(2) specifies overlapping sliding windows where the interval between the start of one interval and the next is defined in eoEnergyParametersIntervalWindow.

A mode of total(3) specifies non-periodic measurement. In this mode only one interval is used as this is a continuous measurement since the last reset. The value of eoEnergyParametersIntervalNumber should be (1) one and eoEnergyParametersIntervalLength is ignored. "

::= { eoEnergyParametersEntry 5 }

eoEnergyParametersIntervalWindow OBJECT-TYPE

SYNTAX TimeInterval

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"The length of the duration window between the starting time of one sliding window and the next starting time in hundredth of seconds, in order to compute the average of eoEnergyConsumed, eoEnergyProduced measurements in the eoEnergyTable table. This is valid only when the eoEnergyParametersIntervalMode is sliding(2). The eoEnergyParametersIntervalWindow value should be a multiple of eoEnergyParametersSampleRate."

::= { eoEnergyParametersEntry 6 }

eoEnergyParametersSampleRate OBJECT-TYPE

SYNTAX Integer32

UNITS "Milliseconds"

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"The sampling rate, in milliseconds, at which the Energy Object should poll power usage in order to compute the average eoEnergyConsumed, eoEnergyProduced measurements in the table eoEnergyTable. The Energy Object should initially set this sampling rate to a reasonable value, i.e., a compromise between intervals that will provide good accuracy by not being too long, but not so short that they affect the Energy Object performance by requesting continuous polling. If the sampling rate is unknown, the value 0 is reported. The sampling rate should be selected so that eoEnergyParametersIntervalWindow is a multiple of eoEnergyParametersSampleRate."

DEFVAL { 1000 }

::= { eoEnergyParametersEntry 7 }

eoEnergyParametersStatus OBJECT-TYPE

SYNTAX RowStatus

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"The status of this row. The eoEnergyParametersStatus is used to start or stop energy usage logging. An entry status may not be active(1) unless all objects in the entry have an appropriate value. If this object is not equal to active(1), all associated usage-data logged into the eoEnergyTable will be deleted. The data can be destroyed by setting up the eoEnergyParametersStatus to destroy(2)."

::= { eoEnergyParametersEntry 8 }

eoEnergyTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoEnergyEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table lists Energy Object energy measurements. Entries in this table are only created if the corresponding value of object eoPowerMeasurementCaliber is active(2), i.e., if the power is actually metered."

::= { energyObjectMibObjects 5 }

eoEnergyEntry OBJECT-TYPE

SYNTAX EoEnergyEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry describing energy measurements."

INDEX { eoEnergyParametersIndex,

eoEnergyCollectionStartTime }

::= { eoEnergyTable 1 }

EoEnergyEntry ::= SEQUENCE {

eoEnergyCollectionStartTime TimeTicks,

eoEnergyConsumed Integer32,

eoEnergyProduced Integer32,

eoEnergyNet Integer32,

eoEnergyUnitMultiplier UnitMultiplier,

eoEnergyAccuracy Integer32,

```
 eoEnergyMaxConsumed Integer32,
 eoEnergyMaxProduced Integer32,
 eoEnergyDiscontinuityTime TimeStamp
}
```

eoEnergyCollectionStartTime OBJECT-TYPE

```
SYNTAX TimeTicks
UNITS "hundredths of seconds"
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
 "The time (in hundredths of a second) since the
 network management portion of the system was last
 re-initialized, as specified in the sysUpTime [RFC3418].
 This object is useful for reference of interval periods
 for which the energy is measured."
 ::= { eoEnergyEntry 1 }
```

eoEnergyConsumed OBJECT-TYPE

```
SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "This object indicates the energy consumed in units of watt-
 hours for the Energy Object over the defined interval.
 This value is specified in the common billing units of watt-
 hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.)
 indicated separately in eoEnergyUnitMultiplier."
 ::= { eoEnergyEntry 2 }
```

eoEnergyProduced OBJECT-TYPE

```
SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "This object indicates the energy produced in units of watt-
 hours for the Energy Object over the defined interval.
 This value is specified in the common billing units of watt-
 hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.)
 indicated separately in eoEnergyUnitMultiplier."
 ::= { eoEnergyEntry 3 }
```

eoEnergyNet OBJECT-TYPE

```
SYNTAX Integer32
UNITS "Watt-hours"
```

MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"This object indicates the resultant of the energy consumed and energy produced for an energy object in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.) indicated separately in eoEnergyUnitMultiplier."  
 ::= { eoEnergyEntry 4 }

eoEnergyUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"This object is the magnitude of watt-hours for the energy field in eoEnergyConsumed, eoEnergyProduced, eoEnergyNet, eoEnergyMaxConsumed, and eoEnergyMaxProduced."  
 ::= { eoEnergyEntry 5 }

eoEnergyAccuracy OBJECT-TYPE

SYNTAX Integer32 (0..10000)  
UNITS "hundredths of percent"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"This object indicates a percentage value, in 100ths of a percent, representing the presumed accuracy of Energy usage reporting. eoEnergyAccuracy is applicable to all Energy measurements in the eoEnergyTable.

For example: 1010 means the reported usage is accurate to +/- 10.1 percent.  
This value is zero if the accuracy is unknown."

::= { eoEnergyEntry 6 }

eoEnergyMaxConsumed OBJECT-TYPE

SYNTAX Integer32  
UNITS "Watt-hours"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION



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"This object is the maximum energy ever observed in eoEnergyConsumed since the monitoring started. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kW-Hr,   MW-Hr, etc.) indicated separately in eoEnergyUnitMultiplier."

::= { eoEnergyEntry 7 }

eoEnergyMaxProduced OBJECT-TYPE

SYNTAX           Integer32

UNITS            "Watt-hours"

MAX-ACCESS       read-only

STATUS           current

DESCRIPTION

"This object is the maximum energy ever observed in eoEnergyEnergyProduced since the monitoring started. This value is specified in the units of watt-hours with the magnitude of watt-hours (kW-Hr,   MW-Hr, etc.) indicated separately in eoEnergyEnergyUnitMultiplier."

::= { eoEnergyEntry 8 }

eoEnergyDiscontinuityTime OBJECT-TYPE

SYNTAX           TimeStamp

MAX-ACCESS       read-only

STATUS           current

DESCRIPTION

"The value of sysUpTime [RFC3418] on the most recent occasion at which any one or more of this entity's energy counters in this table suffered a discontinuity: eoEnergyConsumed, eoEnergyProduced or eoEnergyNet. If no such discontinuities have occurred since the last re-initialization of the local management subsystem, then this object contains a zero value."

::= { eoEnergyEntry 9 }

-- Notifications

eoPowerStateChange NOTIFICATION-TYPE

OBJECTS           {eoPowerAdminState, eoPowerOperState, eoPowerStateEnterReason}

STATUS            current

DESCRIPTION

"The SNMP entity generates the eoPowerStateChange when the value(s) of eoPowerAdminState or eoPowerOperState, in the context of the Power State Set, have changed for the Energy Object represented by the entPhysicalIndex."

```
 ::= { energyObjectMibNotifs 1 }

-- Conformance

energyObjectMibCompliances OBJECT IDENTIFIER
 ::= { energyObjectMib 3 }

energyObjectMibGroups OBJECT IDENTIFIER
 ::= { energyObjectMib 4 }

energyObjectMibFullCompliance MODULE-COMPLIANCE
 STATUS current
 DESCRIPTION
 "When this MIB is implemented with support for
 read-create, then such an implementation can
 claim full compliance. Such devices can then
 be both monitored and configured with this MIB.

 Module Compliance of [EMAN-ENTITY]
 with respect to entity4CRCompliance should
 be supported which requires implementation
 of 3 MIB objects (entPhysicalIndex,
 entPhysicalName and entPhysicalUUID)."
```

```
MODULE -- this module
MANDATORY-GROUPS {
 energyObjectMibTableGroup,
 energyObjectMibStateTableGroup,
 energyObjectMibNotifGroup
}

GROUP energyObjectMibEnergyTableGroup

 DESCRIPTION "A compliant implementation does not
 have to implement.

 Module Compliance of [EMAN-ENTITY]
 with respect to entity4CRCompliance should
 be supported which requires implementation
 of 3 MIB objects (entPhysicalIndex,
 entPhysicalName and entPhysicalUUID)."
```

```
GROUP energyObjectMibEnergyParametersTableGroup

 DESCRIPTION "A compliant implementation does not
 have to implement.
```

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Module Compliance of {EMAN-ENTITY]  
with respect to entity4CRCompliance should  
be supported which requires implementation  
of 3 MIB objects (entPhysicalIndex,  
entPhysicalName and entPhysicalUUID)."

GROUP energyObjectMibMeterCapabilitiesTableGroup

DESCRIPTION "A compliant implementation does not  
have to implement.

Module Compliance of [EMAN-ENTITY]  
with respect to entity4CRCompliance should  
be supported which requires implementation  
of 3 MIB objects (entPhysicalIndex,  
entPhysicalName and entPhysicalUUID)."

::= { energyObjectMibCompliances 1 }

energyObjectMibReadOnlyCompliance MODULE-COMPLIANCE

STATUS current

DESCRIPTION

"When this MIB is implemented without support for  
read-create (i.e. in read-only mode), then such an  
implementation can claim read-only compliance. Such a  
device can then be monitored but cannot be  
configured with this MIB.

Module Compliance of [EMAN-ENTITY]  
with respect to entity4CRCompliance should  
be supported which requires implementation  
of 3 MIB objects (entPhysicalIndex,  
entPhysicalName and entPhysicalUUID)."

MODULE -- this module

MANDATORY-GROUPS {  
energyObjectMibTableGroup,  
energyObjectMibStateTableGroup,  
energyObjectMibNotifGroup  
}

OBJECT eoPowerOperState

MIN-ACCESS read-only

DESCRIPTION

"Write access is not required."

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 ::= { energyObjectMibCompliances 2 }

-- Units of Conformance

```
energyObjectMibTableGroup OBJECT-GROUP
 OBJECTS
 {
 eoPower,
 eoPowerNameplate,
 eoPowerUnitMultiplier,
 eoPowerAccuracy,
 eoPowerMeasurementCaliber,
 eoPowerCurrentType,
 eoPowerOrigin,
 eoPowerAdminState,
 eoPowerOperState,
 eoPowerStateEnterReason
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the objects
 related to the Energy Object."
 ::= { energyObjectMibGroups 1 }
```

```
energyObjectMibStateTableGroup OBJECT-GROUP
 OBJECTS
 {
 eoPowerStateMaxPower,
 eoPowerStatePowerUnitMultiplier,
 eoPowerStateTotalTime,
 eoPowerStateEnterCount
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the
 objects related to the Power State."
 ::= { energyObjectMibGroups 2 }
```

```
energyObjectMibEnergyParametersTableGroup OBJECT-GROUP
 OBJECTS
 {
 eoEnergyObjectIndex,
 eoEnergyParametersIndex,
 eoEnergyParametersIntervalLength,
 eoEnergyParametersIntervalNumber,
 eoEnergyParametersIntervalMode,
 eoEnergyParametersIntervalWindow,
 eoEnergyParametersSampleRate,
 eoEnergyParametersStatus
 }
```

```
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the objects
 related to the configuration of the Energy Table."
 ::= { energyObjectMibGroups 3 }
```

energyObjectMibEnergyTableGroup OBJECT-GROUP

```
 OBJECTS
 {
 -- Note that object
 -- eoEnergyCollectionStartTime is not
 -- included since it is not-accessible

 eoEnergyConsumed,
 eoEnergyProduced,
 eoEnergyNet,
 eoEnergyUnitMultiplier,
 eoEnergyAccuracy,
 eoEnergyMaxConsumed,
 eoEnergyMaxProduced,
 eoEnergyDiscontinuityTime
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the objects
 related to the Energy Table."
 ::= { energyObjectMibGroups 4 }
```

energyObjectMibMeterCapabilitiesTableGroup OBJECT-GROUP

```
 OBJECTS
 {
 eoMeterCapability
 }
 STATUS current
 DESCRIPTION
 "This group contains the object indicating the
 capability of the Energy Object"
 ::= { energyObjectMibGroups 5 }
```

energyObjectMibNotifGroup NOTIFICATION-GROUP

```
 NOTIFICATIONS
 {
 eoPowerStateChange
 }
 STATUS current
 DESCRIPTION
 "This group contains the notifications for the power and
 energy monitoring MIB Module."
```

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 ::= { energyObjectMibGroups 6 }

END

```
-- *****
--
-- This MIB module is used to monitor power characteristics of
-- networked devices with measurements.
--
-- This MIB module is an extension of energyObjectMib module.
--
-- *****
```

POWER-CHARACTERISTICS-MIB DEFINITIONS ::= BEGIN

IMPORTS

MODULE-IDENTITY,  
OBJECT-TYPE,  
mib-2,  
Integer32  
FROM SNMPv2-SMI  
MODULE-COMPLIANCE,  
OBJECT-GROUP  
FROM SNMPv2-CONF  
UnitMultiplier  
FROM ENERGY-OBJECT-MIB  
OwnerString  
FROM RMON-MIB  
entPhysicalIndex  
FROM ENTITY-MIB;

powerCharacteristicsMIB MODULE-IDENTITY

LAST-UPDATED "201210220000Z" -- 22 October 2012

ORGANIZATION "IETF EMAN Working Group"

CONTACT-INFO

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Internet-Draft    <Power and Energy Monitoring MIB>    October 2012  
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DESCRIPTION

Internet-Draft    <Power and Energy Monitoring MIB>    October 2012  
"This MIB is used to report AC power characteristics  
in devices. The table is a sparse augmentation of  
the eoPowerTable table from the energyObjectMib  
module. Both three-phase and single-phase power  
configurations are supported.

As a requirement for this MIB module,  
[EMAN-AWARE-MIB] should be implemented.

Module Compliance of ENTITY-MIB v4  
with respect to entity4CRCompliance should  
be supported which requires implementation  
of 3 MIB objects (entPhysicalIndex,  
entPhysicalName and entPhysicalUUID)."

#### REVISION

"201210220000Z"            -- 22 October 2012

#### DESCRIPTION

"Initial version, published as RFC YYY."

::= { mib-2 yyy }

powerCharacteristicsMIBConform    OBJECT IDENTIFIER  
::= { powerCharacteristicsMIB 0 }

powerCharacteristicsMIBObjects    OBJECT IDENTIFIER  
::= { powerCharacteristicsMIB 1 }

-- Objects

eoACPwrCharacteristicsTable    OBJECT-TYPE  
SYNTAX                          SEQUENCE OF EoACPwrCharacteristicsEntry  
MAX-ACCESS                      not-accessible  
STATUS                          current  
DESCRIPTION  
    "This table defines power characteristics measurements  
    for supported entPhysicalIndex entities. It is a sparse  
    extension of the eoPowerTable."  
::= { powerCharacteristicsMIBObjects 1 }

eoACPwrCharacteristicsEntry    OBJECT-TYPE  
SYNTAX                          EoACPwrCharacteristicsEntry



MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This is a sparse extension of the eoPowerTable with entries for power characteristics measurements or configuration. Each measured value corresponds to an attribute in IEC 61850-7-4 for non-phase measurements within the object MMUX."

INDEX {entPhysicalIndex }

::= { eoACPwrCharacteristicsTable 1 }

EoACPwrCharacteristicsEntry ::= SEQUENCE {

eoACPwrCharacteristicsConfiguration INTEGER,  
eoACPwrCharacteristicsAvgVoltage Integer32,  
eoACPwrCharacteristicsAvgCurrent Integer32,  
eoACPwrCharacteristicsFrequency Integer32,  
eoACPwrCharacteristicsPowerUnitMultiplier UnitMultiplier,  
eoACPwrCharacteristicsPowerAccuracy Integer32,  
eoACPwrCharacteristicsTotalActivePower Integer32,  
eoACPwrCharacteristicsTotalReactivePower Integer32,  
eoACPwrCharacteristicsTotalApparentPower Integer32,  
eoACPwrCharacteristicsTotalPowerFactor Integer32,  
eoACPwrCharacteristicsThdAmpheres Integer32,  
eoACPwrCharacteristicsThdVoltage Integer32

}

eoACPwrCharacteristicsConfiguration OBJECT-TYPE

SYNTAX INTEGER {  
sngl(1),  
del(2),  
wye(3)  
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"Configuration describes the physical configurations of the power supply lines:

- \* alternating current, single phase (SNGL)
- \* alternating current, three phase delta (DEL)
- \* alternating current, three phase Y (WYE)

Three-phase configurations can be either connected in a triangular delta (DEL) or star Y (WYE) system. WYE systems have a shared neutral voltage, while DEL systems do not. Each phase is offset 120 degrees to each other."

```
::= { eoACPwrCharacteristicsEntry 1 }

eoACPwrCharacteristicsAvgVoltage OBJECT-TYPE
 SYNTAX Integer32
 UNITS "0.1 Volt AC"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value for average of the voltage measured
 over an integral number of AC cycles. For a 3-phase
 system, this is the average voltage (V1+V2+V3)/3. IEC
 61850-7-4 measured value attribute 'Vol'"
 ::= { eoACPwrCharacteristicsEntry 2 }

eoACPwrCharacteristicsAvgCurrent OBJECT-TYPE
 SYNTAX Integer32
 UNITS "Amperes"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value of the current per phase. IEC 61850-
 7-4 attribute 'Amp'"
 ::= { eoACPwrCharacteristicsEntry 3 }

eoACPwrCharacteristicsFrequency OBJECT-TYPE
 SYNTAX Integer32 (4500..6500) -- UNITS 0.01 Hertz
 UNITS "hertz"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value for the basic frequency of the AC
 circuit. IEC 61850-7-4 attribute 'Hz'."
 ::= { eoACPwrCharacteristicsEntry 4 }

eoACPwrCharacteristicsPowerUnitMultiplier OBJECT-TYPE
 SYNTAX UnitMultiplier
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "The magnitude of watts for the usage value in
 eoACPwrCharacteristicsTotalActivePower,
 eoACPwrCharacteristicsTotalReactivePower
 and eoACPwrCharacteristicsTotalApparentPower
 measurements.
 For 3-phase power systems, this will also include
 eoACPwrCharacteristicsPhaseActivePower,
 eoACPwrCharacteristicsPhaseReactivePower and
 eoACPwrCharacteristicsPhaseApparentPower"
```

Internet-Draft <Power and Energy Monitoring MIB> October 2012  
 ::= { eoACPwrCharacteristicsEntry 5 }

eoACPwrCharacteristicsPowerAccuracy OBJECT-TYPE

SYNTAX Integer32 (0..10000)  
UNITS "hundredths of percent"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"This object indicates a percentage value, in 100ths of a percent, representing the presumed accuracy of active, reactive, and apparent power usage reporting. For example: 1010 means the reported usage is accurate to +/- 10.1 percent. This value is zero if the accuracy is unknown.

ANSI and IEC define the following accuracy classes for power measurement: IEC 62053-22 & 60044-1 class 0.1, 0.2, 0.5, 1 & 3.

ANSI C12.20 class 0.2 & 0.5"

::= { eoACPwrCharacteristicsEntry 6 }

eoACPwrCharacteristicsTotalActivePower OBJECT-TYPE

SYNTAX Integer32  
UNITS " watts"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"A measured value of the actual power delivered to or consumed by the load. IEC 61850-7-4 attribute 'TotW'."

::= { eoACPwrCharacteristicsEntry 7 }

eoACPwrCharacteristicsTotalReactivePower OBJECT-TYPE

SYNTAX Integer32  
UNITS "volt-amperes reactive"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"A measured value of the reactive portion of the apparent power. IEC 61850-7-4 attribute 'TotVAR'."

::= { eoACPwrCharacteristicsEntry 8 }

eoACPwrCharacteristicsTotalApparentPower OBJECT-TYPE

SYNTAX Integer32  
UNITS "volt-amperes"  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

Internet-Draft <Power and Energy Monitoring MIB> October 2012

"A measured value of the voltage and current which determines the apparent power. The apparent power is the vector sum of real and reactive power.

Note: watts and volt-amperes are equivalent units and may be combined. IEC 61850-7-4 attribute 'TotVA'."

::= { eoACPwrCharacteristicsEntry 9 }

eoACPwrCharacteristicsTotalPowerFactor OBJECT-TYPE

SYNTAX Integer32 (-10000..10000)

UNITS "hundredths of percent"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"A measured value ratio of the real power flowing to the load versus the apparent power. It is dimensionless and expressed here as a percentage value in 100ths of a percent. A power factor of 100% indicates there is no inductance load and thus no reactive power. Power Factor can be positive or negative, where the sign should be in lead/lag (IEEE) form. IEC 61850-7-4 attribute 'TotPF'."

::= { eoACPwrCharacteristicsEntry 10 }

eoACPwrCharacteristicsThdAmperes OBJECT-TYPE

SYNTAX Integer32 (0..10000)

UNITS "hundredths of percent"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"A calculated value for the current total harmonic distortion (THD). Method of calculation is not specified. IEC 61850-7-4 attribute 'ThdAmp'."

::= { eoACPwrCharacteristicsEntry 11 }

eoACPwrCharacteristicsThdVoltage OBJECT-TYPE

SYNTAX Integer32 (0..10000)

UNITS "hundredths of percent"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"A calculated value for the voltage total harmonic distortion (THD). Method of calculation is not specified. IEC 61850-7-4 attribute 'ThdVol'."

::= { eoACPwrCharacteristicsEntry 12 }

eoACPwrCharacteristicsPhaseTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoACPwrCharacteristicsPhaseEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table describes 3-phase power characteristics measurements. It is a sparse extension of the eoACPwrCharacteristicsTable."

::= { powerCharacteristicsMIBObjects 2 }

eoACPwrCharacteristicsPhaseEntry OBJECT-TYPE

SYNTAX EoACPwrCharacteristicsPhaseEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry describes common 3-phase power characteristics measurements."

This optional table describes 3-phase power characteristics measurements, with three entries for each supported entPhysicalIndex entity. Entities having single phase power shall not have any entities.

This table describes attributes common to both WYE and DEL. Entities having single phase power shall not have any entries here. It is a sparse extension of the eoACPwrCharacteristicsTable.

These attributes correspond to IEC 61850-7.4 MMXU phase measurements."

INDEX { entPhysicalIndex, eoPhaseIndex }

::= { eoACPwrCharacteristicsPhaseTable 1 }

EoACPwrCharacteristicsPhaseEntry ::= SEQUENCE {

eoPhaseIndex Integer32,

eoACPwrCharacteristicsPhaseAvgCurrent Integer32,

eoACPwrCharacteristicsPhaseActivePower Integer32,

eoACPwrCharacteristicsPhaseReactivePower Integer32,

eoACPwrCharacteristicsPhaseApparentPower Integer32,

eoACPwrCharacteristicsPhasePowerFactor Integer32,

eoACPwrCharacteristicsPhaseImpedance Integer32

}

eoPhaseIndex OBJECT-TYPE

SYNTAX Integer32 (0..359)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

Internet-Draft    <Power and Energy Monitoring MIB>    October 2012  
    "A phase angle typically corresponding to 0, 120, 240."  
    ::= { eoACPwrCharacteristicsPhaseEntry 1 }

eoACPwrCharacteristicsPhaseAvgCurrent OBJECT-TYPE  
    SYNTAX            Integer32  
    UNITS             "Amperes"  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "A measured value of the current per phase. IEC 61850-  
        7-4 attribute 'A'"  
    ::= { eoACPwrCharacteristicsPhaseEntry 2 }

eoACPwrCharacteristicsPhaseActivePower OBJECT-TYPE  
    SYNTAX            Integer32  
    UNITS             " watts"  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "A measured value of the actual power delivered to or  
        consumed by the load. IEC 61850-7-4 attribute 'W'"  
    ::= { eoACPwrCharacteristicsPhaseEntry 3 }

eoACPwrCharacteristicsPhaseReactivePower OBJECT-TYPE  
    SYNTAX            Integer32  
    UNITS             "volt-amperes reactive"  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "A measured value of the reactive portion of the  
        apparent power. IEC 61850-7-4 attribute 'VAr'"  
    ::= { eoACPwrCharacteristicsPhaseEntry 4 }

eoACPwrCharacteristicsPhaseApparentPower OBJECT-TYPE  
    SYNTAX            Integer32  
    UNITS             "volt-amperes"  
    MAX-ACCESS        read-only  
    STATUS            current  
    DESCRIPTION  
        "A measured value of the voltage and current determines  
        the apparent power. Active plus reactive power equals  
        the total apparent power.

        Note: Watts and volt-amperes are equivalent units and  
        may be combined. IEC 61850-7-4 attribute 'VA'."  
    ::= { eoACPwrCharacteristicsPhaseEntry 5 }

eoACPwrCharacteristicsPhasePowerFactor OBJECT-TYPE

```

Internet-Draft <Power and Energy Monitoring MIB> October 2012
SYNTAX Integer32 (-10000..10000)
UNITS "hundredths of percent"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "A measured value ratio of the real power flowing to
 the load versus the apparent power for this phase. IEC
 61850-7-4 attribute 'PF'. Power Factor can be positive
 or negative where the sign should be in lead/lag (IEEE)
 form."
 ::= { eoACPwrCharacteristicsPhaseEntry 6 }

eoACPwrCharacteristicsPhaseImpedance OBJECT-TYPE
 SYNTAX Integer32
 UNITS "volt-amperes"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value of the impedance. IEC 61850-7-4 attribute
 'Z'."
 ::= { eoACPwrCharacteristicsPhaseEntry 7 }

eoACPwrCharacteristicsDelPhaseTable OBJECT-TYPE
 SYNTAX SEQUENCE OF
EoACPwrCharacteristicsDelPhaseEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table describes DEL configuration phase-to-phase
 power characteristics measurements. This is a sparse
 extension of the eoACPwrCharacteristicsPhaseTable."
 ::= { powerCharacteristicsMIBObjects 3 }

eoACPwrCharacteristicsDelPhaseEntry OBJECT-TYPE
 SYNTAX EoACPwrCharacteristicsDelPhaseEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "An entry describes power characteristics attributes of
 a phase in a DEL 3-phase power system. Voltage
 measurements are provided both relative to each other
 and zero.

 Measured values are from IEC 61850-7-2 MMUX and THD from
 MHAI objects.

```

Internet-Draft <Power and Energy Monitoring MIB> October 2012  
 For phase-to-phase measurements, the eoPhaseIndex is  
 compared against the following phase at +120 degrees.  
 Thus, the possible values are:

| eoPhaseIndex | Next Phase Angle |
|--------------|------------------|
| 0            | 120              |
| 120          | 240              |
| 240          | 0                |

"

```
INDEX { entPhysicalIndex, eoPhaseIndex}
 ::= { eoACPwrCharacteristicsDelPhaseTable 1}
```

```
EoACPwrCharacteristicsDelPhaseEntry ::= SEQUENCE {
 eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage
 Integer32,
 eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage
 Integer32,
 eoACPwrCharacteristicsDelThdCurrent
 Integer32
}
```

```
eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage OBJECT-TYPE
 SYNTAX Integer32
 UNITS "0.1 Volt AC"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value of phase to next phase voltages, where
 the next phase is IEC 61850-7-4 attribute 'PPV'."
 ::= { eoACPwrCharacteristicsDelPhaseEntry 2 }
```

```
eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage OBJECT-TYPE
 SYNTAX Integer32 (0..10000)
 UNITS "hundredths of percent"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A calculated value for the voltage total harmonic
 disortion for phase to next phase. Method of calculation
 is not specified. IEC 61850-7-4 attribute 'ThdPPV'."
 ::= { eoACPwrCharacteristicsDelPhaseEntry 3 }
```

```
eoACPwrCharacteristicsDelThdCurrent OBJECT-TYPE
 SYNTAX Integer32 (0..10000)
 UNITS "hundredths of percent"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
```



```

Internet-Draft <Power and Energy Monitoring MIB> October 2012
 "A calculated value for the voltage total harmonic
 distortion (THD) for phase to phase. Method of
 calculation is not specified.
 IEC 61850-7-4 attribute 'ThdPPV'."
 ::= { eoACPwrCharacteristicsDelPhaseEntry 4 }

eoACPwrCharacteristicsWyePhaseTable OBJECT-TYPE
 SYNTAX SEQUENCE OF
 EoACPwrCharacteristicsWyePhaseEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table describes WYE configuration phase-to-neutral
 power characteristics measurements. This is a sparse
 extension of the eoACPwrCharacteristicsPhaseTable."
 ::= { powerCharacteristicsMIBObjects 4 }

eoACPwrCharacteristicsWyePhaseEntry OBJECT-TYPE
 SYNTAX EoACPwrCharacteristicsWyePhaseEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table describes measurements of WYE configuration
 with phase to neutral power characteristics attributes.
 Three entries are required for each supported
 entPhysicalIndex entry. Voltage measurements are
 relative to neutral.

 This is a sparse extension of the
 eoACPwrCharacteristicsPhaseTable.

 Each entry describes power characteristics attributes of
 one phase of a WYE 3-phase power system.

 Measured values are from IEC 61850-7-2 MMUX and THD from
 MHAI objects."
 INDEX { entPhysicalIndex, eoPhaseIndex }
 ::= { eoACPwrCharacteristicsWyePhaseTable 1}

EoACPwrCharacteristicsWyePhaseEntry ::= SEQUENCE {
 eoACPwrCharacteristicsWyePhaseToNeutralVoltage
 Integer32,
 eoACPwrCharacteristicsWyePhaseCurrent
 Integer32,
 eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage
 Integer32
}

```

```

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eoACPwrCharacteristicsWyePhaseToNeutralVoltage OBJECT-TYPE
 SYNTAX Integer32
 UNITS "0.1 Volt AC"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value of phase to neutral voltage. IEC
 61850-7-4 attribute 'PhV'."
 ::= { eoACPwrCharacteristicsWyePhaseEntry 1 }

eoACPwrCharacteristicsWyePhaseCurrent OBJECT-TYPE
 SYNTAX Integer32
 UNITS "0.1 ampheres AC"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A measured value of phase currents. IEC 61850-7-4
 attribute 'A'."
 ::= { eoACPwrCharacteristicsWyePhaseEntry 2 }

eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage OBJECT-TYPE
 SYNTAX Integer32 (0..10000)
 UNITS "hundredths of percent"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A calculated value of the voltage total harmonic
 distortion (THD) for phase to neutral. IEC 61850-7-4
 attribute 'ThdPhV'."
 ::= { eoACPwrCharacteristicsWyePhaseEntry 3 }

-- Conformance

powerCharacteristicsMIBCompliances OBJECT IDENTIFIER
 ::= { powerCharacteristicsMIB 2 }

powerCharacteristicsMIBGroups OBJECT IDENTIFIER
 ::= { powerCharacteristicsMIB 3 }

powerCharacteristicsMIBFullCompliance MODULE-COMPLIANCE
 STATUS current
 DESCRIPTION
 "When this MIB is implemented with support for read-create,
 then such an implementation can claim full compliance.
 Such devices can then be both monitored and configured with
 this MIB."

```

Internet-Draft   <Power and Energy Monitoring MIB>   October 2012  
Module Compliance of [EMAN-ENTITY] with respect to  
entity4CRCompliance should be supported which requires  
implementation of 3 MIB objects (entPhysicalIndex,  
entPhysicalName and entPhysicalUUID)."

```
MODULE -- this module
MANDATORY-GROUPS {
 powerACPwrCharacteristicsMIBTableGroup
}
```

```
GROUP powerACPwrCharacteristicsOptionalMIBTableGroup
DESCRIPTION
 "A compliant implementation does not have
 to implement."
```

```
GROUP powerACPwrCharacteristicsPhaseMIBTableGroup
DESCRIPTION
 "A compliant implementation does not have to
 implement."
```

```
GROUP powerACPwrCharacteristicsDelPhaseMIBTableGroup
DESCRIPTION
 "A compliant implementation does not have to
 implement."
```

```
GROUP powerACPwrCharacteristicsWyePhaseMIBTableGroup
DESCRIPTION
 "A compliant implementation does not have to
 implement."
```

```
::= { powerCharacteristicsMIBCompliances 1 }
```

-- Units of Conformance

```
powerACPwrCharacteristicsMIBTableGroup OBJECT-GROUP
 OBJECTS
 {
 -- Note that object entPhysicalIndex is NOT
 -- included since it is not-accessible

 eoACPwrCharacteristicsAvgVoltage,
 eoACPwrCharacteristicsAvgCurrent,
```

```

 eoACPwrCharacteristicsFrequency,

 eoACPwrCharacteristicsPowerUnitMultiplier,
 eoACPwrCharacteristicsPowerAccuracy,
 eoACPwrCharacteristicsTotalActivePower,

 eoACPwrCharacteristicsTotalReactivePower,

 eoACPwrCharacteristicsTotalApparentPower,
 eoACPwrCharacteristicsTotalPowerFactor
 }

 STATUS current
 DESCRIPTION
 "This group contains the collection of all the power
 characteristics objects related to the Energy Object."
 ::= { powerCharacteristicsMIBGroups 1 }

powerACPwrCharacteristicsOptionalMIBTableGroup OBJECT-GROUP
 OBJECTS {
 eoACPwrCharacteristicsConfiguration,
 eoACPwrCharacteristicsThdAmperes,
 eoACPwrCharacteristicsThdVoltage
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the power
 characteristics objects related to the Energy Object."
 ::= { powerCharacteristicsMIBGroups 2 }

powerACPwrCharacteristicsPhaseMIBTableGroup OBJECT-GROUP
 OBJECTS {
 -- Note that object entPhysicalIndex is
 -- NOT included since it is
 -- not-accessible
 eoACPwrCharacteristicsPhaseAvgCurrent,
 eoACPwrCharacteristicsPhaseActivePower,

 eoACPwrCharacteristicsPhaseReactivePower,

 eoACPwrCharacteristicsPhaseApparentPower,
 eoACPwrCharacteristicsPhasePowerFactor,

 eoACPwrCharacteristicsPhaseImpedance
 }
 STATUS current
 DESCRIPTION

```

```

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 "This group contains the collection of all 3-phase power
 characteristics objects related to the Power State."
 ::= { powerCharacteristicsMIBGroups 3 }

powerACPwrCharacteristicsDelPhaseMIBTableGroup OBJECT-GROUP
 OBJECTS
 {
 -- Note that object entPhysicalIndex and
 -- eoPhaseIndex are NOT included
 -- since they are not-accessible

eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage ,

eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage,
 eoACPwrCharacteristicsDelThdCurrent
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all power
 characteristic attributes of a phase in a DEL 3-phase
 power system."
 ::= { powerCharacteristicsMIBGroups 4 }

powerACPwrCharacteristicsWyePhaseMIBTableGroup OBJECT-GROUP
 OBJECTS
 {
 -- Note that object entPhysicalIndex and
 -- eoPhaseIndex are NOT included
 -- since they are not-accessible

eoACPwrCharacteristicsWyePhaseToNeutralVoltage,
 eoACPwrCharacteristicsWyePhaseCurrent,

eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all WYE
 configuration phase-to-neutral power characteristics
 measurements."
 ::= { powerCharacteristicsMIBGroups 5 }

END

```

## 11. Security Considerations

Some of the readable objects in these MIB modules (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is

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thus important to control even GET and/or NOTIFY access to these  
objects and possibly to even encrypt the values of these objects  
when sending them over the network via SNMP.

There are a number of management objects defined in these MIB  
modules with a MAX-ACCESS clause of read-write and/or read-  
create. Such objects MAY be considered sensitive or vulnerable  
in some network environments. The support for SET operations in  
a non-secure environment without proper protection can have a  
negative effect on network operations. The following are the  
tables and objects and their sensitivity/vulnerability:

- Unauthorized changes to the eoPowerOperState (via  
theeoPowerAdminState ) MAY disrupt the power settings of the  
differentEnergy Objects, and therefore the state of  
functionality of the respective Energy Objects.
- Unauthorized changes to the eoEnergyParametersTable MAY  
disrupt energy measurement in the eoEnergyTable table.

SNMP versions prior to SNMPv3 did not include adequate security.  
Even if the network itself is secure (for example, by using  
IPsec), there is still no secure control over who on the secure  
network is allowed to access and GET/SET  
(read/change/create/delete) the objects in these MIB modules.

It is RECOMMENDED that implementers consider the security  
features as provided by the SNMPv3 framework (see [RFC3410],  
section 8), including full support for the SNMPv3 cryptographic  
mechanisms (for authentication and privacy).

Further, deployment of SNMP versions prior to SNMPv3 is NOT  
RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to  
enable cryptographic security. It is then a customer/operator  
responsibility to ensure that the SNMP entity giving access to  
an instance of these MIB modules is properly configured to give  
access to the objects only to those principals (users) that have  
legitimate rights to GET or SET (change/create/delete) them.

## 12. IANA Considerations

### 12.1. IANA Considerations for the MIB Modules

The MIB modules in this document uses the following IANA-  
assigned OBJECT IDENTIFIER values recorded in the SMI Numbers  
registry:

| Descriptor              | OBJECT IDENTIFIER value |
|-------------------------|-------------------------|
| energyObjectMib         | { mib-2 xxx }           |
| powerCharacteristicsMIB | { mib-2 yyy }           |

Additions to the MIB modules are subject to Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested MIB objects for completeness and accuracy of the description. Requests for MIB objects that duplicate the functionality of existing objects SHOULD be declined. The smallest available OIDs SHOULD be assigned to the new MIB objects. The specification of new MIB objects SHOULD follow the structure specified in Section 10. and MUST be published using a well-established and persistent publication medium.

## 12.2. IANA Registration of new Power State Set

This document specifies an initial set of Power State Sets. The list of these Power State Sets with their numeric identifiers is given in Section 5.2.1. IANA maintains a Textual Convention IANAPowerStateSet with the initial set of Power State Sets and the Power States within those Power State Sets. The current version of Textual convention can be accessed <http://www.iana.org/assignments/IANAPowerStateSet>

New Assignments to Power State Sets shall be administered by IANA and the guidelines and procedures are listed in this Section.

New assignments for Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description. A pure vendor specific implementation of Power State Set shall not be adopted; since it would lead to proliferation of Power State Sets.

### 12.2.1. IANA Registration of the IEEE1621 Power State Set

This document specifies a set of values for the IEEE1621 Power State Set [IEEE1621]. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) created a new registry for IEEE1621

Internet-Draft <Power and Energy Monitoring MIB> October 2012  
Power State Set identifiers and filled it with the initial  
list in the Textual Convention IANA Power State Set..

New assignments (or potentially deprecation) for IEEE1621 Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description.

#### 12.2.2. IANA Registration of the DMTF Power State Set

This document specifies a set of values for the DMTF Power State Set. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) has created a new registry for DMTF Power State Set identifiers and filled it with the initial list in the Textual Convention IANA Power State Set.

New assignments (or potentially deprecation) for DMTF Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the conformance with the DMTF standard [DMTF], on the top of checking for completeness and accuracy of the description.

#### 12.2.3. IANA Registration of the EMAN Power State Set

This document specifies a set of values for the EMAN Power State Set. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) has created a new registry for EMAN Power State Set identifiers and filled it with the initial list in the Textual Convention IANA Power State Set.

New assignments (or potentially deprecation) for EMAN Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description.

#### 12.3. Updating the Registration of Existing Power State Sets

IANA maintains a Textual Convention IANA Power State Set with the initial set of Power State Sets and the Power States within those Power State Sets. The current version of Textual convention can be accessed  
<http://www.iana.org/assignments/IANA Power State Set>



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With the evolution of standards, over time, it may be important to deprecate some of the existing Power State Sets or some of the states within a Power State Set.

The registrant shall publish an Internet-draft or an individual submission with the clear specification on deprecation of Power State Sets or Power States registered with IANA. The deprecation shall be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The process should also allow for a mechanism for cases where others have significant objections to claims on deprecation of a registration. In cases, where the registrant cannot be reached, IESG can designate an Expert to modify the IANA registry for the deprecation.

## 12. Contributors

This document results from the merger of two initial proposals. The following persons made significant contributions either in one of the initial proposals or in this document.

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## 13. Acknowledgment

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## 14. Open Issues

Internet-Draft <Power and Energy Monitoring MIB> October 2012  
OPEN ISSUE 1 check if all the requirements from [EMAN-REQ] are covered.

OPEN ISSUE 2 IANA Registered Power State Sets deferred to [EMAN-FMWK]

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Energy Management Framework  
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Status of this Memo

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#### Abstract

This document defines a framework for providing Energy Management for devices within or connected to communication networks, and components thereof. The framework defines an Energy Management Domain as a set of Energy Objects, for which each Energy Object is identified, classified and given context. Energy Objects can be monitored and/or controlled with respect to Power, Power State, Energy, Demand, Power Quality, and battery. Additionally the framework models relationships and capabilities between Energy Objects.

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## 1. Introduction

Network management is divided into the five main areas defined in the ISO Telecommunications Management Network model: Fault, Configuration, Accounting, Performance, and Security Management (FCAPS) [X.700]. Absent from this management model is any consideration of Energy Management, which is now becoming a critical area of concern worldwide as seen in [ISO50001].

Note that Energy Management has particular challenges in that a power distribution network is responsible for the supply of energy to various devices and components, while a separate communication network is typically used to monitor and control the power distribution network.

This document defines a framework for providing Energy Management for devices within or connected to communication networks. The framework describes how to identify, classify and provide context for a device in a communications network from the point of view of Energy Management.

The identified device or identified components within a device can then be monitored for Energy Management by obtaining measurements for Power, Energy, Demand and Power Quality. If

a device contains batteries, they can be also be monitored and managed. An Energy Object state can be monitored or controlled by providing an interface expressed as one or more Power State Sets. The most basic example of Energy Management is a single Energy Object reporting information about itself. However, in many cases, energy is not measured by the Energy Object itself, but by a meter located upstream in the power distribution tree. An example is a power distribution unit (PDU) that measures energy received by attached devices and may report this to an Energy Management System (EnMS). Therefore, Energy Objects are recognized as having relationships to other devices in the network from the point of view of Energy Management. These relationships include Aggregation Relationship, Metering Relationship, Power Source Relationship, and Proxy Relationship.

### 1.1. Energy Management Document Overview

The EMAN standard provides a set of specifications for Energy Management. This document specifies the framework, per the Energy Management requirements specified in [EMAN-REQ].

The applicability statement document [EMAN-AS] provides a list of use cases, a cross-reference between existing standards and the EMAN standard, and shows how this framework relates to other frameworks.

The Energy-aware Networks and Devices MIB [EMAN-AWARE-MIB] specifies objects for addressing Energy Object Identification, classification, context information, and relationships from the point of view of Energy Management.

The Power and Energy Monitoring MIB [EMAN-MON-MIB] contains objects for monitoring of Power, Energy, Demand, Power Quality and Power States.

Further, the battery monitoring MIB [EMAN-BATTERY-MIB] defines managed objects that provide information on the status of batteries in managed devices.

## 2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

### EDITOR'S NOTE:

All terms are copied over from the version 6 of the [EMAN-TERMINOLOGY] draft.

### Device

A piece of electrical or non-electrical equipment.  
Reference: Adapted from [IEEE100]

### Component

A part of an electrical or non-electrical equipment (Device).



Reference: Adapted from [ITU-T-M-3400]

## Energy Management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization.

Reference: Adapted from [ITU-T-M-3400]

Example: A set of computer systems that will poll electrical meters and store the readings

NOTES:

1. Energy management refers to the activities, methods, procedures and tools that pertain to measuring, modeling, planning, controlling and optimizing the use of energy in networked systems [NMF].
2. Energy Management is a management domain which is congruent to any of FCAPS areas of management in the ISO/OSI Network Management Model [TMN]. Energy Management for communication networks and attached devices is a subset or part of an organization's greater Energy Management Policies.

#### Energy Management System (EnMS)

An Energy Management System is a combination of hardware and software used to administer a network with the primary purpose being Energy Management.

Reference: Adapted from [1037C]

Example: A single computer system that polls data from devices using SNMP

#### NOTES:

1. An Energy Management System according to [ISO50001] (ISO-EnMS) is a set of systems or procedures upon which organizations can develop and implement an energy policy, set targets, action plans and take into account legal

requirements related to energy use. An EnMS allows organizations to improve energy performance and demonstrate conformity to requirements, standards, and/or legal requirements.

2. Example ISO-EnMS: Company A defines a set of policies and procedures indicating there should exist multiple computerized systems that will poll energy from their meters and pricing / source data from their local utility. Company A specifies that their CFO should collect information and summarize it quarterly to be

sent to an accounting firm to produce carbon accounting reporting as required by their local government.

3. For the purposes of EMAN, the definition from [1037C] is the preferred meaning of an Energy Management System (EnMS). The definition from [ISO50001] can be referred to as ISO Energy Management System (ISO-EnMS).

#### ISO Energy Management System

Energy Management System as defined by [ISO50001]

#### Energy

That which does work or is capable of doing work. As used by electric utilities, it is generally a reference to electrical energy and is measured in kilo-watt hours (kWh).

Reference: [IEEE100]

#### NOTES

1. Energy is the capacity of a system to produce external activity or perform work [ISO50001]

#### Power

The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or in joules per second).

Reference: [IEEE100]

## Demand

The average value of power or a related quantity over a specified interval of time. Note: Demand is expressed in kilowatts, kilovolt-amperes, kilovars, or other suitable units.

Reference: [IEEE100]

### NOTES:

1. Typically kilowatts.

2. Energy providers typically bill by Demand measurements as well as for maximum Demand per billing periods. Power values may spike during short-terms by devices, but Demand measurements recognize that maximum Demand does not equal maximum Power during an interval.

#### Power Characteristics

Measurements of the electrical current, voltage, phase and frequencies at a given point in an electrical power system.

Reference: Adapted from [IEC60050]

#### NOTES:

1. Power Characteristics is not intended to be judgmental with respect to a reference or technical value and are independent of any usage context.

#### Power Quality

Characteristics of the electric current, voltage, phase and frequencies at a given point in an electric power system, evaluated against a set of reference technical parameters. These parameters might, in some cases, relate to the compatibility between electricity supplied in an electric power system and the loads connected to that electric power system.

Reference: [IEC60050]

#### NOTES:

1. Electrical characteristics representing power quality information are typically required by customer facility energy management systems. It is not intended to satisfy the detailed requirements of power quality monitoring. Standards typically also give ranges of allowed values; the information attributes are the raw measurements, not the "yes/no" determination by the various standards.

Reference: [ASHRAE-201]

#### Electrical Equipment

A general term including materials, fittings, devices, appliances, fixtures, apparatus, machines, etc., used as a part of, or in connection with, an electric installation.

Reference: [IEEE100]

#### Non-Electrical Equipment (Mechanical Equipment)

A general term including materials, fittings, devices appliances, fixtures, apparatus, machines, etc., used as a part of, or in connection with, non-electrical power installations.

Reference: Adapted from [IEEE100]

#### Energy Object

An Energy Object (EO) is a piece of equipment that is part of or attached to a communications network that is monitored, controlled, or aids in the management of another device for Energy Management.

#### Electrical Energy Object

An Electrical Energy Object (EEO) is an Energy Object that is a piece of Electrical Equipment



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## Non-Electrical Energy Object

A Non-Electrical Energy Object (NEEO) an Energy  
Object that is a piece of Non-Electrical

Equipment.

#### Energy Monitoring

Energy Monitoring is a part of Energy Management that deals with collecting or reading information from Energy Objects to aid in Energy Management.

NOTES:

1. This could include Energy, Power, Demand, Power Quality, Context and/or Battery information.

#### Energy Control

Energy Control is a part of Energy Management that deals with directing influence over Energy Objects.

NOTES:

1. Typically in order to optimize or ensure its efficiency.

#### Provide Energy:

An Energy Object "provides" energy to another Energy Object if there is an energy flow from this Energy Object to the other one.

#### Receive Energy:

An Energy Object "receives" energy from another Energy Object if there is an energy flow from the other Energy Object to this one.

#### Power Interface

A Power Interface (or simply interface) is an interconnection among devices or components where energy can be provided, received or both.

#### Power Inlet

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A Power Inlet (or simply inlet) is an interface at which a device or component receives energy from another device or component.

#### Power Outlet

A Power Outlet (or simply outlet) is an interface at which a device or component provides energy to another device or component.

#### Energy Management Domain

An Energy Management Domain is a set of Energy Objects where all objects in the domain are considered one unit of management.

For example, power distribution units and all of the attached Energy Objects are part of the same Energy Management Domain.

For example, all EEO's drawing power from the same distribution panel with the same AC voltage within a building, or all EEO's in a building for which there is one main meter, would comprise an Energy Management Domain.

#### NOTES:

1. Typically, this set will have as members all EO's that are powered from the same source.

#### Energy Object Identification

Energy Object Identification is a set of attributes that enable an Energy Object to be: uniquely identified among all Energy Management Domains; linked to other systems; classified as to type, model, and or manufacturer

#### Energy Object Context

Energy Object Context is a set of attributes that allow an Energy Management System to classify the use of the Energy Object within an organization.

#### NOTES:

1. The classification could contain the use and/or the ranking of the Energy Object as compared to other Energy Objects in the Energy Management Domain.

### Energy Object Relationship

An Energy Object Relationship is a functional association among Energy Objects

#### NOTES

1. Relationships can be named and could include Aggregation, Metering, Power Source, and Proxy.
2. The Energy Object is the noun or entity in the relationship with the relationship described as the verb.

Example: If EO x is a piece of Electrical Equipment and EO y is an electrical meter clamped onto x's power cord, then x and y have a Metering Relationship. It follows that y meters x and that x is metered by y.

Reference: Adapted from [CHEN]

### Aggregation Relationship

An Aggregation Relationship is an Energy Object Relationship where one Energy Object aggregates the Energy Management information of one or more other Energy Objects. These Energy Objects are referred to as having an Aggregation Relationship.

#### NOTES:

Aggregate values may be obtained by collecting values from multiple Energy Objects and producing a single value of more significant meaning such as average, count, maximum, median, minimum, mode and most commonly sum [SQL].

### Metering Relationship

A Metering Relationship is an Energy Object Relationship where one Energy Object measures the Power or Energy of one or more other Energy Objects. These Energy Objects are referred to as having a Metering Relationship.

Example: a PoE port on a switch measures the Power it provides to the connected Energy Object.

#### Power Source Relationship

A Power Source Relationship is an Energy Object Relationship where one Energy Object is the source of or distributor of Power to one or more other Energy Objects. These Energy Objects are referred to as having a Power Source Relationship.

Example: a PDU provides power for a connected device.

#### Proxy Relationship

A Proxy Relationship is an Energy Object Relationship where one Energy Object provides the Energy Management capabilities on behalf of one or more other Energy Objects. These Energy Objects are referred to as having a Proxy Relationship.

Example: a protocol gateways device for Building Management Systems (BMS) with subtended devices.

#### Energy Object Parent

An Energy Object Parent is an Energy Object that participates in an Energy Object Relationships and is considered as providing the capabilities in the relationship.

Example: in a Metering Relationship, the Energy Object that is metering is called the Energy Object Parent, while the Energy Object that is metered is called the Energy Object Child.

#### Energy Object Child

An Energy Object Child is an Energy Object that participates in an Energy Object Relationships and is considered as receiving the capabilities in the relationship.

Example: in a Metering Relationship, the Energy Object that is metering is called the Energy Object Parent, while the Energy Object that is metered is called the Energy Object Child.

### Power State

A Power State is a condition or mode of a device that broadly characterizes its capabilities, power consumption, and responsiveness to input.

Reference: Adapted from [IEEE1621]

#### NOTES:

1. A Power State can be seen as a power setting of an Energy Object that influences the power consumption, the available functionality, and the responsiveness of the Energy Object.
2. A Power State can be viewed as one method for Energy Control

### Power State Set

A collection of Power States that comprise one named or logical grouping of control is a Power State Set.

Example: The states {on, off, and sleep} as defined in [IEEE1621], or the 16 power states as defined by the [DMTF] can be considered two different Power State Sets.

### Nameplate Power

The Nameplate Power is the nominal Power of a device as specified by the device manufacturer.

#### NOTES:

1. This is typically determined via load testing and is specified by the manufacturer as the maximum value required for operating the

device. This is sometimes referred to as the worst-case Power. The actual or average Power may be lower. The Nameplate Power is typically used for provisioning and capacity planning.

### 3. Requirements & Use Cases

Requirements for Power and Energy monitoring for networking devices are specified in [EMAN-REQ]. The Energy Management use cases covered by this framework are covered in the EMAN applicability statement document in [EMAN-AS]. Typically requirements and use cases for communication networks cover the devices that make up the communication network and endpoints.

With Energy Management, there exists a wide variety of devices that may be contained in the same deployments as a communication network but comprise a separate facility, home, or power distribution network.

Target devices for Energy Management are all Energy Objects that can directly or indirectly be monitored or controlled by an Energy Management System (EnMS) using the Internet protocol, for example:

- Simple electrical appliances / fixtures
- Hosts, such as a PC, a datacenter server, or a printer
- Routers
- Switches
- A component within devices, such as a battery inside a PC, a line card inside a switch, etc...
- Power over Ethernet (PoE) endpoints
- Power Distribution Units (PDU)
- Protocol gateway devices for Building Management Systems (BMS)
- Electrical meters
- Sensor controllers with subtended sensors

There may also exist varying protocols deployed among these power distributions and communication networks.

For an Energy Management framework to be useful, it should also apply to these types of separate networks as they connect and interact with a communications network.



This is the first version of the IETF Energy Management framework. Though it already covers a wide range of use cases, there are still a lot of potential ones that are not covered, yet. A simple example is the limitation to discrete power states without parameters. Some devices have energy-related properties that not well described with discrete power states, for example a dimmer with a continuous power range from 0%-100%. Other devices may have even more parameters than just a single percentage value.

This framework defines an information model containing various values that are measured on a device for the purpose of monitor and control. The framework does not cover setting bounds or conditions for these values for the purpose of policy management - for example specifying that power MUST NOT exceed a limit. While implementations can set bounds and notification when exceeding those bounds while monitored, physically preventing a device to not exceed the bound is beyond the scope of this framework. It is up to future updates of this document to select more of such use-cases and to cover them by extensions or revisions of the present framework.

#### 4. Energy Management Issues

This section explains special issues of Energy Management particularly concerning power supply, Power and Energy metering, and the reporting of low Power States.

To illustrate the issues we start with a simple and basic scenario with a single powered device that receives Energy and that reports energy-related information about itself to an Energy Management System (EnMS), see Figure 1

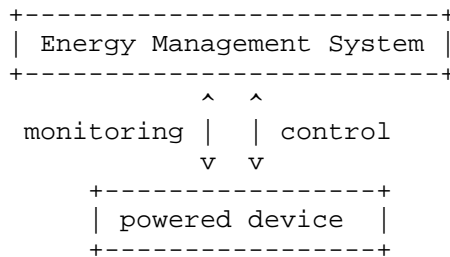


Figure 1: Basic energy management scenario

The powered device may have local energy control mechanisms, for example putting itself into a sleep mode when appropriate, and it may receive energy control commands for similar purposes from the EnMS. Information reported from a powered device to the EnMS includes at least the Power State of the powered device (on, sleep, off, etc.).

This and similar cases are well understood and likely to become very common for Energy Management. They can be handled with well established and standardized management procedures. The only missing components today are standardized information and data models for reporting and configuration, such as, for example, energy-specific MIB modules [RFC2578] and YANG modules [RFC6020].

However, the nature of energy supply and use introduces some issues that are special to Energy Management. The following subsections address these issues and illustrate them by extending the basic scenario in Figure 1.

#### 4.1. Power Supply

A powered device may supply itself with power. Sensors, for example, commonly have batteries or harvest Energy. However, most powered devices that are managed by an EnMS receive external power.

While a huge number of devices receive Power from unmanaged supply systems, the number of manageable power supply devices is increasing.

In datacenters, many Power Distribution Units (PDUs) allow the EnMS to switch power individually for each socket and also to measure the provided Power. Here there is a big difference to many other network management tasks: In such and similar cases, switching power supply for a powered device or monitoring its power is not done by communicating with the actual powered device, but with an external power supply device (in this case, the PDU). Note that those external power supply devices may be an external power meter).

Consequently, a standard for Energy Management must not just cover the powered devices that provide services for users, but

also the power supply devices (which are powered devices as well) that monitor or control the power supply for other powered devices.

A very simple device such as a plain light bulb can be switched on or off only by switching its power supply. More complex devices may have the ability to switch off themselves or to bring themselves to states in which they consume very little power. For these devices as well, it is desirable to monitor and control their power supply.

This extends the basic scenario from Figure 1 by a power supply device, see Figure 2.

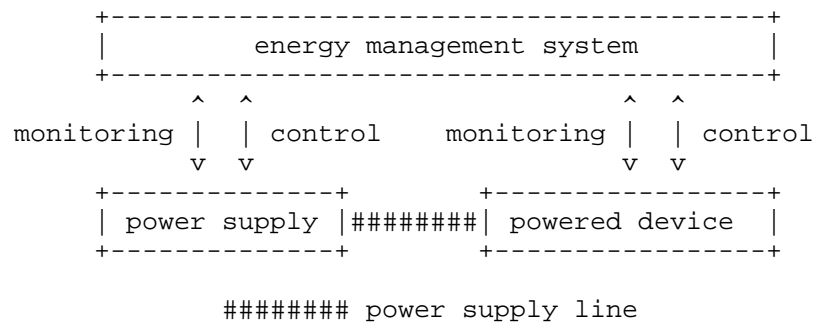


Figure 2: Power Supply

The power supply device can be as simple as a plain power switch. It may offer interfaces to the EnMS to monitor and to control the status of its power outlets, as with PDUs and Power over Ethernet (PoE) [IEEE-802.3at] switches.

The relationship between supply devices and the powered devices they serve creates several problems for managing power supply:

- o Identification of corresponding devices
  - \* A given powered device may need to identify the supplying power supply device.
  - \* A given power supply device may need to identify the corresponding supplied powered device(s).
- o Aggregation of monitoring and control for multiple powered devices
  - \* A power supply device may supply multiple powered devices with a single power supply line.

- o Coordination of power control for devices with multiple power inlets
  - \* A powered device may receive power via multiple power lines controlled by the same or different power supply devices.

#### 4.1.1 Identification of Power Supply and Powered Devices

When a power supply device controls or monitors power supply at one of its power outlets, the effect on other devices is not always clear without knowledge about wiring of power lines. The same holds for monitoring. The power supplying device can report that a particular socket is powered, and it may even be able to measure power and conclude that there is a consumer drawing power at that socket, but it may not know which powered device receives the provided power.

In many cases it is obvious which other device is supplied by a certain outlet, but this always requires additional (reliable) information about power line wiring. Without knowing which device(s) are powered via a certain outlet, monitoring data are of limited value and the consequences of switching power on or off may be hard to predict.

Even in well organized operations, powered devices' power cords can be plugged into the wrong socket, or wiring plans changed without updating the EnMS accordingly.

For reliable monitoring and control of power supply devices, additional information is needed to identify the device(s) that receive power provided at a particular monitored and controlled socket.

This problem also occurs in the opposite direction. If power supply control or monitoring for a certain device is needed, then the supplying power supply device has to be identified.

To conduct Energy Management tasks for both power supply devices and other powered devices, sufficiently unique identities are needed, and knowledge of their power supply relationship is required.

#### 4.1.2 Multiples Devices Supplied by a Single Power Line

The second fundamental problem is the aggregation of monitoring and control that occurs when multiple powered

devices are supplied by a single power supply line. It is often required that the EnMS has the full list of powered devices connected to a single outlet as in Figure 3.

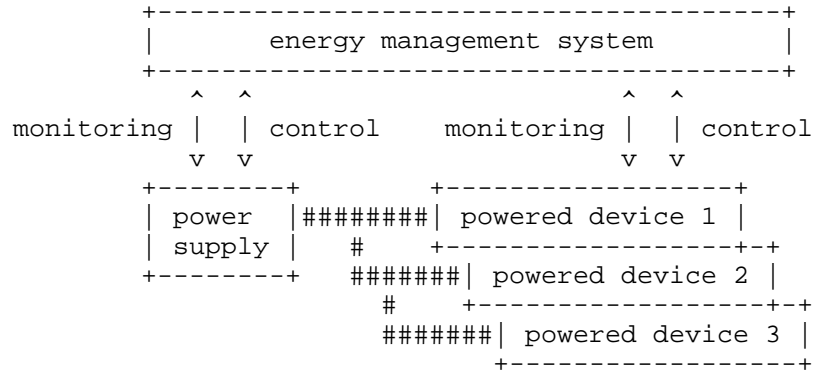


Figure 3: Multiple Powered Devices Supplied by Single Power Line

With this list, the single status value has clear meaning and is the sum of all powered devices. Control functions are limited by the fact that supply for the concerned devices can only be switched on or off for all of them at once. Individual control at the supply is not possible.

If the full list of devices powered by a single supply line is not known by the controlling power supply device, then control of power supply is problematic, because the consequences of control actions can only be partially known.

#### 4.1.3 Multiple Power Supply for a Single Powered Device

The third problem arises from the fact that there are devices with multiple power supplies. Some have this for redundancy of power supply, some for just making internal power converters (for example, from AC mains power to DC internal power) redundant, and some because the capacity of a single supply line is insufficient.

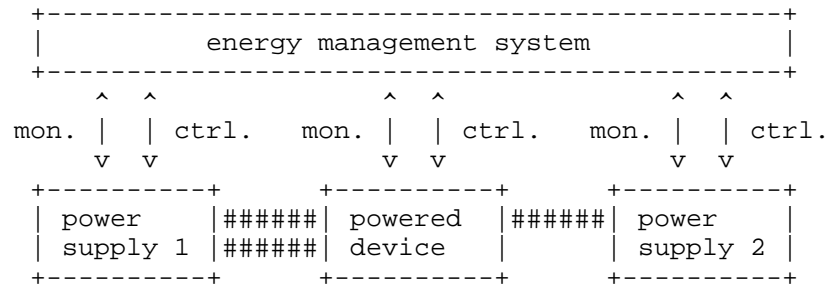


Figure 4: Multiple Power Supply for Single Powered Device

The example in Figure 4 does not necessarily show a real world scenario, but it shows the two cases to consider:

- o multiple power supply lines between a single power supply device and a powered device
- o different power supply devices supplying a single powered device

In any such case there may be a need to identify the supplying power supply device individually for each power inlet of a powered device.

Without this information, monitoring and control of power supply for the powered device may be limited.

#### 4.1.4 Bidirectional Power Interfaces

Low wattage DC systems may allow power to be delivered bi-directionally. Energy stored in batteries on one device can be delivered back to a power hub which redirects the current to power another device. In this situation, the interface can function as both an inlet and outlet.

The framework for Energy Management introduces the notion of Power Interface, which can model a power inlet and a power outlet, depending on the conditions. The Power Interface reports power direction, as well as the energy received, supplied and the net result.

#### 4.1.5 Relevance of Power Supply Issues

In some scenarios, the problems with power supply do not exist or can be sufficiently solved. With Power over Ethernet (PoE)

[IEEE-802.3at], there is always a one-to-one relationship between a Power Sourcing Equipment (PSE) and a Powered Device (PD). Also, the Ethernet link on the line used for powering can be used to identify the two connected devices.

For supply of AC mains power, the three problems described above cannot be solved in general. There is no commonly available protocol or automatic mechanism for identifying endpoints of a power line.

And, AC power lines support supplying multiple powered devices with a single line and commonly do.

#### 4.1.6 Remote Power Supply Control

There are three ways for an energy management system to change the Power State of an powered devices. First is for the EnMS to provide policy or other useful information (like the electricity price) to the powered device for it to use in determining its Power State. The second is sending the powered devices a command to switch to another Power State. The third is to utilize an upstream device (to the powered device) that has capabilities to switch on and off power at its outlet.

Some Energy Objects do not have capabilities for receiving commands or changing their Power States by themselves. Such Energy Objects may be controlled by switching on and off the power supply for them and so have particular need for the third method.

In Figure 4, the power supply can switch on and off power at its power outlet and thereby switch on and off power supply for the connected powered device.

#### 4.2. Power and Energy Measurement

Some devices include hardware to directly measure their Power and Energy consumption. However, most common networked devices do not provide an interface that gives access to Energy and Power measurements. Hardware instrumentation for this kind of measurements is typically not in place and adding it incurs an additional cost.

With the increasing cost of Energy and the growing importance of Energy Monitoring, it is expected that in future more

devices will include instrumentation for power and energy measurements, but this may take quite some time.

#### 4.2.1 Local Estimates

One solution to this problem is for the powered device to estimate its own Power and consumed Energy. For many Energy Management tasks, getting an estimate is much better than not getting any information at all.

Estimates can be based on actual measured activity level of a device or it can just depend on the power state (on, sleep, off, etc.).

The advantage of estimates is that they can be realized locally and with much lower cost than hardware instrumentation. Local estimates can be dealt with in traditional ways. They don't need an extension of the basic scenarios above. However, the powered device needs an energy model of itself to make estimates.

#### 4.2.2 Management System Estimates

Another approach to the lack of instrumentation is estimation by the EnMS. The EnMS can estimate Power based on basic information on the powered device, such as the type of device, or also its brand/model and functional characteristics.

Energy estimates can combine the typical power level by Power State with reported data about the Power State.

If the EnMS has a detailed energy model of the device, it can produce better estimates including the actual power state and actual activity level of the device. Such information can be obtained by monitoring the device with conventional means of performance monitoring.

#### 4.3. Reporting Sleep and Off States

Low power modes pose special challenges for energy reporting because they may preclude a device from listening to and responding to network requests. Devices may still be able to reliably track energy use in these modes, as power levels are



usually static and internal clocks can track elapsed time in these modes.

Some devices do have out-of-band or proxy abilities to respond to network requests in low-power modes. Others could use proxy abilities in an energy management protocol to improve this reporting, particularly if the powered device sends out notifications of power state changes.

#### 4.4. Device and Device Components

While the primary focus of energy management is entire powered Devices, sometimes it is necessary or desirable to manage Components such as line cards, fans, disks, etc.

The concept of a Power Interface may not apply to Components since they may receive Energy from a pool available from the encompassing device. For example, a DC-powered blade server in a chassis may have its own identity on the network and be managed as a single device but its energy may be received from a shared power source among all blades in the chassis.

#### 4.5. Non-Electrical Equipment

The primary focus of this framework is for the management of Electrical Equipment. Some Non-Electrical Equipment may be connected to a communication networks and could have their energy managed if normalize to the electrical units for power and energy.

Some examples of Non-Electrical Equipment that may be connected to a communication network are:

- 1) A controller for compressed air. The controller is electrical only for its network connection. The controller is fueled by natural gas and produces compressed air. The energy transferred via compressed air is distributed to devices on a factory floor via a Power Interface: tools (drills, screwdrivers, assembly line conveyor belts). The energy measured is non-electrical (compressed air).  
EDITOR'S NOTE: Note that, in such as case, some might argue that the "energy interface" term might be more accurate than Power Interface. To be discussed.
- 2) A controller for steam. The controller is electrical for its network attachment but it burns tallow and produces steam to subtended boilers. The energy is non-electrical (steam).

- 3) A controller or regulator for gas. The controller is electrical for its network attachment but it has physical non-electrical components for control. The energy is non-electrical (BTU).

## 5. Energy Management Reference Model

The scope of this framework is to enable network and network-attached devices to be administered for Energy Management. The framework recognizes that in complex deployments Energy Objects may communicate over varying protocols. For example the communications network may use IP Protocols (SNMP) but attached Energy Object Parent may communicate to Energy Object Children over serial communication protocols like BACNET, MODBUS etc. The likelihood of getting these different topologies to convert to a single protocol is not very high considering the rate of upgrades of facilities and energy related devices. Therefore the framework must address the simple case of a uniform IP network and a more complex mixed topology/deployment.

In this section we will describe the topologies that can exist when describing a device, components and the relationships among them in an Energy Management Domain.

We will then generalize those topologies by using an information model based upon relationships. The most abstract and general relationship between devices is a Parent and Child relationship. Specific types of relationships are defined and used in concert to describe the topologies of an Energy Management Domain.

### 5.1. Reference Topologies

The reference model defines physical and logical topologies of devices and the relationship among them in a communication network.

The physical topology defined by the model defines relationships between devices that reflect provisioning, transfer of energy, and aid in management.

Logical topologies concern monitoring and controlling devices and covers metering of energy and power, reporting information relevant for energy management, and energy-related control of devices.

## 5.1.1.1 Power Source Topology

As described in Section 4, the power source(s) of a device is important for energy management. The energy management reference model addresses this by a "Power Source" Relationship. This is a relationship among devices providing energy and devices receiving energy.

A simple example is a PoE PSE, for example, an Ethernet switch, providing power to a PoE PD, for example, a desktop phone. Here the switch provides energy and the phone receives energy. This relationship can be seen in the figure below.

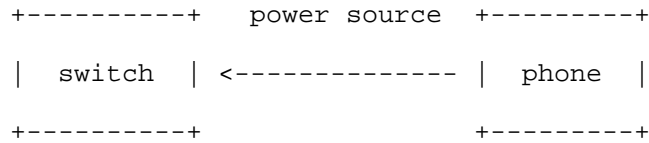


Figure 5: Simple Power Source

A single power provider can act as power source of multiple power receivers. An example is a power distribution unit (PDU) providing AC power for multiple switches.

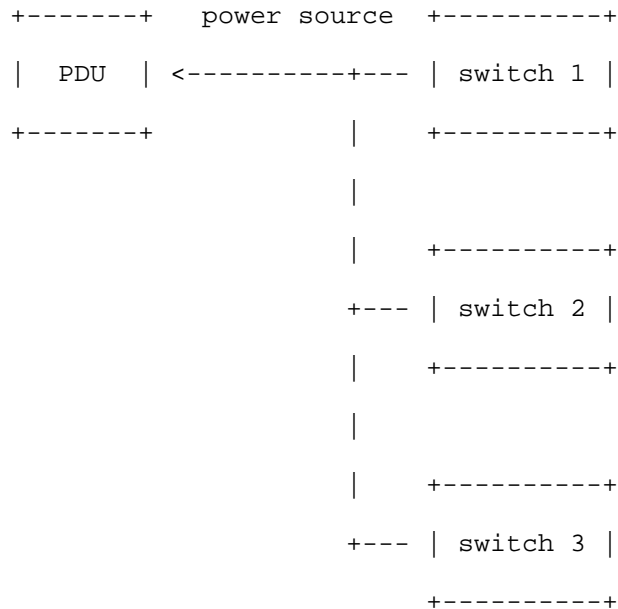


Figure 6: Multiple Power Source

This level of modeling is sufficient if there is no need to distinguish in monitoring and control between the individual receivers at the switch.

However, if there is a need to monitor or control power supply for individual receivers at the power provider, then a more detailed level of modeling is needed.

Devices receive or provide energy at power interfaces connecting them to a transmission medium. . The Power Source relationship can be used also between power interfaces at the power provider side as well as at the power receiver side. The example below shows a power providing device with a power interface (PI) per connected receiving device.

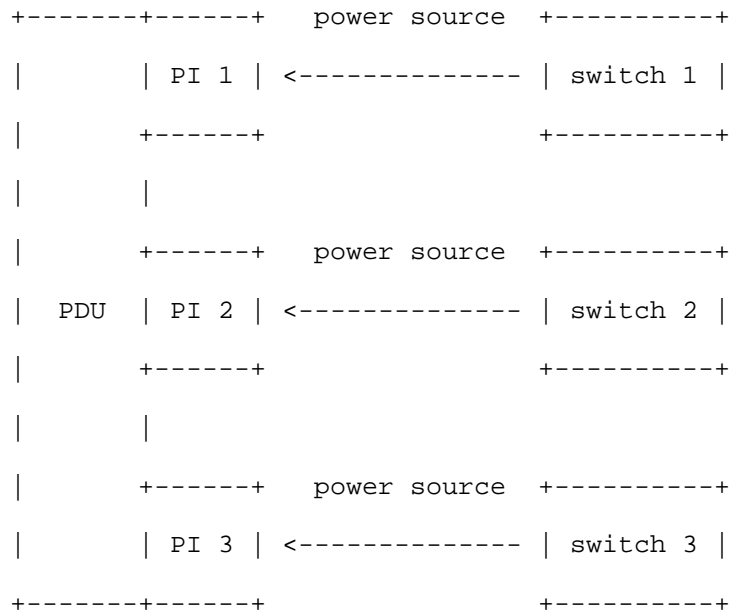


Figure 7: Power Source with Power interfaces

Power interfaces may also be modeled at the receiving device, for examples for consistency.

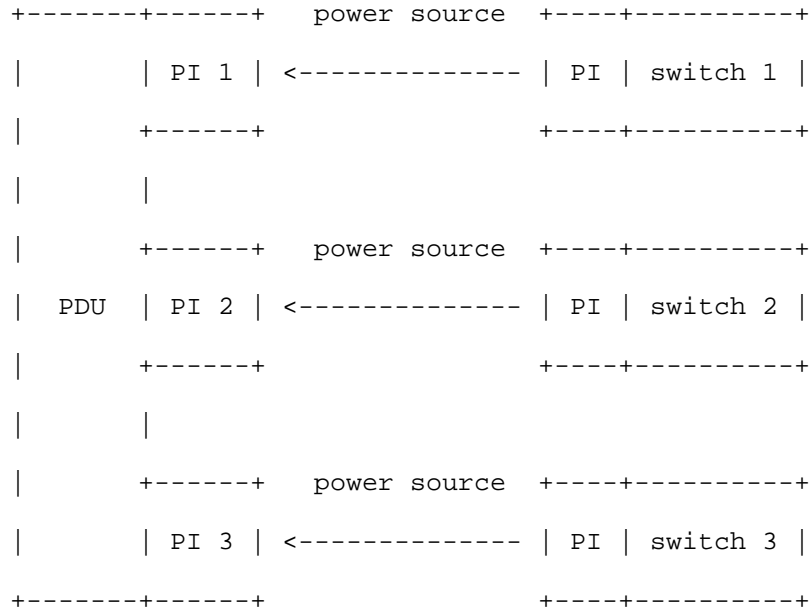


Figure 8: Power Interfaces at Receiving Device

Power Source relationships are between peering devices and their interfaces. They are not transitive. In the examples below there is a PDU powering a switch powering a phone.

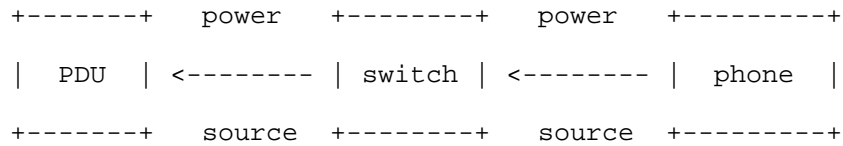


Figure 9: Power Source Non-Transitive

Power Source Relationships are between the PDU and the switch and between the switch and the phone.

Power Source Relationships are between the PDU and the switch and between the switch and the phone. Consequently, there is logically exists a power source relation between the PDU and the phone.

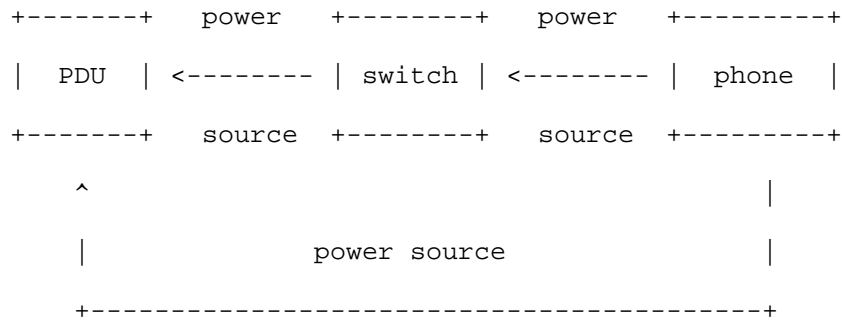


Figure 10: Power Source Transitive

### 5.1.2 Metering Topology

#### Metering Between Two Device

The power metering topology between two devices is closely related to the power source topology. It is based on the assumption that in many cases the power provided and the power received is the same for both peers of a power source relationship. Then power measured at one end can be taken as the actual power value at the other end. Obviously, the same applies to energy at both ends.

We define in this case a Power Metering Relationship between two devices or power interfaces of devices that have a power source relationship. Power and energy values measured at one peer of the power source relationship are reported for the other peer as well.

The Power Metering Relationship is independent of the direction of the Power source Relationship. The more common case is that values measured at the power provider are reported for the power receiver, but also the reverse case is

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possible with values measured at the power receiver being  
reported for the power provider.

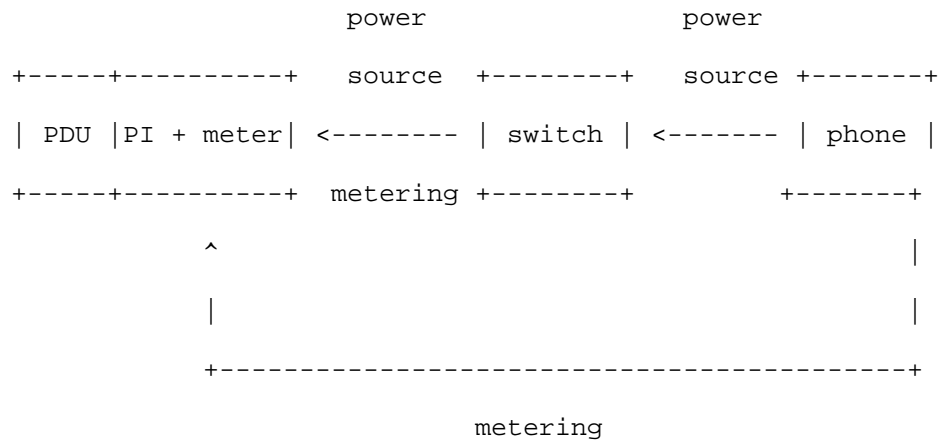


Figure 11: Direct and One Hop Metering

#### Metering At a Point in Power Distribution

A Sub-meter in a power distribution system can logically measure the power or energy for all devices downstream from the meter in the power distribution system. As such a Power metering relationship can be seen as a relationship between a meter and all of the devices downstream from the meter.

We define in this case a Power Metering relationship between a metering device and devices downstream from the meter.

In cases where the Power Source topology cannot be discovered or derived from the information available in the Energy Management Domain, the Metering Topology can be used to relate the upstream meter to the downstream devices in the absence of specific power source relationships.

A metering relationship can occur between devices that are not directly connected as shown by the figure below.

An analogy to communication networks would be modeling connections between servers (meters) and clients (devices) when the complete Layer 2 topology between the servers and clients is not known.

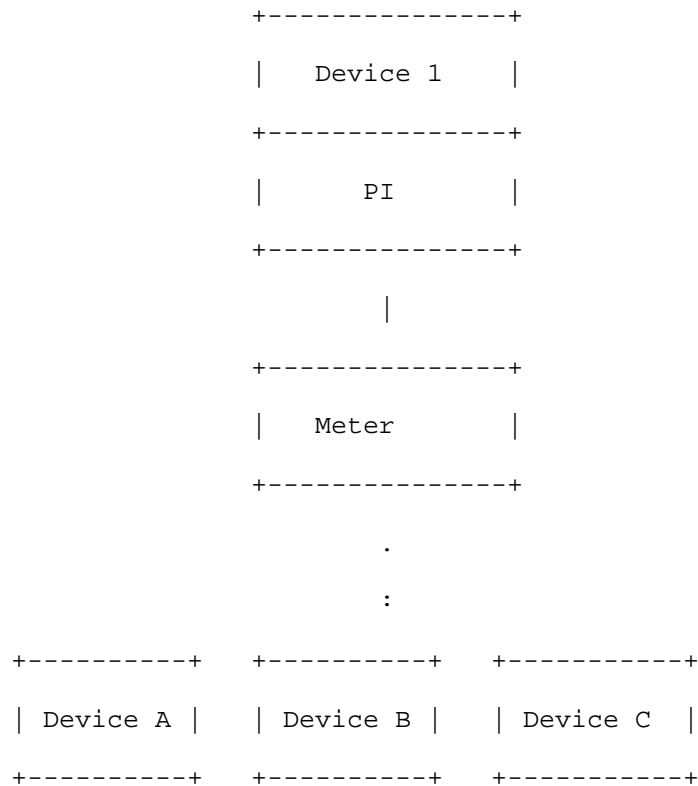


Figure 12: Complex Metering Topology

### 5.1.3 Proxy Topology

Some devices may provide energy management capabilities on behalf of other devices. For example a controller may logically model power interfaces but the physical topology may require that the controller communicate to another device using a BMS protocol. These subtended devices that are represented as power interfaces may be directly connected or may be controlled over a communication network with no direct connection.

While the EnMS may look at the logical representation of the controller as a device with power interfaces, it may require to report the physical topology and relationship to the subtended devices. To model this we define a proxy relationship to provide this visibility.



```
+-----+-----+
| | PI 1 |
| +-----+
| |
| +-----+
| PDU | PI 2 |
| +-----+
| |
| +-----+
| | PI 3 |
+-----+-----+
```

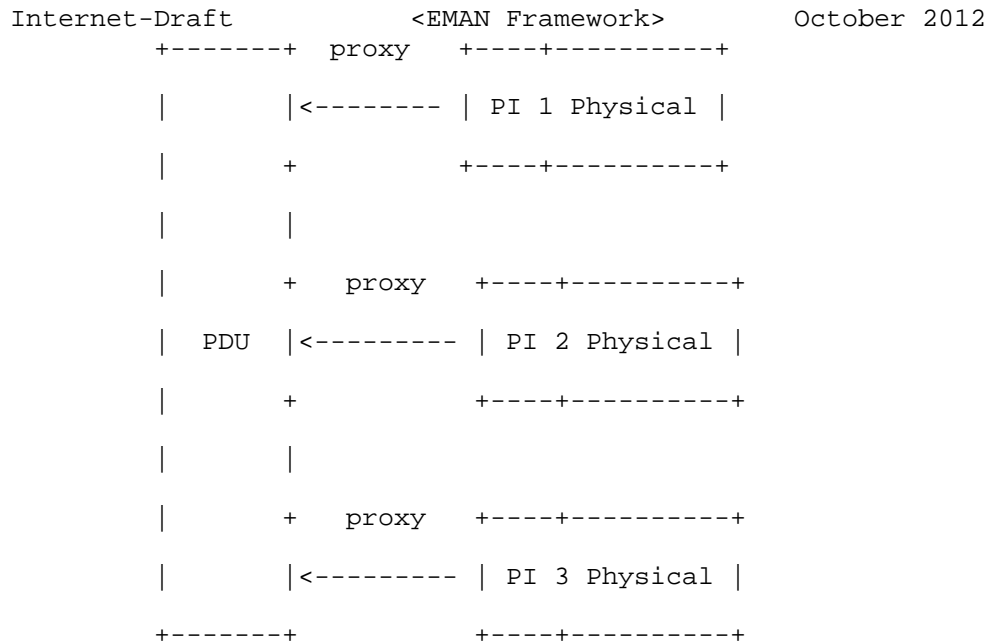


Figure 13: Proxy Relationship Virtual and Physical

#### 5.1.4 Aggregation Topology

Some devices in a domain can act as aggregation points for other devices. For example a PDU controller device may contain the summation of power and energy readings for many PDU devices. The PDU controller will have aggregate values for power and energy for a group of PDU devices.

This aggregation is independent of the physical power or communication topology.

The functions that the aggregation point may perform include values such as average, count, maximum, median, minimum or listing (collection) of the aggregation.

We define in this case an Aggregation Relationship between a device containing aggregate values for arbitrary groups of other devices.

While any power or energy values monitored from a device/power interface can be seen as a summation for all devices downstream from the monitoring device, the aggregation relationship is used to represent a summation when it is not obvious from the powering topology or a device to component containment.

## 5.2. Generalized Relationship Model

As displayed in Figure 5, the most basic energy management reference model is composed of an EnMS that obtains Energy Management information from Energy Objects. The Energy Object (EO) returns information for Energy Management directly to the EnMS.

The protocol of choice for Energy Management is SNMP, as three MIBs are specified for Energy Management: the energy-aware MIB [EMAN-AWARE-MIB], the energy monitoring MIB [EMAN-MON-MIB], and the battery MIB [EMAN-BATTERY-MIB]. However, the EMAN requirement document [EMAN-REQ] also requires support for a push model distribution of time series values. The following diagrams mention IPFIX [RFC5101] as one possible solution for implementing a push mode transfer, however this is for illustration purposes only. The EMAN standard does not require the use of IPFIX and acknowledges that other alternative solutions may also be acceptable.

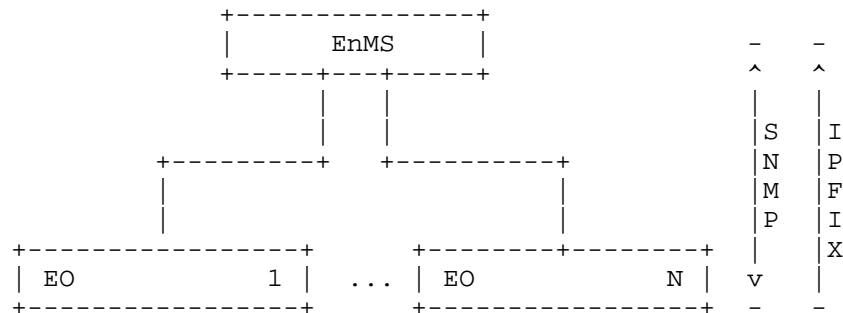


Figure 14: Simple Energy Management

As displayed in the Figure 5, a more complex energy reference model includes Energy Managed Object Parents and Children. The Energy Managed Object Parent returns information for themselves as well as information according to the Energy Managed Object Relationships.

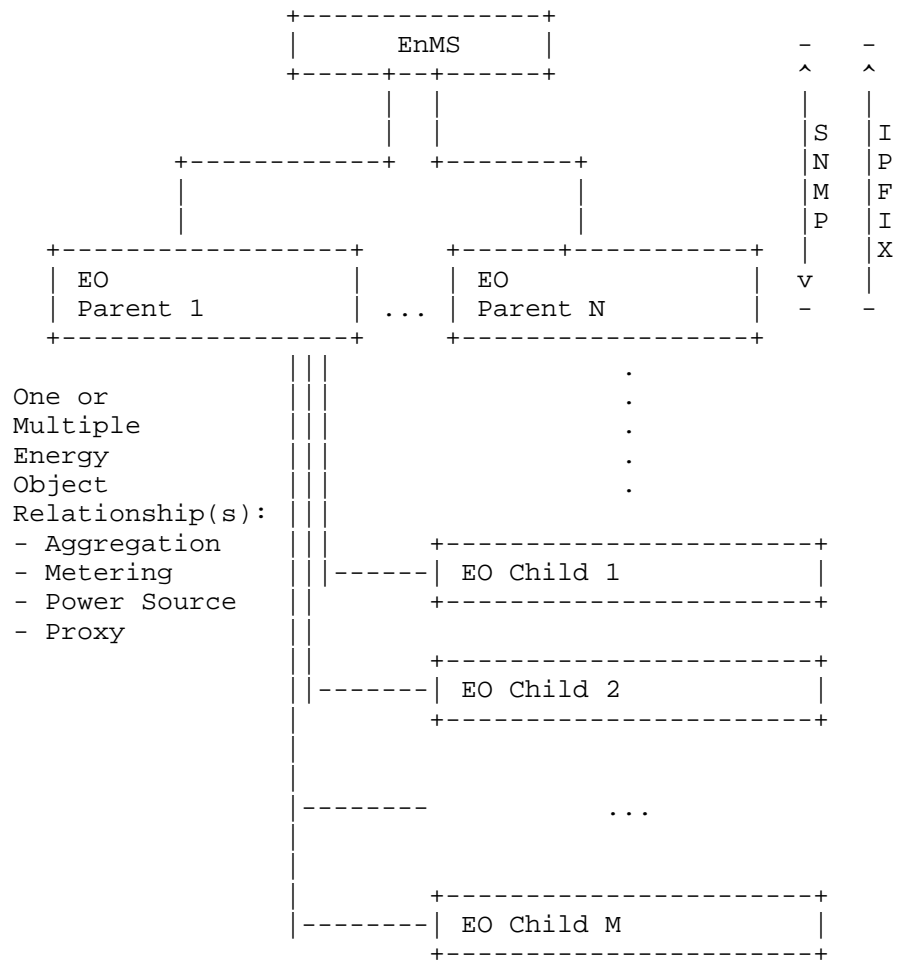


Figure 15: Complex Energy Management Model

While both the simple and complex Energy Management models contain an EnMS, this framework doesn't impose any requirements regarding a topology with a centralized EnMS or one with distributed Energy Management via the Energy Objects within the deployment.

Given the pattern in Figure 6, the complex relationships between Energy Objects can be modeled (refer also to section 5.3):

- A PoE device modeled as an Energy Object Parent with the Power Source, Metering, and Proxy Relationships for one or more Energy Object Children
- A PDU modeled as an Energy Object Parent with the Power Source and Metering Relationships for the plugged in Electrical Equipment (the Energy Object Children)
- Building management gateway, used as proxy for non IP protocols, is modeled as an Energy Object Parent with the Proxy Relationship, and potentially the Aggregation Relationship to the managed Electrical Equipment
- Etc.

The communication between the Energy Object Parent and Energy Object Children is out of the scope of this framework.

### 5.3. Energy Object, Energy Object Components and Containment Tree

The framework for Energy Management manages two different types of Energy Objects: Devices and Components. A typical example of an Device is a switch. However, a port within the switch, which provides Power to one end point, is also an Energy Object if it meters the power provided. A second example is PC, which is a typical Device, while the battery inside the PC is a Component, managed as an individual Energy Object. Some more examples of Components: power supply within a router, an outlet within a smart PDU, etc...

In the [EMAN-AWARE-MIB], each Energy Object is managed with an unique value of the entPhysicalIndex index from the ENTITY-MIB [RFC4133]

The ENTITY-MIB [RFC4133] specifies the notion of physical containment tree, as:

"Each physical component may be modeled as 'contained' within another physical component. A "containment-tree" is the conceptual sequence of entPhysicalIndex values that uniquely specifies the exact physical location of a physical component within the managed system. It is generated by 'following and recording' each 'entPhysicalContainedIn' instance 'up the tree towards the root', until a value of zero indicating no further containment is found."

A Energy Object Component in the Energy Management context is a special Energy Object that is a physical component as specified by the ENTITY-MIB physical containment tree.

## 6. Framework High Level Concepts and Scope

Energy Management can be organized into areas of concern that include:

- Energy Object Identification and Context - for modeling and planning
- Energy Monitoring - for energy measurements
- Energy Control - for optimization
- Energy Procurement - for optimization of resources

While an EnMS may be a central point for corporate reporting, cost, environmental impact, and regulatory compliance, Energy Management in this framework excludes Energy procurement and the environmental impact of energy use. As such the framework does not include:

- Manufacturing costs of an Energy Object in currency or environmental units
- Embedded carbon or environmental equivalences of an Energy Object
- Cost in currency or environmental impact to dismantle or recycle an Energy Object
- Supply chain analysis of energy sources for Energy Object deployment
- Conversion of the usage or production of energy to units expressed from the source of that energy (such as the greenhouse gas emissions associated with 1000kW from a diesel source).

The next sections describe Energy Management organized into the following areas:

- Energy Object and Energy Management Domain
- Energy Object Identification and Context
- Energy Object Relationships
- Energy Monitoring
- Energy Control
- Deployment Topologies

## 6.1. Energy Object and Energy Management Domain

In building management, a meter refers to the meter provided by the utility used for billing and measuring power to an entire building or unit within a building. A sub-meter refers to a customer or user installed meter that is not used by the utility to bill but instead used to get readings from sub portions of a building.

An Energy Management Domain should map 1:1 with a metered or sub-metered portion of the site. An Energy Object is part of a single Energy Management Domain. The Energy Management Domain MAY be configured on an Energy Object: the default value is a zero-length string.

If all Energy Objects in the physical containment tree (see ENTITY-MIB) are part of the same Energy Management Domain, then it is safe to state that the Energy Object at the root of that containment tree is in that Energy Management Domain.

An Energy Object Child may inherit the domain value from an Energy Object Parent or the Energy Management Domain may be configured directly in an Energy Object Child.

## 6.2. Power Interface

There are some similarities between Power Interfaces and network interfaces. A network interface can be used in different modes, such as sending or receiving on an attached line. The Power Interface can be receiving or providing power.

Most Power Interfaces never change their mode, but as the mode is simply a recognition of the current direction of electricity flow, there is no barrier to a mode change.

A power interface can have capabilities for metering power and other electric quantities at the shared power transmission medium.

This capability is modeled by an association to a power meter.

In analogy to MAC addresses of network interfaces, a globally unique identifier is assigned to each Power Interface.

Physically, a Power Interface can be located at an AC power

### 6.3. Energy Object Identification and Context

#### 6.3.1 Energy Object Identification

Energy Objects MUST be associated with a value that uniquely identifies the Energy Object among all the Energy Management Domains within an EnMS. A Universal Unique Identifier (UUID) [RFC4122] MUST be used to uniquely and persistently identify an Energy Object.

Every Energy Object SHOULD have a unique printable name within the Energy Management Domain. Possible naming conventions are: textual DNS name, MAC-address of the device, interface ifName, or a text string uniquely identifying the Energy Object. As an example, in the case of IP phones, the Energy Object name can be the device's DNS name.

#### 6.3.2 Context in General

In order to aid in reporting and in differentiation between Energy Objects, each Energy Object optionally contains information establishing its business, site, or organizational context within a deployment, i.e. the Energy Object Context.

##### Context: Importance

An Energy Object can provide an importance value in the range of 1 to 100 to help rank a device's use or relative value to the site. The importance range is from 1 (least important) to 100 (most important). The default importance value is 1.

For example: A typical office environment has several types of phones, which can be rated according to their business impact. A public desk phone has a lower importance (for example, 10) than a business-critical emergency phone (for example, 100). As another example: A company can consider that a PC and a phone for a customer-service engineer is more important than a PC and a phone for lobby use.



Although EnMS and administrators can establish their own ranking, the following is a broad recommendation:

- . 90 to 100 Emergency response
- . 80 to 90 Executive or business-critical
- . 70 to 79 General or Average
- . 60 to 69 Staff or support
- . 40 to 59 Public or guest
- . 1 to 39 Decorative or hospitality

#### Context: Keywords

An Energy Object can provide a set of keywords. These keywords are a list of tags that can be used for grouping, summary reporting within or between Energy Management Domains, and for searching. All alphanumeric characters and symbols (other than a comma), such as #, (, \$, !, and &, are allowed. Potential examples are: IT, lobby, HumanResources, Accounting, StoreRoom, CustomerSpace, router, phone, floor2, or SoftwareLab. There is no default value for a keyword.

Multiple keywords can be assigned to a device. White spaces before and after the commas are excluded, as well as within a keyword itself. In such cases, the keywords are separated by commas and no spaces between keywords are allowed. For example, "HR,Bldg1,Private".

#### Context: Role

An Energy Object can provide a "role description" string that indicates the purpose the Energy Object serves in the EnMS. This could be a string describing the context the device fulfills in deployment.

Administrators can define any naming scheme for the role of a device. As guidance a two-word role that combines the service the device provides along with type can be used [IPENERGY]

Internet-Draft                      <EMAN Framework>                      October 2012  
Example types of devices: Router, Switch, Light, Phone,  
WorkStation, Server, Display, Kiosk, HVAC.

Example Services by Line of Business:

| Line of Business | Service                                       |
|------------------|-----------------------------------------------|
| Education        | Student, Faculty, Administration,<br>Athletic |
| Finance          | Trader, Teller, Fulfillment                   |
| Manufacturing    | Assembly, Control, Shipping                   |
| Retail           | Advertising, Cashier                          |
| Support          | Helpdesk, Management                          |
| Medical          | Patient, Administration, Billing              |

Role as a two-word string: "Faculty Desktop", "Teller Phone",  
"Shipping HVAC", "Advertising Display", "Helpdesk Kiosk",  
"Administration Switch".

#### 6.4. Energy Object Relationships

Two Energy Objects MAY establish an Energy Object Relationship. Within a relationship one Energy Object becomes an Energy Object Parent while the other becomes an Energy Object Child.

The Power Source Relationship gives the view the wiring topology. For example: a data center server receiving power from two specific Power Interfaces from two different PDUs.

The Metering Relationship gives the view of the metering topology. Standalone meters can be placed anywhere in a power distribution tree. For example, utility meters monitor and report accumulated power consumption of the entire building. Logically, the metering topology overlaps with the wiring topology, as meters are connected to the wiring topology. A typical example is meters that clamp onto the existing wiring.

The Proxy Relationship allows software objects to be inserted into the wiring or metering topology to aid in managing (monitoring and/or control) the Energy Domain.

From a EnMS management point of view, this implies that there is yet another management topology that EnMS will need to be aware of.

In the ideal situation, the wiring, the metering, and the management topologies overlap. For Example: A Power-over-Ethernet (PoE) device (such as an IP phone or an access point) is attached to a switch port. The switch port is the source of power for the attached device, so the Energy Object Parent is the switch port, which acts as a Power Interface, and the Energy Object Child is the device attached to the switch. This Energy Object Parent (the switch) has three Energy Object Relations with this Energy Object Child (the remote Energy Object): Power Source Relationship, Metering Relationship, and Proxy Relationship.

However, the three topologies (wiring, metering, and management) don't always overlap. For example, when a protocol gateways device for Building Management Systems (BMS) controls subtended devices, which themselves receive Power from PDUs or wall sockets.

Note: The Aggregation Relationship is slightly different compared to the other relationships (Power Source, Metering, and Proxy Relationships) as this refers more to a management function.

The communication between the parent and child for monitoring or collection of power data is left to the device manufacturer. For example: A parent switch may use LLDP to communicate with a connected child, and a parent lighting controller may use BACNET to communicate with child lighting devices.

The Energy Object Child MUST keep track of its Energy Object Parent(s) along with the Energy Object Relationships type(s). The Energy Object Parent MUST keep track of its Energy Object Child(ren), along with the Energy Object Relationships type(s).

#### 6.4.1 Energy Object Children Discovery

There are multiple ways that the Energy Object Parent can discover its Energy Object Children: :

- . In case of PoE, the Energy Object Parent automatically discovers an Energy Object Child when the Child requests power.
- . The Energy Object Parent and Children may run the Link Layer Discovery Protocol [LLDP], or any other discovery protocol, such as Cisco Discovery Protocol (CDP). The Energy Object Parent might even support the LLDP-MED MIB [LLDP-MED-MIB], which returns extra information on the Energy Object Children.
- . The Energy Object Parent may reside on a network connected to a facilities gateway. A typical example is a converged building gateway, monitoring several other devices in the building, and serving as a proxy between SNMP and a protocol such as BACNET.
- . A different protocol between the Energy Object Parent and the Energy Object Children. Note that the communication specifications between the Energy Object Parent and Children is out of the scope of this document.

However, in some situations, it is not possible to discover the Energy Object Relationships, and they must be set manually. For example, in today's network, an administrator must assign the connected Energy Object to a specific PDU Power Interface, with no means of discovery other than that manual connection.

When an Energy Object Parent is a Proxy, the Energy Object Parent SHOULD enumerate the capabilities it is providing for the Energy Object Child. The child would express that it wants its parent to proxy capabilities such as, energy reporting, power state configurations, non physical wake capabilities (such as WoL), or any combination of capabilities.

#### 6.4.2 Energy Object Relationship Conventions and Guidelines

This Energy Management framework does not impose many "MUST" rules related to Energy Object Relationships. There are always corner cases that could be excluded with too strict specifications of relationships. However, this Energy Management framework proposes a series of guidelines, indicated with "SHOULD" and "MAY".

Aggregation

Aggregation relationships are intended to identify when one device is used to accumulate values from other devices. Typically this is for energy or power values among devices and not for Components or Power Interfaces on the same device. The intent of Aggregation relationships is to indicate when one device is providing aggregate values for a set of other devices when it is not obvious from the power source or simple containment within a device.

Establishing aggregation relationships within the same device would make modeling more complex and the aggregated values can be implied from the use of Power Inlets, outlet and Energy Object value on the same device.

Additionally since an EnMS is naturally a point of aggregation for information in an Energy Management Domain it is not necessary to model aggregation for an EnMS(s).

Aggregation SHOULD be used for power and energy. It MAY be used for aggregation of other values from the information model for example but the rules and logical ability to aggregated each attribute is out of scope for this document.

- A Device SHOULD NOT establish an Aggregation Relationship with a Component.
- A Device SHOULD NOT establish an Aggregation Relationship with the Power Interfaces contained on the same device.
- A Device SHOULD NOT establish an Aggregation Relationship with the an EnMS.
- Aggregators SHOULD log or provide notification in the case of errors or missing values while performing aggregation.

#### Power Source

Power Source relationships are intended to identify the connections between Power Interfaces. This is analogous to a Layer 2 connection in networking devices (a "one hop" connection).

The preferred modeling would be for Power Interfaces to participate in Power Source Relationships.

It may happen that the some Energy Objects may not have the capability to model Power Interfaces. Therefore, it may happen that a Power Source Relationship is established between two Energy Objects or two non-connected Power Interfaces.

While strictly speaking Components and Power Interfaces on the same device do provide or receive energy from each other the Power Source relationship is intended to show energy transfer between Devices. Therefore relationship is implied on the same Device.

- An Energy Object SHOULD NOT establish a Power Source Relationship with a Component.
- A Power Source Relationship SHOULD be established with next known Power Interface in the wiring topology.
  - o The next known Power Interface in the wiring topology would be the next device implementing the framework. In some cases the domain of devices under management may include some devices that do not implement the framework As such the Power Source relationship can be established with the next device in the topology that implements the framework and logically shows the Power Source of the device.
- Transitive Power Source relationships SHOULD NOT be established. For examples if an Energy Object A has a Power Source Relationship "Poweredby" with the Energy Object B, and if the Energy Object B has a Power Source Relationship "Poweredby" with the Energy Object C, then the Energy Object A SHOULD NOT have a Power Source Relationship "PoweredBby" the Energy Object C.

#### Metering Relationship

Metering Relationships are intended to show when one Device is measuring the power or energy at a point in a power distribution system. Since one point of a power distribution system may cover many Devices with a complex wiring topology, this relationship type can be seen as an arbitrary set.

Additionally, Devices may include metering hardware for components and Power Interfaces or for the entire Device.

For example some PDU's may have the ability to measure Power for each Power Interface (metered by outlet). Others may only be able to control power at each Power Interface but only measure Power at the Power Inlet and a total for all Power Interfaces (metered by device).

In such cases a Device SHOULD be modeled as an Energy Object that meters all of its Power Outlets and each Power Outlet MAY be metered by the Energy Object representing the Device.

- A Meter Relationship MAY be established with any other Energy Object, Component, or Power Interface.
- Transitive Meter relationships MAY be used.
- When there is a series of meters for one Energy Object, the Energy Object MAY establish a relationship with one or more of the meters.

#### Proxy

A Proxy relationship is intended to show when one Device is providing the Energy Object capabilities for another Device typically for protocol translations. Strictly speaking a Component of a Device may provide the Energy Object capabilities for that Device (and vice versa) this relationship is intended to model relationships between Devices.

- A Proxy relationship SHOULD be limited when possible to Energy Objects of different Devices.

#### 6.4.3 Energy Objects Relationship Extensions

This framework for Energy Management, is based on four Energy Objects Relationships: Aggregation Relationship, Metering Relationship, Power Source Relationship, and Proxy Relationship.

This framework is defined with possible extension of new Energy Objects Relationships in mind. For example, a Power Distribution Unit (PDU) that allows physical entities like outlets to be "ganged" together as a logical entity for simplified management purposes, could be modeled with a future extension based on "gang relationship", whose semantic would specify the Energy Objects grouping.

#### 6.5. Energy Monitoring

For the purposes of this framework energy will be limited to electrical energy in watt hours. Other forms of Energy Objects that use or produce non-electrical energy may be part of an Energy Management Domain (See Section 4.5. ) but MUST provide information converted to and expressed in watt hours.

An analogy for understanding power versus energy measurements can be made to speed and distance in automobiles. Just as a

speedometer indicates the rate of change of distance, a power meter indicates the rate of transfer of energy. The odometer in an automobile measures the cumulative distance traveled and an energy meter indicates the accumulate energy transferred. So a less formal statement of the analogy is that power meters measures "speed" while energy meters measure "distance".

Each Energy Object will have information that describes power information, along with how that measurement was obtained or derived (actual measurement, estimated, or presumed). For Energy Objects that can report actual power readings, an optional energy measurement can be provided.

Optionally, an Energy Object can further describe the Power information with Power Quality information reflecting the electrical characteristics of the measurement.

Optionally, an Energy Object that can report actual power readings can have energy meters that provide the energy used, produced, and net energy in kWh. These values are energy meters that accumulate the power readings. If energy values are returned then the three energy meters must be provided along with a description of accuracy.

Optionally, an Energy Object can provide demand information over time.

#### 6.5.1 Power Measurement

A power measurement MUST be qualified with the units, magnitude, direction of power flow, and SHOULD be qualified by what means the measurement was made (ex: Root Mean Square versus Nameplate).

In addition, the Energy Object should describe how it intends to measure power as one of consumer, producer or meter of usage. Given the intent, readings can be summarized or analyzed by an EnMS. For example metered usage reported by a meter and consumption usage reported by a device connected to that meter may naturally measure the same usage. With the two measurements identified by intent a proper summarization can be made by an EnMS.

Power measurement magnitude should conform to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure. Measured values are



represented in SI units obtained by  $\text{BaseValue} * (10 ^ \text{Scale})$ . For example, if current power usage of an Energy Object is 3, it could be 3 W, 3 mW, 3 KW, or 3 MW, depending on the value of the scaling factor. 3W implies that the BaseValue is 3 and Scale = 0, whereas 3mW implies BaseValue = 3 and ScaleFactor = -3.

Energy is often billed in kilowatt-hours instead of megajoules from the SI units. Similarly, battery charge is often measured as miliamperes-hour (mAh) instead of coulombs from the SI units. The units used in this framework are: W, A, Wh, Ah, V. A conversion from Wh to Joule and from Ah to Coulombs is obviously possible, and can be described if required.

In addition to knowing the usage and magnitude, it is useful to know how an Energy Object usage measurement was obtained:

- . Whether the measurements were made at the device itself or from a remote source.

- . Description of the method that was used to measure the power and whether this method can distinguish actual or estimated values.

An EnMS can use this information to account for the accuracy and nature of the reading between different implementations.

The EnMS can use the Nameplate Power for provisioning, capacity planning and potentially billing.

#### 6.5.2 Optional Power Quality

Given a power measurement, it may in certain circumstances be desirable to know the Power Quality associated with that measurement. The information model must adhere to the IEC 61850 7-2 standard for describing AC measurements. Note that the Power Quality includes two sets of characteristics: characteristics as received from the utility, and characteristics depending on how the power is used.

In some Energy Management Domains, the power quality may not be needed, available, or relevant to the EnMS.

Optional Demand

It is well known in commercial electrical utility rates that demand is part of the calculation for billing. The highest peak demand measured over a time horizon, such as 1 month or 1 year, is often the basis for charges. A single window of time of high usage can penalize the consumer with higher energy consumption charges. However, it is relevant to measure the demand only when there are actual power measurements from an Energy Object, and not when the power measurement is assumed or predicted.

#### Optional Battery

Some Energy Objects may use batteries for storing energy and for receiving power supply. These Energy Objects should report their current power supply (battery, power line, etc.) and the battery status for each contained battery. Battery-specific information to be reported should include the number of batteries contained in the device and per battery the state information as defined in [EMAN-REQ].

Beyond that a device containing a battery should be able to generate alarms when the battery charge falls below a given threshold and when the battery needs to be replaced.

### 6.6. Energy Control

An Energy Object can be controlled by setting it to a specific Power State. An Object implements a set of Power States consisting of at least two states, an on state and an off state.

A Power State is an interface by which an Energy Object can be controlled. Each Energy Object should indicate the set of Power States that it implements. Well known Power States / Sets should be registered with IANA.

When a device is set to a particular Power State, it may be busy. The device will set the desired Power State and then update the actual Power State when it changes. There are then two Power State control variables: actual and desired.

There are many existing standards for and implementations of Power States. An Energy Object can support a mixed set of Power States defined in different standards. A basic example is given by the three Power States defined in IEEE1621

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[IEEE1621]: on, off, and sleep. The DMTF [DMTF], ACPI [ACPI],  
and PWG define larger numbers of Power States.

The semantics of a power state is specified by

- a) the functionality provided by an Energy Object in this state,
- b) a limitation of the power that an Energy Object uses in this state,
- c) a combination of a) and b)

The semantics of a Power State should be clearly defined. Limitation (curtailment) of the power used by an Energy Object in a state can be specified by

- an absolute power value
- a percentage value of power relative to the energy object's nameplate power
- an indication of used power relative to another power state - for example: by stating used power in state A is less than in state B.

For supporting Power State management it is useful to provide statistics on Power States including the time an Energy Object spent in a certain Power State and/or the number of times an Energy Object entered a power state.

Power States should be registered at IANA with a name and a number.

When requesting an Energy object to enter a Power State an indication of its name or its number can be used. Optionally an absolute or percentage of Nameplate Power can be provided to allow the Energy Object to transition to a nearest or equivalent Power State.

#### 6.6.1 EMAN Power State Set

An EMAN Power State Set represents an attempt for a standard approach to model the different levels of power of a device. The EMAN Power States are an expansion of the basic Power States as defined in [IEEE1621] that also incorporates the Power States defined in [ACPI] and [DMTF]. Therefore, in addition to the non-operational states as defined in [ACPI]

There are twelve Power States, that expand on [IEEE1621] on, sleep and off. The expanded list of Power States are divided into six operational states, and six non-operational states. The lowest non-operational state is 1 and the highest is 6. Each non-operational state corresponds to an [ACPI] Global and System states between G3 (hard-off) and G1 (sleeping). Each operational state represents a performance state, and may be mapped to [ACPI] states P0 (maximum performance power) through P5 (minimum performance and minimum power).

In each of the non-operational states (from mechoff(1) to ready(6)), the Power State preceding it is expected to have a lower Power value and a longer delay in returning to an operational state:

      mechoff(1) : An off state where no Energy Object features are available. The Energy Object is unavailable. No energy is being consumed and the power connector can be removed. This corresponds to ACPI state G3.

      softoff(2) : Similar to mechoff(1), but some components remain powered or receive trace power so that the Energy Object can be awakened from its off state. In softoff(2), no context is saved and the device typically requires a complete boot when awakened. This corresponds to ACPI state G2.

      hibernate(3): No Energy Object features are available. The Energy Object may be awakened without requiring a complete boot, but the time for availability is longer than sleep(4). An example for state hibernate(3) is a save to-disk state where DRAM context is not maintained. Typically, energy consumption is zero or close to zero. This corresponds to state G1, S4 in ACPI.

      sleep(4) : No Energy Object features are available, except for out-of-band management, such as wake-up mechanisms. The time for availability is longer than standby(5). An example for state sleep(4) is a save-to-RAM state, where DRAM context is maintained. Typically, energy consumption is close to zero. This corresponds to state G1, S3 in ACPI.

      standby(5) : No Energy Object features are available, except for out-of-band management, such as wake-up mechanisms.

This mode is analogous to cold-standby. The time for availability is longer than ready(6). For example, the processor context is not maintained. Typically, energy consumption is close to zero. This corresponds to state G1, S2 in ACPI.

ready(6) : No Energy Object features are available, except for out-of-band management, such as wake-up mechanisms. This mode is analogous to hot-standby. The Energy Object can be quickly transitioned into an operational state. For example, processors are not executing, but processor context is maintained. This corresponds to state G1, S1 in ACPI.

lowMinus(7) : Indicates some Energy Object features may not be available and the Energy Object has selected measures/options to provide less than low(8) usage. This corresponds to ACPI State G0. This includes operational states lowMinus(7) to full(12).

low(8) : Indicates some features may not be available and the Energy Object has taken measures or selected options to provide less than mediumMinus(9) usage.

mediumMinus(9): Indicates all Energy Object features are available but the Energy Object has taken measures or selected options to provide less than medium(10) usage.

medium(10) : Indicates all Energy Object features are available but the Energy Object has taken measures or selected options to provide less than highMinus(11) usage.

highMinus(11): Indicates all Energy Object features are available and power usage is less than high(12).

high(12) : Indicates all Energy Object features are available and the Energy Object is consuming the highest power.

A comparison of Power States can be seen in the following table:

| IEEE1621               | DMTF       | ACPI   | EMAN         |
|------------------------|------------|--------|--------------|
| Non-operational states |            |        |              |
| off                    | Off-Hard   | G3, S5 | MechOff(1)   |
| off                    | Off-Soft   | G2, S5 | SoftOff(2)   |
| sleep                  | Hibernate  | G1, S4 | Hibernate(3) |
| sleep                  | Sleep-Deep | G1, S3 | Sleep(4)     |

|                     |             |                  |                |
|---------------------|-------------|------------------|----------------|
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| sleep               | Sleep-Light | G1, S2           | Standby(5)     |
| sleep               | Sleep-Light | G1, S1           | Ready(6)       |
| Operational states: |             |                  |                |
| on                  | on          | G0, S0, P5       | LowMinus(7)    |
| on                  | on          | G0, S0, P4       | Low(8)         |
| on                  | on          | G0, S0, P3       | MediumMinus(9) |
| on                  | on          | G0, S0, P2       | Medium(10)     |
| on                  | on          | G0, S0, P1       | HighMinus(11)  |
| on                  | on          | G0, S0, P0       | High(12)       |

Figure 16: Comparison of Power States

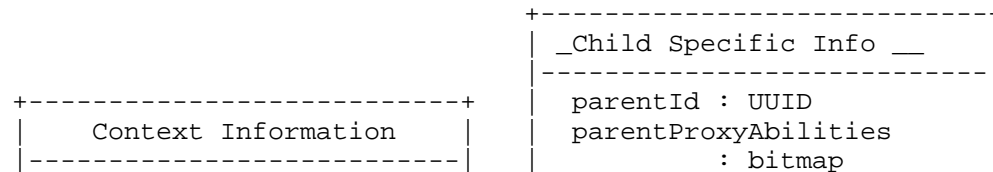
## 7. Structure of the Information Model: UML Representation

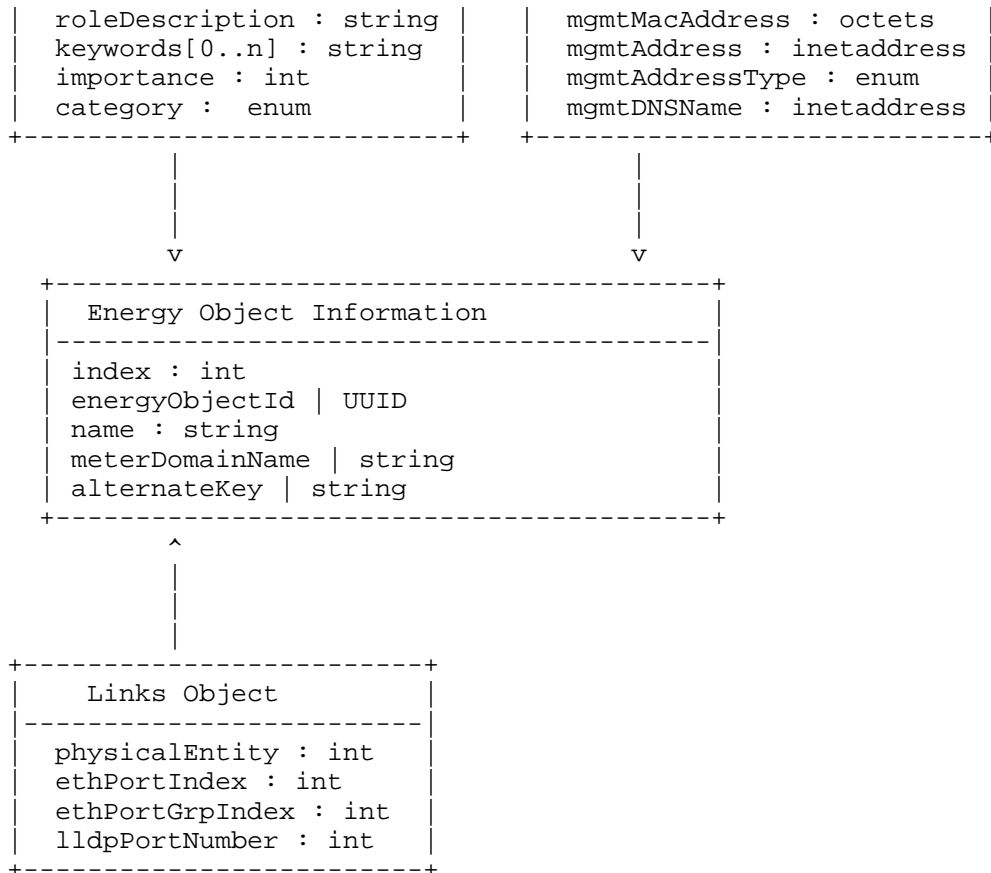
The following basic UML represents an information model expression of the concepts in this framework. This information model, provided as a reference for implementers, is represented as a MIB in the different related IETF Energy Monitoring documents. However, other programming structure with different data models could be used as well.

Notation is a shorthand UML with lowercase types considered platform or atomic types (i.e. int, string, collection). Uppercase types denote classes described further. Collections and cardinality are expressed via qualifier notation. Attributes labeled static are considered class variables and global to the class. Algorithms for class variable initialization, constructors or destructors are not shown

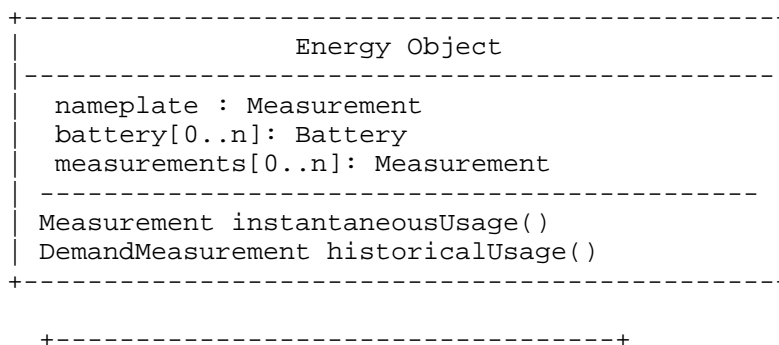
EDITOR'S NOTE: the first part of the UML must be aligned with the latest [EMAN-AWARE-MIB] document version. Also, received the following comment referring to the arrows in the following figure: "It is not clear to me what UML relationships are being specified here in the ASCIIified UML relationships. Please provide a legend to make your conventions for mapping to UML clear."

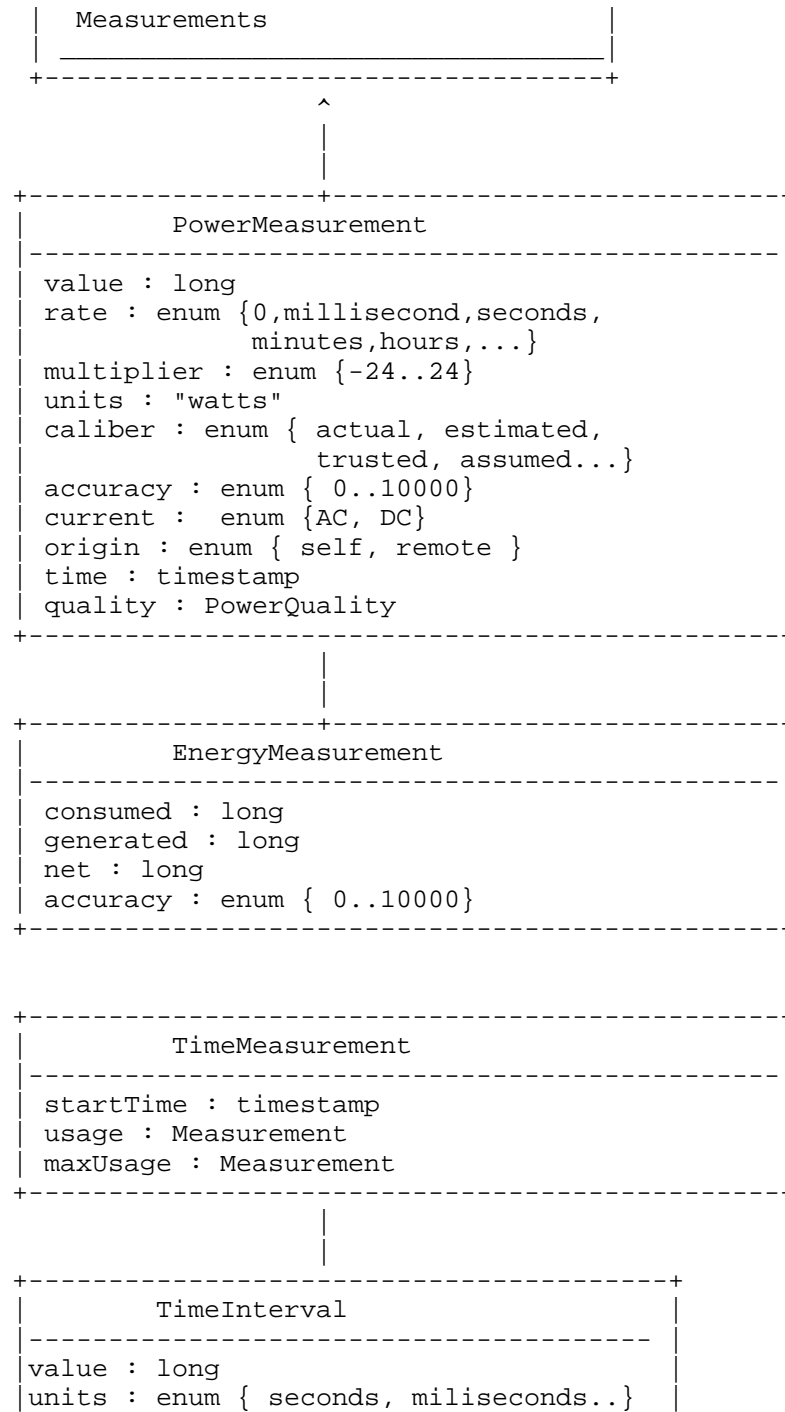
### EO RELATIONSHIPS AND CONTEXT



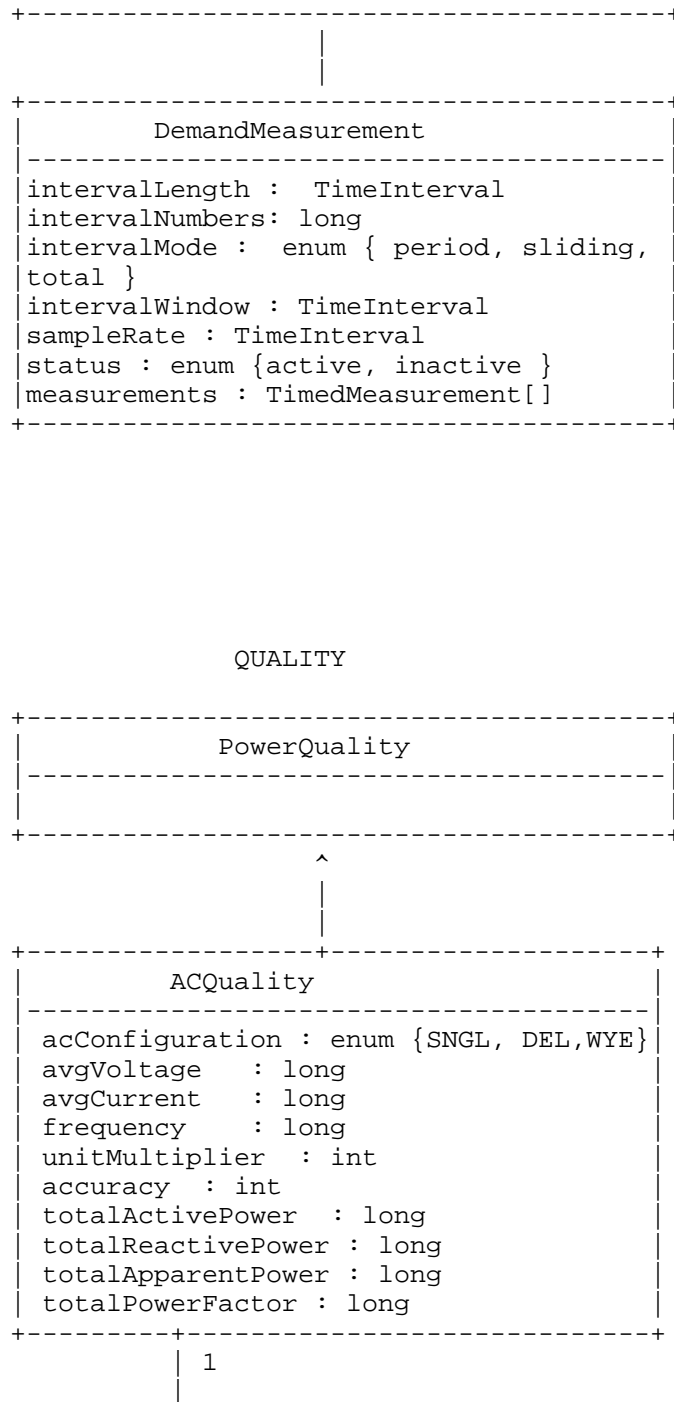


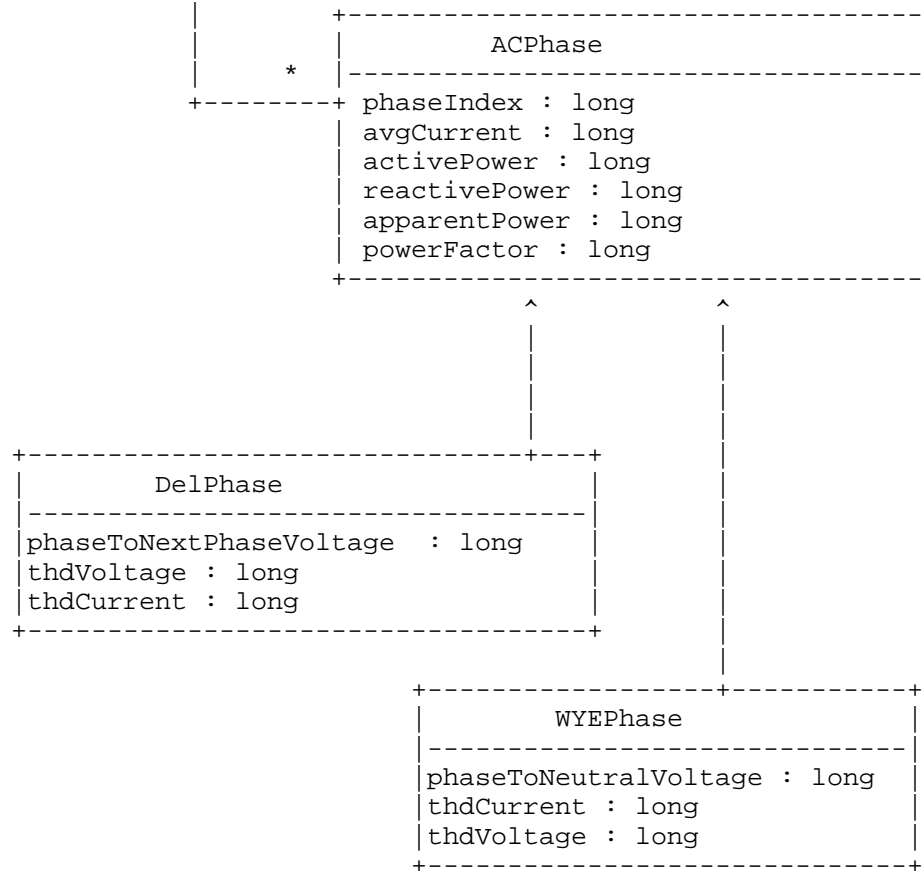
## EO AND MEASUREMENTS



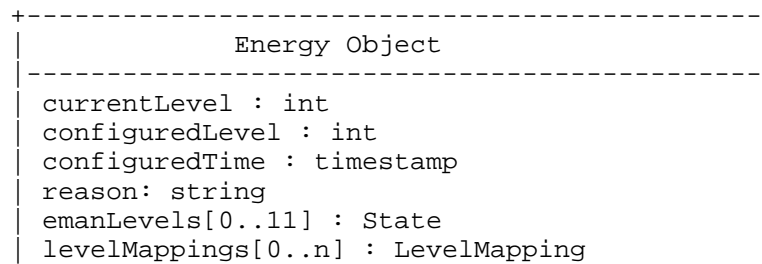








## EO &amp; STATES



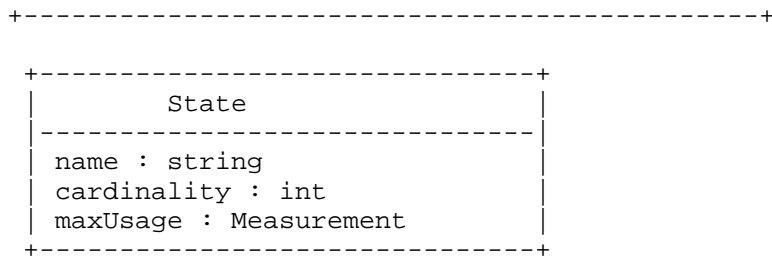


Figure 17: Information Model UML Representation

## 8. Configuration

This power management framework allows the configuration of the following key parameters:

- . Energy Object name: A unique printable name for the Energy Object.
- . Energy Object role: An administratively assigned name to indicate the purpose an Energy Object serves in the network.
- . Energy Object importance: A ranking of how important the Energy Object is, on a scale of 1 to 100, compared with other Energy Objects in the same Energy Management Domain.
- . Energy Object keywords: A list of keywords that can be used to group Energy Objects for reporting or searching.
- . Energy Management Domain: Specifies the name of an Energy Management Domain for the Energy Object.
- . Energy Object Power State: Specifies the current Power State for the Energy Object.
- . Demand parameters: For example, which interval length to report the Demand over, the number of intervals to keep, etc.
- . Assigning an Energy Object Parent to an Energy Object Child
- . Assigning an Energy Object Child to an Energy Object Parent.

This framework supports multiple means for setting the Power State of a specific Energy Objects. However, the Energy Object might be busy executing an important task that requires the current Power State for some more time. For example, a PC might have to finish a backup first, or an IP phone might be busy with a current phone call. Therefore a second value contains the actual Power State. A difference in values between the two objects indicates that the Energy Object is currently in Power State transition.

Other, already well established means for setting Power States, such as DASH [DASH], already exist. Such a protocol may be implemented between the Energy Object Parent and the Energy Object Child, when the Energy Object Parent acts as a Proxy. Note that the Wake-up-on-Lan (WoL) mechanism allows to transition a device out of the Off Power State.

## 9. Fault Management

[EMAN-REQ] specifies some requirements about Power States such as "the current state - the time of the last change", "the total time spent in each state", "the number of transitions to each state", etc. Such requirements are fulfilled via the pmPowerStateChange NOTIFICATION-TYPE [EMAN-MON-MIB]. This SNMP notification is generated when the value(s) of Power State has changed for the Energy Object.

Regarding high and low thresholding mechanism, the RMON alarm and event [RFC2819] allows to periodically takes statistical samples from Energy Object variables, compares them to previously configured thresholds, and to generate an event (i.e. an SNMP notification) if the monitored variable crosses a threshold. The RMON alarm can monitor variables that resolve to an ASN.1 primitive type of INTEGER (INTEGER, Integer32, Counter32, Counter64, Gauge32, or TimeTicks), so basically most the variables in [EMAN-MON-MIB].

## 10. Examples

In this section we will give examples of how to use the Energy Management framework. In each example we will show how it can be applied when Devices have the capability to model Power Interfaces. We will also show in each example how the framework can be applied when devices cannot support Power

Interfaces but only monitor information or control the Device as a whole. For instance a PDU may only be able to measure power and energy for the entire unit without the ability to distinguish among the inlets or outlet.

Together these examples show how the framework can be adapted for Devices with different capabilities (typically hardware) for Energy Management.

Given for all Examples:

Device W: A computer with one power supply. Power interface 1 is an inlets for Device W.

Device X: A computer with two power supplies. Power interface 1 and power interface 2 are both inlets for Device X.

Device Y: A PDU with multiple Power Interfaces numbered 0..10, Power interface 0 is an inlet and power interface 1..10 are outlets.

Device Z: A PDU with multiple Power Interfaces numbered 0..10, Power interface 0 is an inlet and power interface 1..10 are outlets.

#### Example I: Simple Device with one Source

##### Topology:

Device W inlet 1 is plugged into Device Y outlet 8.

##### With Power Interfaces:

Device W has an Energy Object representing the computer itself as well as one Power Interface defined as an inlet.

Device Y would have an Energy Object representing the PDU itself (the Device) with a Power Interface 0 defined as an inlet and Power Interfaces 1..10 defined as outlets.

The interfaces of the devices would have a Power Source Relationship such that:

Device W inlet 1 is powered by Device Y outlet 8

##### Without Power Interfaces:

In this case Device W has an Energy Object representing the computer. Device Y would have an Energy Object representing the PDU.

The devices would have a Power Source Relationship such that:  
Device W is powered by Device Y.

#### Example II: Multiple Inlets

##### Topology:

Device X inlet 1 is plugged into Device Y outlet 8.  
Device X inlet 2 is plugged into Device Y outlet 9.

##### With Power Interfaces:

Device X has an Energy Object representing the computer itself. It contains two Power Interface defined as inlets.

Device Y would have an Energy Object representing the PDU itself (the Device) with a Power Interface 0 defined as an inlet and Power Interface 1..10 defined as outlets.

The interfaces of the devices would have a Power Source Relationship such that:  
Device X inlet 1 is powered by Device Y outlet 8  
Device X inlet 2 is powered by Device Y outlet 9

##### Without Power Interfaces:

In this case Device X has an Energy Object representing the computer. Device Y would have an Energy Object representing the PDU.

The devices would have a Power Source Relationship such that:  
Device X is powered by Device Y.

#### Example III: Multiple Sources

##### Topology:

Device X inlet 1 is plugged into Device Y outlet 8.  
Device X inlet 2 is plugged into Device Z outlet 9

## With Power Interfaces:

Device X has an Energy Object representing the computer itself. It contains two Power Interface defined as inlets.

Device Y would have an Energy Object representing the PDU itself (the Device) with a Power Interface 0 defined as an inlet and Power Interface 1..10 defined as outlets.

Device Z would have an Energy Object representing the PDU itself (the Device) with a Power Interface 0 defined as an inlet and Power Interface 1..10 defined as outlets.

The interfaces of the devices would have a Power Source Relationship such that:

Device X inlet 1 is powered by Device Y outlet 8

Device X inlet 2 is powered by Device Z outlet 9

## Without Power Interfaces:

In this case Device X has an Energy Object representing the computer. Device Y and Z would both have respective Energy Objects representing each entire PDU.

The devices would have a Power Source Relationship such that:

Device X is powered by Device Y and powered by Device Z.

## 11. Relationship with Other Standards Development Organizations

### 11.1. Information Modeling

This power management framework should, as much as possible, reuse existing standards efforts, especially with respect to information modeling and data modeling [RFC3444].

The data model for power and energy related objects is based on IEC 61850.

Specific examples include:

- . The scaling factor, which represents Energy Object usage magnitude, conforms to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure.

- . The electrical characteristic is based on the ANSI and IEC Standards, which require that we use an accuracy class for power measurement. ANSI and IEC define the following accuracy classes for power measurement:
  - . IEC 62053-22 60044-1 class 0.1, 0.2, 0.5, 1 3.
  - . ANSI C12.20 class 0.2, 0.5
- . The electrical characteristics and quality adheres closely to the IEC 61850 7-2 standard for describing AC measurements.
- . The power state definitions are based on the DMTF Power State Profile and ACPI models, with operational state extensions.

## 12. Security Considerations

Regarding the data attributes specified here, some or all may be considered sensitive or vulnerable in some network environments. Reading or writing these attributes without proper protection such as encryption or access authorization may have negative effects on the network capabilities.

### 12.1 Security Considerations for SNMP

Readable objects in a MIB modules (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control GET and/or NOTIFY access to these objects and possibly to encrypt the values of these objects when sending them over the network via SNMP.

The support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations. For example:

- . Unauthorized changes to the Power Domain or business context of an Energy Object may result in misreporting or interruption of power.
- . Unauthorized changes to a power state may disrupt the power settings of the different Energy Objects, and therefore the state of functionality of the respective Energy Objects.
- . Unauthorized changes to the demand history may disrupt proper accounting of energy usage.



With respect to data transport SNMP versions prior to SNMPv3 did not include adequate security. Even if the network itself is secure (for example, by using IPsec), there is still no secure control over who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in these MIB modules.

It is recommended that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

Further, deployment of SNMP versions prior to SNMPv3 is not recommended. Instead, it is recommended to deploy SNMPv3 and to enable cryptographic security. It is then a customer/operator responsibility to ensure that the SNMP entity giving access to an instance of these MIB modules is properly configured to give access to the objects only to those principals (users) that have legitimate rights to GET or SET (change/create/delete) them.

### 13. IANA Considerations

AUTHORS NOTE: Section needs to be modified to reflect Power States text introduce in version 06

Initial values for the Power State Sets, together with the considerations for assigning them, are defined in [EMAN-MON-MIB].

### 14. Acknowledgments

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Requirements for Energy Management  
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Abstract

This document defines requirements for standards specifications for energy management. The requirements defined in this document concern monitoring functions as well as control functions. In detail, the focus of the requirements is on the following features: identification of energy-managed devices and their components, monitoring of their Power State, power inlets, power outlets, actual power, power properties, received energy, provided energy, and contained batteries. Further requirements are included to enable control of their power supply and Power State. This document does not specify the features that must be implemented by compliant implementations but rather features that must be supported by standards for energy management.

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## 1. Introduction

With rising energy cost and with an increasing awareness of the ecological impact of running IT equipment, energy management functions and interfaces are becoming an additional basic requirement for network management systems and devices connected to a network.

This document defines requirements for standards specifications for energy management, both monitoring functions and control functions. Subject of energy management are entities in the network. An entity is either a device or one of a device's components that is subject to individual energy monitoring or control or both.

In detail, the requirements listed are focused on the following features: identification of entities, monitoring of their Power State, power inlets, power outlets, actual power, power properties, received energy, provided energy, and contained batteries. Further included is control of entities' power supply and Power State.

The main subject of energy management are devices and their components that receive and provide electric energy. Devices may have an IP address, such as hosts, routers, and middleboxes, or they are connected indirectly to the Internet via a proxy with an IP address providing a management interface for the device. An example are devices in a building infrastructure using non-IP protocols and a gateway to the Internet.

These requirements concern the standards specification process and not the implementation of specified standards. All requirements in this document must be reflected by standards specifications to be developed. However, which of the features specified by these standards will be mandatory, recommended, or optional for compliant implementations is to be defined by standards track document(s) and not in this document.

Section 3 elaborates a set of general needs for energy management. Requirements for an energy management standard are specified in Sections 4 to 8.

Sections 4 to 6 contain conventional requirements specifying information on entities and control functions.

Sections 7 and 8 contain requirements specific to energy management. Due to the nature of power supply, some monitoring and control functions are not conducted by interacting with the entity of interest, but with other entities, for example, entities upstream in a power distribution tree.

### 1.1. Conventional Requirements For Energy Management

The specification of requirements for an energy management standard starts with Section 4 addressing the identification of entities and the granularity of reporting of energy-related information. A standard must support unique identification of entities, reporting per entire device, and reporting energy-related information on individual components of a device or subtended devices.

Section 5 specifies requirements related to monitoring of entities. This includes general (type, context) information and specific information on Power States, power inlets, power outlets, power, energy, and batteries. Control Power State and power supply of entities is covered by requirements specified in Section 6.

### 1.2. Specific Requirements for Energy Management

While the conventional requirements summarized above seem to be all that would be needed for energy management, there are significant differences between energy management and most well known network management functions. The most significant difference is the need for some devices to report on other entities. There are three major reasons for this.

- o For monitoring a particular entity it is not always sufficient to communicate with the entity only. When the entity has no instrumentation for determining power, it might still be possible to obtain power values for the entity by communication with other entities in its power distribution tree.  
A simple example is retrieving power values from a power meter at the power line into the entity. Common examples are a Power Distribution Unit (PDU) and a Power over Ethernet (PoE) switch. Both supply power to other entities at sockets or ports, respectively, and are often instrumented to measure power per socket or port.
- o Similar considerations apply to controlling power supply of a entity which often needs direct or indirect communications with another entity upstream in the power distribution tree. Again, a PDU and a PoE switch are common examples, if they have the capability to switch on or off power at their sockets or ports, respectively.
- o Energy management often extends beyond entities with IP network interfaces, to non-IP building systems accessed via a gateway. Requirements in this document do not cover details of these networks, but specify means for opening IP network management towards them.

These specific issues of energy management and a set of further ones are covered by requirements specified in Sections 7 and 8.

The requirements in these sections need a new energy management framework that deals with the specific nature of energy management. The actual standards documents, such as MIB module specifications, address conformance by specifying which feature must, should, or may be implemented by compliant implementations.

## 2. Terminology

### Energy

That which does work or is capable of doing work. As used by electric utilities, it is generally a reference to electrical energy and is measured in kilo-watt hours (kWh) [IEEE-100].

### Power

The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or in joules per second) [IEEE-100].

### Energy management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization [ITU-M.3400].

### Energy management system

An Energy Management System is a combination of hardware and software used to administer a network with the primary purpose being energy management [Fed-Std-1037C].

### Energy monitoring

Energy monitoring is a part of energy management that deals with collecting or reading information from network elements and attached devices and their components to aid in energy management.

### Energy control

Energy control is a part of energy management that deals with directing influence over network elements and attached devices and their components.

#### Power Interface

A Power Interface is an interface at which a device is connected to a power transmission medium at which it can receive power, provide power, or both.

#### Power inlet

A power inlet is a Power Interface at which a device can receive power from other devices.

#### Power outlet

A power outlet is a Power Interface at which a device can provide power to other devices.

#### Power State

A Power State is a condition or mode of a device that broadly characterizes its capabilities, power consumption, and responsiveness to input [IEEE-1621].

### 3. General Considerations Related to Energy Management

The basic objective of energy management is operating sets of devices with minimal energy, while maintaining a certain level of service. Use cases for energy management can be found in [I-D.ietf-eman-applicability-statement].

#### 3.1. Power States

entities can be set to an operational state that results in the lowest power level that still meets the service level performance objectives. In principle, there are four basic types of Power States for an entity or for a whole system:

- o full Power State
- o reduced Power States (e.g. lower clock rate for processor, lower data rate on a link, etc.)
- o sleep state (not functional, but immediately available)
- o off state (may require significant time to become operational)

In specific devices, the number of Power States and their properties varies considerably. Simple entities may just have only the extreme states, full power and off state. Many devices have three basic Power States: on, off, and sleep. However, more finely grained Power States can be implemented.

### 3.2. Saving Energy versus Maintaining Service Level Agreements

While the general objective of energy management is quite clear, the way to attain that goal is often difficult. In many cases there is no way of reducing power without the consequence of a potential performance, service, or capacity degradation. Then a trade-off needs to be dealt with between service level objectives and energy minimization. In other cases a reduction of power can easily be achieved while still maintaining sufficient service level performance, for example, by switching entities to lower Power States when higher performance is not needed.

### 3.3. Local Versus network-Wide energy Management

Many energy saving functions are executed locally by an entity; it monitors its usage and dynamically adapts its power according to the required performance. It may, for example, switch to a sleep state when it is not in use or out of scheduled business hours. An energy management system may observe an entity's power state and configure its power saving policies.

Energy savings can also be achieved with policies implemented by a network management system that controls Power States of managed entities. Information about the power received and provided by entities in different Power States may be required to set policies. Often this information is acquired best through monitoring.

Both methods, network-wide and local energy management, have advantages and disadvantages and often it is desirable to combine them. Central management is often favorable for setting Power States of a large number of entities at the same time, for example, at the beginning and end of business hours in a building. Local management is often preferable for power saving measures based on local observations, such as high or low load of an entity.

### 3.4. Energy Monitoring Versus Energy Saving

Monitoring energy, power, and Power States alone does not reduce the energy needed to run an entity. In fact, it may even increase it slightly due to monitoring instrumentation that needs energy. Reporting measured quantities over the network may also increase energy use, though the acquired information may be an essential input to control loops that save energy.

Monitoring energy and Power States can also be required for other purposes including:

- o investigating energy saving potential
- o evaluating the effectiveness of energy saving policies and measures
- o deriving, implementing, and testing power management strategies
- o accounting for the total power received and provided by an entity, a network, or a service
- o predicting an entity's reliability based on power usage
- o choosing time of next maintenance cycle for an entity

### 3.5. Overview Of Energy Management Requirements

The following basic management functions are required:

- o monitoring Power States
- o monitoring power (energy conversion rate)
- o monitoring (accumulated) received and provided energy
- o monitoring power properties
- o setting Power States

Power control is complementary to other energy savings measures such as low power electronics, energy saving protocols, energy-efficient device design (for example, low-power modes for components), and energy-efficient network architectures. Measurement of received and provided energy can provide useful data for developing these technologies.

## 4. Identification Of Entities

Entities must be uniquely identified. This includes entities that are components of managed devices as well as entire devices.

For entities that report on or control other entities it is important to identify the entities they report on or control, see Section 7 or Section 8, respectively.

An entity may be an entire device or a component of it. Examples of components of interest are a hard drive, a battery, or a line card. It may be required to be able to control individual components to save energy. For example, server blades can be switched off when the overall load is low or line cards at switches may be powered down at night.

Identifiers for devices and components are already defined in standard MIB modules, such as the LLDP MIB module [IEEE-802.1AB] and the LLDP-MED MIB module [ANSI-TIA-1057] for devices and the Entity MIB module [RFC4133] and the Power Ethernet MIB [RFC3621] for components of devices. Energy management needs means to link energy-related information to such identifiers.



Instrumentation for measuring received and provided energy of a device is typically more expensive than instrumentation for retrieving its Power State. Many devices may provide Power State information for all individual components separately, while reporting the received and provided energy only for the entire device.

#### 4.1. Identifying entities

The standard must provide means for uniquely identifying entities. Uniqueness must be preserved such that collisions of identities are avoided at potential receivers of monitored information.

#### 4.2. Persistence of identifiers

The standard must provide means for indicating whether identifiers of entities are persistent across a re-start of the entity.

#### 4.3. Using entity identifiers of other MIB modules

The standard must provide means for re-using entity identifiers from other standards including at least the following:

- o the entPhysicalIndex in the Entity MIB module [RFC4133]
- o the LldpPortNumber in the LLDP MIB module [IEEE-802.1AB] and in the LLDP-MED MIB module [ANSI-TIA-1057]
- o the pethPsePortIndex and the pethPsePortGroupIndex in the Power Ethernet MIB [RFC3621]

Generic means for re-using other entity identifiers must be provided.

### 5. Information On Entities

This section describes information on entities for which the standard must provide means for retrieving and reporting.

Required information can be structured into seven groups.

Section 5.1 specifies requirements for general information on entities, such as type of entity or context information.

Requirements for information on power inlets and power outlets of entities are specified in Section 5.2. Monitoring of power and energy is covered by Sections 5.3 and 5.5, respectively. Section 5.4 covers requirements related to entities' Power States. Section 5.6 specifies requirements for monitoring batteries. Finally, the reporting of time series of values is covered by Section 5.7.

#### 5.1. General Information On Entities

For energy management it may be required to understand the role and context of an entity. An energy management system may aggregate

values of received and provided energy according to a defined grouping of entities. When controlling and setting Power States it may be helpful to understand the grouping of the entity and role of an entity in a network, for example, it may be important to exclude some vital network devices from being switched to lower power or even from being switched off.

#### 5.1.1. Type of entity

The standard must provide means to configure, retrieve and report a textual name or a description of an entity.

#### 5.1.2. Context of an entity

The standard must provide means for retrieving and reporting context information on entities, for example, tags associated with an entity that indicate the entity's role.

#### 5.1.3. Significance of entities

The standard must provide means for retrieving and reporting the significance of entities within its context, for example, how important the entity is.

#### 5.1.4. Power priority

The standard must provide means for retrieving and reporting power priorities of entities. Power priorities indicate an order in which Power States of entities are changed, for example, to lower Power States for saving power.

#### 5.1.5. Grouping of entities

The standard must provide means for grouping entities. This can be achieved in multiple ways, for example, by providing means to tag entities, to assign them to domains, or to assign device types to them.

### 5.2. Power Interfaces

A Power Interface is either an inlet or an outlet. Some Power Interfaces can change over time from being an inlet to being an outlet and vice versa. However most power interfaces never change.

entities have power inlets at which they are supplied with electric power. Most entities have a single power inlet, while some have multiple inlets. Different power inlets on a device are often connected to separate power distribution trees. For energy

monitoring, it is useful to retrieve information on the number of inlets of an entity, the availability of power at inlets and which of them are actually in use.

Entities can have one or more power outlets for supplying other entities with electric power.

For identifying and potentially controlling the source of power received at an inlet, it may be required to identify the power outlet of another entity at which the received power is provided. Analogously, for each outlet it is of interest to identify the power inlets that receive the power provided at a certain outlet. Such information is also required for constructing the wiring topology of electrical power distribution to entities.

Static properties of each Power Interface are required information for energy management. Static properties include the kind of electric current (AC or DC), the nominal voltage, the nominal AC frequency, and the number of AC phases.

#### 5.2.1. Lists of Power Interfaces

The standard must provide means for monitoring the list of Power Interfaces.

#### 5.2.2. Corresponding power outlet

The standard must provide means for identifying the power outlet that provides the power received at a power inlet.

#### 5.2.3. Corresponding power inlets

The standard must provide means for identifying the list of power inlets that receive the power provided at a power outlet.

#### 5.2.4. Availability of power

The standard must provide means for monitoring the availability of power at each Power Interface. This indicates whether at a Power Interfaces power supply is switched on or off.

#### 5.2.5. Use of power

The standard must provide means for monitoring for each Power Interfaces if it is in actual use. For inlets this means that the entity actually receives power at the inlet. For outlets this means that power is actually provided from it to one or more entities.

#### 5.2.6. Type of current

The standard must provide means for reporting the type of current (AC or DC) for each Power Interface as well as for an entire entity.

#### 5.2.7. Nominal voltage

The standard must provide means for reporting the nominal voltage for each Power Interface.

#### 5.2.8. Nominal AC frequency

The standard must provide means for reporting the nominal AC frequency for each Power Interface.

#### 5.2.9. Number of AC phases

The standard must provide means for reporting the number of AC phases for each Power Interface.

### 5.3. Power

Power is measured as an instantaneous value or as the average over a time interval.

Obtaining highly accurate values for power and energy may be costly if it requires dedicated metering hardware. Entities without the ability to measure their power and received and provided energy with high accuracy may just report estimated values, for example based on load monitoring, Power State, or even just the entity type.

Depending on how power and energy values are obtained, the confidence in the reported value and its accuracy will vary. Entities reporting such values should qualify the confidence in the reported values and quantify the accuracy of measurements. For reporting accuracy, the accuracy classes specified in IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22] should be considered.

Further properties of the supplied power are also of interest. For AC power supply, power attributes beyond the real power to be reported include the apparent power, the reactive power, and the phase angle of the current or the power factor. For both AC and DC power the power characteristics are also subject of monitoring. Power parameters include the actual voltage, the actual frequency, the Total Harmonic Distortion (THD) of voltage and current, the impedance of an AC phase or of the DC supply. Power monitoring should be in line with existing standards, such as [IEC.61850-7-4].

For some network management tasks it is desirable to receive notifications from entities when their power value exceeds or falls below given thresholds.

#### 5.3.1. Real power

The standard must provide means for reporting the real power for each Power Interface as well as for an entire entity. Reporting power includes reporting the direction of power flow.

#### 5.3.2. Power measurement interval

The standard must provide means for reporting the corresponding time or time interval for which a power value is reported. The power value can be measured at the corresponding time or averaged over the corresponding time interval.

#### 5.3.3. Power measurement method

The standard must provide means to indicate the method how these values have been obtained. Based on how the measurement was conducted, it is possible to associate a certain degree of confidence with the reported power value. For example, there are methods of measurement such as direct power measurement, or by estimation based on performance values, or hard coding average power values for an entity.

#### 5.3.4. Accuracy of power and energy values

The standard must provide means for reporting the accuracy of reported power and energy values.

#### 5.3.5. Actual voltage and current

The standard must provide means for reporting the actual voltage and actual current for each power interface as well as for an entire entity. In case of AC power supply, means must be provided for reporting the actual voltage and actual current per phase.

#### 5.3.6. High/low power notifications

The standard must provide means for creating notifications if power values of an entity rise above or fall below given thresholds.

#### 5.3.7. Complex power

The standard must provide means for reporting the complex power for each Power Interface and for each phase at a Power Interface.

Besides the real power, at least two out of the following three quantities need to be reported: apparent power, reactive power, phase angle. The phase angle can be substituted by the power factor.

#### 5.3.8. Actual AC frequency

The standard must provide means for reporting the actual AC frequency for each Power Interface.

#### 5.3.9. Total harmonic distortion

The standard must provide means for reporting the Total Harmonic Distortion (THD) of voltage and current for each Power Interface. In case of AC power supply, means must be provided for reporting the THD per phase.

#### 5.3.10. Power supply impedance

The standard must provide means for reporting the impedance of power supply for each Power Interface. In case of AC power supply, means must be provided for reporting the impedance per phase.

### 5.4. Power State

Many entities have a limited number of discrete Power States.

There is a need to report the actual Power State of an entity, and means for retrieving the list of all supported Power States.

Different standards bodies have already defined sets of Power States for some entities, and others are creating new Power State sets. In this context, it is desirable that the standard support many of these power state standards. In order to support multiple management systems possibly using different Power State sets, while simultaneously interfacing with a particular entity, the energy management standard must provide means for supporting multiple Power State sets used simultaneously at an entity.

Power States have parameters that describe its properties. It is required to have standardized means for reporting some key properties, such as average power and maximum power of an entity in a certain state.

There also is a need to report statistics on Power States including the time spent and the received and provided energy in a Power State.

#### 5.4.1. Actual Power State

The standard must provide means for reporting the actual Power State of an entity.

#### 5.4.2. List of supported Power States

The standard must provide means for retrieving the list of all potential Power States of an entity.

#### 5.4.3. Multiple Power State sets

The standard must provide means for supporting multiple Power State sets simultaneously at an entity.

#### 5.4.4. List of supported Power State sets

The standard must provide means for retrieving the list of all Power State sets supported by an entity.

#### 5.4.5. List of supported Power States within a set

The standard must provide means for retrieving the list of all potential Power States of an entity for each supported Power State set.

#### 5.4.6. Maximum and average power per Power State

The standard must provide means for retrieving the maximum power and the average power for each supported Power State. These values may be static.

#### 5.4.7. Power State statistics

The standard must provide means for monitoring statistics per Power State including the total time spent in a Power State, the number of times each state was entered and the last time each state was entered. More Power State statistics are addressed by requirement 5.5.3.

#### 5.4.8. Power State changes

The standard must provide means for generating a notification when the actual Power State of an entity changes.

## 5.5. Energy

Monitoring of electrical energy received or provided by an entity is a core function of energy management. Since energy is an accumulated quantity, it is always reported for a certain interval of time. This can be, for example, the time from the last restart of the entity to the reporting time, the time from another past event to the reporting time, the last given amount of time before the reporting time, or a certain interval specified by two time stamps in the past.

It is useful for entities to record their received and provided energy per Power State and report these quantities.

### 5.5.1. Energy

The standard must provide means for reporting measured values of energy and the direction of the energy flow received or provided by an entity. The standard must also provide the means to report the energy passing through each Power Interface.

### 5.5.2. Time intervals

The standard must provide means for reporting the time interval for which an energy value is reported.

### 5.5.3. Energy per Power State

The standard must provide means for reporting the received and provided energy for each individual power state. This extends the requirement 5.4.7 on Power State statistics.

## 5.6. Battery State

Many entities contain batteries that supply them with power when disconnected from electrical power distribution grids. The status of these batteries is typically controlled by automatic functions that act locally on the entity and manually by users of the entity. There is a need to monitor the battery status of these entities by network management systems.

Devices containing batteries can be modeled in two ways. The entire device can be modeled as a single entity on which energy-related information is reported or the battery can be modeled as an individual entity for which energy-related information is monitored individually according to requirements in Sections 5.1 to 5.5.

Further information on batteries is of interest for energy management, such as the current charge of the battery, the number of



completed charging cycles, the charging state of the battery, and further static and dynamic battery properties. It is desirable to receive notifications if the charge of a battery becomes very low or if a battery needs to be replaced.

#### 5.6.1. Battery charge

The standard must provide means for reporting the current charge of a battery.

#### 5.6.2. Battery charging state

The standard must provide means for reporting the charging state (charging, discharging, etc.) of a battery.

#### 5.6.3. Battery charging cycles

The standard must provide means for reporting the number of completed charging cycles of a battery.

#### 5.6.4. Actual battery capacity

The standard must provide means for reporting the actual capacity of a battery.

#### 5.6.5. Static battery properties

The standard must provide means for reporting static properties of a battery, including the nominal capacity, the number of cells, the nominal voltage, and the battery technology.

#### 5.6.6. Low battery charge notification

The standard must provide means for generating a notification when the charge of a battery decreases below a given threshold.

#### 5.6.7. Battery replacement notification

The standard must provide means for generating a notification when the number of charging cycles of battery exceeds a given threshold.

#### 5.6.8. Multiple batteries

The standard must provide means for meeting requirements 5.6.1 to 5.6.7 for each individual battery contained in a single entity.

### 5.7. Time Series Of Measured Values

For some network management tasks, it is required to obtain time series of measured values from entities, such as power, energy, battery charge, etc.

In general time series measurements could be obtained in many different ways. It should be avoided that such time series can only be obtained through regular polling by the energy management system. Means should be provided to either push such values from the location where they are available to the management system or to have them stored locally for a sufficiently long period of time such that a management system can retrieve full time series.

The following issues are to be considered when designing time series measurement and reporting functions:

1. Which quantities should be reported?
2. Which time interval type should be used (total, delta, sliding window)?
3. Which measurement method should be used (sampled, continuous)?
4. Which reporting model should be used (push or pull)?

The most discussed and probably most needed quantity is energy. But a need for others, such as power and battery charge can be identified as well.

There are three time interval types under discussion for accumulated quantities such as energy. They can be reported as total values, accumulated between the last restart of the measurement and a certain timestamp. Alternatively, energy can be reported as delta values between two consecutive timestamps. Another alternative is reporting values for sliding windows as specified in [IEC.61850-7-4].

For non-accumulative quantities, such as power, different measurement methods are considered. Such quantities can be reported using values sampled at certain time stamps or alternatively by mean values for these quantities averaged between two (consecutive) time stamps or over a sliding window.

Finally, time series can be reported using different reporting models, particularly push-based or pull-based. Push-based reporting can, for example, be realized by reporting power or energy values using the IPFIX protocol [RFC5101],[RFC5102]. SNMP [RFC3411] is an example for a protocol that can be used for realizing pull-based reporting of time series.

For reporting time series of measured values the following requirements have been identified. Further decisions concerning

issues discussed above need to be made when developing concrete energy management standards.

#### 5.7.1. Time series of energy values

The standard must provide means for reporting time series of energy values.

#### 5.7.2. Time series storage capacity

The management standard should provide means for reporting the number of values of a time series that can be stored for later reporting.

### 6. Control Of Entities

Many entities control their Power State locally. Other entities need interfaces for an energy management system to control their Power State.

Power supply is typically not self-managed by entities. And controlling power supply is typically not conducted as interaction between energy management system and the entity itself. It is rather an interaction between the management system and an entity providing power at its power outlets. Similar to Power State control, power supply control may be policy driven. Note that shutting down the power supply abruptly may have severe consequences for the entity.

#### 6.1. Controlling Power States

The standard must provide means for setting Power States of entities.

#### 6.2. Controlling power supply

The standard must provide means for switching power supply off or turning power supply on at power outlets providing power to one or more entity.

### 7. Reporting On Other Entities

As discussed in Section 5, not all energy-related information may be available at the concerned entity. Such information may be provided by other entities. This section covers reporting of information only. See Section 8 for requirements on controlling other entities.

There are cases where a power supply unit switches power for several entities by turning power on or off at a single power outlet or where

a power meter measures the accumulated power of several entities at a single power line. Consequently, it should be possible to report that a monitored value does not relate to just a single entity, but is an accumulated value for a set of entities. All of these entities belonging to that set need to be identified.

If an entity has information about where energy-related information on itself can be retrieved, then it would be useful to communicate this information. This applies even if the information only provides accumulated quantities for several entities.

#### 7.1. Reports on other entities

The standard must provide means for an entity to report information on another entity.

#### 7.2. Identity of other entities on which is reported

For entities that report on one or more other entities, the standard must provide means for reporting the identity of other entities on which information is reported.

#### 7.3. Reporting quantities accumulated over multiple entities

The standard must provide means for reporting the list of all entities from which contributions are included in an accumulated value.

#### 7.4. List of all entities on which is reported

For entities that report on one or more other entities, the standard must provide means for reporting the complete list of all those entities on which energy-related information can be reported.

#### 7.5. Content of reports on other entities

For entities that report on one or more other entities, the standard must provide means for indicating which energy-related information can be reported for which of those entities.

#### 7.6. Indicating source of remote information

For an entity that has one or more other entities reporting on its behalf, the standard must provide means for the entity to indicate which information is available at which other entity.

## 8. Controlling Other Entities

This section specifies requirements for controlling Power States and power supply of entities by communicating with other entities that have means for controlling Power State or power supply of others.

### 8.1. Controlling Power States Of Other Entities

Some entities have control over Power States of other entities. For example a gateway to a building system may have means to control the Power State of entities in the building that do not have an IP interface. For this scenario and other similar cases means are needed to make this control accessible to the energy management system.

In addition to this, it is required that an entity that has its state controlled by other entities has means to report the list of these other entities.

#### 8.1.1. Control of Power States of other entities

The standard must provide means for an energy management system to send Power State control commands to an entity that concern the Power States of other entities than the one the command was sent to.

#### 8.1.2. Identity of other Power State controlled entities

The standard must provide means for reporting the identities of the entities for which the reporting entity has means to control their Power States.

#### 8.1.3. List of all Power State controlled entities

The standard must provide means for an entity to report the list of all entities for which it can control the Power State.

#### 8.1.4. List of all Power State controllers

The standard must provide means for an entity that receives commands controlling its Power State from other entities to report the list of all those entities.

### 8.2. Controlling Power Supply

Some entities may have control of the power supply of other entities, for example, because the other entity is supplied via a power outlet of the entity. For this and similar cases means are needed to make this control accessible to the energy management system. This need

is already addressed by requirement 6.2.

In addition, it is required that an entity that has its supply controlled by other entities has means to report the list of these other entities. This need is already addressed by requirements 5.2.2 and 5.2.3.

## 9. Security Considerations

Controlling Power State and power supply of entities are highly sensitive actions since they can significantly affect the operation of directly and indirectly affected devices. Therefore all control actions addressed in 6 and 8 must be sufficiently protected through authentication, authorization, and integrity protection mechanisms.

Monitoring energy-related quantities of an entity addressed in Sections 5 - 8 can be used to derive more information than just the received and provided energy, so monitored data requires privacy protection. Monitored data may be used as input to control, accounting, and other actions, so integrity of transmitted information and authentication of the origin may be needed.

### 9.1. Secure energy management

The standard must provide privacy, integrity, and authentication mechanisms for all actions addressed in Sections 5 - 8. The security mechanisms must address all threats listed in Section 1.4 of [RFC3411].

## 10. IANA Considerations

This document has no actions for IANA.

## 11. Acknowledgements

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## Appendix A. Existing Standards

This section analyzes existing standards for energy and Power State monitoring. It shows that there are already several standards that cover only some part of the requirements listed above, but even all together they do not cover all of the requirements for energy management.

### A.1. Existing IETF Standards

There are already RFCs available that address a subset of the requirements.

#### A.1.1. ENTITY MIB

The ENTITY-MIB module defined in [RFC4133] was designed to model physical and logical entities of a managed system. A physical entity is an identifiable physical component. A logical entity can use one or more physical entities. From an energy monitoring perspective of a managed system, the ENTITY-MIB modeling framework can be reused and whenever RFC 4133 [RFC4133] has been implemented. The entPhysicalIndex from entPhysicalTable can be used to identify an entity/component. However, there are use cases of energy monitoring, where the application of the ENTITY-MIB does not seem readily apparent and some of those entities could be beyond the original scope and intent of the ENTITY-MIB.

Consider the case of remote devices attached to the network, and the network device could collect the energy measurement and report on behalf of such attached devices. Some of the remote devices such as PoE phones attached to a switch port have been considered in the Power-over-Ethernet MIB module [RFC3621]. However, there are many other devices such as a computer, which draw power from a wall outlet or building HVAC devices which seem to be beyond the original scope of the ENTITY-MIB.

Yet another example, is smart-PDUs, which can report the energy provided to the device attached to the power outlet of the PDU. In some cases, the device can be attached to multiple to power outlets. Thus, the energy measured at multiple outlets need to be aggregated to determine the energy provided to a single device. From mapping

perspective, between the PDU outlets and the device this is a many-to-one mapping. It is not clear if such a many-to-one mapping is feasible within the ENTITY-MIB framework.

#### A.1.2. ENTITY STATE MIB

RFC 4268 [RFC4268] defines the ENTITY STATE MIB module. Implementations of this module provide information on entities including the standby status (hotStandby, coldStandby, providingService), the operational status (disabled, enabled, testing), the alarm status (underRepair, critical, major, minor, warning), and the usage status (idle, active, busy). This information is already useful as input for policy decisions and for other network management tasks. However, the number of states would cover only a small subset of the requirements for Power State monitoring and it does not provide means for energy monitoring. For associating the information conveyed by the ENTITY STATE MIB to specific components of a device, the ENTITY STATE MIB module makes use of the means provided by the ENTITY MIB module [RFC4133]. Particularly, it uses the entPhysicalIndex for identifying entities.

The standby status provided by the ENTITY STATE MIB module is related to Power States required for energy management, but the number of states is too restricted for meeting all energy management requirements. For energy management several more Power States are required, such as different sleep and operational states as defined by the Advanced Configuration and Power Interface (ACPI) [ACPI.R30b] or the DMTF Power State Management Profile [DMTF.DSP1027].

#### A.1.3. ENTITY SENSOR MIB

RFC 3433 [RFC3433] defines the ENTITY SENSOR MIB module. Implementations of this module offer a generic way to provide data collected by a sensor. A sensor could be an energy meter delivering measured values in Watt. This could be used for reporting current power of an entity and its components. Furthermore, the ENTITY SENSOR MIB can be used to retrieve the accuracy of the used power meter.

Similar to the ENTITY STATE MIB module, the ENTITY SENSOR MIB module makes use of the means provided by the ENTITY MIB module [RFC4133] for relating provided information to components of a device.

However, there is no unit available for reporting energy quantities, such as, for example, watt seconds or kilowatt hours, and the ENTITY SENSOR MIB module does not support reporting accuracy of measurements according to the IEC / ANSI accuracy classes, which are commonly in use for electric power and energy measurements. The ENTITY SENSOR

MIB modules only provides a coarse-grained method for indicating accuracy by stating the number of correct digits of fixed point values.

#### A.1.4. UPS MIB

RFC 1628 [RFC1628] defines the UPS MIB module. Implementations of this module provide information on the current real power of entities attached to an uninterruptible power supply (UPS) device. This application would require identifying which entity is attached to which port of the UPS device.

UPS MIB provides information on the state of the UPS network. The MIB module contains several variables that are used to identify the UPS entity (name, model,...), the Battery State, to characterize the input load to the UPS, to characterize the output from the UPS, to indicate the various alarm events. The measurements of power in UPS MIB are in Volts, Amperes and Watts. The units of power measurement are RMS volts, RMS Amperes and are not based on Entity-Sensor MIB [RFC3433].

#### A.1.5. POWER ETHERNET MIB

Similar to the UPS MIB, implementations of the POWER ETHERNET MIB module defined in RFC3621 [RFC3621] provide information on the current power of the entities that receive Power over Ethernet (PoE). This information can be retrieved at the power sourcing equipment. Analogous to the UPS MIB, it is required to identify which entities are attached to which port of the power sourcing equipment.

The POWER ETHERNET MIB does not report power and energy on a per port basis, but can report aggregated values for groups of ports. It does not use objects of the ENTITY MIB module for identifying entities, although this module existed already when the POWER ETHERNET MIB modules was standardized.

#### A.1.6. LLDP MED MIB

The Link Layer Discovery Protocol (LLDP) defined in IEEE 802.1ab is a data link layer protocol used by network devices for advertising of their identities, capabilities, and interconnections on a LAN network. The Media Endpoint Discovery (MED) (ANSI-TIA-1057) is an enhancement of LLDP known as LLDP-MED. The LLDP-MED enhancements specifically address voice applications. LLDP-MED covers 6 basic areas: capabilities discovery, LAN speed and duplex discovery, network policy discovery, location identification discovery, inventory discovery, and power discovery.

## A.2. Existing standards of other bodies

### A.2.1. DMTF

The DMTF has defined a Power State management profile [DMTF.DSP1027] that is targeted at computer systems. It is based on the DMTF's Common Information Model (CIM) and it is rather an entity profile than an actual energy monitoring standard.

The Power State management profile is used to describe and to manage the Power State of computer systems. This includes e.g. means to change the Power State of an entity (e.g. to shutdown the entity) which is an aspect of but not sufficient for active energy management.

### A.2.2. ODVA

ODVA is an association consisting of members from industrial automation companies. ODVA supports standardization of network technologies based on the Common Industrial Protocol (CIP). Within ODVA, there is a special interest group focused on energy and standardization and inter-operability of energy aware entities.

### A.2.3. IEEE-ISTO Printer WG

The charter of the IEEE-ISTO Printer Working Group is for open standards that define printer related protocols, that printer manufacturers and related software vendors shall benefit from the interoperability provided by conformance to these standards. One particular aspect the Printer WG is focused on is power monitoring and management of network printers and imaging systems PWG Power Management Model for Imaging Systems [IEEE-ISTO]. 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. IEEE-ISTO Printer working group has defined MIB modules for monitoring power and Power State series that can be useful for power management of printers. The energy management framework should also take into account the standards defined in the Printer working group. In terms of other standards, IETF Printer MIB RFC3805 [RFC3805] has been standardized, however, this MIB module does not address power management of printers.

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Abstract

A nanogrid is a very small electricity domain that is distinct from any other grid it is connected to in voltage, reliability, quality, or price. Nanogrids could form the basis of a future electricity system built on a bottom-up, decentralized, and distributed network model rather than the top-down centralized grid we have today in most parts of the world. This document introduces the idea of a nanogrid to the IETF community for two purposes -- to inform the work on energy management presently underway in the EMAN working group, and to describe how future communications within and between grids could be accomplished with protocols that are the product of the IETF. There appears to be no fundamental conflict between the nanogrid concept and the current drafts in the EMAN working group.

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## 1. Overview

A nanogrid is a very small electricity domain that is distinct from any other grid it is connected to in voltage, reliability, quality, or price [CIGRE] (also [NG-2009]). Nanogrids could form the basis of a future electricity system built on a bottom-up, decentralized, and distributed network model rather than the top-down centralized grid we have today in most parts of the world. Central to nanogrids is the ability to communicate electricity price and availability to enable matching demand with varying supply of electricity. For the remainder of this document, we use "nanogrid" to refer to those which use price to manage supply and demand. Nanogrids bring an Internet approach and architecture to our electricity system.

## 2. How Nanogrids Work

A nanogrid must have at least one load or sink of power (which could be electricity storage) and at least one gateway to the outside. Electricity storage may or may not be present. Electricity sources are not part of the nanogrid, but often a source will be connected only to a single nanogrid. Interfaces to other power entities are through gateways within the nanogrid controller. Nanogrids implement power distribution only and not any functional aspects of the devices (or loads) that connect to the nanogrid. Thus, the components of a nanogrid are a controller, loads, storage (optional), and gateways. Figure 1 is a schematic of a nanogrid. A nanogrid manages the power distributed to its loads. All power flows are accompanied by communications and all communications are bi-directional. Communication - either wired or wireless - is used to mediate local electricity supply and demand using price, both within the nanogrid and in exchanges across the gateways. The nanogrid controller receives requests for power, grants or revokes them, measures or estimates power, and sets the local price. Loads take the price into account in deciding how to operate. Controllers negotiate with each other across gateways to buy or sell power. Battery storage is optional - batteries can increase the reliability and stability of a

nanogrid.

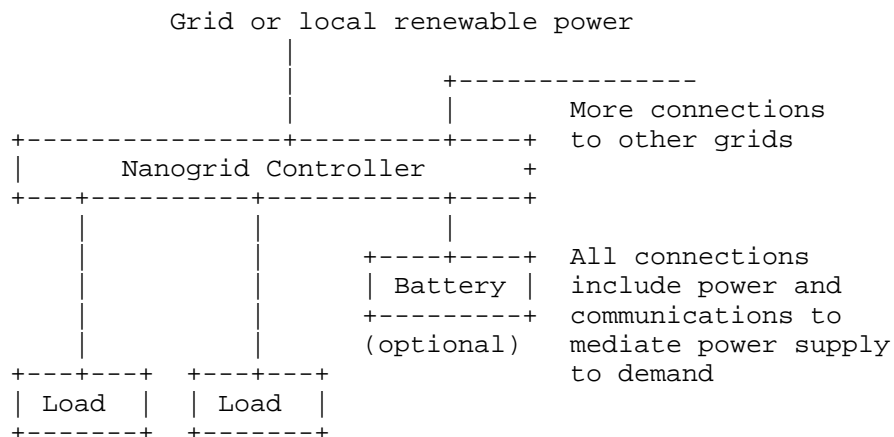


Figure 1: Conceptual diagram of a nanogrid

Controllers may resemble existing Power over Ethernet (PoE) switches, however unlike PoE they need not be limited to one device per port. To set the local price, the controller takes into account the price of any utility grid electricity it has access to, as well as the quantity and price of any local power sources. A nanogrid can exchange power with other nanogrids or with microgrids whenever mutually beneficial (as indicated by relative price). This enables optimal allocation of scarce and/or expensive power among loads and among local grids. A price will typically be a current price and non-binding forecast of future prices, up to one day in advance.

Devices that connect to a nanogrid will ship with default price preference functions that make sense given typical grid prices. When a nanogrid is connected to the grid, the grid price will be a strong influence on the local price, though local generation and storage can dramatically change that dependency. When not grid-connected, the local price will reflect the local supply/demand condition, the estimated replacement cost for battery power (which may be future grid power), and an assessment of battery capacity. Nanogrid policies establish the local price and load policies establish the price a given load is willing to pay.

A core principle is to separate power distribution technologies from functional control technology. Power distribution is envisioned to have three layers: layer 1 is power; layer 2 is power coordination; and layer 3 is device functionality. Nanogrids implement layer 2 to improve the efficiency and flexibility of power distribution and use (layer 1), and isolate power distribution from device functionality

(layer 3). Separating power coordination from functionality has several purposes. In future usage, devices that are in the same room or otherwise need to coordinate functionally will often be powered differently, and devices that share a power infrastructure may not have functional relationships. Separating power distribution into different functional layers allows each function to evolve separately, greatly easing and simplifying the development of new technologies and deploying them alongside existing products.

To develop useful nanogrid technology we need standards for communication internal to nanogrids, and for communication between them via gateways.

Nanogrids use price to mediate their internal supply and demand with attached loads, and to determine how power is acquired from external grids and exchanged between nanogrids. They require energy price information, common communications protocols and interfaces, and standardized semantics.

### 3. Benefits

Nanogrids could offer many benefits, broadly including:

- o Local Renewables
- o Storage and Reliability
- o Security, Privacy, and Reliability
- o System Reliability
- o Demand Response
- o Smart Grid
- o New Electricity Users
- o Disaster Relief
- o Military Applications
- o Reduced Capital Costs
- o Reduced Energy Use
- o Mobile and Off-Grid

Nanogrids could provide smart grid benefits at the small (local) scale, a capability we lack today; smart grid efforts only address grid connected and large scale contexts. Nascent nanogrids are common today in digitally managed forms (technologies including USB and Power over Ethernet (PoE)), and unmanaged ones (vehicles, emergency circuits, etc.). However, they all lack the ability to use price as the core prioritization mechanism and lack the ability to exchange power with each other; a fully functioning "managed" nanogrid can do both. Such future nanogrids could be connected in arbitrary and dynamic networks to each other, to microgrids, and to the utility grid.

Nanogrids are a new mechanism for managing power at the local level, useful in a wide variety of applications. They particularly enable more and better use of local generation (including intermittent renewables) and local storage, as well as facilitate "Direct DC" - powering loads with local renewable power without converting to and from AC. Recent studies have estimated 5-13% electricity savings from Direct DC in residences [DIRECTDC], and local renewables also avoid transmission system losses. Many people value local renewable energy more than grid power and value the reliability and certainty of local storage and off-grid capability.

Nanogrids offer the possibility of moving to a less reliable large-scale grid, providing increased quality and reliability locally, and saving capital and energy in a distributed, bottom-up manner. While the smart grid will better match supply and demand at the large scale, we lack mechanisms to do this at small scales. Nanogrids fill this gap. Microgrids are important and necessary, but lack near-term potential for dramatic scale-up of deployment, lack standards-based plug-and-play technologies, lack comprehensive visibility into individual loads, and lack pervasive use of price. Nanogrids build on standard semiconductor and communications technologies already produced at mass-scale, and can be deployed incrementally and at low capital and installation cost. This will enable them to spread rapidly and quickly become a standard fixture in buildings.

While existing nanogrid technologies enable only relatively small loads, there is no power limit to nanogrid loads or controllers. While nanogrids work best with communicating loads, for legacy devices, with one device per port, the controller can implement the load control function itself for on/off loads, as well as variable loads like lights and motors.

By being directly and correctly responsive to the most local conditions of energy supply, storage, and demand, nanogrids can provide price and other control abilities not possible with other technologies which treat electricity distribution at a more aggregated and abstracted level. Nanogrids are also inherently more flexible and should be less capital-intensive than alternatives, and provide a more nimble infrastructure for local generation and storage.

#### 4. Implications for EMAN

The concept of power interface in the current EMAN drafts is consistent with the interfaces that nanogrids have, both those from controllers to loads, and those at gateways between nanogrids. A load could report via EMAN protocols directly, or a controller could

report information about loads on their behalf; these are both basic EMAN functions. The role that batteries play in nanogrids is consistent with EMAN's treatment of them.

Nanogrids enable bi-directional exchange of power between grids; recent versions of EMAN documents acknowledge this as a possibility and support it (of course, the power flows in only one direction at any given time). Two existing power distribution technologies, UPAMD and HDBaseT, support bi-directional power flows.

Nanogrids have two characteristics that could be challenging for EMAN to handle and deserve further consideration. The first is that grids can be arranged in any topology and may lack a single "root" as the utility grid generally provides. The second is that connections among grids and connections to loads may be intermittent and dynamic. Accommodating these does not seem contrary to the goals of EMAN, but EMAN semantics could be defined in a way which makes doing so difficult or impossible.

## 5. Other Implications

Communication internal to a nanogrid will be specific to the particular physical layer technology. USB, for example, could add nanogrid capability by simply extending the existing protocols it provides for coordinating power distribution on USB links. For PoE, it would be possible to do this with LLDP, or with some higher-layer protocol. Communication between nanogrids will require standards for gateways between them that cover both electrical and communications aspects. IEEE is a likely choice for at least most of this. Some of these may benefit from using IETF protocols, though core to the concept of local power distribution is that it only requires communication between immediately adjacent (electrically-connected) grids - just one hop.

Whether or not the IETF is involved in power distribution protocols, most of the devices in future that are on nanogrids, and the controllers themselves, will likely also implement IETF protocols, so that semantic consistency between the two domains would be extremely beneficial. Just as EMAN provides visibility into device power (measurement and control) at the network level, the IETF may want to in future support management protocols for small (microgrid or smaller) grids (that is, not intruding into the utility grid space where other standards organizations are active).

## 6. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

## 7. Security Considerations

This mechanism introduces no information security vulnerabilities. A security advantage of nanogrids is that they only need to communicate with other grids (or power sources) to which they are directly electrically connected. This requirement for physical connection greatly reduces their vulnerability, and is in sharp contrast to many grid architectures which require communication across many network links.

## 8. Privacy Considerations

Nanogrid gateways need only communicate information about the price and quantity of electricity, not about their internal structure or electricity-consuming loads. This makes them exceptionally protective of privacy.

## 9. References

### 9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

### 9.2. Informative References

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## Abstract

This memo defines a portion of the Management Information Base (MIB), the GreenUsage MIB, for use with network management protocols in the Internet community. In particular, the GreenUsage MIB can be used to monitor the power-on/power-off status of electrical devices.

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## 1. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP).

Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies a MIB module that is compliant to the SMIV2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

## 2. Overview

### 2.1. The GreenUsage monitoring concept

Monitor the power-on/power-off status of electrical devices. If a device is in power-on state beyond business hours, it is wasteful usage of electricity. The GreenUsage concept aims to monitor and reduce this wastage.

This document defines a set of managed objects (MOs) that can be used to monitor the power-on/power-off status of electrical devices.

### 2.2. Terminology

Electrical device: a device that consumes electricity. Power-on/power-off status indicates whether the device is powered on or not. Often it is not possible to get a direct indication of whether a device is powered on or not. But indirect means may be used to infer the power-on/power-off status of a device. For example, if a device shows some network activity, it can be inferred that the device is powered on. Note that it is difficult to infer that a device is powered off. Also, there may be several states between power-on and power-off e.g. sleep state, power-saving state etc.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14, RFC 2119 [RFC2119].

## 3. GreenUsage Monitoring Requirements

Multiple mechanisms may be used to determine whether a device is powered on or not. The mechanisms will depend on the nature of the device. Since the number of devices may be very large, the identification, usage type, and location of devices needs to be addressed with care.

#### 4. MIB Design

The basic principle has been to keep the MIB as simple as possible and at the same time to make it effective enough so that the essential needs of monitoring are met.

The GreenUsage-MIB is composed of the following

- device Table: a list of the devices that will be monitored
- deviceStatus Table: the power-on/power-off status of the devices

## 5. MIB Definitions

### 5.1 The GreenUsage MIB

```
GREENUSAGE-MIB DEFINITIONS ::= BEGIN
 IMPORTS
 MODULE-IDENTITY, mib-2, Unsigned32, OBJECT-TYPE
 FROM SNMPv2-SMI -- RFC 2578
 TimeStamp, MacAddress, TEXTUAL-CONVENTION
 FROM SNMPv2-TC -- RFC 2579
 MODULE-COMPLIANCE, OBJECT-GROUP
 FROM SNMPv2-CONF -- RFC 2580
 SnmpAdminString
 FROM SNMP-FRAMEWORK-MIB
 ;

greenUsageMIB MODULE-IDENTITY
 LAST-UPDATED "201207070000Z" -- 7th July, 2012
 ORGANIZATION "PREDICT Working Group"
 CONTACT-INFO
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Support Group E-mail: xxxxxxxxxxxxxxxx

"

DESCRIPTION

"This MIB module is for monitoring the power-on/power-off  
status of electrical devices.

Copyright (C) The IETF Trust (2012). This version of  
this MIB module is part of RFC XXXX; see the RFC itself for  
full legal notices.

"

-- RFC Ed.: replace XXXX with the actual RFC number & remove this  
-- note

```
REVISION "201207070000Z" -- 7th July, 2012
DESCRIPTION
 "The initial version, published as RFC XXXX."

-- RFC Ed.: replace XXXX with the actual RFC number & remove this
-- note

 ::= { mib-2 YYY1 } -- Will be assigned by IANA

-- IANA Reg.: Please assign a value for "YYY1" under the
-- 'mib-2' subtree and record the assignment in the SMI
-- Numbers registry.

-- RFC Ed.: When the above assignment has been made, please
-- remove the above note
-- replace "YYY1" here with the assigned value and
-- remove this note.

-- -----
-- Textual Conventions
-- -----

GumStatusDetectionMethod ::= TEXTUAL-CONVENTION
 STATUS current
 DESCRIPTION
 "The object specifies the technology which is used
 to detect the power-on/power-off status of a device.
 The enumerated values and the corresponding
 technology are as follows:
 reserved (0): reserved (Not used)
 arpSensing (1): arp packets from the
 device
 neighborDiscoverySensing (2): neighbor discovery
 packets from the device
 icmpEchoProbing (3): ICMP echo packets
 switchMonitoring (4): switch monitoring
 "
 SYNTAX INTEGER
 {
 reserved (0),
 arpSensing (1),
 neighborDiscoverySensing (2),
 icmpEchoProbing (3),
```

```

 switchMonitoring (4)
 }

GumDeviceStatus ::= TEXTUAL-CONVENTION
 STATUS current
 DESCRIPTION
 "The object represents the power-on/power-off
 status of a monitored device.
 unknown (0)
 powerOn (1): device is powered on
 powerOff (2): device is powered off
 sleepMode (3): device is in sleep mode
 powerSavingMode (4): device is in
 powersaving mode
 "
 SYNTAX INTEGER
 {
 unknown (0),
 powerOn (1),
 powerOff (2),
 sleepMode (3),
 powerSavingMode (4)
 }

```

-- The GREENUSAGE MIB has the following 3 primary groups

```

gumNotifications OBJECT IDENTIFIER ::= { greenUsageMIB 0 }
gumObjects OBJECT IDENTIFIER ::= { greenUsageMIB 1 }
gumConformance OBJECT IDENTIFIER ::= { greenUsageMIB 2 }

gumDeviceTable OBJECT-TYPE
 SYNTAX SEQUENCE OF GumDeviceEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table models the device list

 Entries in this table are required to survive
 a reboot of the managed entity.
 "
 ::= { gumObjects 1 }

gumDeviceEntry OBJECT-TYPE
 SYNTAX GumDeviceEntry

```



```
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
 "This entry represents a conceptual row in the
 gumDevice table. It represents a device that
 will be monitored for power-on/power-off status.
 "
INDEX { gumDeviceID }
 ::= { gumDeviceTable 1 }

GumDeviceEntry ::=
SEQUENCE {
 gumDeviceID Unsigned32,
 gumDeviceName SnmpAdminString,
 gumDeviceMacAddress MacAddress,
 gumDeviceType SnmpAdminString,
 gumDeviceLocation SnmpAdminString
}

gumDeviceID OBJECT-TYPE
SYNTAX Unsigned32
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
 "A unique arbitrary identifier for this device."
 ::= { gumDeviceEntry 1 }

gumDeviceName OBJECT-TYPE
SYNTAX SnmpAdminString (SIZE(1..64))
MAX-ACCESS read-create
STATUS current
DESCRIPTION
 "Administratively assigned textual name of this
 device."
 ::= { gumDeviceEntry 2 }

gumDeviceMacAddress OBJECT-TYPE
SYNTAX MacAddress
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "MAC Address of this device.
 If there is no MAC address, this object will be
 inaccessible."
 ::= { gumDeviceEntry 3 }
```

```
gumDeviceType OBJECT-TYPE
 SYNTAX SnmpAdminString (SIZE(1..64))
 MAX-ACCESS read-create
 STATUS current
 DESCRIPTION
 "Administratively assigned textual description about
 usage type of this device."
 ::= { gumDeviceEntry 4 }

gumDeviceLocation OBJECT-TYPE
 SYNTAX SnmpAdminString (SIZE(1..64))
 MAX-ACCESS read-create
 STATUS current
 DESCRIPTION
 "Administratively assigned textual location
 name of this device."
 ::= { gumDeviceEntry 5 }

gumDevUsageTable OBJECT-TYPE
 SYNTAX SEQUENCE OF GumDevUsageEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table models the device usage status

 Entries in this table are required to survive
 a reboot of the managed entity.
 "
 ::= { gumObjects 2 }

gumDevUsageEntry OBJECT-TYPE
 SYNTAX GumDevUsageEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This entry represents a conceptual row in the
 gumDevUsage table. It represents a power-on/power-off
 status of a monitored device.
 "
 INDEX { gumDeviceID, gumDevUsageDetID }
 ::= { gumDevUsageTable 1 }

GumDevUsageEntry ::=
 SEQUENCE {
 gumDevUsageDetID GumStatusDetectionMethod,
```

```

 gumDevUsageDetStatus GumDeviceStatus,
 gumDevUsageDetTimeStamp TimeStamp
}

gumDevUsageDetID OBJECT-TYPE
 SYNTAX GumStatusDetectionMethod
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "The detection method by which the usage status is
 computed."
 ::= { gumDevUsageEntry 1 }

gumDevUsageDetStatus OBJECT-TYPE
 SYNTAX GumDeviceStatus
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "the usage status of the device."
 ::= { gumDevUsageEntry 2 }

gumDevUsageDetTimeStamp OBJECT-TYPE
 SYNTAX TimeStamp
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "the time at which the usage status of the
 device was computed."
 ::= { gumDevUsageEntry 3 }

-- Units of conformance
gumGroups OBJECT IDENTIFIER ::= { gumConformance 1}
gumCompliances OBJECT IDENTIFIER ::= { gumConformance 2}

gumObjectsGroup OBJECT-GROUP
 OBJECTS {
 gumDeviceName,
 gumDeviceMacAddress,
 gumDeviceType,
 gumDeviceLocation,
 gumDevUsageDetStatus,
 gumDevUsageDetTimeStamp
 }
 STATUS current
 DESCRIPTION
```

```
 " A collection of objects for basic GreenUsage
 monitoring."
 ::= { gumGroups 1 }

-- Compliance statements
gumCompliance MODULE-COMPLIANCE
 STATUS current
 DESCRIPTION
 "The compliance statement for SNMP entities
 which implement the GREENUSAGE-MIB
 "
 MODULE -- this module
 MANDATORY-GROUPS { gumObjectsGroup
 }
 ::= { gumCompliances 1 }

END
```

## 6. Security Considerations

There are no management objects defined in this MIB module with a MAX-ACCESS clause of read-write. Some of the readable objects in this MIB module (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control even GET and/or NOTIFY access to these objects and possibly to even encrypt the values of these objects when sending them over the network via SNMP. These are the tables and objects and their sensitivity/vulnerability:

- gumDeviceName,
- gumDeviceMacAddress,
- gumDeviceType,
- gumDeviceLocation,
- gumDevUsageDetStatus,
- gumDevUsageDetTimeStamp

The above objects may be used to identify users and their activities. Thus these objects may be considered to be particularly sensitive and/or private.

SNMP versions prior to SNMPv3 did not include adequate security. Even if the network itself is secure (for example by using IPsec), even then, there is no control as to who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in this MIB module.

It is RECOMMENDED that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

Further, deployment of SNMP versions prior to SNMPv3 is NOT RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to enable cryptographic security. It is then a customer/operator responsibility to ensure that the SNMP entity giving access to an instance of this MIB module is properly configured to give access to the objects only to those principals (users) that have legitimate rights to indeed GET or SET (change/create/delete) them.

## 7. IANA Considerations

IANA should assign

1. a base arc in the 'mib-2' (standards track) OID tree for the 'greenUsageMIB' MODULE-IDENTITY defined in the

GREENUSAGE-MIB.

## 8. References

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## 9. Acknowledgements

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Use Cases for Power-Aware Networks  
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Abstract

Power Aware Network (PANET) has attracted strong interest from both carriers and vendors. Several use cases are investigated in this document to exhibit the potential usage of PANET in both backbone and data center networks.

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## 1. Introduction

Networks are usually provisioned for peak hours and potential network failures and network devices are powered on all the time without consideration on energy efficient. In practice, however, the traffic load of a network is low most of the time and redundant network equipments are used for failure recovery occasionally.

In the past years, vendors had paid a great effort on improving the network energy efficiency at the device level: when the traffic load is low, a network equipment should accordingly operate with less power draw. However, network equipments have never become fully power proportional. Even few or no traffic is carried, a powered-on network device draws a considerable amount of power, which means energy is being wasted. There is an explicit gap for idle network devices to be shut down or put into sleeping state to save more energy. In order to fill this gap, the network control plane and management system should become power aware to coordinate network devices therefore the sleeping or off network devices do not bring disruption to the network.

This documents investigated several use cases on power aware network which include both backbone networks and data center networks. As for the energy efficiency of backbone networks, only intra-domain use cases are considered. Trying to be energy efficient in the inter-domain scale seems technically feasible, for now though, energy efficient solutions can easily end up lack of business motivation, this document leaves them for future study.

### 1.1. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

### 1.2. Terminology

PANET: Power Aware NETwork

## 2. Power Awareness in Backbone Networks

The IETF Energy Management (eman) Working Group works on the management of power-aware network devices. Basically, the power states of power-aware network devices are reported and recorded in MIB. However, there is a gap on how to make use of this kind of data to achieve energy efficient networks. With energy aware control plane [power-control], it becomes possible to make use of these measurements and power control ability to achieve the energy

efficiency of a whole network.

This section lists several use cases for backbone networks. Take a router system as an example, the start-up of it may take several minutes and the stabilization of it may takes much longer time. It is unrealistic to switch off and on a whole node in backbone networks frequently to achieve energy efficient, so this document only investigates the cases in which links (i.e., links' attached components) are shut-down for energy conservation.

### 2.1. Use Case 1: Sleeping Links

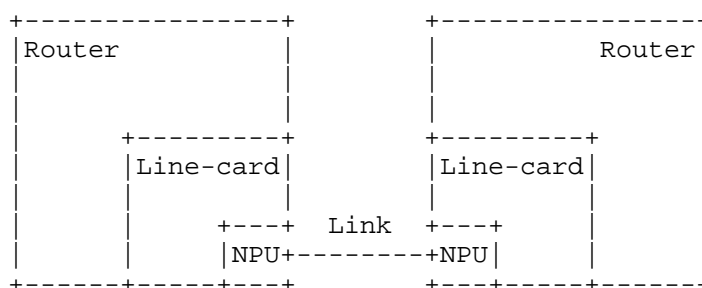


Figure 2.1: Power Aware Line-cards

The power draw on line-cards occupies a great portion in the total power consumption of a whole routing system. For high-end routers, this portion may be higher than 50%.

Network devices and their processing capacity are provisioned for worst cases such as traffic burst and busy hours. Most of the time, the network is lightly loaded. Unfortunately, the power consumption of network devices is not proportional to the traffic load on them. Even there is no load on them, there is still a considerable base power consumption. Unlike personal PCs which can be shut down or enter power saving modes (such as sleeping), network devices are powered on and running even they are idle. This reality means that the network is wasting powers.

The conception that "a link is put into sleep state" is frequently mentioned. In this document, this conception is formalized as follows. The coupled end-points (such as interfaces, NPU or whole line-cards) attached to a idle link (as shown in Figure 2.1) enter the sleeping mode to save energy.

Traffic aggregation are used to create the opportunity for more links to become idle. This process can be automated through the control plane, such as Traffic Engineering [GreenTE].

The essentials of this use case:

- o Devices to be Power Aware: Routers and their line-cards.
- o What actions to take: NMS measures the traffic load and power profile each link [eman]; Routers execute the green TE algorithm; Routers send out signals to trigger the power-on/power-off of a NPU on a line card.

## 2.2. Use Case 2: Composite Links

A composite link is logical link composed of multiple physical [I-D.ietf-rtgwg-cl-requirement]. The composite link attached end-points are responsible to map traffic onto the component links and maintain the state of the composite link. Power awareness can be applied to composite links as well. When the traffic volume on the composite link is low, some component links can be shut down to conserve energy consumption. When the traffic volume becomes high, the sleeping members links can be waken up to absorb the traffic load.

Compared to use case 1, the advantage of executing energy saving for composite link is that the connectivity of the composite link does not suffer unless all the component links are cut off. In this way, the control plane of the component link is not disrupted. In other words, when the end points of the composite link execute the energy conservation action, they can do it in a distributed way and decisions are made locally.

The essentials of this use case:

- o Devices to be Power Aware: Composite links attached end-points.
- o What actions to take: NMS measures the traffic load and power profile of component links; Attached end-points adaptively turn-on/turn-off component links according to the traffic load on the composite link.

Use case 1 and use case 2 may be combined in a real network to achieve more energy saving.

## 3. Power Aware in Data Center Networks

Servers, network devices (ICT equipments) are intensively placed in Data Centers. In comparison with ISP backbone networks, the operating of Data Center Networks are more power hungry. The growing amount of energy consumed by a Data Center has led to high operating costs.

Although non-ICT equipments, such as lighting and air conditioners,



in a Data Center consumes a notable large amount of energy as well, this section concentrate on talking about right sizing ICT equipments for energy conservation. Energy conservation of non-ICT equipments are out of the scope of this document.

### 3.1. Server Consolidation

With virtualization technology, Virtual Machines (VMs) can be consolidated to fewer physical servers while idled servers can be put into power saving mode or turned off to achieve energy conservation of the whole Data Center. Virtualization technology allows the administration of a Data Center Network respond rapidly to the fluctuating capacity requirements.

Through monitoring of the work load and power profile, the Data Center Network Management System (Orchestrator) can judge in which hours workload is high and in which hours workload is low. For example, nights are generally off-peak hours in which workload is at low level. Virtual machines can be moved to fewer servers therefore idle servers can powered off or put into sleep to save energy. Before peak hours (e.g., in the morning), sleeping or powered off servers should be waken up to accommodate more active virtual machines (VMs).

The essentials of this use case:

- o Devices to be Power Aware: All servers in a data center.
- o What actions to take: NMS measures the work load and power profile of servers; The orchestrator of a Data Center Network adaptively triggers the actions of VM migration, the power-off and power-on of servers according to the workload.

### 3.2. Power Aware Load Balancing Among Multiple Sites

An enterprise may have multiple data centers which spread out in different geographic locations. Generally, the ICT resources in these data centers are well replicated and a job can be directed to any of them for execution. These data centers form a large distributed Internet scale systems and the price of power supply for them varies between two different locations. The operating cost of such a system highly depends on the load balancing scheme. Being power aware, the system can map requests to locations where energy price is cheaper.

This use case makes use of the difference of the prices of power draw in different locations. The orchestration of data centers (the NMS) is responsible for monitoring the power profile and work load of the ICT devices located in different data centers.

The essentials of this use case:

- o Devices to be Power Aware: All ICT-equipments in a data center.
- o What actions to take: ICT devices report their work load and power consumption profile to NMS. The orchestration (NMS) of the Data Center Networks adaptively map the request onto sites in consideration of reducing the overall power bill of the system.

### 3.3. Elastic Network Infrastructure

Traffic load of a data center is generated by the work load on servers and applied on the network infrastructure. The changing work load determines that the traffic load varies as time goes on. However, network devices are always left on even though the traffic load fluctuates, which wastes energy inevitably when the traffic load is low.

Ideally, the network infrastructure is elastic and can fit the traffic pattern with minimum subset to minimize the energy consumption of the network infrastructure. For now, Data Center Networks generally work at layer 2. So this use case should be realized through manipulating switching paths, in comparison with the power aware routing at layer 3. Openflow switches of SDN may be utilized to achieve this goal [ElasticTree].

The essentials of this use case:

- o Devices to be Power Aware: All network equipments in a data center.
- o What actions to take: Network devices report their traffic load and power consumption profile to NMS. The orchestrator (NMS) of a Data Center Network adaptively build the switching paths upon the network infrastructure. The idled links are put into power saving mode (e.g., sleeping), so that the network infrastructure becomes energy efficient.

### 6. Security Considerations

This document raises no new security issues.

### 7. IANA Considerations

No new registry is requested to be assigned by IANA. RFC Editor: please remove this section before publication.

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