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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 '7fffffff'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 '7fffffff'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.

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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.

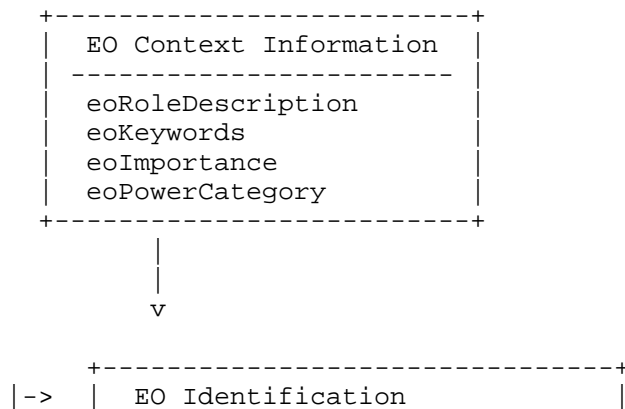
```
+-- eoTable(2)
|
|  +- eoEntry(1) [entPhysicalIndex]
|  |
|  |  +-- r-n PethPsePortIndexOrZero      eoEthPortIndex(1)
|  |  +-- r-n PethPsePortGroupIndexOrZero  eoEthPortGrpIndex(2)
|  |  +-- r-n LldpPortNumberOrZero         eoLldpPortNumber(3)
|  |  +-- rwn MacAddress                   eoMgmtMacAddress(4)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

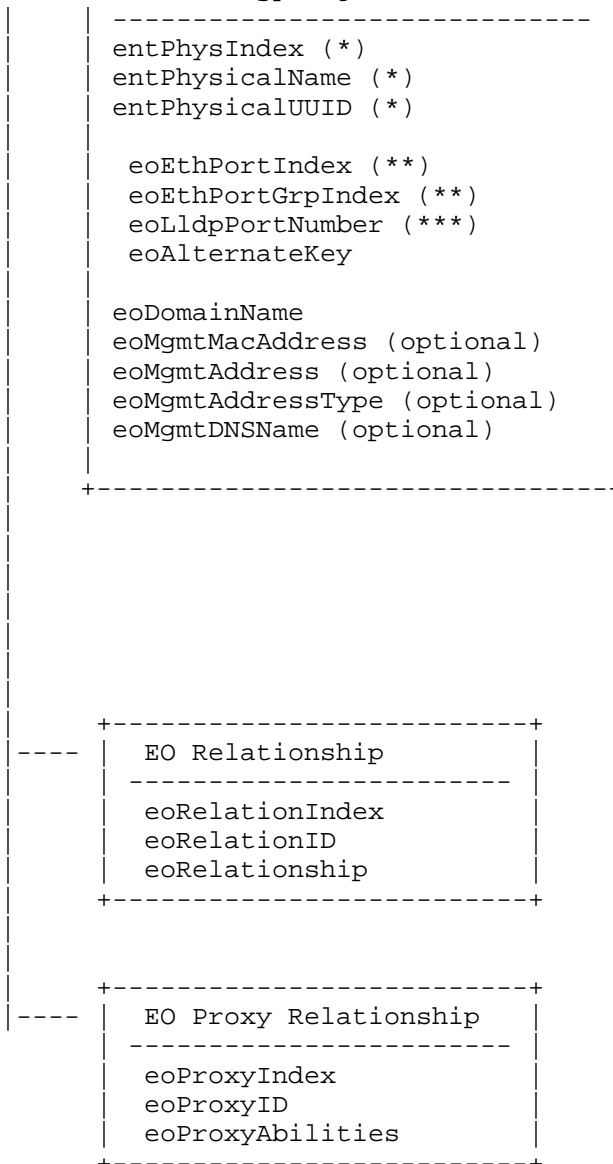
```

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

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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)

```

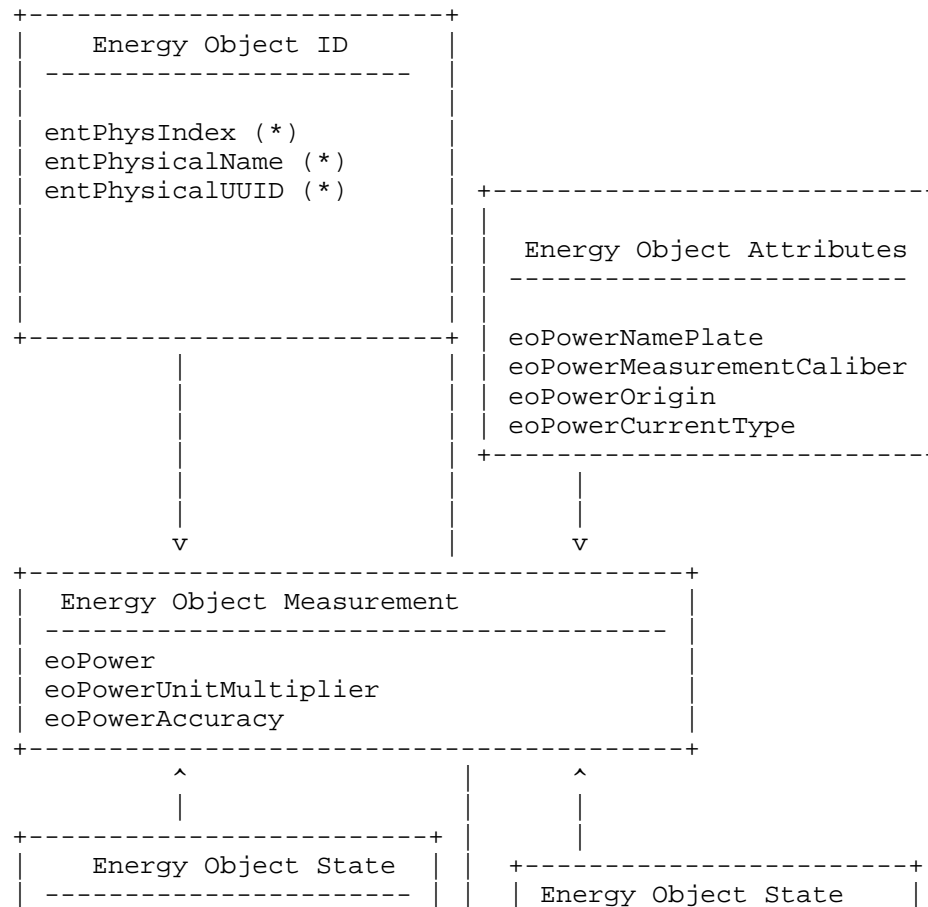


```

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|
| +-- r-n Integer32
| | 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.



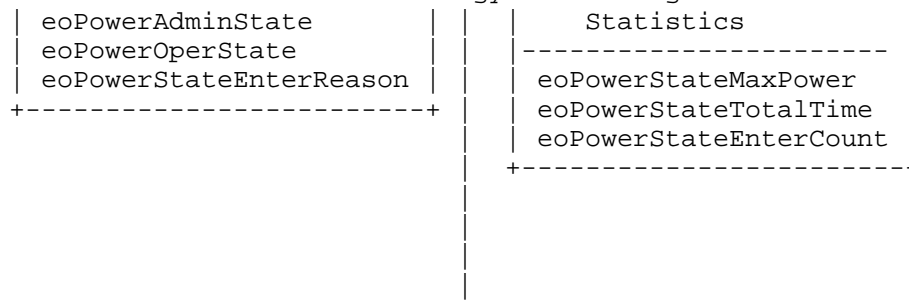
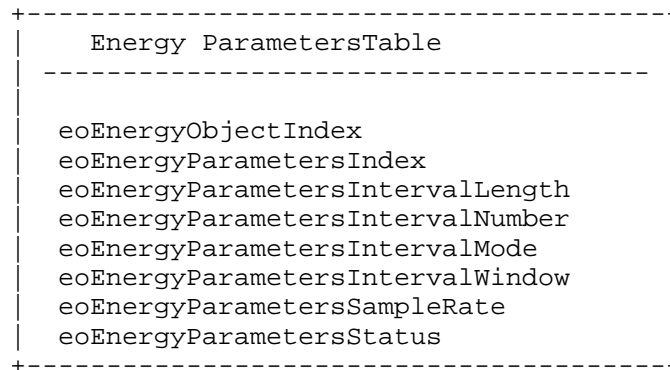


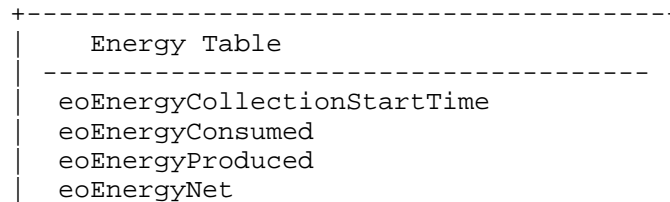
Figure 1:UML diagram for energyObjectMib

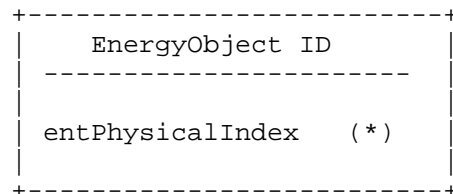
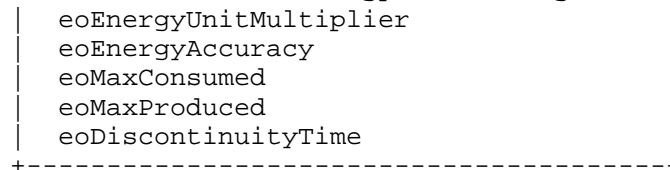
(\*)    Link with the ENTITY-MIB

V

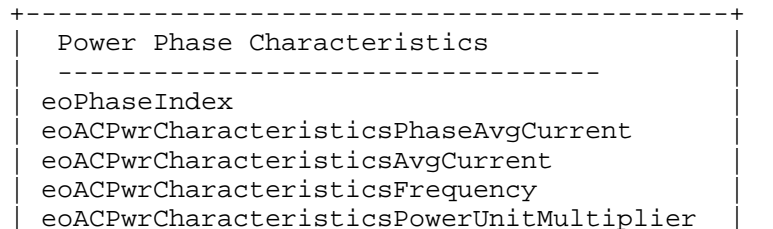
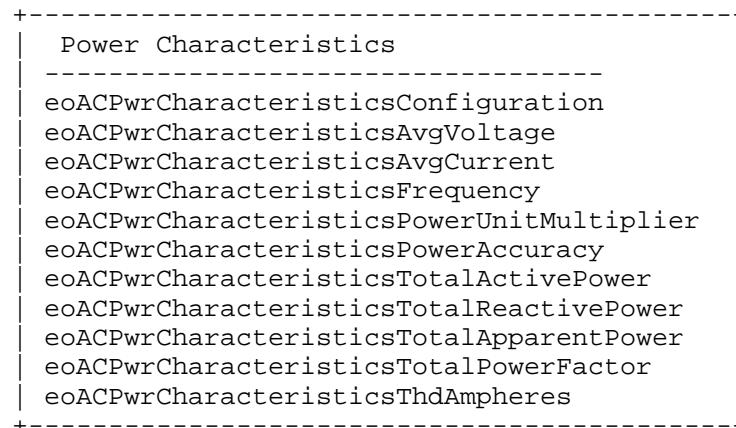


V





↓  
v



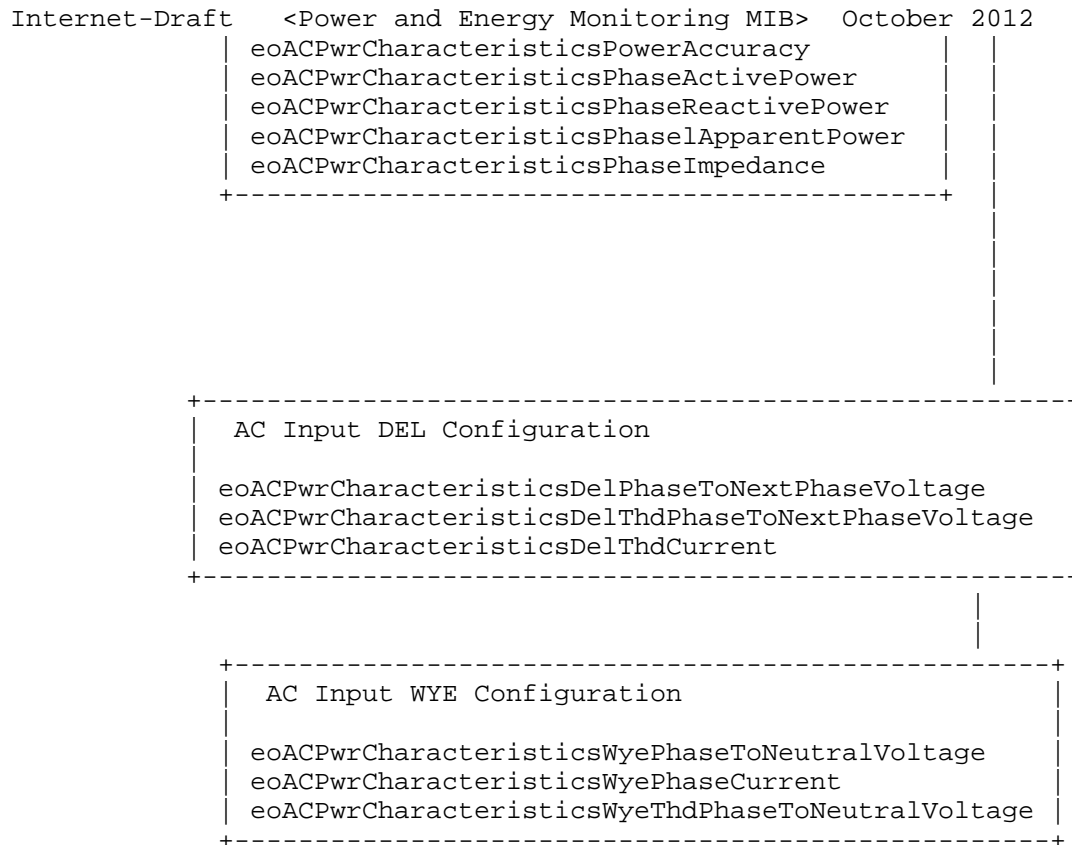


Figure 2: UML diagram for the powerCharacteristicsMIB

(\*) 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

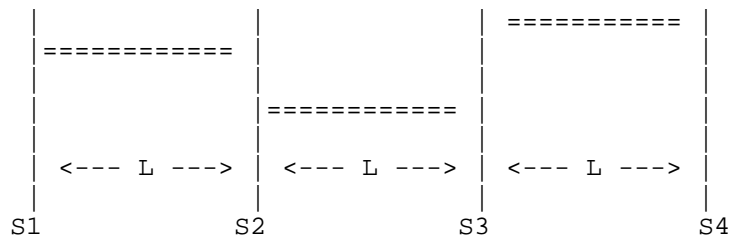


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 Energy Object, the duration of measurement intervals in seconds,  
 (eoEnergyParametersIntervalLength), the number of successive  
 intervals to be stored in the eoEnergyTable,  
 (eoEnergyParametersIntervalNumber), the type of measurement  
 technique (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.



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

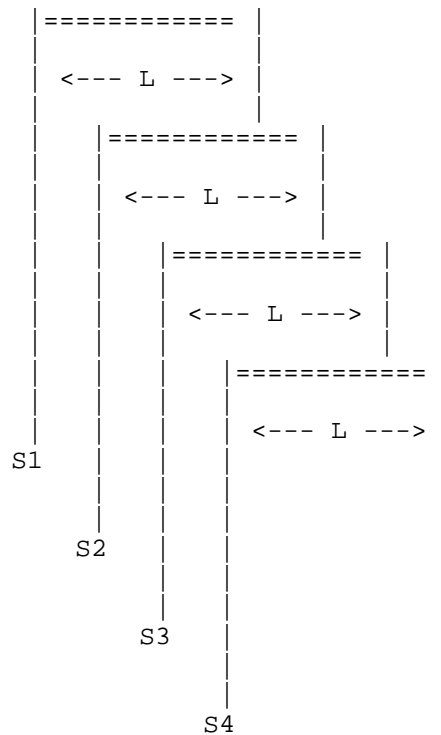
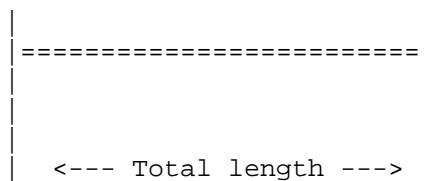


Figure 5 : Sliding eoEnergyParametersIntervalMode

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.

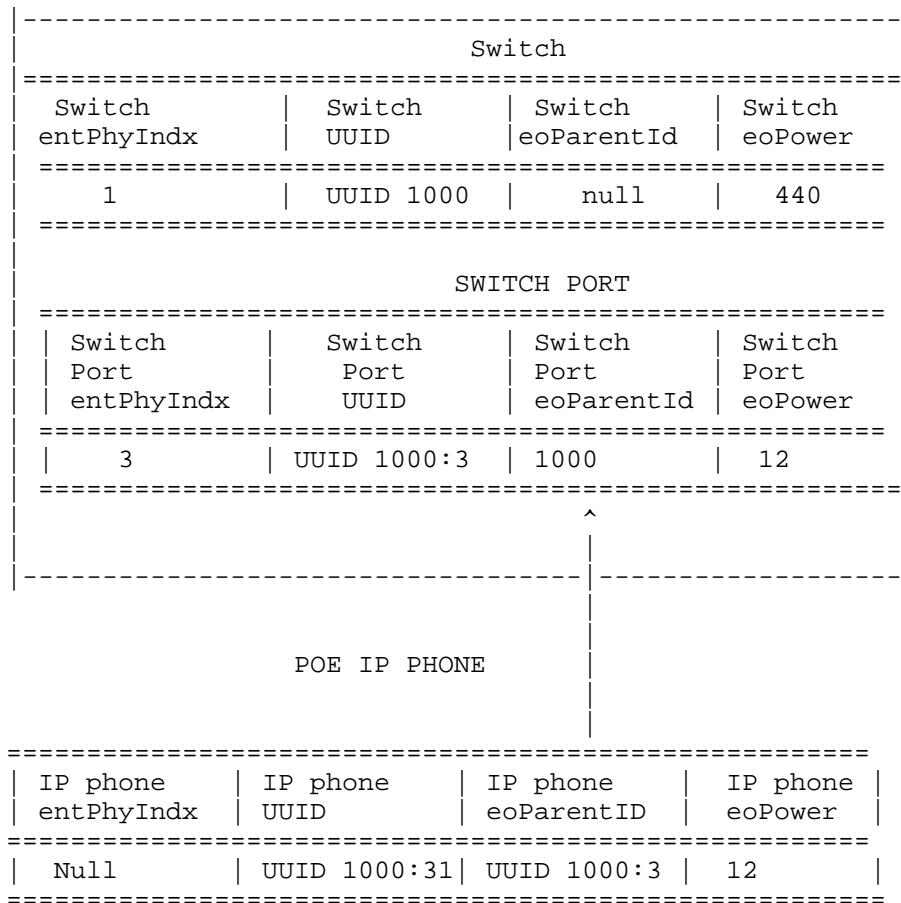
The IP phone consumes power from the PoE switch, while the PC  
consumes power from the wall outlet.

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:

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#### 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

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                   "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

        "WG charter:

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

    Mailing Lists:

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

    To Subscribe:

<https://www.ietf.org/mailman/listinfo/eman>

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Archive:  
<http://www.ietf.org/mail-archive/web/eman>

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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

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



Internet-Draft <Power and Energy Monitoring MIB> October 2012  
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 and device components within or connected to communication networks. 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 Attributes, and Battery. Additionally the framework models relationships and capabilities between Energy Objects.

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## OPEN ISSUES:

Are Tracked via Issue Tracker. See

<https://trac.tools.ietf.org/wg/eman/trac/report/1>

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## 1. Introduction

Network management is often divided into the five main areas defined in the ISO Telecommunications Management Network model: Fault, Configuration, Accounting, Performance, and Security Management (FCAPS) [X.700]. Not covered by this management model is Energy Management, which is now becoming a critical area of concern worldwide as seen in [ISO50001].

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 such devices.

The devices, or components of these devices, can then be monitored and controlled. Monitoring includes power, energy, demand, and attributes of power. Control for energy can be achieved by setting devices or components power state. If a device contains batteries, these can be also be monitored and controlled.

The most basic example of Energy Management is a single device reporting information about itself. However, in many cases, energy is not measured by the device itself, but by a meter located upstream in the power distribution tree. An example is a power distribution unit (PDU) that measures energy supplied to attached devices and reports this to an energy management system. Therefore, devices and their components are recognized as having relationships to other devices or components in the network from the point of view of energy management. There are further relationships between devices and components, respectively, including aggregation relationship, metering relationship, power source relationship, and proxy relationship.

### Energy Management Documents 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 Object Context MIB [EMAN-OBJECT-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 Attributes 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].

Some terms have a NOTE that is not part of the definition itself, but is present to take into account differences between terminologies of different standards organizations or to add a comment to help clarify the definition.

### 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]

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]

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 ISO-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).

#### 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 (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. For EMAN we use kilowatts.

#### Power Attributes

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

#### 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.

#### Energy Control

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

#### 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

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 that is considered one unit of management.

#### Energy Object Identification

Energy Object Identification is a set of attributes that enable an Energy Object to be universally unique or linked to other systems.

#### Energy Object Context

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

## Energy Object Relationship

An Energy Object Relationship is an association among Energy Objects

### NOTES

1. Relationships can be named and could include Aggregation, Metering, Power Source, and Proxy.

Reference: Adapted from [CHEN]

## Aggregation Relationship

An Aggregation Relationship is an Energy Object Relationship where one Energy Object aggregates Energy

Management information of one or more other Energy Objects.  
The aggregating Energy Object has an Aggregation  
Relationship with each of the other Energy Objects.

#### Metering Relationship

A Metering Relationship is an Energy Object Relationship where one Energy Object measures power, energy, demand or power attributes of one or more other Energy Objects. The measuring Energy Object has a Metering Relationship with each of the measured objects.

#### Power Source Relationship

A Power Source Relationship is an Energy Object Relationship where one Energy Object provides power to one or more Energy Objects. These Energy Objects are referred to as having a Power Source Relationship.

#### 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.

## Energy Object Parent

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

#### 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.

#### 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]

#### Power State Set

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

#### Nameplate Power

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

### 3. Issues Specific to Energy Management

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.

Internet-Draft

<EMAN Framework>

February 2013

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 server, or a printer
- switches, routers, base stations, and other network equipment and middleboxes
- 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

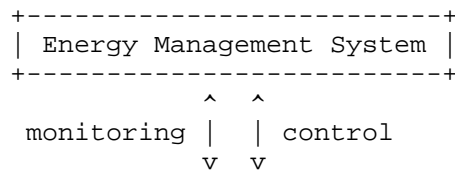
There may also exist varying protocols deployed among these power distributions and communication networks.

An Energy Management framework should also apply to these types of separate networks as they connect and interact with a communications network.

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

Energy Management has particular challenges in that a power distribution network is used 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.

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





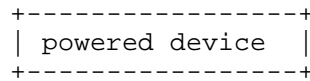


Figure 1: Basic energy management scenario

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.

WRT to Energy management there nothing new for faults, config, performance or security management. We can re-use those aspects of network management for an EnMS. But when there are aspects specific to EM then this framework adds them. For example with faults we can re-use rmon or snmp traps. For security existing means like SNMPv3 security can be used.

### 3.1. 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 many devices receive Power from unmanaged supply systems, the number of manageable power supply devices is increasing.

In datacenters, for example, many Power Distribution Units (PDUs) allow the EnMS to switch power individually for each socket and also to measure the provided Power. This is an

action much different from 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 itself, but with an external device (in this case, the PDU)

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 simple device such as a 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.

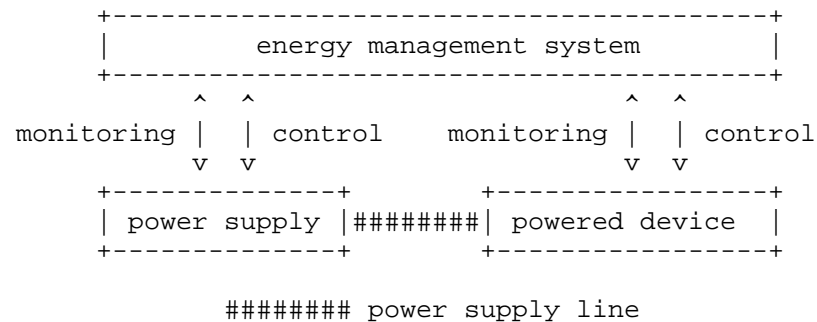


Figure 2: Power Supply

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.

#### 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(s) 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.

## 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 for the EnMS to discover the full list of powered devices connected to a power supply line, as in Figure 3.

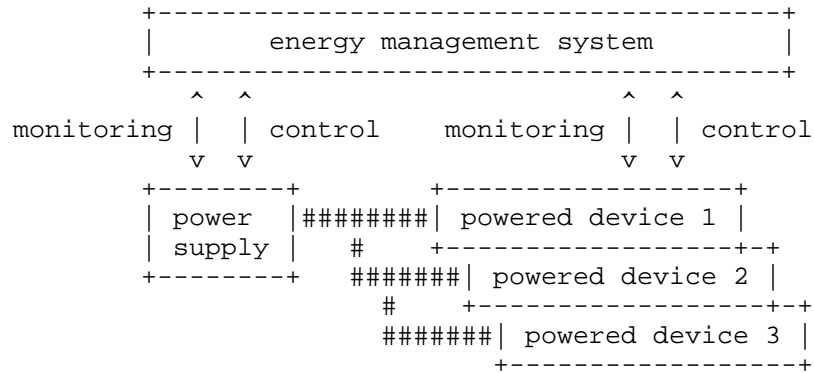


Figure 3: Multiple Powered Devices Supplied  
by Single Power Line

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.

## 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.

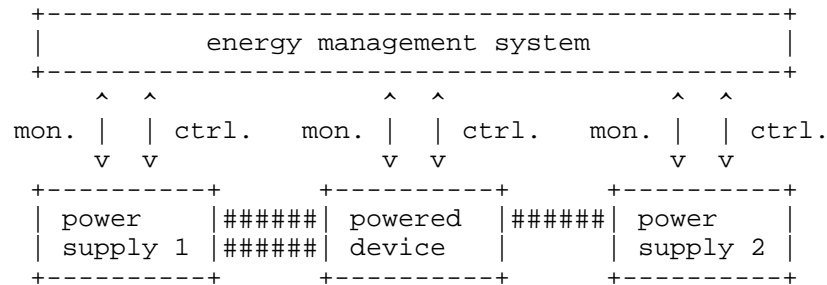


Figure 4: Multiple Power Supply for Single Powered Device

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.

#### Bidirectional Power Interfaces

Some power technologies (mostly low power DC) allow power to be delivered bi-directionally. In the example, energy stored in batteries on one device can be delivered back to a power hub which redirects the power to another device. In this situation, the interface can function as both an inlet and outlet (at different times).

A Power Interface can model a power inlet or a power outlet, depending on the conditions. Information of interest Power Interfaces include the power direction, as well as the energy received, provided, and the net result.

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 PD and in many cases also the PSE.

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.

#### Remote Power Supply Control

There are three ways for an energy management system to change the Power State of 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 devices 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.

#### 3.2. 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

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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.

#### 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.).

An 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.

#### 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.

### 3.3. 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 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.

#### 3.4. Device and Device Components

While the typical focus of energy management is entire powered devices, sometimes it is desirable to manage individual components of devices, such as line cards, fans, disks, etc.

This framework uses a much simpler model for components than for entire devices. The concept of Power Interfaces is not used between a device and its contained components. Reporting of energy-related quantities for individual components is limited to the most important ones. Simplifications for components in this framework include

- o identifying components like devices but without distinct context information,
- o reporting a containment relationship to the containing device,
- o inheriting all context information from the containing device,
- o not modeling power interfaces and power lines between the a component and its containing device or other components,
- o only reporting real power and energy values for components,
- o supporting power state monitoring and control for components.

In rare cases where there is a need to model components of a device in more detail, components of a device can be modeled as an individual device. Then all considerations for devices also apply to these components. The overhead of this model is higher and it should be applied only when needed. If used, it is not necessarily visible whether or not a set of components belongs to a single device, but for energy management purposes this might not be of high relevance.



### 3.5. 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 normalized 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).
- 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).

## 4. Energy Management Abstraction

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

#### 4.1. Energy Object and Energy Management Domain

A meter is a type of device and any device can perform metering.

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 can be any collection of devices in a building but is recommended to 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.

#### 4.2. 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 socket, an AC power cord attached to a device, an 8P8C (RJ45) PoE socket, etc.

#### 4.3. Energy Object Identification and Context

##### Energy Object Identification

A Universal Unique Identifier (UUID) [RFC4122] MUST be used to uniquely and persistently identify an Energy Object. Ideally the UUID should be used to distinguish the Energy Object among all Energy Management Domains within the EnMS.

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.

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 [CISCO-EW]:

- . 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]

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, 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".

#### 4.4. 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 a view of wiring topology. For example: a data center server receiving power from two specific Power Interfaces from two different PDUs.

Note: A power source relationship may or may not change as the direction of power changes between two Energy Objects. The relationship may remain to indicate the change of power direction was unintended or an error condition.

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 management (monitoring and/or control).

In many situations, the wiring, metering, and 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 is 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 SHOULD keep track of its Energy Object Parent(s) along with the Energy Object Relationships type(s). The Energy Object Parent SHOULD keep track of its Energy Object Child(ren), along with the Energy Object Relationships type(s).

#### 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.

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 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.

#### 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.

## 4.5. 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 3.5) 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.

## 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.

Electricity is usually billed in kilowatt-hours (not megajoules, the SI units). Similarly, battery charge is often measured as miliamperes-hour (mAh) instead of the SI unit coulomb. The units used in this framework are: W, A, Wh, Ah, V.

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 Attributes

Given a power measurement, it may be desirable to know additional power attributes associated with that measurement.

## Optional Power Quality

The information model should adhere to the IEC 61850 7-2 standard for describing AC measurements.

## 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.

## 4.6. 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 requested.

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 [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.

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] and [DMTF] standards, several intermediate operational states have been defined.

There are twelve Power States, that expand on [IEEE1621]. The expanded list of Power States are derived from [CISCO-EW] and 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.



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 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)       |
| 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 5: Comparison of Power States

#### 4.7. 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.

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

#### 4.8 Using Device Relationships to Create Topologies

The reference models here define physical and logical topologies of devices 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.

##### 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.

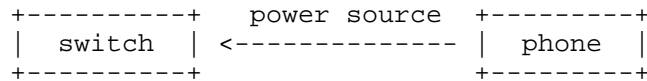
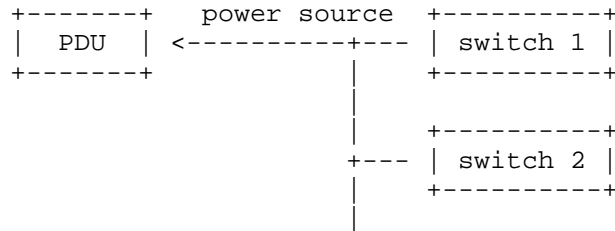


Figure 6: Simple Power Source

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.



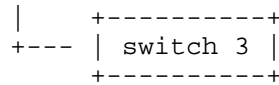


Figure 7: Multiple Power Source

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.

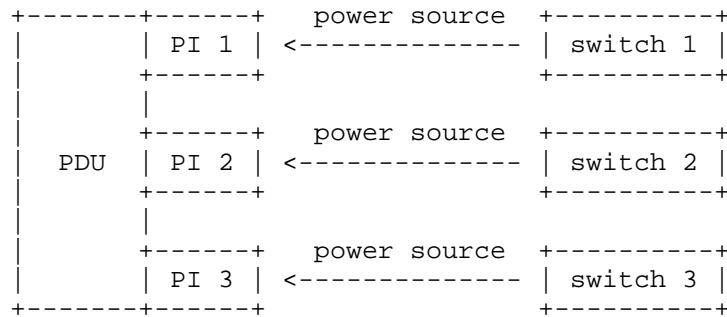
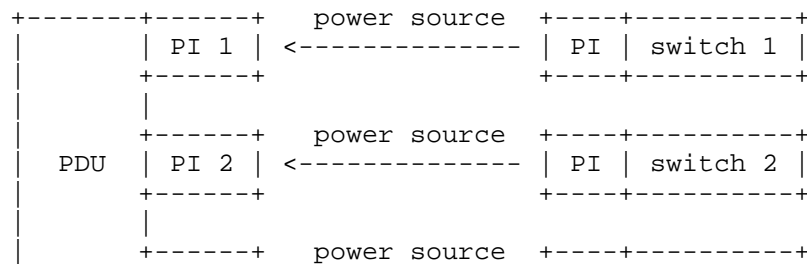


Figure 8: Power Source with Power interfaces

Power interfaces may also be modeled at the receiving device, for examples for consistency.



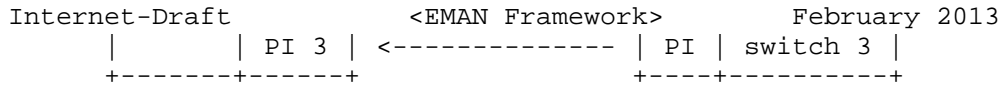


Figure 9: Power Interfaces at Receiving Device

Power Source relationships are between devices and their interfaces. They are not transitive. In the examples below there is a PDU powering a switch powering a phone.

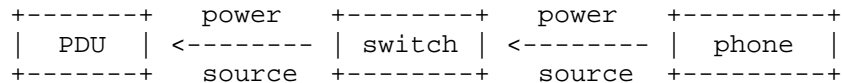


Figure 10: Power Source Non-Transitive

Power Source Relationships are between the PDU and the switch and between the switch and the phone. Transitively , there exists a Power Source Relationship between the PDU and the phone. .

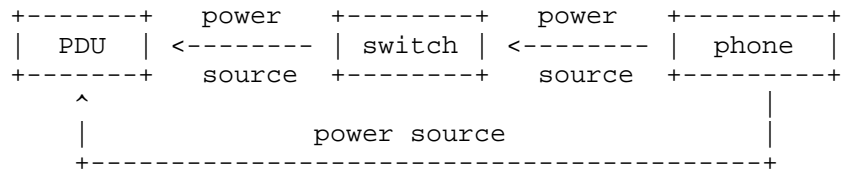


Figure 11: Power Source Transitive

## Metering Topology

### Case 1: Metering between two devices

The 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 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 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 possible with values measured at the power receiver being reported for the power provider.

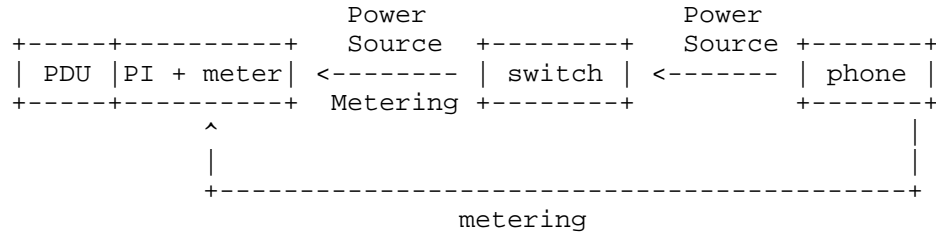


Figure 12: Direct and One Hop Metering

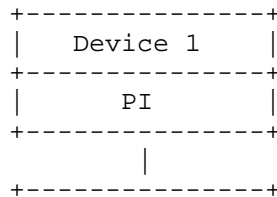
#### Case 2: Metering at a point in power distribution

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 13.





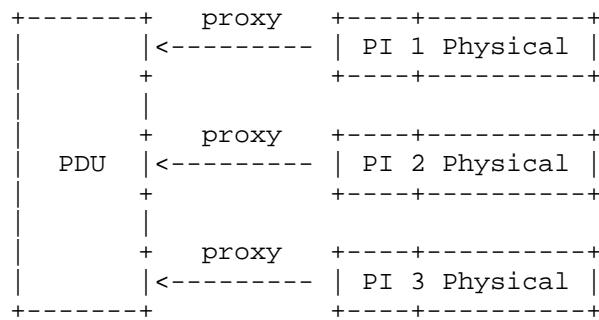


Figure 15: Proxy Relationship Virtual and Physical

### Aggregation Topology

Some devices 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.

An Aggregation Relationship is an Energy Object Relationship where one Energy Object (called the Aggregate 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.

The functions that the aggregation point may perform include the calculation of values such as average, count, maximum, median, minimum, or the listing (collection) of the aggregation values, etc.

Based on the experience gained on aggregations at the IETF [draft-ietf-ipfix-a9n-08], the aggregation function in the EMAN framework is limited to the summation.

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 SHOULD BE instantiated to represent a

summation when it is not obvious from the powering topology or a device to component containment.

The Aggregation Relationship is then specified between the Energy Object device containing aggregate values and each of the other Energy Object devices for which the aggregation is reported. If it does not exist, a new Aggregate Energy Object specific for the Aggregation Relationship MUST be created.

EDITORS NOTE: add an outlet gang example and expand below.

A method to report on collections and summations of data is to create special pseudo-devices. These could be tagged in the MIB as not being a real device, but this may not be needed. ThisA pseudo-device would have no power PIs Power Interfaces, as to make clear that it does not interact with the real power world. It contains components which are actually entities from real devices and can be any combination of devices, PIs, and real components. Most commonly, a pseudo-device would contain a consistent set of entities -

- a set of devices, a set of PIs, or a set of components. The power/energy values for the entire pseudo-device would be the sum of the components, as on a normal device. This provides an easy way to access the sum, as well as full documentation of what the components of that sum are. This method is completely flexible and adds no complexity to the EMAN framework or MIBs. Implementation of this mechanism would be completely optional for EMAN devices; likely most would not.

When aggregation occurs across a set of entities, values to be aggregated may be missing for some entities. The EMAN framework does not specify how these should be treated, as different implementations may have good reason to take different approaches. One common treatment is to define the aggregation as missing if any of the constituent elements are missing (useful to be most precise). Another is to treat the missing value as zero (useful to have continuous data streams).

The specifications of this aggregation function are out of scope of the EMAN framework, but must be clearly specified by the equipment vendor.



EDITOR'S NOTE: 4 solutions discussed on December 12th

- pseudo device. Aggregate Energy Object
- A semantic field (ex: summation): extra index in every measurement MIB table.
- Multiply the variables => doesn't work
- Remove aggregation

PREFERRED: take the proposal from Bruce (below) and let's call pseud-device differently. Example Aggregate Energy Object

#### 4.9 Generalized Relationship Model

As displayed in Figure 15, 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 object context MIB [EMAN-OBJECT-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.

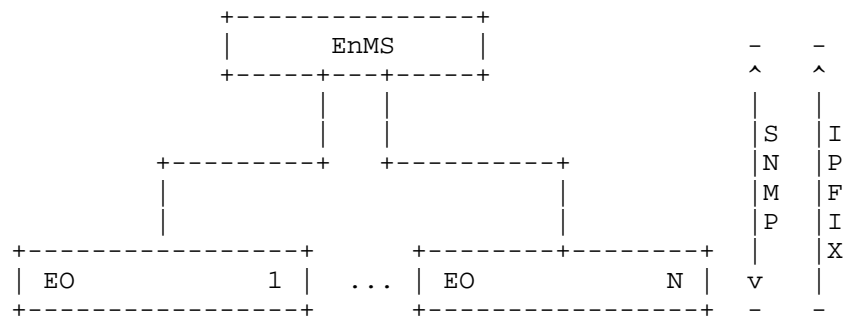


Figure 15: Simple Energy Management

As displayed in the Figure 16, 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.

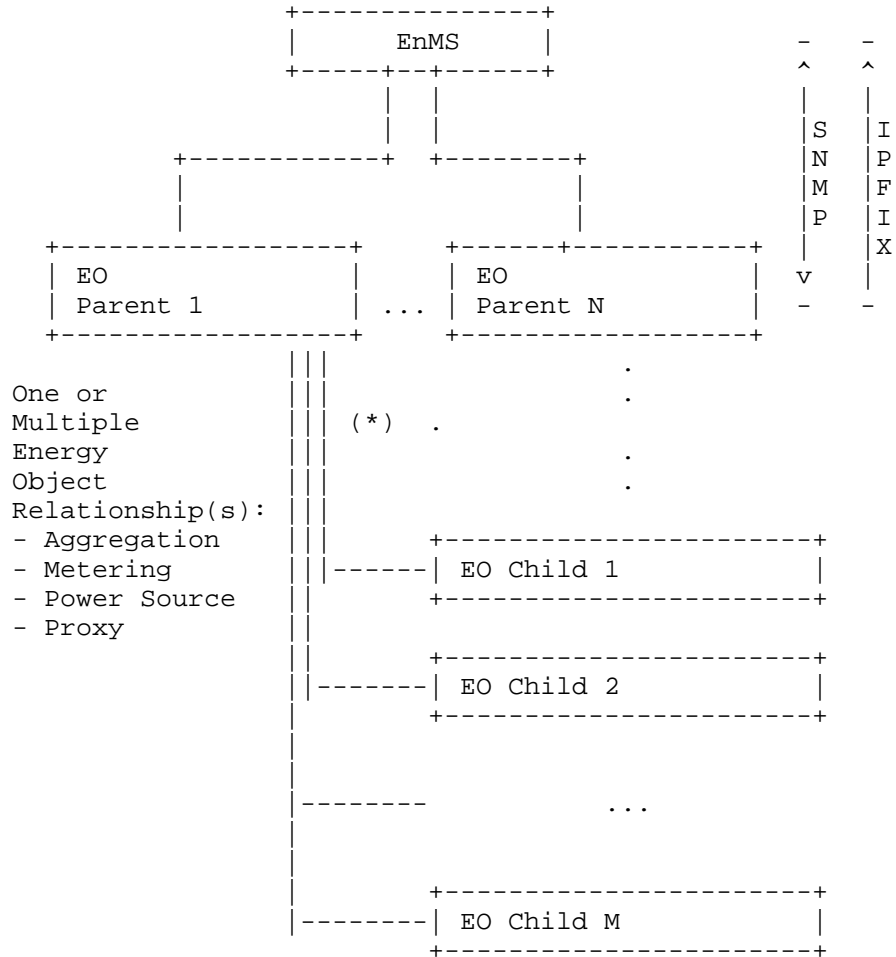


Figure 16: Complex Energy Management Model

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(s) or one with distributed Energy Management via the Energy Objects within the deployment.

Given the pattern in Figure 16, 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.

(\*) If there is any communication between the Energy Object Parent and Energy Object Children, it can be via EMAN and SNMP (or IPFIX) but may be any other protocol IP or otherwise.

In the [EMAN-OBJECT-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:

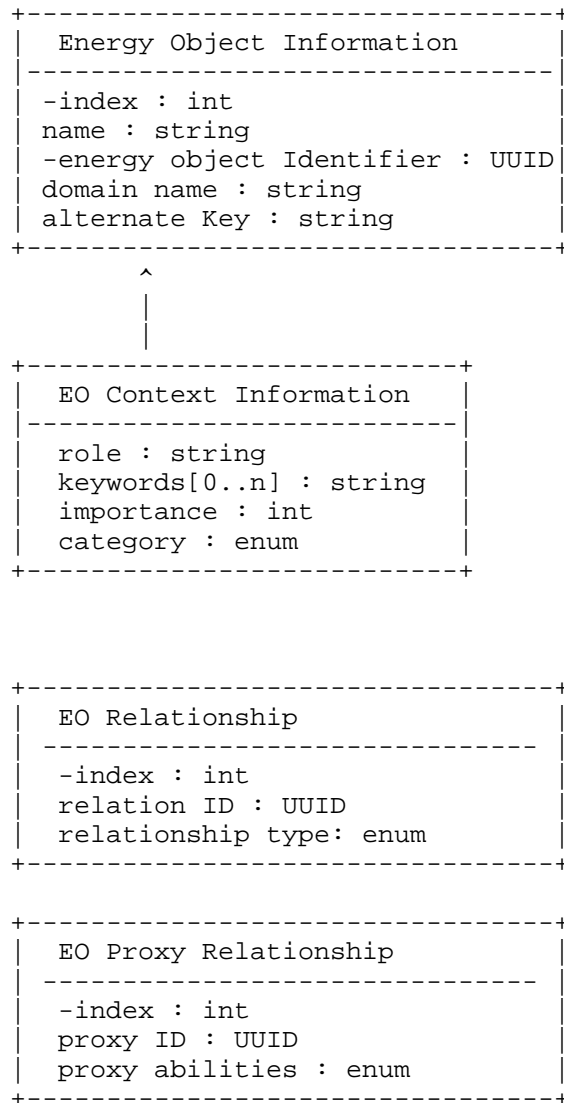
"Each physical component may be modeled as 'contained' within another physical component. A "containment-tree" is the conceptual sequence of entPhysicalIndex values that uniquely specifies the exact physical location of a physical component within the managed system. It is generated by 'following and recording' each 'entPhysicalContainedIn' instance 'up the tree towards the root', until a value of zero indicating no further containment is found."

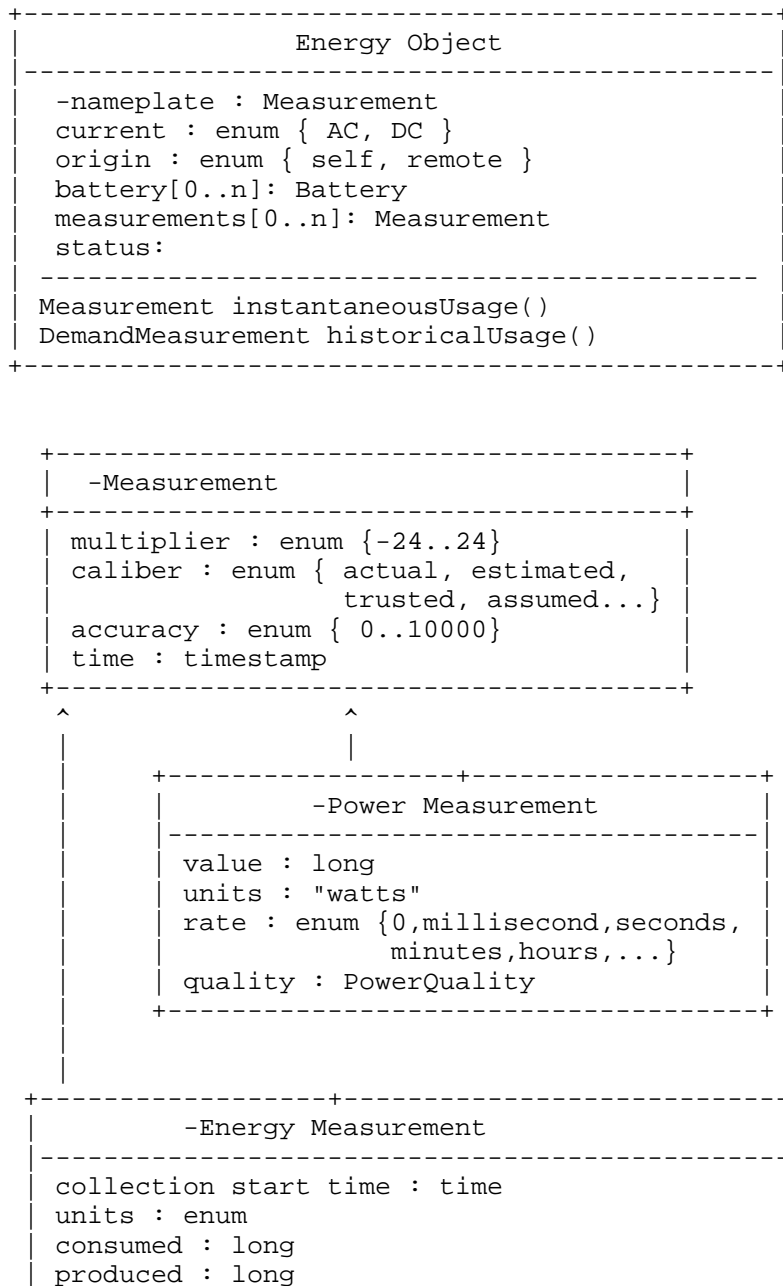
A Energy Object Component is a special Energy Object that is a physical component as specified by the ENTITY-MIB physical containment tree.

## 5. Energy Management Information Model

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. Arrows indicate inheritance. Algorithms for class variable initialization, constructors or destructors are not shown. Attributes and structures are considered readable and writeable prefixed by a dash (-) which indicates readonly.



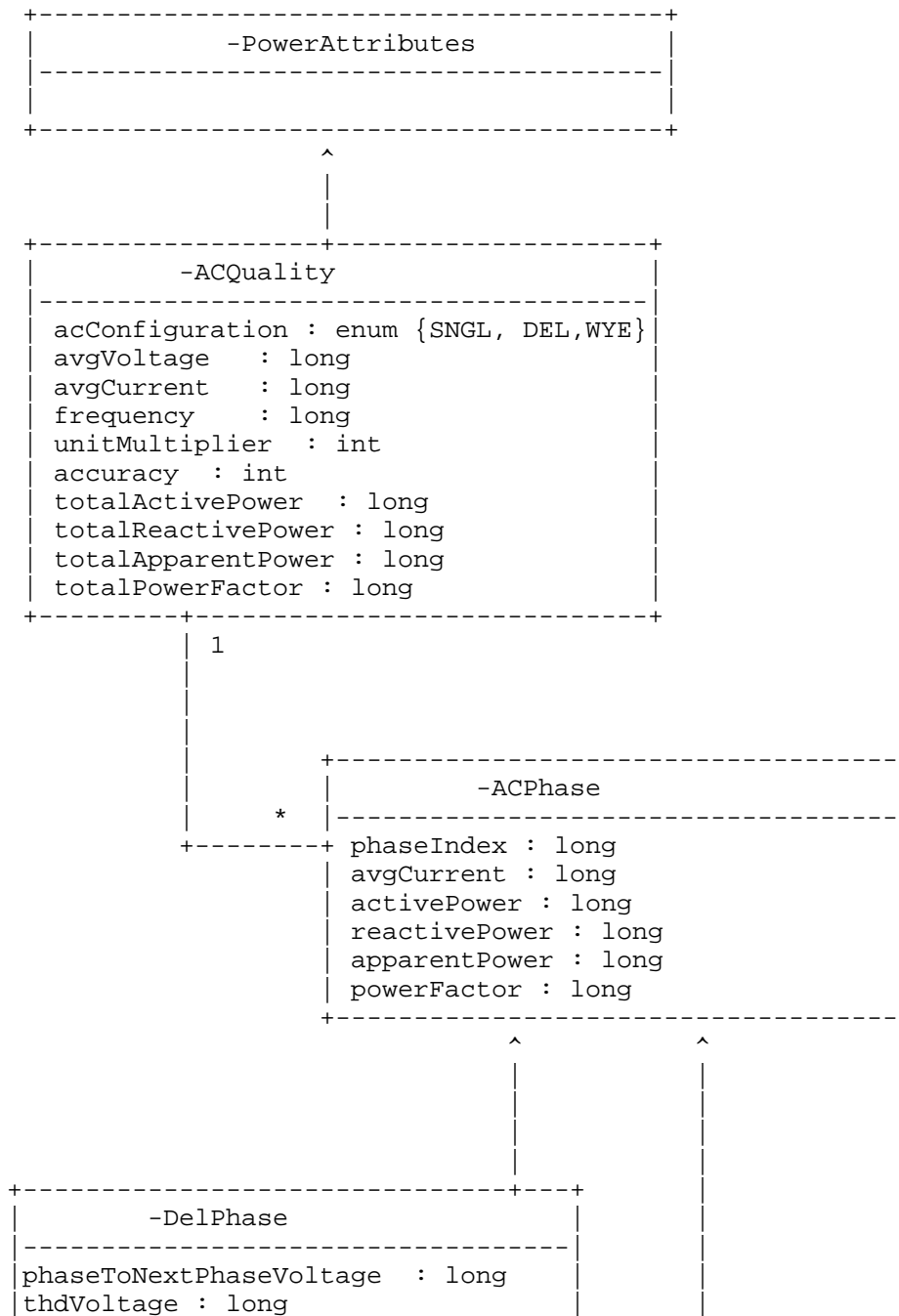


|                                                          |
|----------------------------------------------------------|
| net : long<br>max consumed : long<br>max produced : long |
|----------------------------------------------------------|

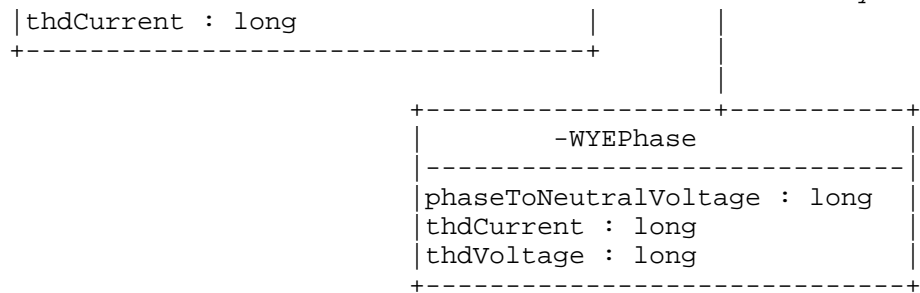
|                                                                        |
|------------------------------------------------------------------------|
| -Time                                                                  |
| startTime : timestamp<br>usage : Measurement<br>maxUsage : Measurement |

|                                                         |
|---------------------------------------------------------|
| -TimeInterval                                           |
| value : long<br>units : enum { seconds, milliseconds..} |

|                                                                                                                                                                                                                                                     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -DemandMeasurement                                                                                                                                                                                                                                  |
| intervalLength : TimeInterval<br>intervalNumbers: long<br>intervalMode : enum { period, sliding,<br>total }<br>intervalWindow : TimeInterval<br>sampleRate : TimeInterval<br>status : enum {active, inactive }<br>measurements : TimedMeasurement[] |







## EO & STATES

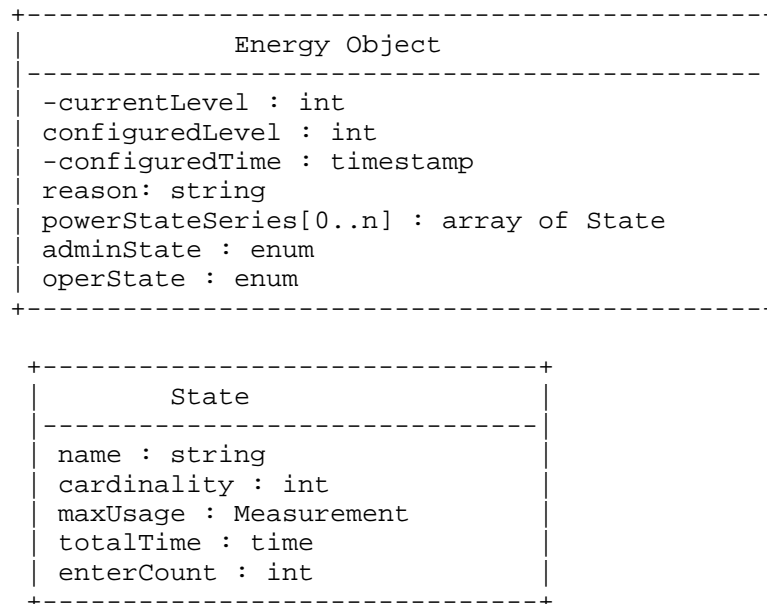


Figure 17: Information Model UML Representation

## 6. Example Topologies

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.

## 6.1 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.

## 6.2 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.

## 6.3 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.

## 7. Relationship with Other Standards

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.

## 8. 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.

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 Energy Management 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

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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.

## 9. IANA Considerations

Initial values for the Power State Sets, together with the  
considerations for assigning them, are defined in [EMAN-MON-  
MIB].

## 10. Acknowledgments

The authors would like to Michael Brown for improving the text  
dramatically, and Rolf Winter for his feedback. The award for  
the best feedback and reviews goes to Bill Mielke.

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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. Monitoring functions include identification of energy-managed devices and their components, monitoring of their power states, power inlets, power outlets, actual power, power properties, received energy, provided energy, and contained batteries. Control functions serve for controlling power supply and power state of energy-managed devices and their components.

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 information technology 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. Subjects of energy management are entities in the network. An entity is a device or one of a device's components, which is subject to individual energy monitoring and/or control.

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; and control of their 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 might be 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 (sometimes called an energy management system or controller). Requirements in this document do not cover details of these networks and devices, 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 in a manner appropriate to 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 controlling energy supply and power state of 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 three basic types of Power States for an entity or for a whole system:

- o full Power State
- 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. Examples are various operational low power states in which a device requires less energy than in the full power "on" state, but - compared to the sleep state - is still operational with reduced performance or functionality.

### 3.2. Saving Energy Versus Maintaining Service Level

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 service (performance or capacity) degradation. In this case, a trade-off needs to be made 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 functional 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. Change Of Identifiers

The standard must provide means to indicate any change of entity identifiers.

#### 4.4. Using Entity Identifiers Of Existing MIB Modules

The standard must provide means for re-using entity identifiers from existing 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 mission critical 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 an interface at which a device is connected to a Power transmission medium at which it can receive Power, provide Power, or both.

A Power Interface is either an inlet or an outlet. Some Power Interfaces change over time from being an inlet to being an outlet and vice versa. However most Power Interfaces never change.

Devices have Power Inlets at which they are supplied with electric Power. Most devices 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 a device, the availability of Power at inlets and which of them are actually in use.

Devices can have one or more Power Outlets for supplying other devices 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 device 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 devices.

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. Note that often the nominal voltage is not a single value but a voltage range, such as, for example, (100V-120V), (100V-240V), (100V-120V,220V-240V).

#### 5.2.1. Lists Of Power Interfaces

The standard must provide means for monitoring the list of Power Interfaces of a device.

#### 5.2.2. Operational Mode Of Power Interfaces

The standard must provide means for monitoring the operational mode of a Power Interface which is either "Power Inlet" or "Power Outlet".

#### 5.2.3. Corresponding Power Outlet

The standard must provide means for identifying the Power Outlet that provides the Power received at a Power Inlet.

#### 5.2.4. Corresponding Power Inlets

The standard must provide means for identifying the list of Power Inlets that receive the Power provided at a Power Outlet.

#### 5.2.5. 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.

#### 5.2.6. Use Of Power

The standard must provide means for monitoring for each Power Interface if it is in actual use. For inlets this means that the device actually receives Power at the inlet. For outlets this means that Power is actually provided from it to one or more devices.

#### 5.2.7. 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 a device.

#### 5.2.8. Nominal Voltage Range

The standard must provide means for reporting the nominal voltage range for each Power Interface.

#### 5.2.9. Nominal AC Frequency

The standard must provide means for reporting the nominal AC frequency for each Power Interface.

#### 5.2.10. 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 Power supplied to a device are also of interest. Particularly for AC Power supply, several Power properties beyond the real Power are of potential interest to Energy Management Systems. The set of these properties include the the complex Power properties (apparent power, reactive power, and phase angle of the current or power factor) as well as the actual voltage, the actual AC frequency, the Total Harmonic Distortion (THD) of voltage and current, and the impedance of an AC phase or of the DC supply. A new standard for monitoring these Power properties should be in line with already 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 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 a device. 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 / Power Factor

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 the typical 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. Typical Power Per Power State

The standard must provide means for retrieving the typical Power for each supported Power State.

#### 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, it's temperature, 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. Actual Battery Capacity

The standard must provide means for reporting the actual temperature of a battery.

#### 5.6.6. 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.

#### 5.6.7. Low battery Charge Notification

The standard must provide means for generating a notification when the charge of a battery decreases below a given threshold.

#### 5.6.8. Battery Replacement Notification

The standard must provide means for generating a notification when the number of charging cycles of battery exceeds a given threshold.

#### 5.6.9. Multiple Batteries

The standard must provide means for meeting requirements 5.6.1 to 5.6.8 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 Interval Types

The standard must provide means for supporting alternative interval types. Requirement 5.5.2 applies to every reported time value.

#### 5.7.3. Time Series Storage Capacity

The 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 devices. And controlling Power supply is typically not conducted as interaction

between Energy Management System and the device itself. It is rather an interaction between the management system and a device 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 device.

#### 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 Interfaces providing Power to one or more device.

### 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.

#### 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. Note that, in some situations, a manual configuration might be required to populate this information.

#### 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.

### 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 doing that control.

#### 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 entities other 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. Note that, in some situations, a manual configuration might be required to populate this information.

#### 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 5.2.3 and 5.2.4.

### 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 protection. This protection includes authentication and authorization of entities requesting access to monitored data as well as privacy protection during transmission of monitored data. 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. Acknowledgments

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Entity MIB (Version 4)  
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## 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 describes managed objects used for managing multiple logical and physical entities managed by a single SNMP agent. This document specifies version 4 of the Entity MIB. This memo obsoletes version 3 of Entity MIB module published as RFC 4133.

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## 1. The SNMP 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].

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. Overview

There is a need for a standardized way of representing a single agent, which supports multiple instances of one MIB module. This is presently true for at least 3 standard MIB modules, and is likely to become true for more and more MIB modules as time passes. For example:

- multiple instances of a bridge supported within a single device that has a single agent;
- multiple repeaters supported by a single agent;
- multiple OSPF backbone areas, each operating as part of its own Autonomous System, and each identified by the same area-id (e.g., 0.0.0.0), supported inside a single router with one agent.

The single agent present in each of these cases implies a relationship binds these entities. Effectively, there is some "overall" physical entity which houses the sum of the things managed by that one agent, i.e., there are multiple "logical" entities within a single physical entity. Sometimes, the overall physical entity contains multiple (smaller) physical entities, and each logical

entity is associated with a particular physical entity. Sometimes, the overall physical entity is a "compound" of multiple physical entities (e.g., a stack of stackable hubs).

What is needed is a way to determine exactly which logical entities are managed by the agent (with some version of SNMP) in order to communicate with the agent about a particular logical entity. When different logical entities are associated with different physical entities within the overall physical entity, it is also useful to be able to use this information to distinguish between logical entities.

In these situations, there is no need for varbinds for multiple logical entities to be referenced in the same SNMP message (although that might be useful in the future). Rather, it is sufficient, and in some situations preferable, to have the context/community in the message identify the logical entity to which the varbinds apply.

Version 2 of this MIB addresses new requirements, which have emerged since the publication of the first Entity MIB (RFC 2037 [RFC2037]). There is a need for a standardized way of providing non-volatile, administratively-assigned identifiers for physical components represented with the Entity MIB. There is also a need to align the Entity MIB with the SNMPv3 administrative framework (STD 62, RFC 3411 [RFC3411]). Implementation experience has shown that additional physical component attributes are also desirable.

Version 3 of this MIB addresses new requirements, which have emerged since the publication of the second Entity MIB (RFC 2737 [RFC2737]). There is a need to identify physical entities that are central processing units (CPUs) and a need to provide a textual convention that identifies an entPhysicalIndex value or zero, where the value zero has application-specific semantics. Two new objects have been added to the entPhysicalTable to identify the manufacturing date and provide additional URIs for a particular physical entity.

Version 4 of this MIB module addresses new requirements, which have emerged since the publication of the third version of Entity MIB RFC 4133 [RFC4133]. There is a need to add new enumerated values for entity physical classes, a need to provide identification information for physical entities using a Universal Unique Identifier (UUID) format, and there is a need to have compliant implementations of Entity MIB with a smaller subsets of MIB objects, for devices with constrained resources.

The PhysicalClass Textual Convention (TC) was deprecated and a new IANAPhysicalClass TC (maintained by IANA) was created. A new TC UUIDorZero was created to represent a UUID and a new MIB object was added to the entPhysicalTable to identify an entity. A new compliance

statement entity4CRCompliance has been added for possible implementation of a selected subset of MIB objects by entities with constrained resources.

## 2.1. Terms

Some new terms are used throughout this document:

- Naming Scope

A "naming scope" represents the set of information that may be potentially accessed through a single SNMP operation. All instances within the naming scope share the same unique identifier space. For SNMPv1, a naming scope is identified by the value of the associated 'entLogicalCommunity' instance. For SNMPv3, the term 'context' is used instead of 'naming scope'. The complete definition of an SNMP context can be found in section 3.3.1 of RFC 3411 [RFC3411].

- Multi-Scoped Object

A MIB object, for which identical instance values identify different managed information in different naming scopes, is called a "multi-scoped" MIB object.

- Single-Scoped Object

A MIB object, for which identical instance values identify the same managed information in different naming scopes, is called a "single-scoped" MIB object.

- Logical Entity

A managed system contains one or more logical entities, each represented by at most one instantiation of each of a particular set of MIB objects. A set of management functions is associated with each logical entity. Examples of logical entities include routers, bridges, print-servers, etc.

- Physical Entity

A "physical entity" or "physical component" represents an identifiable physical resource within a managed system. Zero or more logical entities may utilize a physical resource at any given time. Determining which physical components are represented by an agent in the EntPhysicalTable is an implementation-specific matter. Typically, physical resources (e.g., communications ports, backplanes, sensors, daughter-cards, power supplies, the overall chassis), which can be managed via functions associated with one or more logical entities, are included in the MIB.

- Containment Tree

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.

## 2.2. Relationship to Community Strings

For community-based SNMP, differentiating logical entities is one (but not the only) purpose of the community string (RFC 1157 [RFC1157]). This is accommodated by representing each community string as a logical entity.

Note that different logical entities may share the same naming scope and, therefore, the same values of entLogicalCommunity. This is possible, providing they have no need for the same instance of a MIB object to represent different managed information.

## 2.3. Relationship to SNMP Contexts

Version 2 of the Entity MIB contains support for associating SNMPv3 contexts with logical entities. Two new MIB objects, defining an SnmpEngineID and ContextName pair, are used together to identify an SNMP context associated with a logical entity. This context can be used (in conjunction with the entLogicalTAddress and entLogicalTDomain MIB objects) to send SNMPv3 messages on behalf of a particular logical entity.

## 2.4. Relationship to Proxy Mechanisms

The Entity MIB is designed to allow functional component discovery. The administrative relationships between different logical entities are not visible in any Entity MIB tables. A Network Management System (NMS) cannot determine whether MIB instances in different naming scopes are realized locally or remotely (e.g., via some proxy mechanism) by examining any particular Entity MIB objects.

The management of administrative framework functions is not an explicit goal of the Entity MIB WG at this time. This new area of functionality may be revisited after some operational experience with the Entity MIB is gained.

Note that for community-based versions of SNMP, a network administrator will likely be able to associate community strings with naming scopes that have proprietary mechanisms, as a matter of configuration. There are no mechanisms for managing naming scopes defined in this MIB.

## 2.5. Relationship to a Chassis MIB

Some readers may recall that a previous IETF working group attempted to define a Chassis MIB. No consensus was reached by that working group, possibly because its scope was too broad. As such, it is not the purpose of this MIB to be a "Chassis MIB replacement", nor is it within the scope of this MIB module to contain all the information which might be necessary to manage a "chassis". On the other hand, the entities represented by an implementation of this MIB module might well be contained in a chassis.

## 2.6. Relationship to the Interfaces MIB

The Entity MIB contains a mapping table identifying physical components that have 'external values' (e.g., ifIndex) associated with them within a given naming scope. This table can be used to identify the physical location of each interface in the ifTable (RFC 2863 [RFC2863]). Because ifIndex values in different contexts are not related to one another, the interface to physical component associations are relative to the same logical entity within the agent.

The Entity MIB also contains 'entPhysicalName' and 'entPhysicalAlias' objects, which approximate the semantics of the 'ifName' and 'ifAlias' objects (respectively) from the Interfaces MIB [RFC2863], for all types of physical components.

## 2.7. Relationship to the Other MIB modules

The Entity MIB contains a mapping table identifying physical components that have identifiers from other standard MIB modules associated with them. For example, this table can be used along with the physical mapping table to identify the physical location of each repeater port in the rpPtrPortTable, or each interface in the ifTable.

## 2.8. Relationship to Naming Scopes

There is some question as to which MIB objects may be returned within a given naming scope. MIB objects which are not multi-scoped within a managed system are likely to ignore context information in implementation. In such a case, it is likely such objects will be returned in all naming scopes (e.g., not just the 'default' naming scope or the SNMPv3 default context).

For example, a community string used to access the management information for logical device 'bridge2' may allow access to all the non-bridge related objects in the 'default' naming scope, as well as a second instance of the Bridge MIB (RFC 4188 [RFC4188]).

The isolation of single-scoped MIB objects by the agent is an implementation-specific matter. An agent may wish to limit the objects returned in a particular naming scope to only the multi-scoped objects in that naming scope (e.g., system group and the Bridge MIB). In this case, all single-scoped management information would belong to a common naming scope (e.g., 'default'), which itself may contain some multi-scoped objects (e.g., system group).

## 2.9. Multiple Instances of the Entity MIB

It is possible that more than one agent may exist in a managed system. In such cases, multiple instances of the Entity MIB (representing the same managed objects) may be available to an NMS.

In order to reduce complexity for agent implementation, multiple instances of the Entity MIB are not required to be equivalent or even consistent. An NMS may be able to 'align' instances returned by different agents by examining the columns of each table, but vendor-specific identifiers and (especially) index values are likely to be different. Each agent may be managing different subsets of the entire chassis as well.

When all of a physically-modular device is represented by a single agent, the entry (for which `entPhysicalContainedIn` has the value zero) would likely have 'chassis' as the value of its `entPhysicalClass`. Alternatively, for an agent on a module where the agent represents only the physical entities on that module (not those on other modules), the entry (for which `entPhysicalContainedIn` has the value zero) would likely have 'module' as the value of its `entPhysicalClass`.

An agent implementation of the `entLogicalTable` is not required to contain information about logical entities managed primarily by other agents. That is, the `entLogicalTAddress` and `entLogicalTDomain` objects in the `entLogicalTable` are provided to support an historical multiplexing mechanism, not to identify other SNMP agents.

Note that the Entity MIB is a single-scoped MIB, in the event an agent represents the MIB in different naming scopes.

## 2.10. Re-Configuration of Entities

Most of the MIB objects defined in this MIB have, at most, a read-only MAX-ACCESS clause. This is a conscious decision by the working group to limit this MIB's scope. The second version of the Entity MIB allows a network administrator to configure some common attributes of physical components.



## 2.11. Textual Convention Change

Version 1 of the Entity MIB contains three MIB objects defined with the (now obsolete) DisplayString textual convention. In version 2 of the Entity MIB, the syntax for these objects has been updated to use the (now preferred) SnmpAdminString textual convention.

The entmib working group (which was in charge with the document at that point) realized that this change is not strictly supported by SMIV2. In their judgment, the alternative of deprecating the old objects and defining new objects would have had a more adverse impact on backward compatibility and interoperability, given the particular semantics of these objects.

## 2.12. MIB Structure

The Entity MIB contains five groups of MIB objects:

- entityPhysical group  
Describes the physical entities managed by a single agent.
- entityLogical group  
Describes the logical entities managed by a single agent.
- entityMapping group  
Describes the associations between the physical entities, logical entities, interfaces, and non-interface ports managed by a single agent.
- entityGeneral group  
Describes general system attributes shared by potentially all types of entities managed by a single agent.
- entityNotifications group  
Contains status indication notifications.

### 2.12.1. entityPhysical Group

This group contains a single table to identify physical system components, called the entPhysicalTable.

The entPhysicalTable contains one row per physical entity, and must always contain at least one row for an "overall" physical entity, which should have an entPhysicalClass value of 'stack(11)', 'chassis(3)' or 'module(9)'.

Each row is indexed by an arbitrary, small integer, and contains a description and type of the physical entity. It also optionally

contains the index number of another entPhysicalEntry, indicating a containment relationship between the two.

Version 2 of the Entity MIB provides additional MIB objects for each physical entity. Some common read-only attributes have been added, as well as three writable string objects.

- entPhysicalAlias  
This string can be used by an NMS as a non-volatile identifier for the physical component. Maintaining a non-volatile string for every physical component represented in the entPhysicalTable can be costly and unnecessary. An agent may algorithmically generate 'entPhysicalAlias' strings for particular entries (e.g., based on the entPhysicalClass value).
- entPhysicalAssetID  
This string is provided to store a user-specific asset identifier for removable physical components. In order to reduce the non-volatile storage needed by a particular agent, a network administrator should only assign asset identifiers to physical entities that are field-replaceable (i.e., not permanently contained within another physical entity).
- entPhysicalSerialNum  
This string is provided to store a vendor-specific serial number string for physical components. This writable object is used when an agent cannot identify the serial numbers of all installed physical entities, and a network administrator wishes to configure the non-volatile serial number strings manually (via an NMS application).

Version 3 of the Entity MIB provides two additional MIB objects for each physical entity:

- entPhysicalMfgDate  
This object contains the date of manufacturing of the managed entity. If the manufacturing date is unknown or not supported the object is not instantiated. The special value '0000000000000000'H may also be returned in this case.
- entPhysicalUris  
This object provides additional identification information about the physical entity.

This object contains one or more Uniform Resource Identifiers (URIs) and, therefore, the syntax of this object must conform to RFC 3986 [RFC3986] section 2. Uniform Resource Names (URNs), RFC 3406 [RFC3406], are resource identifiers with the specific

requirements for enabling location independent identification of a resource, as well as longevity of reference. URNs are part of the larger URI family with the specific goal of providing persistent naming of resources. URI schemes and URN name spaces are registered by IANA (see <http://www.iana.org/assignments/uri-schemes> and <http://www.iana.org/assignments/urn-namespaces>).

For example, the `entPhysicalUris` object may be used to encode a URI containing a Common Language Equipment Identifier (CLEI) URN for the managed physical entity. The URN name space for CLEIs is defined in [RFC4152], and the CLEI format is defined in [T1.213][T1.213a]. For example, an `entPhysicalUris` instance may have the value of

URN:CLEI:D4CE18B7AA

[RFC3986] and [RFC4152] identify this as a URI in the CLEI URN name space. The specific CLEI code, D4CE18B7AA, is based on the example provided in [T1.213a].

Multiple URIs may be present and are separated by white space characters. Leading and trailing white space characters are ignored.

If no additional identification information is known about the physical entity or supported, the object is not instantiated.

Version 4 of the Entity MIB module provides an additional MIB object for each physical entity.

- `entPhysicalUUID`

This object provides an unique identification about the physical entity. This object contains a globally unique identifier for the physical entity with the format as defined in RFC 4122 [RFC4122].

To support the existing implementations of ENTITY-MIB version 3 [RFC4133], `entPhysicalUris` object should be used to store the UUID value of the physical entity as well in URN format. This duplication of information enables backward compatibility. Note that `entPhysicalUris` allows write access while `entPhysicalUUID` is read-only.

#### 2.12.2. `entityLogical` Group

This group contains a single table to identify logical entities, called the `entLogicalTable`.

The entLogicalTable contains one row per logical entity. Each row is indexed by an arbitrary, small integer and contains a name, description, and type of the logical entity. It also contains information to allow access to the MIB information for the logical entity. This includes SNMP versions that use a community name (with some form of implied context representation) and SNMP versions that use the SNMP ARCH [RFC3411] method of context identification.

If an agent represents multiple logical entities with this MIB, then this group must be implemented for all logical entities known to the agent.

If an agent represents a single logical entity, or multiple logical entities within a single naming scope, then implementation of this group may be omitted by the agent.

#### 2.12.3. entityMapping Group

This group contains three tables to identify associations between different system components.

- entLPMappingTable  
This table contains mappings between entLogicalIndex values (logical entities) and entPhysicalIndex values (the physical components supporting that entity). A logical entity can map to more than one physical component, and more than one logical entity can map to (share) the same physical component. If an agent represents a single logical entity, or multiple logical entities within a single naming scope, then implementation of this table may be omitted by the agent.
- entAliasMappingTable  
This table contains mappings between entLogicalIndex, entPhysicalIndex pairs, and 'alias' object identifier values. This allows resources managed with other MIB modules (e.g., repeater ports, bridge ports, physical and logical interfaces) to be identified in the physical entity hierarchy. Note that each alias identifier is only relevant in a particular naming scope. If an agent represents a single logical entity, or multiple logical entities within a single naming scope, then implementation of this table may be omitted by the agent.
- entPhysicalContainsTable  
This table contains simple mappings between 'entPhysicalContainedIn' values for each container/'containee' relationship in the managed system. The indexing of this table allows an NMS to quickly discover the 'entPhysicalIndex' values for

all children of a given physical entity.

#### 2.12.4. entityGeneral Group

This group contains general information relating to the other object groups.

At this time, the entGeneral group contains a single scalar object (entLastChangeTime), which represents the value of sysUptime when any part of the Entity MIB configuration last changed.

#### 2.12.5. entityNotifications Group

This group contains notification definitions relating to the overall status of the Entity MIB instantiation.

#### 2.13. Multiple Agents

Even though a primary motivation for this MIB is to represent the multiple logical entities supported by a single agent, another motivation is to represent multiple logical entities supported by multiple agents (in the same "overall" physical entity). Indeed, it is implicit in the SNMP architecture that the number of agents is transparent to a network management station.

However, there is no agreement at this time as to the degree of cooperation that should be expected for agent implementations. Therefore, multiple agents within the same managed system are free to implement the Entity MIB independently. (For more information, refer to Section 2.9, "Multiple Instances of the Entity MIB".)

#### 2.14. Changes Since RFC 2037

##### 2.14.1. Textual Conventions

The PhysicalClass TC text has been clarified, and a new enumeration to support 'stackable' components has been added. The SnmpEngineIdOrNone TC has been added to support SNMPv3.

##### 2.14.2. New entPhysicalTable Objects

The entPhysicalHardwareRev, entPhysicalFirmwareRev, and entPhysicalSoftwareRev objects have been added for revision identification.

The entPhysicalSerialNum, entPhysicalMfgName, entPhysicalModelName, and entPhysicalIsFru objects have been added for better vendor identification for physical components. In the event the agent

cannot identify this information, the entPhysicalSerialNum object can be set by a management station.

The entPhysicalAlias and entPhysicalAssetID objects have been added for better user component identification. These objects are intended to be set by a management station and preserved by the agent across restarts.

#### 2.14.3. New entLogicalTable Objects

The entLogicalContextEngineID and entLogicalContextName objects have been added to provide an SNMP context for SNMPv3 access on behalf of a logical entity.

#### 2.14.4. Bug Fixes

A bug was fixed in the entLogicalCommunity object. The subrange was incorrect (1..255) and is now (0..255). The description clause has also been clarified. This object is now deprecated.

The entLastChangeTime object description has been changed to generalize the events that cause an update to the last change timestamp.

The syntax was changed from DisplayString to SnmpAdminString for the entPhysicalDescr, entPhysicalName, and entLogicalDescr objects.

### 2.15. Changes Since RFC 2737

#### 2.15.1. Textual Conventions

The PhysicalIndexOrZero TC has been added to allow objects to reference an entPhysicalIndex value or zero. The PhysicalClass TC has been extended to support a new enumeration for central processing units.

#### 2.15.2. New Objects

The entPhysicalMfgDate object has been added to the entPhysicalTable to provide the date of manufacturing of the managed entity.

The entPhysicalUris object has been added to the entPhysicalTable to provide additional identification information about the physical entity, such as a Common Language Equipment Identifier (CLEI) URN.

### 2.15.3. Bug Fixes

The syntax was changed from INTEGER to Integer32 for the entPhysicalParentRelPos, entLogicalIndex, and entAliasLogicalIndexOrZero objects, and from INTEGER to PhysicalIndexOrZero for the entPhysicalContainedIn object.

### 2.16. Changes Since RFC 4133

#### 2.16.1. MIB module addition

Over time, there may be the need to add new enumerated values to the PhysicalClass textual convention. To allow for such additions without requiring to re-issue this MIB module, a new MIB module called IANA-ENTITY-MIB has been created which provides the IANA-maintained textual convention IANAPhysicalClass. The PhysicalClass TC has been deprecated.

#### 2.16.2. Modification to some of the MIB objects

Addition of a new MIB object to the entPhysicalTable - entPhysicalUUID. In comparison to entPhysicalUris the new object is read-only and restricted to a fixed size to allow only for RFC 4122 [RFC4122] compliant values. The PhysicalClass Textual Convention (TC) was deprecated and a new IANAPhysicalClass TC (maintained by IANA) has been created.

Creation of two new MODULE-COMPLIANCE modules entity4Compliance for full compliance with version 4 of the Entity MIB and entity4CRCompliance for devices with constrained resources like batteries, which might require a limited number of objects to be supported (entPhysicalClass, entPhysicalName, entPhysicalUUID).

#### 2.16.3. New TC for Universal Unique Identifier

A new Textual Convention (TC) UUIDorZero was created to represent a Universal Unique Identifier (UUID), with a syntax that conforms to RFC 4122, section 4.1. Defining it as a TC will allow for future re-use in other MIB modules that will import the TC. This Textual Convention is included in the UUID-TC-MIB module.

## 3. MIB Definitions

### 3.1. ENTITY MIB

```
ENTITY-MIB DEFINITIONS ::= BEGIN
```

```
IMPORTS
```

```
MODULE-IDENTITY, OBJECT-TYPE, mib-2, NOTIFICATION-TYPE,
Integer32
 FROM SNMPv2-SMI
TDomain, TAddress, TEXTUAL-CONVENTION,
AutonomousType, RowPointer, TimeStamp, TruthValue,
DateAndTime
 FROM SNMPv2-TC
MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP
 FROM SNMPv2-CONF
SnmpAdminString
 FROM SNMP-FRAMEWORK-MIB
UUIDorZero
 FROM UUID-TC-MIB
IANAPhysicalClass
 FROM IANA-ENTITY-MIB;
```

```
entityMIB MODULE-IDENTITY
 LAST-UPDATED "201302050000Z"
 ORGANIZATION "IETF Energy Management Working Group"
 CONTACT-INFO
 "
 WG E-mail: eman@ietf.org
 Mailing list subscription info:
 http://www.ietf.org/mailman/listinfo/eman

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```



Bangalore 560103  
IN  
Phone: +91 80 4429 2409  
Email: moulchan@cisco.com"

## DESCRIPTION

"The MIB module for representing multiple logical entities supported by a single SNMP agent.

Copyright (C) The Internet Society (2013). This version of this MIB module is part of RFC xxxx; see the RFC itself for full legal notices."

REVISION "201302050000Z"

## DESCRIPTION

"Entity MIB (Version 4).  
This revision obsoletes RFC 4133.  
- Creation of a new MIB module IANA-ENTITY-MIB which makes the PhysicalIndex TC an IANA-maintained Textual Convention. IANAPhysicalClass is now imported from the IANA-ENTITY-MIB  
- Addition of a new MIB object to the entPhysicalTable - entPhysicalUUID. UUIDorZero is imported from the UUID-TC-MIB  
- New MODULE-COMPLIANCE clauses entity4Compliance and entity4CRCompliance  
This version published as RFC xxxx."

REVISION "200508100000Z"

## DESCRIPTION

"Initial Version of Entity MIB (Version 3).  
This revision obsoletes RFC 2737.  
Additions:  
- cpu(12) enumeration added to IANAPhysicalClass TC  
- DISPLAY-HINT clause to PhysicalIndex TC  
- PhysicalIndexOrZero TC  
- entPhysicalMfgDate object  
- entPhysicalUris object  
Changes:  
- entPhysicalContainedIn SYNTAX changed from INTEGER to PhysicalIndexOrZero

This version published as RFC 4133."

REVISION "199912070000Z"

## DESCRIPTION

"Initial Version of Entity MIB (Version 2).  
This revision obsoletes RFC 2037.

This version published as RFC 2737."

```
REVISION "199610310000Z"
DESCRIPTION
 "Initial version (version 1), published as
 RFC 2037."
 ::= { mib-2 47 }
```

```
entityMIBObjects OBJECT IDENTIFIER ::= { entityMIB 1 }
```

-- MIB contains four groups

```
entityPhysical OBJECT IDENTIFIER ::= { entityMIBObjects 1 }
entityLogical OBJECT IDENTIFIER ::= { entityMIBObjects 2 }
entityMapping OBJECT IDENTIFIER ::= { entityMIBObjects 3 }
entityGeneral OBJECT IDENTIFIER ::= { entityMIBObjects 4 }
```

-- Textual Conventions

```
PhysicalIndex ::= TEXTUAL-CONVENTION
 DISPLAY-HINT "d"
 STATUS current
 DESCRIPTION
 "An arbitrary value that uniquely identifies the physical
 entity. The value should be a small, positive integer.
 Index values for different physical entities are not
 necessarily contiguous."
 SYNTAX Integer32 (1..2147483647)
```

```
PhysicalIndexOrZero ::= TEXTUAL-CONVENTION
 DISPLAY-HINT "d"
 STATUS current
 DESCRIPTION
 "This textual convention is an extension of the
 PhysicalIndex convention, which defines a greater than zero
 value used to identify a physical entity. 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)
```

```
SnmpEngineIdOrNone ::= TEXTUAL-CONVENTION
```

STATUS current

DESCRIPTION

"A specially formatted SnmpEngineID string for use with the Entity MIB.

If an instance of an object of SYNTAX SnmpEngineIdOrNone has a non-zero length, then the object encoding and semantics are defined by the SnmpEngineID textual convention (see STD 62, RFC 3411 [RFC3411]).

If an instance of an object of SYNTAX SnmpEngineIdOrNone contains a zero-length string, then no appropriate SnmpEngineID is associated with the logical entity (i.e., SNMPv3 is not supported)."

SYNTAX OCTET STRING (SIZE(0..32)) -- empty string or SnmpEngineID

PhysicalClass ::= TEXTUAL-CONVENTION

STATUS deprecated

DESCRIPTION

"Starting with Version 4 of the ENTITY-MIB this TC is deprecated and the usage of the IANAPhysicalClass TC from the IANA-ENTITY-MIB is recommended instead.

An enumerated value which provides an indication of the general hardware type of a particular physical entity. There are no restrictions as to the number of entPhysicalEntries of each entPhysicalClass, which must be instantiated by an agent.

The enumeration 'other' is applicable if the physical entity class is known, but does not match any of the supported values.

The enumeration 'unknown' is applicable if the physical entity class is unknown to the agent.

The enumeration 'chassis' is applicable if the physical entity class is an overall container for networking equipment. Any class of physical entity, except a stack, may be contained within a chassis; and a chassis may only be contained within a stack.

The enumeration 'backplane' is applicable if the physical entity class is some sort of device for aggregating and forwarding networking traffic, such as a shared backplane in a modular ethernet switch. Note that an agent may model a backplane as a single physical entity, which is actually

implemented as multiple discrete physical components (within a chassis or stack).

The enumeration 'container' is applicable if the physical entity class is capable of containing one or more removable physical entities, possibly of different types. For example, each (empty or full) slot in a chassis will be modeled as a container. Note that all removable physical entities should be modeled within a container entity, such as field-replaceable modules, fans, or power supplies. Note that all known containers should be modeled by the agent, including empty containers.

The enumeration 'powerSupply' is applicable if the physical entity class is a power-supplying component.

The enumeration 'fan' is applicable if the physical entity class is a fan or other heat-reduction component.

The enumeration 'sensor' is applicable if the physical entity class is some sort of sensor, such as a temperature sensor within a router chassis.

The enumeration 'module' is applicable if the physical entity class is some sort of self-contained sub-system. If the enumeration 'module' is removable, then it should be modeled within a container entity, otherwise it should be modeled directly within another physical entity (e.g., a chassis or another module).

The enumeration 'port' is applicable if the physical entity class is some sort of networking port, capable of receiving and/or transmitting networking traffic.

The enumeration 'stack' is applicable if the physical entity class is some sort of super-container (possibly virtual), intended to group together multiple chassis entities. A stack may be realized by a 'virtual' cable, a real interconnect cable, attached to multiple chassis, or may in fact be comprised of multiple interconnect cables. A stack should not be modeled within any other physical entities, but a stack may be contained within another stack. Only chassis entities should be contained within a stack.

The enumeration 'cpu' is applicable if the physical entity class is some sort of central processing unit."

```
SYNTAX INTEGER {
 other(1),
```

```

 unknown(2),
 chassis(3),
 backplane(4),
 container(5), -- e.g., chassis slot or daughter-card holder
 powerSupply(6),
 fan(7),
 sensor(8),
 module(9), -- e.g., plug-in card or daughter-card
 port(10),
 stack(11), -- e.g., stack of multiple chassis entities
 cpu(12)
 }

-- The Physical Entity Table
entPhysicalTable OBJECT-TYPE
 SYNTAX SEQUENCE OF EntPhysicalEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table contains one row per physical entity. There is
 always at least one row for an 'overall' physical entity."
 ::= { entityPhysical 1 }

entPhysicalEntry OBJECT-TYPE
 SYNTAX EntPhysicalEntry
 MAX-ACCESS not-accessible

 STATUS current
 DESCRIPTION
 "Information about a particular physical entity.

 Each entry provides objects (entPhysicalDescr,
 entPhysicalVendorType, and entPhysicalClass) to help an NMS
 identify and characterize the entry, and objects
 (entPhysicalContainedIn and entPhysicalParentRelPos) to help
 an NMS relate the particular entry to other entries in this
 table."
 INDEX { entPhysicalIndex }
 ::= { entPhysicalTable 1 }

EntPhysicalEntry ::= SEQUENCE {
 entPhysicalIndex PhysicalIndex,
 entPhysicalDescr SnmpAdminString,
 entPhysicalVendorType AutonomousType,
 entPhysicalContainedIn PhysicalIndexOrZero,

```

```
 entPhysicalClass IANAPhysicalClass,
 entPhysicalParentRelPos Integer32,
 entPhysicalName SnmpAdminString,
 entPhysicalHardwareRev SnmpAdminString,
 entPhysicalFirmwareRev SnmpAdminString,
 entPhysicalSoftwareRev SnmpAdminString,
 entPhysicalSerialNum SnmpAdminString,
 entPhysicalMfgName SnmpAdminString,
 entPhysicalModelName SnmpAdminString,
 entPhysicalAlias SnmpAdminString,
 entPhysicalAssetID SnmpAdminString,
 entPhysicalIsFRU TruthValue,
 entPhysicalMfgDate DateAndTime,
 entPhysicalUris OCTET STRING,
 entPhysicalUUID UUIDorZero
}

entPhysicalIndex OBJECT-TYPE
 SYNTAX PhysicalIndex
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "The index for this entry."
 ::= { entPhysicalEntry 1 }

entPhysicalDescr OBJECT-TYPE
 SYNTAX SnmpAdminString
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "A textual description of physical entity. This object
 should contain a string that identifies the manufacturer's
 name for the physical entity, and should be set to a
 distinct value for each version or model of the physical
 entity."
 ::= { entPhysicalEntry 2 }

entPhysicalVendorType OBJECT-TYPE
 SYNTAX AutonomousType
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "An indication of the vendor-specific hardware type of the
 physical entity. Note that this is different from the
 definition of MIB-II's sysObjectID.

 An agent should set this object to an enterprise-specific
```

registration identifier value indicating the specific equipment type in detail. The associated instance of entPhysicalClass is used to indicate the general type of hardware device.

If no vendor-specific registration identifier exists for this physical entity, or the value is unknown by this agent, then the value { 0 0 } is returned."

::= { entPhysicalEntry 3 }

entPhysicalContainedIn OBJECT-TYPE

SYNTAX PhysicalIndexOrZero

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The value of entPhysicalIndex for the physical entity which 'contains' this physical entity. A value of zero indicates this physical entity is not contained in any other physical entity. Note that the set of 'containment' relationships define a strict hierarchy; that is, recursion is not allowed.

In the event that a physical entity is contained by more than one physical entity (e.g., double-wide modules), this object should identify the containing entity with the lowest value of entPhysicalIndex."

::= { entPhysicalEntry 4 }

entPhysicalClass OBJECT-TYPE

SYNTAX IANAPhysicalClass

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"An indication of the general hardware type of the physical entity.

An agent should set this object to the standard enumeration value that most accurately indicates the general class of the physical entity, or the primary class if there is more than one entity.

If no appropriate standard registration identifier exists for this physical entity, then the value 'other(1)' is returned. If the value is unknown by this agent, then the value 'unknown(2)' is returned."

```
::= { entPhysicalEntry 5 }
```

entPhysicalParentRelPos OBJECT-TYPE

SYNTAX Integer32 (-1..2147483647)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"An indication of the relative position of this 'child' component among all its 'sibling' components. Sibling components are defined as entPhysicalEntries that share the same instance values of each of the entPhysicalContainedIn and entPhysicalClass objects.

An NMS can use this object to identify the relative ordering for all sibling components of a particular parent (identified by the entPhysicalContainedIn instance in each sibling entry).

If possible, this value should match any external labeling of the physical component. For example, for a container (e.g., card slot) labeled as 'slot #3', entPhysicalParentRelPos should have the value '3'. Note that the entPhysicalEntry for the module plugged in slot 3 should have an entPhysicalParentRelPos value of '1'.

If the physical position of this component does not match any external numbering or clearly visible ordering, then user documentation or other external reference material should be used to determine the parent-relative position. If this is not possible, then the agent should assign a consistent (but possibly arbitrary) ordering to a given set of 'sibling' components, perhaps based on internal representation of the components.

If the agent cannot determine the parent-relative position for some reason, or if the associated value of entPhysicalContainedIn is '0', then the value '-1' is returned. Otherwise, a non-negative integer is returned, indicating the parent-relative position of this physical entity.

Parent-relative ordering normally starts from '1' and continues to 'N', where 'N' represents the highest positioned child entity. However, if the physical entities (e.g., slots) are labeled from a starting position of zero, then the first sibling should be associated with an entPhysicalParentRelPos value of '0'. Note that this ordering may be sparse or dense, depending on agent



implementation.

The actual values returned are not globally meaningful, as each 'parent' component may use different numbering algorithms. The ordering is only meaningful among siblings of the same parent component.

The agent should retain parent-relative position values across reboots, either through algorithmic assignment or use of non-volatile storage."

::= { entPhysicalEntry 6 }

entPhysicalName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The textual name of the physical entity. The value of this object should be the name of the component as assigned by the local device and should be suitable for use in commands entered at the device's 'console'. This might be a text name (e.g., 'console') or a simple component number (e.g., port or module number, such as '1'), depending on the physical component naming syntax of the device.

If there is no local name, or if this object is otherwise not applicable, then this object contains a zero-length string.

Note that the value of entPhysicalName for two physical entities will be the same in the event that the console interface does not distinguish between them, e.g., slot-1 and the card in slot-1."

::= { entPhysicalEntry 7 }

entPhysicalHardwareRev OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The vendor-specific hardware revision string for the physical entity. The preferred value is the hardware revision identifier actually printed on the component itself (if present).

Note that if revision information is stored internally in a

non-printable (e.g., binary) format, then the agent must convert such information to a printable format, in an implementation-specific manner.

If no specific hardware revision string is associated with the physical component, or if this information is unknown to the agent, then this object will contain a zero-length string."

::= { entPhysicalEntry 8 }

entPhysicalFirmwareRev OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The vendor-specific firmware revision string for the physical entity.

Note that if revision information is stored internally in a non-printable (e.g., binary) format, then the agent must convert such information to a printable format, in an implementation-specific manner.

If no specific firmware programs are associated with the physical component, or if this information is unknown to the agent, then this object will contain a zero-length string."

::= { entPhysicalEntry 9 }

entPhysicalSoftwareRev OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The vendor-specific software revision string for the physical entity.

Note that if revision information is stored internally in a non-printable (e.g., binary) format, then the agent must convert such information to a printable format, in an implementation-specific manner.

If no specific software programs are associated with the physical component, or if this information is unknown to the agent, then this object will contain a zero-length string."

::= { entPhysicalEntry 10 }

entPhysicalSerialNum OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..32))

MAX-ACCESS read-write  
STATUS current  
DESCRIPTION

"The vendor-specific serial number string for the physical entity. The preferred value is the serial number string actually printed on the component itself (if present).

On the first instantiation of an physical entity, the value of entPhysicalSerialNum associated with that entity is set to the correct vendor-assigned serial number, if this information is available to the agent. If a serial number is unknown or non-existent, the entPhysicalSerialNum will be set to a zero-length string instead.

Note that implementations that can correctly identify the serial numbers of all installed physical entities do not need to provide write access to the entPhysicalSerialNum object. Agents which cannot provide non-volatile storage for the entPhysicalSerialNum strings are not required to implement write access for this object.

Not every physical component will have a serial number, or even need one. Physical entities for which the associated value of the entPhysicalIsFRU object is equal to 'false(2)' (e.g., the repeater ports within a repeater module), do not need their own unique serial number. An agent does not have to provide write access for such entities, and may return a zero-length string.

If write access is implemented for an instance of entPhysicalSerialNum, and a value is written into the instance, the agent must retain the supplied value in the entPhysicalSerialNum 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 network management system, including those resulting in a change of the physical

entity's entPhysicalIndex value."  
::= { entPhysicalEntry 11 }

entPhysicalMfgName OBJECT-TYPE  
SYNTAX SnmpAdminString  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION

"The name of the manufacturer of this physical component. The preferred value is the manufacturer name string actually printed on the component itself (if present).

Note that comparisons between instances of the entPhysicalModelName, entPhysicalFirmwareRev, entPhysicalSoftwareRev, and the entPhysicalSerialNum objects, are only meaningful amongst entPhysicalEntries with the same value of entPhysicalMfgName.

If the manufacturer name string associated with the physical component is unknown to the agent, then this object will contain a zero-length string."

::= { entPhysicalEntry 12 }

entPhysicalModelName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The vendor-specific model name identifier string associated with this physical component. The preferred value is the customer-visible part number, which may be printed on the component itself.

If the model name string associated with the physical component is unknown to the agent, then this object will contain a zero-length string."

::= { entPhysicalEntry 13 }

entPhysicalAlias OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..32))

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object is an 'alias' name for the physical entity, as specified by a network manager, and provides a non-volatile 'handle' for the physical entity.

On the first instantiation of a physical entity, the value of entPhysicalAlias associated with that entity is set to the zero-length string. However, the agent may set the value to a locally unique default value, instead of a zero-length string.

If write access is implemented for an instance of entPhysicalAlias, and a value is written into the instance, the agent must retain the supplied value in the

entPhysicalAlias 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 network management system, including those resulting in a change of the physical entity's entPhysicalIndex value."

::= { entPhysicalEntry 14 }

entPhysicalAssetID OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..32))

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object is a user-assigned asset tracking identifier (as specified by a network manager) for the physical entity, and provides non-volatile storage of this information.

On the first instantiation of a physical entity, the value of entPhysicalAssetID associated with that entity is set to the zero-length string.

Not every physical component will have an asset tracking identifier, or even need one. Physical entities for which the associated value of the entPhysicalIsFRU object is equal to 'false(2)' (e.g., the repeater ports within a repeater module), do not need their own unique asset tracking identifier. An agent does not have to provide write access for such entities, and may instead return a zero-length string.

If write access is implemented for an instance of entPhysicalAssetID, and a value is written into the instance, the agent must retain the supplied value in the entPhysicalAssetID 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 network management system, including those resulting in a change of the physical entity's entPhysicalIndex value.

If no asset tracking information is associated with the physical component, then this object will contain a zero-length string."

::= { entPhysicalEntry 15 }

entPhysicalIsFRU OBJECT-TYPE

SYNTAX TruthValue

MAX-ACCESS read-only

STATUS current  
DESCRIPTION  
"This object indicates whether or not this physical entity is considered a 'field replaceable unit' by the vendor. If this object contains the value 'true(1)' then this entPhysicalEntry identifies a field replaceable unit. For all entPhysicalEntries that represent components permanently contained within a field replaceable unit, the value 'false(2)' should be returned for this object."  
 ::= { entPhysicalEntry 16 }

entPhysicalMfgDate OBJECT-TYPE  
SYNTAX DateAndTime  
MAX-ACCESS read-only  
STATUS current  
DESCRIPTION  
"This object contains the date of manufacturing of the managed entity. If the manufacturing date is unknown or not supported, the object is not instantiated. The special value '0000000000000000'H may also be returned in this case."  
 ::= { entPhysicalEntry 17 }

entPhysicalUris OBJECT-TYPE  
SYNTAX OCTET STRING  
MAX-ACCESS read-write  
STATUS current  
DESCRIPTION  
"This object contains identification information about the physical entity. The object contains URIs and, therefore, the syntax of this object must conform to RFC 3986, section 2.  
  
Multiple URIs may be present and are separated by white space characters. Leading and trailing white space characters are ignored.  
  
If no URI identification information is known about the physical entity, the object is not instantiated. A zero length octet string may also be returned in this case."  
REFERENCE  
"RFC 3986, Uniform Resource Identifiers (URI): Generic Syntax, section 2, August 1998."  
  
 ::= { entPhysicalEntry 18 }

entPhysicalUUID OBJECT-TYPE

SYNTAX           UUIDorZero  
 MAX-ACCESS   read-only  
 STATUS        current  
 DESCRIPTION  
     "This object contains identification information  
     about the physical entity. The object contains a Universal  
     Unique Identifier, the syntax of this object must conform  
     to RFC 4122, section 4.1.

    A zero length octet string is returned if no UUID  
     information is known."

REFERENCE  
     "RFC 4122, A Universally Unique Identifier (UUID) URN  
     Namespace, section 4.1, July 2005."

::= { entPhysicalEntry 19 }

--               The Logical Entity Table  
 entLogicalTable OBJECT-TYPE  
     SYNTAX       SEQUENCE OF EntLogicalEntry  
     MAX-ACCESS   not-accessible  
     STATUS       current  
     DESCRIPTION  
         "This table contains one row per logical entity. For agents  
         that implement more than one naming scope, at least one  
         entry must exist. Agents which instantiate all MIB objects  
         within a single naming scope are not required to implement  
         this table."  
     ::= { entityLogical 1 }

entLogicalEntry       OBJECT-TYPE  
     SYNTAX       EntLogicalEntry  
     MAX-ACCESS   not-accessible  
     STATUS       current  
     DESCRIPTION  
         "Information about a particular logical entity. Entities  
         may be managed by this agent or other SNMP agents (possibly)  
         in the same chassis."  
     INDEX        { entLogicalIndex }  
     ::= { entLogicalTable 1 }

EntLogicalEntry ::= SEQUENCE {  
     entLogicalIndex       Integer32,  
     entLogicalDescr       SnmpAdminString,  
     entLogicalType        AutonomousType,  
     entLogicalCommunity   OCTET STRING,

```
 entLogicalTAddress TAddress,
 entLogicalTDomain TDomain,
 entLogicalContextEngineID SnmpEngineIdOrNone,
 entLogicalContextName SnmpAdminString
}
```

```
entLogicalIndex OBJECT-TYPE
 SYNTAX Integer32 (1..2147483647)
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
```

"The value of this object uniquely identifies the logical entity. The value should be a small positive integer; index values for different logical entities are not necessarily contiguous."

```
::= { entLogicalEntry 1 }
```

```
entLogicalDescr OBJECT-TYPE
 SYNTAX SnmpAdminString
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
```

"A textual description of the logical entity. This object should contain a string that identifies the manufacturer's name for the logical entity, and should be set to a distinct value for each version of the logical entity."

```
::= { entLogicalEntry 2 }
```

```
entLogicalType OBJECT-TYPE
 SYNTAX AutonomousType
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
```

"An indication of the type of logical entity. This will typically be the OBJECT IDENTIFIER name of the node in the SMI's naming hierarchy which represents the major MIB module, or the majority of the MIB modules, supported by the logical entity. For example:

a logical entity of a regular host/router -> mib-2

a logical entity of a 802.1d bridge -> dot1dBridge

a logical entity of a 802.3 repeater -> snmpDot3RptrMgmt

If an appropriate node in the SMI's naming hierarchy cannot be identified, the value 'mib-2' should be used."

```
::= { entLogicalEntry 3 }
```



## entLogicalCommunity OBJECT-TYPE

SYNTAX OCTET STRING (SIZE (0..255))

MAX-ACCESS read-only

STATUS deprecated

## DESCRIPTION

"An SNMPv1 or SNMPv2C community-string, which can be used to access detailed management information for this logical entity. The agent should allow read access with this community string (to an appropriate subset of all managed objects) and may also return a community string based on the privileges of the request used to read this object. Note that an agent may return a community string with read-only privileges, even if this object is accessed with a read-write community string. However, the agent must take

care not to return a community string that allows more privileges than the community string used to access this object.

A compliant SNMP agent may wish to conserve naming scopes by representing multiple logical entities in a single 'default' naming scope. This is possible when the logical entities, represented by the same value of entLogicalCommunity, have no object instances in common. For example, 'bridge1' and 'repeater1' may be part of the main naming scope, but at least one additional community string is needed to represent 'bridge2' and 'repeater2'.

Logical entities 'bridge1' and 'repeater1' would be represented by sysOREntries associated with the 'default' naming scope.

For agents not accessible via SNMPv1 or SNMPv2C, the value of this object is the empty string. This object may also contain an empty string if a community string has not yet been assigned by the agent, or if no community string with suitable access rights can be returned for a particular SNMP request.

Note that this object is deprecated. Agents which implement SNMPv3 access should use the entLogicalContextEngineID and entLogicalContextName objects to identify the context associated with each logical entity. SNMPv3 agents may return a zero-length string for this object, or may continue to return a community string (e.g., tri-lingual agent support)."

```
::= { entLogicalEntry 4 }
```

entLogicalTAddress OBJECT-TYPE

```
SYNTAX TAddress
MAX-ACCESS read-only
STATUS current
DESCRIPTION
```

"The transport service address by which the logical entity receives network management traffic, formatted according to the corresponding value of entLogicalTDomain.

For snmpUDPDomain, a TAddress is 6 octets long: the initial 4 octets contain the IP-address in network-byte order and the last 2 contain the UDP port in network-byte order. Consult 'Transport Mappings for the Simple Network Management Protocol' (STD 62, RFC 3417 [RFC3417]) for further information on snmpUDPDomain."

```
::= { entLogicalEntry 5 }
```

entLogicalTDomain OBJECT-TYPE

```
SYNTAX TDomain
MAX-ACCESS read-only
STATUS current
DESCRIPTION
```

"Indicates the kind of transport service by which the logical entity receives network management traffic. Possible values for this object are presently found in the Transport Mappings for Simple Network Management Protocol' (STD 62, RFC 3417 [RFC3417])."

```
::= { entLogicalEntry 6 }
```

entLogicalContextEngineID OBJECT-TYPE

```
SYNTAX SnmpEngineIdOrNone
MAX-ACCESS read-only
STATUS current
DESCRIPTION
```

"The authoritative contextEngineID that can be used to send an SNMP message concerning information held by this logical entity, to the address specified by the associated 'entLogicalTAddress/entLogicalTDomain' pair.

This object, together with the associated entLogicalContextName object, defines the context associated with a particular logical entity, and allows access to SNMP engines identified by a contextEngineId and contextName

pair.

If no value has been configured by the agent, a zero-length string is returned, or the agent may choose not to instantiate this object at all."

::= { entLogicalEntry 7 }

entLogicalContextName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The contextName that can be used to send an SNMP message concerning information held by this logical entity, to the address specified by the associated 'entLogicalTAddress/entLogicalTDomain' pair.

This object, together with the associated entLogicalContextEngineID object, defines the context associated with a particular logical entity, and allows

access to SNMP engines identified by a contextEngineId and contextName pair.

If no value has been configured by the agent, a zero-length string is returned, or the agent may choose not to instantiate this object at all."

::= { entLogicalEntry 8 }

entLPMappingTable OBJECT-TYPE

SYNTAX SEQUENCE OF EntLPMappingEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table contains zero or more rows of logical entity to physical equipment associations. For each logical entity known by this agent, there are zero or more mappings to the physical resources, which are used to realize that logical entity.

An agent should limit the number and nature of entries in this table such that only meaningful and non-redundant information is returned. For example, in a system that contains a single power supply, mappings between logical entities and the power supply are not useful and should not be included.

Also, only the most appropriate physical component, which is closest to the root of a particular containment tree, should be identified in an entLPMapping entry.

For example, suppose a bridge is realized on a particular module, and all ports on that module are ports on this bridge. A mapping between the bridge and the module would be useful, but additional mappings between the bridge and each of the ports on that module would be redundant (because the entPhysicalContainedIn hierarchy can provide the same information). On the other hand, if more than one bridge were utilizing ports on this module, then mappings between each bridge and the ports it used would be appropriate.

Also, in the case of a single backplane repeater, a mapping for the backplane to the single repeater entity is not necessary."

```
::= { entityMapping 1 }
```

```
entLPMappingEntry OBJECT-TYPE
 SYNTAX EntLPMappingEntry
 MAX-ACCESS not-accessible
```

```
 STATUS current
```

```
 DESCRIPTION
```

```
 "Information about a particular logical entity to physical
 equipment association. Note that the nature of the
 association is not specifically identified in this entry.
 It is expected that sufficient information exists in the
 MIB modules used to manage a particular logical entity to
 infer how physical component information is utilized."
```

```
 INDEX { entLogicalIndex, entLPPPhysicalIndex }
```

```
::= { entLPMappingTable 1 }
```

```
EntLPMappingEntry ::= SEQUENCE {
 entLPPPhysicalIndex PhysicalIndex
}
```

```
entLPPPhysicalIndex OBJECT-TYPE
```

```
 SYNTAX PhysicalIndex
```

```
 MAX-ACCESS read-only
```

```
 STATUS current
```

```
 DESCRIPTION
```

```
 "The value of this object identifies the index value of a
 particular entPhysicalEntry associated with the indicated
 entLogicalEntity."
```

```

 ::= { entLPMappingEntry 1 }

-- logical entity/component to alias table
entAliasMappingTable OBJECT-TYPE
 SYNTAX SEQUENCE OF EntAliasMappingEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table contains zero or more rows, representing
 mappings of logical entity and physical component to
 external MIB identifiers. Each physical port in the system
 may be associated with a mapping to an external identifier,
 which itself is associated with a particular logical
 entity's naming scope. A 'wildcard' mechanism is provided
 to indicate that an identifier is associated with more than
 one logical entity."
 ::= { entityMapping 2 }

entAliasMappingEntry OBJECT-TYPE
 SYNTAX EntAliasMappingEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "Information about a particular physical equipment, logical

 entity to external identifier binding. Each logical
 entity/physical component pair may be associated with one
 alias mapping. The logical entity index may also be used as
 a 'wildcard' (refer to the entAliasLogicalIndexOrZero object
 DESCRIPTION clause for details.)

 Note that only entPhysicalIndex values that represent
 physical ports (i.e., associated entPhysicalClass value is
 'port(10)') are permitted to exist in this table."
 INDEX { entPhysicalIndex, entAliasLogicalIndexOrZero }
 ::= { entAliasMappingTable 1 }

EntAliasMappingEntry ::= SEQUENCE {
 entAliasLogicalIndexOrZero Integer32,
 entAliasMappingIdentifier RowPointer
}

entAliasLogicalIndexOrZero OBJECT-TYPE
 SYNTAX Integer32 (0..2147483647)
 MAX-ACCESS not-accessible

```

STATUS current

DESCRIPTION

"The value of this object identifies the logical entity that defines the naming scope for the associated instance of the 'entAliasMappingIdentifier' object.

If this object has a non-zero value, then it identifies the logical entity named by the same value of entLogicalIndex.

If this object has a value of zero, then the mapping between the physical component and the alias identifier for this entAliasMapping entry is associated with all unspecified logical entities. That is, a value of zero (the default mapping) identifies any logical entity that does not have an explicit entry in this table for a particular entPhysicalIndex/entAliasMappingIdentifier pair.

For example, to indicate that a particular interface (e.g., physical component 33) is identified by the same value of ifIndex for all logical entities, the following instance might exist:

```
entAliasMappingIdentifier.33.0 = ifIndex.5
```

In the event an entPhysicalEntry is associated differently for some logical entities, additional entAliasMapping entries may exist, e.g.:

```
entAliasMappingIdentifier.33.0 = ifIndex.6
entAliasMappingIdentifier.33.4 = ifIndex.1
entAliasMappingIdentifier.33.5 = ifIndex.1
entAliasMappingIdentifier.33.10 = ifIndex.12
```

Note that entries with non-zero entAliasLogicalIndexOrZero index values have precedence over zero-indexed entries. In this example, all logical entities except 4, 5, and 10, associate physical entity 33 with ifIndex.6."

```
::= { entAliasMappingEntry 1 }
```

entAliasMappingIdentifier OBJECT-TYPE

SYNTAX RowPointer

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The value of this object identifies a particular conceptual

row associated with the indicated entPhysicalIndex and entLogicalIndex pair.

Because only physical ports are modeled in this table, only entries that represent interfaces or ports are allowed. If an ifEntry exists on behalf of a particular physical port, then this object should identify the associated 'ifEntry'. For repeater ports, the appropriate row in the 'rpPtrPortGroupTable' should be identified instead.

For example, suppose a physical port was represented by entPhysicalEntry.3, entLogicalEntry.15 existed for a repeater, and entLogicalEntry.22 existed for a bridge. Then there might be two related instances of entAliasMappingIdentifier:

```
entAliasMappingIdentifier.3.15 == rpPtrPortGroupIndex.5.2
entAliasMappingIdentifier.3.22 == ifIndex.17
```

It is possible that other mappings (besides interfaces and repeater ports) may be defined in the future, as required.

Bridge ports are identified by examining the Bridge MIB and appropriate ifEntries associated with each 'dot1dBasePort', and are thus not represented in this table."

```
::= { entAliasMappingEntry 2 }
```

```
-- physical mapping table
```

```
entPhysicalContainsTable OBJECT-TYPE
```

```
SYNTAX SEQUENCE OF EntPhysicalContainsEntry
MAX-ACCESS not-accessible
STATUS current
```

#### DESCRIPTION

"A table that exposes the container/'containee' relationships between physical entities. This table provides all the information found by constructing the virtual containment tree for a given entPhysicalTable, but in a more direct format.

In the event a physical entity is contained by more than one other physical entity (e.g., double-wide modules), this table should include these additional mappings, which cannot be represented in the entPhysicalTable virtual containment tree."

```
::= { entityMapping 3 }
```

```
entPhysicalContainsEntry OBJECT-TYPE
 SYNTAX EntPhysicalContainsEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "A single container/'containeer' relationship."
 INDEX { entPhysicalIndex, entPhysicalChildIndex }
 ::= { entPhysicalContainsTable 1 }

EntPhysicalContainsEntry ::= SEQUENCE {
 entPhysicalChildIndex PhysicalIndex
}

entPhysicalChildIndex OBJECT-TYPE
 SYNTAX PhysicalIndex
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "The value of entPhysicalIndex for the contained physical
 entity."
 ::= { entPhysicalContainsEntry 1 }

-- last change time stamp for the whole MIB
entLastChangeTime OBJECT-TYPE
 SYNTAX TimeStamp
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "The value of sysUpTime at the time a conceptual row is
 created, modified, or deleted in any of these tables:
 - entPhysicalTable
 - entLogicalTable
 - entLPMappingTable
 - entAliasMappingTable

 - entPhysicalContainsTable
 "
 ::= { entityGeneral 1 }

-- Entity MIB Trap Definitions
entityMIBTraps OBJECT IDENTIFIER ::= { entityMIB 2 }
entityMIBTrapPrefix OBJECT IDENTIFIER ::= { entityMIBTraps 0 }

entConfigChange NOTIFICATION-TYPE
 STATUS current
```



## DESCRIPTION

"An entConfigChange notification is generated when the value of entLastChangeTime changes. It can be utilized by an NMS to trigger logical/physical entity table maintenance polls.

An agent should not generate more than one entConfigChange 'notification-event' in a given time interval (five seconds is the suggested default). A 'notification-event' is the transmission of a single trap or inform PDU to a list of notification destinations.

If additional configuration changes occur within the throttling period, then notification-events for these changes should be suppressed by the agent until the current throttling period expires. At the end of a throttling period, one notification-event should be generated if any configuration changes occurred since the start of the throttling period. In such a case, another throttling period is started right away.

An NMS should periodically check the value of entLastChangeTime to detect any missed entConfigChange notification-events, e.g., due to throttling or transmission loss."

```
::= { entityMIBTrapPrefix 1 }
```

```
-- conformance information
```

```
entityConformance OBJECT IDENTIFIER ::= { entityMIB 3 }
```

```
entityCompliances OBJECT IDENTIFIER ::= { entityConformance 1 }
```

```
entityGroups OBJECT IDENTIFIER ::= { entityConformance 2 }
```

```
-- compliance statements
```

```
entityCompliance MODULE-COMPLIANCE
```

```
 STATUS deprecated
```

## DESCRIPTION

"The compliance statement for SNMP entities that implement version 1 of the Entity MIB."

```
MODULE -- this module
```

```
 MANDATORY-GROUPS {
```

```
 entityPhysicalGroup,
 entityLogicalGroup,
 entityMappingGroup,
```

```
 entityGeneralGroup,
 entityNotificationsGroup
 }
 ::= { entityCompliances 1 }

entity2Compliance MODULE-COMPLIANCE
 STATUS deprecated
 DESCRIPTION
 "The compliance statement for SNMP entities that implement
 version 2 of the Entity MIB."
 MODULE -- this module
 MANDATORY-GROUPS {
 entityPhysicalGroup,
 entityPhysical2Group,
 entityGeneralGroup,
 entityNotificationsGroup
 }
 GROUP entityLogical2Group
 DESCRIPTION
 "Implementation of this group is not mandatory for agents
 that model all MIB object instances within a single naming
 scope."

 GROUP entityMappingGroup
 DESCRIPTION
 "Implementation of the entPhysicalContainsTable is mandatory
 for all agents. Implementation of the entLPMappingTable and
 entAliasMappingTables are not mandatory for agents that
 model all MIB object instances within a single naming scope.

 Note that the entAliasMappingTable may be useful for all
 agents; however, implementation of the entityLogicalGroup or
 entityLogical2Group is required to support this table."

 OBJECT entPhysicalSerialNum
 MIN-ACCESS not-accessible
 DESCRIPTION
 "Read and write access is not required for agents that
 cannot identify serial number information for physical
 entities, and/or cannot provide non-volatile storage for

 NMS-assigned serial numbers.

 Write access is not required for agents that can identify
 serial number information for physical entities, but cannot
 provide non-volatile storage for NMS-assigned serial
```

numbers.

Write access is not required for physical entities for which the associated value of the entPhysicalIsFRU object is equal to 'false(2)'."

OBJECT entPhysicalAlias

MIN-ACCESS read-only

DESCRIPTION

"Write access is required only if the associated entPhysicalClass value is equal to 'chassis(3)'."

OBJECT entPhysicalAssetID

MIN-ACCESS not-accessible

DESCRIPTION

"Read and write access is not required for agents that cannot provide non-volatile storage for NMS-assigned asset identifiers.

Write access is not required for physical entities for which the associated value of the entPhysicalIsFRU object is equal to 'false(2)'."

OBJECT entPhysicalClass

SYNTAX INTEGER {

other(1),  
unknown(2),  
chassis(3),  
backplane(4),  
container(5),  
powerSupply(6),  
fan(7),  
sensor(8),  
module(9),  
port(10),  
stack(11)

}

DESCRIPTION

"Implementation of the 'cpu(12)' enumeration is not required."

::= { entityCompliances 2 }

entity3Compliance MODULE-COMPLIANCE

STATUS deprecated

DESCRIPTION

"The compliance statement for SNMP entities that implement

```
version 3 of the Entity MIB."
MODULE -- this module
 MANDATORY-GROUPS {
 entityPhysicalGroup,
 entityPhysical2Group,
 entityPhysical3Group,
 entityGeneralGroup,
 entityNotificationsGroup
 }
 GROUP entityLogical2Group
 DESCRIPTION
 "Implementation of this group is not mandatory for agents
 that model all MIB object instances within a single naming
 scope."

 GROUP entityMappingGroup
 DESCRIPTION
 "Implementation of the entPhysicalContainsTable is mandatory
 for all agents. Implementation of the entLPMappingTable and
 entAliasMappingTables are not mandatory for agents that
 model all MIB object instances within a single naming scope.

 Note that the entAliasMappingTable may be useful for all
 agents; however, implementation of the entityLogicalGroup or
 entityLogical2Group is required to support this table."

 OBJECT entPhysicalSerialNum
 MIN-ACCESS not-accessible
 DESCRIPTION
 "Read and write access is not required for agents that
 cannot identify serial number information for physical
 entities, and/or cannot provide non-volatile storage for
 NMS-assigned serial numbers.

 Write access is not required for agents that can identify
 serial number information for physical entities, but cannot
 provide non-volatile storage for NMS-assigned serial
 numbers.

 Write access is not required for physical entities for
 which the associated value of the entPhysicalIsFRU object
 is equal to 'false(2)'."

 OBJECT entPhysicalAlias
 MIN-ACCESS read-only
 DESCRIPTION
 "Write access is required only if the associated
 entPhysicalClass value is equal to 'chassis(3)'."
```

```
OBJECT entPhysicalAssetID
MIN-ACCESS not-accessible
DESCRIPTION
 "Read and write access is not required for agents that
 cannot provide non-volatile storage for NMS-assigned asset
 identifiers.

 Write access is not required for physical entities for which
 the associated value of entPhysicalIsFRU is equal to
 'false(2)'."
 ::= { entityCompliances 3 }
```

```
entity4Compliance MODULE-COMPLIANCE
STATUS current
DESCRIPTION
 "The compliance statement for SNMP entities that implement
 the full version 4 (full compliance) of the Entity MIB."
MODULE -- this module
MANDATORY-GROUPS {
 entityPhysicalGroup,
 entityPhysical2Group,
 entityPhysical3Group,
 entityGeneralGroup,
 entityNotificationsGroup,
 entityPhysical4Group
}
GROUP entityLogical2Group
DESCRIPTION
 "Implementation of this group is not mandatory for agents
 that model all MIB object instances within a single naming
 scope."

GROUP entityMappingGroup
DESCRIPTION
 "Implementation of the entPhysicalContainsTable is mandatory
 for all agents. Implementation of the entLPMappingTable and
 entAliasMappingTables are not mandatory for agents that
 model all MIB object instances within a single naming scope.

 Note that the entAliasMappingTable may be useful for all
 agents; however, implementation of the entityLogicalGroup or
 entityLogical2Group is required to support this table."

OBJECT entPhysicalSerialNum
MIN-ACCESS not-accessible
```

## DESCRIPTION

"Read and write access is not required for agents that cannot identify serial number information for physical entities, and/or cannot provide non-volatile storage for NMS-assigned serial numbers.

Write access is not required for agents that can identify serial number information for physical entities, but cannot provide non-volatile storage for NMS-assigned serial numbers.

Write access is not required for physical entities for which the associated value of the entPhysicalIsFRU object is equal to 'false(2)'."

## OBJECT entPhysicalAlias

MIN-ACCESS read-only

## DESCRIPTION

"Write access is required only if the associated entPhysicalClass value is equal to 'chassis(3)'."

## OBJECT entPhysicalAssetID

MIN-ACCESS not-accessible

## DESCRIPTION

"Read and write access is not required for agents that cannot provide non-volatile storage for NMS-assigned asset identifiers.

Write access is not required for physical entities for which the associated value of entPhysicalIsFRU is equal to 'false(2)'."

::= { entityCompliances 4 }

## entity4CRCompliance MODULE-COMPLIANCE

STATUS current

## DESCRIPTION

"The compliance statement for SNMP entities that implement version 4 of the Entity MIB on devices with constrained resources."

MODULE -- this module

MANDATORY-GROUPS {

entityPhysicalCRGroup,  
entityPhysical4Group

}

```
::= { entityCompliances 5 }

-- MIB groupings
entityPhysicalGroup OBJECT-GROUP
 OBJECTS {
 entPhysicalDescr,
 entPhysicalVendorType,
 entPhysicalContainedIn,
 entPhysicalClass,
 entPhysicalParentRelPos,
 entPhysicalName
 }
 STATUS current
 DESCRIPTION
 "The collection of objects used to represent physical
 system components, for which a single agent provides
 management information."
 ::= { entityGroups 1 }

entityLogicalGroup OBJECT-GROUP
 OBJECTS {
 entLogicalDescr,
 entLogicalType,
 entLogicalCommunity,
 entLogicalTAddress,
 entLogicalTDomain
 }
 STATUS deprecated
 DESCRIPTION
 "The collection of objects used to represent the list of
 logical entities, for which a single agent provides
 management information."

 ::= { entityGroups 2 }

entityMappingGroup OBJECT-GROUP
 OBJECTS {
 entLPPPhysicalIndex,
 entAliasMappingIdentifier,
 entPhysicalChildIndex
 }
 STATUS current
 DESCRIPTION
 "The collection of objects used to represent the
```

```
 associations between multiple logical entities, physical
 components, interfaces, and port identifiers, for which a
 single agent provides management information."
 ::= { entityGroups 3 }

entityGeneralGroup OBJECT-GROUP
 OBJECTS {
 entLastChangeTime
 }
 STATUS current
 DESCRIPTION
 "The collection of objects used to represent general entity
 information, for which a single agent provides management
 information."
 ::= { entityGroups 4 }

entityNotificationsGroup NOTIFICATION-GROUP
 NOTIFICATIONS { entConfigChange }
 STATUS current
 DESCRIPTION
 "The collection of notifications used to indicate Entity MIB
 data consistency and general status information."
 ::= { entityGroups 5 }

entityPhysical2Group OBJECT-GROUP
 OBJECTS {
 entPhysicalHardwareRev,
 entPhysicalFirmwareRev,
 entPhysicalSoftwareRev,
 entPhysicalSerialNum,
 entPhysicalMfgName,
 entPhysicalModelName,
 entPhysicalAlias,
 entPhysicalAssetID,
 entPhysicalIsFRU
 }
 STATUS current

 DESCRIPTION
 "The collection of objects used to represent physical
 system components, for which a single agent provides
 management information. This group augments the objects
 contained in the entityPhysicalGroup."
 ::= { entityGroups 6 }

entityLogical2Group OBJECT-GROUP
```



```
OBJECTS {
 entLogicalDescr,
 entLogicalType,
 entLogicalTAddress,
 entLogicalTDomain,
 entLogicalContextEngineID,
 entLogicalContextName
}
STATUS current
DESCRIPTION
 "The collection of objects used to represent the
 list of logical entities, for which a single SNMP entity
 provides management information."
::= { entityGroups 7 }

entityPhysical3Group OBJECT-GROUP
OBJECTS {
 entPhysicalMfgDate,
 entPhysicalUris
}
STATUS current
DESCRIPTION
 "The collection of objects used to represent physical
 system components, for which a single agent provides
 management information. This group augments the objects
 contained in the entityPhysicalGroup."
::= { entityGroups 8 }

entityPhysical4Group OBJECT-GROUP
OBJECTS {
 entPhysicalUUID
}
STATUS current
DESCRIPTION
 "The collection of objects used to represent physical
 system components, for which a single agent provides
 management information. This group augments the objects
 contained in the entityPhysicalGroup and
 entityPhysicalCRGroup."
::= { entityGroups 9 }

entityPhysicalCRGroup OBJECT-GROUP
OBJECTS {
 entPhysicalClass,
 entPhysicalName
}
```

STATUS current

DESCRIPTION

"The collection of objects used to represent physical system components for constrained resourced devices, for which a single agent provides management information."

::= { entityGroups 10 }

END

### 3.2. IANA-ENTITY-MIB

IANA-ENTITY-MIB DEFINITIONS ::= BEGIN

IMPORTS

MODULE-IDENTITY, mib-2

FROM SNMPv2-SMI

TEXTUAL-CONVENTION

FROM SNMPv2-TC

;

ianaEntityMIB MODULE-IDENTITY

LAST-UPDATED "201302010000Z" -- February 1, 2013

ORGANIZATION "IANA"

CONTACT-INFO

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Postal: ICANN

4676 Admiralty Way, Suite 330

Marina del Rey, CA 90292

Tel: +1-310-823-9358

EMail: iana@iana.org"

DESCRIPTION

"This MIB module defines a Textual Convention that provides an indication of the general hardware type of a particular physical entity.

Copyright (C) The IETF Trust (2013).

The initial version of this MIB module was published in

RFC yyyy; for full legal notices see the RFC itself.

Supplementary information may be available at:

<http://www.ietf.org/copyrights/ianamib.html>"

REVISION "201302010000Z" -- February 1, 2013  
DESCRIPTION "Initial version of this MIB as published in  
RFC yyyy."

::= { mib-2 xxx }

-- RFC Editor, please replace xxx with the IANA allocation  
-- for this MIB module and yyyy with the number of the  
-- approved RFC

-- Textual Conventions

IANAPhysicalClass ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"An enumerated value which provides an indication of the general hardware type of a particular physical entity. There are no restrictions as to the number of entPhysicalEntries of each entPhysicalClass, which must be instantiated by an agent.

The enumeration 'other' is applicable if the physical entity class is known, but does not match any of the supported values.

The enumeration 'unknown' is applicable if the physical entity class is unknown to the agent.

The enumeration 'chassis' is applicable if the physical entity class is an overall container for networking equipment. Any class of physical entity, except a stack, may be contained within a chassis; and a chassis may only be contained within a stack.

The enumeration 'backplane' is applicable if the physical entity class is some sort of device for aggregating and forwarding networking traffic, such as a shared backplane in a modular ethernet switch. Note that an agent may model a backplane as a single physical entity, which is actually implemented as multiple discrete physical components (within a chassis or stack).

The enumeration 'container' is applicable if the physical entity class is capable of containing one or more removable physical entities, possibly of different types. For example, each (empty or full) slot in a chassis will be modeled as a container. Note that all

removable physical entities should be modeled within a container entity, such as field-replaceable modules, fans, or power supplies. Note that all known containers should be modeled by the agent, including empty containers.

The enumeration 'powerSupply' is applicable if the physical entity class is a power-supplying component.

The enumeration 'fan' is applicable if the physical entity class is a fan or other heat-reduction component.

The enumeration 'sensor' is applicable if the physical entity class is some sort of sensor, such as a temperature sensor within a router chassis.

The enumeration 'module' is applicable if the physical entity class is some sort of self-contained sub-system. If the enumeration 'module' is removable, then it should be modeled within a container entity, otherwise it should be modeled directly within another physical entity (e.g., a chassis or another module).

The enumeration 'port' is applicable if the physical entity class is some sort of networking port, capable of receiving and/or transmitting networking traffic.

The enumeration 'stack' is applicable if the physical entity class is some sort of super-container (possibly virtual), intended to group together multiple chassis entities. A stack may be realized by a 'virtual' cable, a real interconnect cable, attached to multiple chassis, or may in fact be comprised of multiple interconnect cables. A stack should not be modeled within any other physical entities, but a stack may be contained within another stack. Only chassis entities should be contained within a stack.

The enumeration 'cpu' is applicable if the physical entity class is some sort of central processing unit.

The enumeration 'energyObject' is applicable if the physical entity is some sort of a energy object i.e. 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.

The enumeration 'battery' is applicable if the physical entity class is some sort of a battery. "

```
SYNTAX INTEGER {
 other(1),
 unknown(2),
 chassis(3),
 backplane(4),
 container(5), -- e.g., chassis slot or daughter-card holder
 powerSupply(6),
 fan(7),
 sensor(8),
 module(9), -- e.g., plug-in card or daughter-card
 port(10),
 stack(11), -- e.g., stack of multiple chassis entities
 cpu(12),
 energyObject(13),
 battery (14)
}
```

END

### 3.3. UUID-TC-MIB

UUID-TC-MIB DEFINITIONS ::= BEGIN

IMPORTS

```
MODULE-IDENTITY, mib-2
FROM SNMPv2-SMI
TEXTUAL-CONVENTION
FROM SNMPv2-TC
;
```

uuidTCMIB MODULE-IDENTITY

LAST-UPDATED "201302040000Z" -- February 4, 2013

ORGANIZATION "IETF Energy Management Working Group"

CONTACT-INFO "

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#### DESCRIPTION

"This MIB module defines Textual Conventions  
representing Universal Unique IDentifiers (UUIDs).

Copyright (C) The IETF Trust (2013).  
The initial version of this MIB module was  
published in RFC yyyy; for full legal notices  
see the RFC itself.

Supplementary information may be available at:  
<http://www.ietf.org/copyrights/ianamib.html>"

REVISION "201302040000Z" -- February 4, 2013  
DESCRIPTION "Initial version of this MIB as published in  
RFC yyyy."

::= { mib-2 zzz }

-- RFC Editor, please replace xxx with the IANA allocation for  
-- this MIB module and yyyy with the number of the approved RFC

-- Textual Conventions

UUID ::= TEXTUAL-CONVENTION  
DISPLAY-HINT "4x-2x-2x-1x1x-6x"  
STATUS current

## DESCRIPTION

"Universal Unique Identifier information. The syntax must conform to RFC 4122, section 4.1."

SYNTAX OCTET STRING (SIZE (16))

UIDorZero ::= TEXTUAL-CONVENTION

DISPLAY-HINT "4x-2x-2x-1x1x-6x"

STATUS current

## DESCRIPTION

"Universal Unique Identifier information. The syntax must conform to RFC 4122, section 4.1."

The semantics of the value zero-length OCTET STRING are object-specific and must therefore be defined as part of the description of any object that uses this syntax."

SYNTAX OCTET STRING (SIZE (0|16))

END

#### 4. Usage Examples

The following sections iterate the instance values for two example networking devices. These examples are kept simple to make them more understandable. Auxiliary components such as fans, sensors, empty slots, and sub-modules are not shown, but might be modeled in real implementations.

##### 4.1. Router/Bridge

The first example is a router containing two slots. Each slot contains a 3 port router/bridge module. Each port is represented in the ifTable. There are two logical instances of OSPF running and two logical bridges:

Physical entities -- entPhysicalTable:

1 Field-replaceable physical chassis:

```
entPhysicalDescr.1 == 'Acme Chassis Model 100'
entPhysicalVendorType.1 == acmeProducts.chassisTypes.1
entPhysicalContainedIn.1 == 0
entPhysicalClass.1 == chassis(3)
entPhysicalParentRelPos.1 == 0
entPhysicalName.1 == '100-A'
entPhysicalHardwareRev.1 == 'A(1.00.02)'
entPhysicalSoftwareRev.1 == ''
```

```

entPhysicalFirmwareRev.1 == ''
entPhysicalSerialNum.1 == 'C100076544'
entPhysicalMfgName.1 == 'Acme'
entPhysicalModelName.1 == '100'
entPhysicalAlias.1 == 'cl-SJ17-3-006:rack1:rtr-U3'
entPhysicalAssetID.1 == '0007372293'
entPhysicalIsFRU.1 == true(1)
entPhysicalMfgDate.1 == '2002-5-26,13:30:30.0,-4:0'
entPhysicalUris.1 == 'URN:CLEI:CNME120ARA'
2 slots within the chassis:
entPhysicalDescr.2 == 'Acme Chassis Slot Type AA'
entPhysicalVendorType.2 == acmeProducts.slotTypes.1
entPhysicalContainedIn.2 == 1
entPhysicalClass.2 == container(5)
entPhysicalParentRelPos.2 == 1
entPhysicalName.2 == 'S1'
entPhysicalHardwareRev.2 == 'B(1.00.01)'
entPhysicalSoftwareRev.2 == ''
entPhysicalFirmwareRev.2 == ''
entPhysicalSerialNum.2 == ''
entPhysicalMfgName.2 == 'Acme'
entPhysicalModelName.2 == 'AA'
entPhysicalAlias.2 == ''
entPhysicalAssetID.2 == ''
entPhysicalIsFRU.2 == false(2)
entPhysicalMfgDate.2 == '2002-7-26,12:22:12.0,-4:0'
entPhysicalUris.2 == 'URN:CLEI:CNME123ARA'

entPhysicalDescr.3 == 'Acme Chassis Slot Type AA'
entPhysicalVendorType.3 == acmeProducts.slotTypes.1
entPhysicalContainedIn.3 == 1
entPhysicalClass.3 == container(5)
entPhysicalParentRelPos.3 == 2
entPhysicalName.3 == 'S2'
entPhysicalHardwareRev.3 == '1.00.07'
entPhysicalSoftwareRev.3 == ''
entPhysicalFirmwareRev.3 == ''
entPhysicalSerialNum.3 == ''
entPhysicalMfgName.3 == 'Acme'
entPhysicalModelName.3 == 'AA'
entPhysicalAlias.3 == ''
entPhysicalAssetID.3 == ''
entPhysicalIsFRU.3 == false(2)
entPhysicalMfgDate.3 == '2002-7-26,12:12:12.0,-4:0'
entPhysicalUris.3 == 'URN:CLEI:CNME123ARA'

```

2 Field-replaceable modules:

Slot 1 contains a module with 3 ports:



```

entPhysicalDescr.4 == 'Acme Router-100'
entPhysicalVendorType.4 == acmeProducts.moduleTypes.14
entPhysicalContainedIn.4 == 2
entPhysicalClass.4 == module(9)
entPhysicalParentRelPos.4 == 1
entPhysicalName.4 == 'M1'
entPhysicalHardwareRev.4 == '1.00.07'
entPhysicalSoftwareRev.4 == '1.4.1'
entPhysicalFirmwareRev.4 == 'A(1.1)'
entPhysicalSerialNum.4 == 'C100087363'
entPhysicalMfgName.4 == 'Acme'
entPhysicalModelName.4 == 'R100-FE'
entPhysicalAlias.4 == 'rtr-U3:m1:SJ17-3-eng'
entPhysicalAssetID.4 == '0007372462'
entPhysicalIsFRU.4 == true(1)
entPhysicalMfgDate.4 == '2003-7-18,13:30:30.0,-4:0'
entPhysicalUris.4 == 'URN:CLEI:CNRU123CAA'

entPhysicalDescr.5 == 'Acme Ethernet-100 Port'
entPhysicalVendorType.5 == acmeProducts.portTypes.2
entPhysicalContainedIn.5 == 4
entPhysicalClass.5 == port(10)
entPhysicalParentRelPos.5 == 1
entPhysicalName.5 == 'P1'
entPhysicalHardwareRev.5 == 'G(1.02)'
entPhysicalSoftwareRev.5 == ''
entPhysicalFirmwareRev.5 == '1.1'
entPhysicalSerialNum.5 == ''
entPhysicalMfgName.5 == 'Acme'
entPhysicalModelName.5 == 'FE-100'
entPhysicalAlias.5 == ''
entPhysicalAssetID.5 == ''
entPhysicalIsFRU.5 == false(2)
entPhysicalMfgDate.5 == '2003-7-18,14:20:22.0,-4:0'
entPhysicalUris.5 == 'URN:CLEI:CNMES23ARA'

entPhysicalDescr.6 == 'Acme Ethernet-100 Port'
entPhysicalVendorType.6 == acmeProducts.portTypes.2
entPhysicalContainedIn.6 == 4
entPhysicalClass.6 == port(10)
entPhysicalParentRelPos.6 == 2
entPhysicalName.6 == 'P2'
entPhysicalHardwareRev.6 == 'G(1.02)'
entPhysicalSoftwareRev.6 == ''
entPhysicalFirmwareRev.6 == '1.1'
entPhysicalSerialNum.6 == ''
entPhysicalMfgName.6 == 'Acme'
entPhysicalModelName.6 == 'FE-100'

```

```

entPhysicalAlias.6 == ''
entPhysicalAssetID.6 == ''
entPhysicalIsFRU.6 == false(2)
entPhysicalMfgDate.6 == '2003-7-19,10:15:15.0,-4:0'
entPhysicalUris.6 == 'URN:CLEI:CNMES23ARA'

```

```

entPhysicalDescr.7 == 'Acme Router-100 FDDI-Port'
entPhysicalVendorType.7 == acmeProducts.portTypes.3
entPhysicalContainedIn.7 == 4
entPhysicalClass.7 == port(10)
entPhysicalParentRelPos.7 == 3
entPhysicalName.7 == 'P3'
entPhysicalHardwareRev.7 == 'B(1.03)'
entPhysicalSoftwareRev.7 == '2.5.1'
entPhysicalFirmwareRev.7 == '2.5F'
entPhysicalSerialNum.7 == ''
entPhysicalMfgName.7 == 'Acme'
entPhysicalModelName.7 == 'FDDI-100'
entPhysicalAlias.7 == ''
entPhysicalAssetID.7 == ''
entPhysicalIsFRU.7 == false(2)

```

Slot 2 contains another 3-port module:

```

entPhysicalDescr.8 == 'Acme Router-100 Comm Module'
entPhysicalVendorType.8 == acmeProducts.moduleTypes.15
entPhysicalContainedIn.8 == 3
entPhysicalClass.8 == module(9)
entPhysicalParentRelPos.8 == 1
entPhysicalName.8 == 'M2'
entPhysicalHardwareRev.8 == '2.01.00'
entPhysicalSoftwareRev.8 == '3.0.7'
entPhysicalFirmwareRev.8 == 'A(1.2)'
entPhysicalSerialNum.8 == 'C100098732'
entPhysicalMfgName.8 == 'Acme'
entPhysicalModelName.8 == 'C100'
entPhysicalAlias.8 == 'rtr-U3:m2:SJ17-2-eng'
entPhysicalAssetID.8 == '0007373982'
entPhysicalIsFRU.8 == true(1)
entPhysicalMfgDate.8 == '2002-5-26,13:30:15.0,-4:0'
entPhysicalUris.8 == 'URN:CLEI:CNRT321MAA'

```

```

entPhysicalDescr.9 == 'Acme Fddi-100 Port'
entPhysicalVendorType.9 == acmeProducts.portTypes.5
entPhysicalContainedIn.9 == 8
entPhysicalClass.9 == port(10)
entPhysicalParentRelPos.9 == 1
entPhysicalName.9 == 'FDDI Primary'
entPhysicalHardwareRev.9 == 'CC(1.07)'

```

```

entPhysicalSoftwareRev.9 == '2.0.34'
entPhysicalFirmwareRev.9 == '1.1'
entPhysicalSerialNum.9 == ''
entPhysicalMfgName.9 == 'Acme'
entPhysicalModelName.9 == 'FDDI-100'
entPhysicalAlias.9 == ''
entPhysicalAssetID.9 == ''
entPhysicalIsFRU.9 == false(2)

entPhysicalDescr.10 == 'Acme Ethernet-100 Port'
entPhysicalVendorType.10 == acmeProducts.portTypes.2
entPhysicalContainedIn.10 == 8
entPhysicalClass.10 == port(10)
entPhysicalParentRelPos.10 == 2
entPhysicalName.10 == 'Ethernet A'
entPhysicalHardwareRev.10 == 'G(1.04)'
entPhysicalSoftwareRev.10 == ''
entPhysicalFirmwareRev.10 == '1.3'
entPhysicalSerialNum.10 == ''
entPhysicalMfgName.10 == 'Acme'
entPhysicalModelName.10 == 'FE-100'
entPhysicalAlias.10 == ''
entPhysicalAssetID.10 == ''
entPhysicalIsFRU.10 == false(2)
entPhysicalMfgDate.10 == '2002-7-26,13:30:15.0,-4:0'
entPhysicalUris.10 == 'URN:CLEI:CNMES23ARA'

entPhysicalDescr.11 == 'Acme Ethernet-100 Port'
entPhysicalVendorType.11 == acmeProducts.portTypes.2
entPhysicalContainedIn.11 == 8
entPhysicalClass.11 == port(10)
entPhysicalParentRelPos.11 == 3
entPhysicalName.11 == 'Ethernet B'
entPhysicalHardwareRev.11 == 'G(1.04)'
entPhysicalSoftwareRev.11 == ''
entPhysicalFirmwareRev.11 == '1.3'
entPhysicalSerialNum.11 == ''
entPhysicalMfgName.11 == 'Acme'
entPhysicalModelName.11 == 'FE-100'
entPhysicalAlias.11 == ''
entPhysicalAssetID.11 == ''
entPhysicalIsFRU.11 == false(2)
entPhysicalMfgDate.11 == '2002-8-16,15:35:15.0,-4:0'
entPhysicalUris.11 == 'URN:CLEI:CNMES23ARA'

```

Logical entities -- entLogicalTable; no SNMPv3 support

2 OSPF instances:

```
entLogicalDescr.1 == 'Acme OSPF v1.1'
```

```

entLogicalType.1 == ospf
entLogicalCommunity.1 == 'public-ospf1'
entLogicalTAddress.1 == 192.0.2.1:161
entLogicalTDomain.1 == snmpUDPDomain
entLogicalContextEngineID.1 == ''
entLogicalContextName.1 == ''

entLogicalDescr.2 == 'Acme OSPF v1.1'
entLogicalType.2 == ospf
entLogicalCommunity.2 == 'public-ospf2'
entLogicalTAddress.2 == 192.0.2.1:161
entLogicalTDomain.2 == snmpUDPDomain
entLogicalContextEngineID.2 == ''
entLogicalContextName.2 == ''

2 logical bridges:
entLogicalDescr.3 == 'Acme Bridge v2.1.1'
entLogicalType.3 == dot1dBridge
entLogicalCommunity.3 == 'public-bridge1'
entLogicalTAddress.3 == 192.0.2.1:161
entLogicalTDomain.3 == snmpUDPDomain
entLogicalContextEngineID.3 == ''
entLogicalContextName.3 == ''

entLogicalDescr.4 == 'Acme Bridge v2.1.1'
entLogicalType.4 == dot1dBridge
entLogicalCommunity.4 == 'public-bridge2'
entLogicalTAddress.4 == 192.0.2.1:161
entLogicalTDomain.4 == snmpUDPDomain
entLogicalContextEngineID.4 == ''
entLogicalContextName.4 == ''

Logical to Physical Mappings:
1st OSPF instance: uses module 1-port 1
 entLPPhysicalIndex.1.5 == 5

2nd OSPF instance: uses module 2-port 1
 entLPPhysicalIndex.2.9 == 9

1st bridge group: uses module 1, all ports

[ed. -- Note that these mappings are included in the table because
another logical entity (1st OSPF) utilizes one of the
ports. If this were not the case, then a single mapping
to the module (e.g., entLPPhysicalIndex.3.4) would be
present instead.]
 entLPPhysicalIndex.3.5 == 5
 entLPPhysicalIndex.3.6 == 6

```

```
entLPPhysicalIndex.3.7 == 7
```

2nd bridge group: uses module 2, all ports

```
entLPPhysicalIndex.4.9 == 9
```

```
entLPPhysicalIndex.4.10 == 10
```

```
entLPPhysicalIndex.4.11 == 11
```

Physical to Logical to MIB Alias Mappings -- entAliasMappingTable:

Example 1: ifIndex values are global to all logical entities

```
entAliasMappingIdentifier.5.0 == ifIndex.1
```

```
entAliasMappingIdentifier.6.0 == ifIndex.2
```

```
entAliasMappingIdentifier.7.0 == ifIndex.3
```

```
entAliasMappingIdentifier.9.0 == ifIndex.4
```

```
entAliasMappingIdentifier.10.0 == ifIndex.5
```

```
entAliasMappingIdentifier.11.0 == ifIndex.6
```

Example 2: ifIndex values are not shared by all logical entities;

(Bridge-1 uses ifIndex values 101 - 103 and Bridge-2 uses

ifIndex values 204-206.)

```
entAliasMappingIdentifier.5.0 == ifIndex.1
```

```
entAliasMappingIdentifier.5.3 == ifIndex.101
```

```
entAliasMappingIdentifier.6.0 == ifIndex.2
```

```
entAliasMappingIdentifier.6.3 == ifIndex.102
```

```
entAliasMappingIdentifier.7.0 == ifIndex.3
```

```
entAliasMappingIdentifier.7.3 == ifIndex.103
```

```
entAliasMappingIdentifier.9.0 == ifIndex.4
```

```
entAliasMappingIdentifier.9.4 == ifIndex.204
```

```
entAliasMappingIdentifier.10.0 == ifIndex.5
```

```
entAliasMappingIdentifier.10.4 == ifIndex.205
```

```
entAliasMappingIdentifier.11.0 == ifIndex.6
```

```
entAliasMappingIdentifier.11.4 == ifIndex.206
```

Physical Containment Tree -- entPhysicalContainsTable

chassis has two containers:

```
entPhysicalChildIndex.1.2 == 2
```

```
entPhysicalChildIndex.1.3 == 3
```

container 1 has a module:

```
entPhysicalChildIndex.2.4 == 4
```

container 2 has a module:

```
entPhysicalChildIndex.3.8 == 8
```

module 1 has 3 ports:

```
entPhysicalChildIndex.4.5 == 5
```

```
entPhysicalChildIndex.4.6 == 6
```

```
entPhysicalChildIndex.4.7 == 7
```

```

module 2 has 3 ports:
 entPhysicalChildIndex.8.9 == 9
 entPhysicalChildIndex.8.10 == 10
 entPhysicalChildIndex.8.11 == 11

```

#### 4.2. Repeaters

The second example is a 3-slot Hub with 2 backplane ethernet segments. Slot three is empty, and the remaining slots contain ethernet repeater modules.

Note that this example assumes an older Repeater MIB implementation, (RFC 2108 [RFC2108]) rather than the new Repeater MIB (RFC 2108 [RFC2108]). The new version contains an object called 'rpPtrPortRpPtrId', which should be used to identify repeater port groupings, rather than using community strings or contexts.

Physical entities -- entPhysicalTable:

```

1 Field-replaceable physical chassis:
 entPhysicalDescr.1 == 'Acme Chassis Model 110'
 entPhysicalVendorType.1 == acmeProducts.chassisTypes.2
 entPhysicalContainedIn.1 == 0
 entPhysicalClass.1 == chassis(3)
 entPhysicalParentRelPos.1 ==0
 entPhysicalName.1 == '110-B'
 entPhysicalHardwareRev.1 == 'A(1.02.00)'
 entPhysicalSoftwareRev.1 == ''
 entPhysicalFirmwareRev.1 == ''
 entPhysicalSerialNum.1 == 'C100079294'
 entPhysicalMfgName.1 == 'Acme'
 entPhysicalModelName.1 == '110'
 entPhysicalAlias.1 == 'bldg09:floor1:rpPtr18:0067eea0229f'
 entPhysicalAssetID.1 == '0007386327'
 entPhysicalIsFRU.1 == true(1)

2 Chassis Ethernet Backplanes:
 entPhysicalDescr.2 == 'Acme Ethernet Backplane Type A'
 entPhysicalVendorType.2 == acmeProducts.backplaneTypes.1
 entPhysicalContainedIn.2 == 1
 entPhysicalClass.2 == backplane(4)
 entPhysicalParentRelPos.2 == 1
 entPhysicalName.2 == 'B1'
 entPhysicalHardwareRev.2 == 'A(2.04.01)'
 entPhysicalSoftwareRev.2 == ''
 entPhysicalFirmwareRev.2 == ''
 entPhysicalSerialNum.2 == ''
 entPhysicalMfgName.2 == 'Acme'
 entPhysicalModelName.2 == 'BK-A'

```

```
entPhysicalAlias.2 == ''
entPhysicalAssetID.2 == ''
entPhysicalIsFRU.2 == false(2)

entPhysicalDescr.3 == 'Acme Ethernet Backplane Type A'
entPhysicalVendorType.3 == acmeProducts.backplaneTypes.1
entPhysicalContainedIn.3 == 1
entPhysicalClass.3 == backplane(4)
entPhysicalParentRelPos.3 == 2
entPhysicalName.3 == 'B2'
entPhysicalHardwareRev.3 == 'A(2.04.01)'
entPhysicalSoftwareRev.3 == ''
entPhysicalFirmwareRev.3 == ''
entPhysicalSerialNum.3 == ''
entPhysicalMfgName.3 == 'Acme'
entPhysicalModelName.3 == 'BK-A'
entPhysicalAlias.3 == ''
entPhysicalAssetID.3 == ''
entPhysicalIsFRU.3 == false(2)

3 slots within the chassis:
entPhysicalDescr.4 == 'Acme Hub Slot Type RB'
entPhysicalVendorType.4 == acmeProducts.slotTypes.5
entPhysicalContainedIn.4 == 1
entPhysicalClass.4 == container(5)
entPhysicalParentRelPos.4 == 1
entPhysicalName.4 == 'Slot 1'
entPhysicalHardwareRev.4 == 'B(1.00.03)'
entPhysicalSoftwareRev.4 == ''
entPhysicalFirmwareRev.4 == ''
entPhysicalSerialNum.4 == ''
entPhysicalMfgName.4 == 'Acme'
entPhysicalModelName.4 == 'RB'
entPhysicalAlias.4 == ''
entPhysicalAssetID.4 == ''
entPhysicalIsFRU.4 == false(2)

entPhysicalDescr.5 == 'Acme Hub Slot Type RB'
entPhysicalVendorType.5 == acmeProducts.slotTypes.5
entPhysicalContainedIn.5 == 1
entPhysicalClass.5 == container(5)
entPhysicalParentRelPos.5 == 2
entPhysicalName.5 == 'Slot 2'
entPhysicalHardwareRev.5 == 'B(1.00.03)'
entPhysicalSoftwareRev.5 == ''
entPhysicalFirmwareRev.5 == ''
entPhysicalSerialNum.5 == ''
entPhysicalMfgName.5 == 'Acme'
```

```
entPhysicalModelName.5 == 'RB'
entPhysicalAlias.5 == ''
entPhysicalAssetID.5 == ''
entPhysicalIsFRU.5 == false(2)

entPhysicalDescr.6 == 'Acme Hub Slot Type RB'
entPhysicalVendorType.6 == acmeProducts.slotTypes.5
entPhysicalContainedIn.6 == 1
entPhysicalClass.6 == container(5)
entPhysicalParentRelPos.6 == 3
entPhysicalName.6 == 'Slot 3'
entPhysicalHardwareRev.6 == 'B(1.00.03)'
entPhysicalSoftwareRev.6 == ''
entPhysicalFirmwareRev.6 == ''
entPhysicalSerialNum.6 == ''
entPhysicalMfgName.6 == 'Acme'
entPhysicalModelName.6 == 'RB'
entPhysicalAlias.6 == ''
entPhysicalAssetID.6 == ''
entPhysicalIsFRU.6 == false(2)
```

Slot 1 contains a plug-in module with 4 10-BaseT ports:

```
entPhysicalDescr.7 == 'Acme 10Base-T Module 114'
entPhysicalVendorType.7 == acmeProducts.moduleTypes.32
entPhysicalContainedIn.7 == 4
entPhysicalClass.7 == module(9)
entPhysicalParentRelPos.7 == 1
entPhysicalName.7 == 'M1'
entPhysicalHardwareRev.7 == 'A(1.02.01)'
entPhysicalSoftwareRev.7 == '1.7.2'
entPhysicalFirmwareRev.7 == 'A(1.5)'
entPhysicalSerialNum.7 == 'C100096244'
entPhysicalMfgName.7 == 'Acme'
entPhysicalModelName.7 == '114'
entPhysicalAlias.7 == 'bldg09:floor1:eng'
entPhysicalAssetID.7 == '0007962951'
entPhysicalIsFRU.7 == true(1)

entPhysicalDescr.8 == 'Acme 10Base-T Port RB'
entPhysicalVendorType.8 == acmeProducts.portTypes.10
entPhysicalContainedIn.8 == 7
entPhysicalClass.8 == port(10)
entPhysicalParentRelPos.8 == 1
entPhysicalName.8 == 'Ethernet-A'
entPhysicalHardwareRev.8 == 'A(1.04F)'
entPhysicalSoftwareRev.8 == ''
entPhysicalFirmwareRev.8 == '1.4'
entPhysicalSerialNum.8 == ''
```



```
entPhysicalMfgName.8 == 'Acme'
entPhysicalModelName.8 == 'RB'
entPhysicalAlias.8 == ''
entPhysicalAssetID.8 == ''
entPhysicalIsFRU.8 == false(2)

entPhysicalDescr.9 == 'Acme 10Base-T Port RB'
entPhysicalVendorType.9 == acmeProducts.portTypes.10
entPhysicalContainedIn.9 == 7
entPhysicalClass.9 == port(10)
entPhysicalParentRelPos.9 == 2
entPhysicalName.9 == 'Ethernet-B'
entPhysicalHardwareRev.9 == 'A(1.04F)'
entPhysicalSoftwareRev.9 == ''
entPhysicalFirmwareRev.9 == '1.4'
entPhysicalSerialNum.9 == ''
entPhysicalMfgName.9 == 'Acme'
entPhysicalModelName.9 == 'RB'
entPhysicalAlias.9 == ''
entPhysicalAssetID.9 == ''
entPhysicalIsFRU.9 == false(2)

entPhysicalDescr.10 == 'Acme 10Base-T Port RB'
entPhysicalVendorType.10 == acmeProducts.portTypes.10
entPhysicalContainedIn.10 == 7
entPhysicalClass.10 == port(10)
entPhysicalParentRelPos.10 == 3
entPhysicalName.10 == 'Ethernet-C'
entPhysicalHardwareRev.10 == 'B(1.02.07)'
entPhysicalSoftwareRev.10 == ''
entPhysicalFirmwareRev.10 == '1.4'
entPhysicalSerialNum.10 == ''
entPhysicalMfgName.10 == 'Acme'
entPhysicalModelName.10 == 'RB'
entPhysicalAlias.10 == ''
entPhysicalAssetID.10 == ''
entPhysicalIsFRU.10 == false(2)

entPhysicalDescr.11 == 'Acme 10Base-T Port RB'
entPhysicalVendorType.11 == acmeProducts.portTypes.10
entPhysicalContainedIn.11 == 7
entPhysicalClass.11 == port(10)
entPhysicalParentRelPos.11 == 4
entPhysicalName.11 == 'Ethernet-D'
entPhysicalHardwareRev.11 == 'B(1.02.07)'
entPhysicalSoftwareRev.11 == ''
entPhysicalFirmwareRev.11 == '1.4'
entPhysicalSerialNum.11 == ''
```

```
entPhysicalMfgName.11 == 'Acme'
entPhysicalModelName.11 == 'RB'
entPhysicalAlias.11 == ''
entPhysicalAssetID.11 == ''
entPhysicalIsFRU.11 == false(2)
```

Slot 2 contains another ethernet module with 2 ports.

```
entPhysicalDescr.12 == 'Acme 10Base-T Module Model 4'
entPhysicalVendorType.12 == acmeProducts.moduleTypes.30
entPhysicalContainedIn.12 == 5
entPhysicalClass.12 == module(9)
entPhysicalParentRelPos.12 == 1
entPhysicalName.12 == 'M2'
entPhysicalHardwareRev.12 == 'A(1.01.07)'
entPhysicalSoftwareRev.12 == '1.8.4'
entPhysicalFirmwareRev.12 == 'A(1.8)'
entPhysicalSerialNum.12 == 'C100102384'
entPhysicalMfgName.12 == 'Acme'
entPhysicalModelName.12 == '4'
entPhysicalAlias.12 == 'bldg09:floor1:devtest'
entPhysicalAssetID.12 == '0007968462'
entPhysicalIsFRU.12 == true(1)
```

```
entPhysicalDescr.13 == 'Acme 802.3 AUI Port'
entPhysicalVendorType.13 == acmeProducts.portTypes.11
entPhysicalContainedIn.13 == 12
entPhysicalClass.13 == port(10)
entPhysicalParentRelPos.13 == 1
entPhysicalName.13 == 'AUI'
entPhysicalHardwareRev.13 == 'A(1.06F)'
entPhysicalSoftwareRev.13 == ''
entPhysicalFirmwareRev.13 == '1.5'
entPhysicalSerialNum.13 == ''
entPhysicalMfgName.13 == 'Acme'
entPhysicalModelName.13 == ''
entPhysicalAlias.13 == ''
entPhysicalAssetID.13 == ''
entPhysicalIsFRU.13 == false(2)
```

```
entPhysicalDescr.14 == 'Acme 10Base-T Port RD'
entPhysicalVendorType.14 == acmeProducts.portTypes.14
entPhysicalContainedIn.14 == 12
entPhysicalClass.14 == port(10)
entPhysicalParentRelPos.14 == 2
entPhysicalName.14 == 'E2'
entPhysicalHardwareRev.14 == 'B(1.01.02)'
entPhysicalSoftwareRev.14 == ''
entPhysicalFirmwareRev.14 == '2.1'
```

```

entPhysicalSerialNum.14 == ''
entPhysicalMfgName.14 == 'Acme'
entPhysicalModelName.14 == ''
entPhysicalAlias.14 == ''
entPhysicalAssetID.14 == ''
entPhysicalIsFRU.14 == false(2)

```

Logical entities -- entLogicalTable; with SNMPv3 support

Repeater 1--comprised of any ports attached to backplane 1

```

entLogicalDescr.1 == 'Acme repeater v3.1'
entLogicalType.1 == snmpDot3RptrMgt
entLogicalCommunity.1 == 'public-repeater1'
entLogicalTAddress.1 == 192.0.2.1:161
entLogicalTDomain.1 == snmpUDPDomain
entLogicalContextEngineID.1 == '80000777017c7d7e7f'H
entLogicalContextName.1 == 'repeater1'

```

Repeater 2--comprised of any ports attached to backplane 2:

```

entLogicalDescr.2 == 'Acme repeater v3.1'
entLogicalType.2 == snmpDot3RptrMgt
entLogicalCommunity.2 == 'public-repeater2'
entLogicalTAddress.2 == 192.0.2.1:161
entLogicalTDomain.2 == snmpUDPDomain
entLogicalContextEngineID.2 == '80000777017c7d7e7f'H
entLogicalContextName.2 == 'repeater2'

```

Logical to Physical Mappings -- entLPMappingTable:

repeater1 uses backplane 1, slot 1-ports 1 & 2, slot 2-port 1  
 [ed. -- Note that a mapping to the module is not included,  
 because this example represents a port-switchable hub.  
 Even though all ports on the module could belong to the  
 same repeater as a matter of configuration, the LP port  
 mappings should not be replaced dynamically with a single  
 mapping for the module (e.g., entLPPhysicalIndex.1.7).  
 If all ports on the module shared a single backplane connection,  
 then a single mapping for the module would be more appropriate.]

```

entLPPhysicalIndex.1.2 == 2
entLPPhysicalIndex.1.8 == 8
entLPPhysicalIndex.1.9 == 9
entLPPhysicalIndex.1.13 == 13

```

repeater2 uses backplane 2, slot 1-ports 3 & 4, slot 2-port 2

```

entLPPhysicalIndex.2.3 == 3
entLPPhysicalIndex.2.10 == 10
entLPPhysicalIndex.2.11 == 11
entLPPhysicalIndex.2.14 == 14

```

Physical to Logical to MIB Alias Mappings -- entAliasMappingTable:

Repeater Port Identifier values are shared by both repeaters:

```
entAliasMappingIdentifier.8.0 == rptrPortGroupIndex.1.1
entAliasMappingIdentifier.9.0 == rptrPortGroupIndex.1.2
entAliasMappingIdentifier.10.0 == rptrPortGroupIndex.1.3
entAliasMappingIdentifier.11.0 == rptrPortGroupIndex.1.4
entAliasMappingIdentifier.13.0 == rptrPortGroupIndex.2.1
entAliasMappingIdentifier.14.0 == rptrPortGroupIndex.2.2
```

Physical Containment Tree -- entPhysicalContainsTable

chassis has two backplanes and three containers:

```
entPhysicalChildIndex.1.2 == 2
entPhysicalChildIndex.1.3 == 3
entPhysicalChildIndex.1.4 == 4
entPhysicalChildIndex.1.5 == 5
entPhysicalChildIndex.1.6 == 6
```

container 1 has a module:

```
entPhysicalChildIndex.4.7 == 7
```

container 2 has a module

```
entPhysicalChildIndex.5.12 == 12
```

[ed. -- in this example, container 3 is empty.]

module 1 has 4 ports:

```
entPhysicalChildIndex.7.8 == 8
entPhysicalChildIndex.7.9 == 9
entPhysicalChildIndex.7.10 == 10
entPhysicalChildIndex.7.11 == 11
```

module 2 has 2 ports:

```
entPhysicalChildIndex.12.13 == 13
entPhysicalChildIndex.12.14 == 14
```

#### 4.3. EMAN Example

As an example, to illustrate the use of the MIB objects introduced with EMAN applications, consider a router and which has 16 slots, with Line cards. Example of the entPhysicalTable is given for 3 components of the router, a Chassis, a slot and a Line card in that slot. The chassis contains the slot and the slot contains the Line card.

```
entPhysicalDescr.1 == 'ACME Series 16 Slots'
entPhysicalVendorType.1 == acmeProducts.chassisTypes.1
entPhysicalContainedIn.1 == 0
entPhysicalClass.1 == chassis(3)
entPhysicalParentRelPos.1 == -1
```

```
entPhysicalName.1 == 'Router 0 Chassis'
entPhysicalHardwareRev.1 == ''
entPhysicalSoftwareRev.1 == ''
entPhysicalFirmwareRev.1 == ''
entPhysicalSerialNum.1 == 'abcd1234'
entPhysicalMfgName.1 == 'ACME'
entPhysicalModelName.1 == 'ACME-16-LCC'
entPhysicalAlias.1 == ''
entPhysicalAssetID.1 == ''
entPhysicalIsFRU.1 == true(1)
entPhysicalMfgDate.1 == '2008-7-28,13:30:30.0,-4:0'
entPhysicalUris.1 == 'urn:f81d4fae-7dec-11d0-a765-00a0c91e6bf6'
entPhysicalUUID.1 == 'f81d4fae-7dec-11d0-a765-00a0c91e6bf6'

entPhysicalDescr.2 == 'ACME Line Card Slot'
entPhysicalVendorType.2 == acmeProducts.slotTypes.1
entPhysicalContainedIn.2 == 1
entPhysicalClass.2 = container(5)
entPhysicalParentRelPos.2 == 6
entPhysicalName.2 == 'Slot 6'
entPhysicalHardwareRev.2 == ''
entPhysicalFirmwareRev.2 == ''
entPhysicalSoftwareRev.2 == ''
entPhysicalSerialNum.2 == ''
entPhysicalMfgName.2 == 'ACME'
entPhysicalModelName.2 == ''
entPhysicalAlias.2 == ''
entPhysicalAssetID.2 == ''
entPhysicalIsFRU.2 == false(2)
entPhysicalUris.2 == 'urn:7dc53df5-703e-49b3-8670-b1c468f47f1f'
entPhysicalUUID.2 == '7dc53df5-703e-49b3-8670-b1c468f47f1f'

entPhysicalDescr.4 == 'ACME Series1 Line Card'
entPhysicalVendorType.4 == acmeProducts.moduleTypes.14
entPhysicalContainedIn.4 == 2
entPhysicalClass.4 == module(9)
entPhysicalParentRelPos.4 == 0
entPhysicalName.4 == 'Series1 Linecard '
entPhysicalHardwareRev.4 == ''
entPhysicalFirmwareRev.4 == ''
entPhysicalSoftwareRev.4 == ''
entPhysicalSerialNum.4 == ''
entPhysicalMfgName.4 == 'ACME'
entPhysicalModelName.4 == ''
entPhysicalAlias.4 == ''
```

```
entPhysicalAssetID.4 == ''
entPhysicalIsFRU.4 == true(1)
entPhysicalUris.4 == 'urn:01c47915-4777-11d8-bc70-0090272ff725'
entPhysicalUUID.4 == '01c47915-4777-11d8-bc70-0090272ff725'
```

## 5. Security Considerations

There are a number of management objects defined in this MIB module 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. These are the tables and objects and their sensitivity/vulnerability:

```
entPhysicalSerialNum
entPhysicalAlias
entPhysicalAssetID
entPhysicalUris
```

These objects contain information about the physical entities within a managed system, which may be used to identify the serial number, identification of assets and managed components, and handling of the managed objects. Their mis-configuration or disclosure may reveal sensitive information on assets or perturb the management of entities.

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:

```
entPhysicalDescr
entPhysicalVendorType
entPhysicalHardwareRev
entPhysicalFirmwareRev
entPhysicalSoftwareRev
entPhysicalMfgName
entPhysicalModelName
entPhysicalUUID
```

These objects expose information about the physical entities within a managed system, which may be used to identify the vendor, model, and version information of each system component.

entLogicalDescr  
entLogicalType

These objects expose the type of logical entities present in the managed system.

entLogicalCommunity

This object exposes community names associated with particular logical entities within the system.

entLogicalTAddress  
entLogicalTDomain

These objects expose network addresses that can be used to communicate with an SNMP agent on behalf of particular logical entities within the system.

entLogicalContextEngineID  
entLogicalContextName

These objects identify the authoritative SNMP engine that contains information on behalf of particular logical entities within the system.

SNMP versions prior to SNMPv3 did not include adequate security. Even if the network itself is secure (for example by using IPsec), 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.

Implementations SHOULD provide the security features described by the SNMPv3 framework (see [RFC3410]), and implementations claiming compliance to the SNMPv3 standard MUST include full support for authentication and privacy via the User-based Security Model (USM) [RFC3414] with the AES cipher algorithm [RFC3826]. Implementations MAY also provide support for the Transport Security Model (TSM) [RFC5591] in combination with a secure transport such as SSH [RFC5592] or TLS/DTLS [RFC6353].

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.

## 6. IANA Considerations

This document defines first version of the IANA-maintained IANA-ENTITY-MIB module, which will allow for new physical classes to be added to the enumeration in IANAPhysicalClass. An Expert Review, as defined in RFC 5226 [RFC5226], is REQUIRED, for each modification.

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

| Descriptor                                                 | OBJECT IDENTIFIER value |
|------------------------------------------------------------|-------------------------|
| -----                                                      | -----                   |
| entityMIB                                                  | { mib-2 47 }            |
| IANA will allocate two OBJECT IDENTIFIERS under mib-2 for: |                         |
| Descriptor                                                 | OBJECT IDENTIFIER value |
| -----                                                      | -----                   |
| ianaEntityMIB                                              | { mib-2 xxx }           |
| uuidTCMIB                                                  | { mib-2 zzz }           |

## 7. Acknowledgements

The first three versions of RFCs on the ENTITY MIB modules were authored by A. Bierman and K. McCloghrie. The authors would like thank A. Bierman and K. McCloghrie for the earlier versions of ENTITY MIB.

The motivation for the extension to RFC 4133 stems from the requirements of the EMAN WG at IETF.

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## Abstract

In the current Internet, it is implicitly assumed that a network node is always active so that it can receive the incoming packets at any time. Current networking services and applications are commonly designed to be fully available at all times with minimal response times. This assumption keeps network nodes from entering sleeping mode in order to reduce energy consumption. Further, during sleeping mode, network nodes may not immediately respond to the incoming packets or even lose them. If network nodes are allowed to go into a sleeping mode, they can effectively reduce energy consumption during idle period. Network proxy allows to delegate network node's traffic processing to an external system within a network, so that the nodes maintain network presence during their sleep. This document describes communication mechanism between network nodes and proxy in order to accelerate the wider deployment of network proxy mechanism.

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## 1. Introduction

Information and Communications Technology (ICT) sector is facing rapid growth and consuming a lot of power in order to provide large bandwidth and complex application services.

According to an ITU-T report, wired and wireless networks consume large amount of power and the amount of green-house gas emissions caused by ICT sector is estimated 2% of total man-made emissions. It is also estimated that network sector including network equipment and equipment connected to networks contributes to 4% of world power consumption. Further, it is observed that the power consumption is higher at access networks and users, so how to reduce the power consumption in these areas is becoming an important issue [ITU].

According to recent surveys, network equipment show a constant power consumption profile irrespective of their utilization level, i.e., energy-agnostic power profile. Such equipment represent the worst case in terms of utilization and power consumption profile. On the contrary, ideally, energy-aware equipment represent power consumption pattern proportional to their utilization or offered load. Practical approaches for realizing the energy-aware equipment are implementing multi-stepped power profiles in order to adapt to the utilization level [EPC][GreenSurvey][EEE].

There is another research direction for improving energy efficiency of network equipment using network proxy technology [I-D.winter-energy-efficient-internet][PROXZZZY][NCP]. Network proxy describes technologies that maintain network connectivity for other devices so that these can go into low power sleep modes. This mainly targets the reduction of unnecessary energy waste through edge devices.

There are typically two types of network proxies: internal and external, respectively.

- o Internal Proxy: proxy functionality is implemented within the ICT product, such as network interface card.
- o External Proxy: proxy functionality is placed within other network equipment such as switch and external server in networks.

This document describes a protocol that is need for communication between external proxies and network hosts.

ECMA International has published a proxying document [PROXZZZY]. This specification describes an overall architecture for network proxying and provides capabilities that a proxy may expose to a host.

Also, information that must be exchanged between a host and a proxy, and required and optional behavior of a proxy during its operation are described.

Within IETF, there are several documents related with the functionality of network proxy [RFC6762][RFC6763][I-D.cheshire-edns0-owner-option]. These documents defines DNS messages-based service discovery mechanisms, which can be used for facilitating various services. These mechanisms may be used for providing some of network proxy functionality, but generalized network proxy functionality is not fully supported.

Generalized network proxy is capable of providing full network presence for a broad range of network protocols and applications. The generalized network proxy include a list of packet types that may require routine reply, autogeneration, and wakeup, as well as the detailed steps and methods for state information transfer each requires [EEEC].

It is well known that many network hosts are in active state in order to maintain network presence and this behavior hinders hosts from entering energy saving state. Even when a node is idle with no running applications, background traffic is received that needs to be processed which inhibits the node from sleeping. Network proxy is one of the possible solutions for resolve this issue. The general framework of network proxy was developed, but the control and communication mechanisms between network hosts and proxies has not been developed. Thus, in order to promote the wider deployment of network proxy mechanism, the control and communication protocol should be specified.

This document defines a control protocol for external network proxy operation and relevant messages in order to increase energy efficiency of network hosts.

## 2. Conventions and 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 [RFC2119].



### 3. Overview of Network Proxy

Network proxy refers to a set of mechanisms dedicated to put network interfaces and network nodes into energy saving sleeping mode. Energy consumption in sleeping mode is less than active mode in general, so the longer the sleeping periods is, the higher the achievable energy saving can be. The network proxy enables network nodes to maintain network connectivity during sleep period. Figure 1 shows the typical operational scenario of network proxy [PROXZZZY]. When a host wants to enter sleeping mode, the host delivers its network status and state to a network proxy and goes into sleeping mode. Then, the network proxy responds to periodic messages on behalf of the host in sleeping mode. If the proxy receives a message that it cannot process, it sends a wake-up message to the host so that the host can process the message after wake-up.

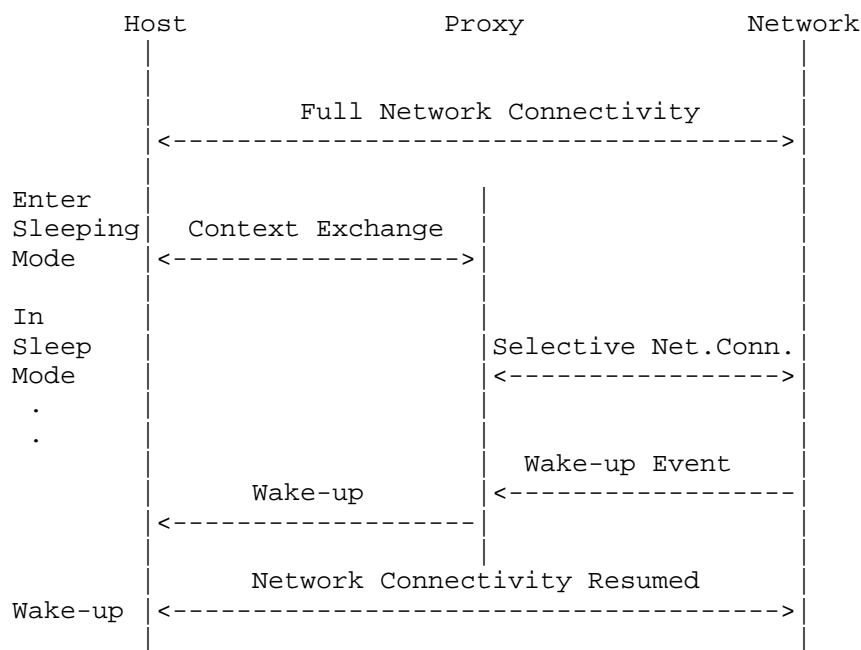


Figure 1: Operational scenario of network proxy

According to the survey, even though a host is in idle mode, background network traffic is received and needs to be processed, which prevents the host from going into sleeping mode. Also, it is known that most of the incoming traffic received during the host's idle period may be simply dropped or do not require more than a minimal computation and response. For instance, most broadcast packets or traffic related to port scanning may simply be ignored.

Usual exchanges, such as Address Resolution Protocol (ARP) processing, Internet Control Message Protocol (ICMP) echo answering or Dynamic Host Configuration Protocol (DHCP) rebinding, are simple tasks that could be easily performed directly by network proxy. The idea behind network proxy is delegating the processing of such traffic. Processing can imply plain filtering or may require simple responses (e.g., in the case of ARP, ICMP, DHCP), or even more complex task. Such tasks can be delegated from the CPUs of hosts to an external network proxy in networks [GreenSurvey].

The following list summarizes requirement status about what types of protocols network proxy should support [PROXZZZY]. Among them, this document describes ARP related operation first and other mandatory protocols will be defined later version of this document.

Mandatory 1: Media (802.3, 802.11)

Mandatory 2: IPv4 ARP

Mandatory 3: IPv6 Neighbor Discovery

Mandatory 4: Wake Packets

Option 1: DNS

Option 2: DHCP

Option 3: IGMP

Option 4: MLD

Option 5: Remote Access using SIP and IPv4

Option 6: Remote Access using Teredo for IPv6

Option 7: SNMP

Option 8: Service Discovery using mDNS

Option 9: Name Resolution with LLNMR

#### 4. Network Proxy Operation

This section describes network proxy operation between proxy server and network nodes to support mandatory protocols. Figure 2 shows network proxy operations for IPv4 ARP. When a network host wants to enter sleeping mode in order to save energy, the host exchanges Proxy Solicitation and Advertisement messages with network proxy in network. Proxy may be implemented as a function within a switch or router, or it may be implemented as a separate server. Proxy Solicitation message queries to network, whether network proxy functionality can be supported within the host's network. If there is a network proxy that can provide proxy functionality, it replies to the host by using Proxy Advertisement message. Network proxy supports required functional behavior defined in [PROXZZZY] in order to support IPv4 ARP.

After the network proxy discovery procedure, the host sends Sleep Request message to network proxy. The Request message contains the host's MAC address(es) and IP address(es). After receiving the Sleep Confirm message from the network proxy, the host enters sleeping mode. Then the network proxy discards ARP Request messages sent from other hosts in the network. By doing so, the host can sleep without receiving or processing ARP broadcast message not destined to the node itself. If the network proxy receives an ARP request message for sleeping host, it sends a reply message on behalf of the sleeping hosts using the host's MAC and IP address. When the network proxy receives a packet that it cannot process, the proxy sends a Wake-up packet to the sleeping host in order to wake it up. During its wake-up process, proxy may buffer additional packets destined to the sleeping hosts. After the sleeping node wakes up it can communicate with remote hosts. When Sleep Timer expires, the sleeping host wakes up and sends a Wake-up Report message to the network proxy. Then, the network proxy cleans up the state information for the sleeping host and replies with Wake-up confirm message.

Note that Figure 2 shows network proxy operation for processing ARP messages and operation for other mandatory protocols specified in [PROXZZZY] will be defined later version of this document.

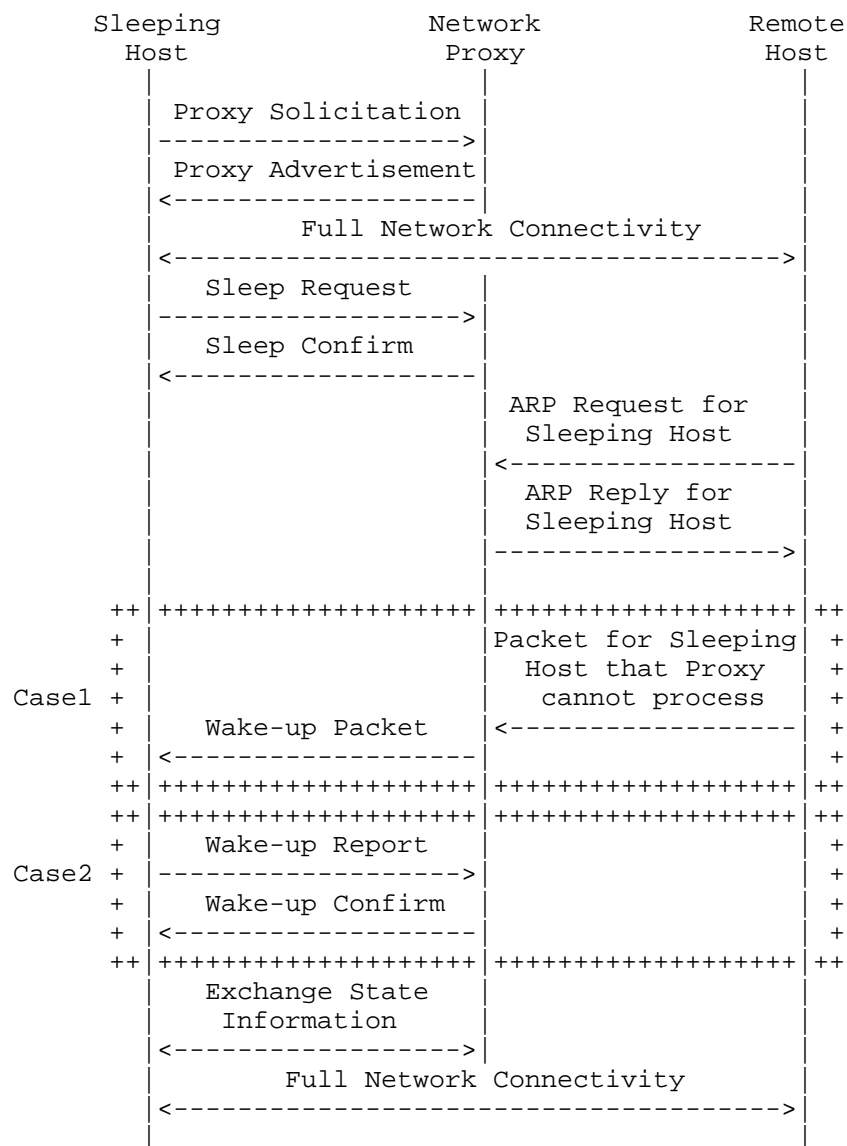


Figure 2: Network proxy operation for IPv4 ARP

## 5. Message Formats

Figure 3 depicts two types of new ICMP messages for Proxy Request/Reply messages. The messages are defined as follows.

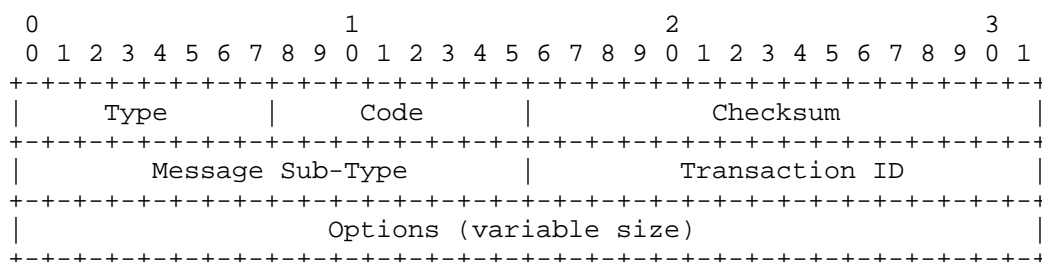


Figure 3: Proxy request message

|                  |                                                                                                                                                                              |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type             | <TBD> (Proxy Request)<br><TBD> (Proxy Reply)                                                                                                                                 |
| Code             | 0 Success<br>1 Fail                                                                                                                                                          |
| Checksum         | The 16-bit one's complement of the one's complement sum of the ICMP message, starting with the ICMP Type.                                                                    |
| Message Sub-Type | 1 Proxy Solicitation Message<br>2 Proxy Advertisement Message<br>3 Sleep Request Message<br>4 Sleep Confirm Message<br>5 Wake-up Report Message<br>6 Wake-up Confirm Message |
| Transaction ID   | Unique identifier created each time a host starts proxy operation                                                                                                            |
| Options          | Optional data for Sub-Type messages                                                                                                                                          |

Figure 4 shows the Option format for Sub-Type messages. The Option format is defined as a TLV format.

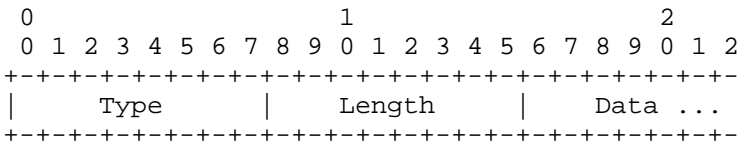


Figure 4: Option format

|        |                                                                                                                                                                                                                     |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type   | Indicates the particular sub-type option.<br>1 Proxy Solicitation Option<br>2 Proxy Advertisement Option<br>3 Sleep Request Option<br>4 Sleep Confirm Option<br>5 Wake-up Report Option<br>6 Wake-up Confirm Option |
| Length | Indicates the length (in bytes) of the data field within this option. The length does not include the Type and Length bytes.                                                                                        |
| Data   | The particular data associated with this option. This field may be zero or more bytes in length. The format and length of the data field is determined by the type and length fields.                               |

Figure 5 depicts Option format of Proxy Solicitation Sub-Type message. The sub-type message is broadcasted in order to discover proxy in networks. It contains 2 bytes Identifier and 2 bytes sequence number. Currently the detail of Identifier has not been developed, but its format and allocation method will be determined later.

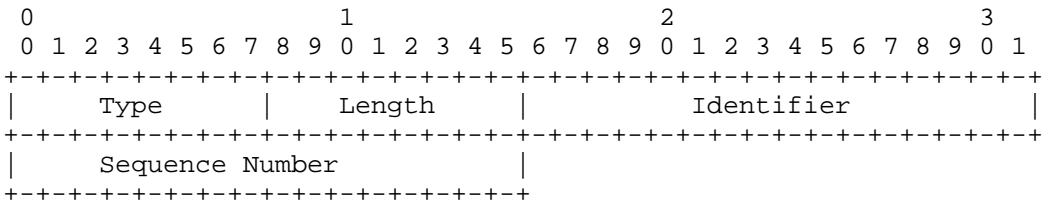


Figure 5: Proxy solicitation option

Figure 6 shows Option format for Proxy Advertisement Sub-Type message used for notifying the Proxy Server's presence in network. It is periodically broadcasted to networks and unicasted to a network node

that sent a Proxy Solicitation message. The Advertisement message contains the address of Proxy Server's IP address(es) and Preference(s).

| 0                    |   |   |   |   |   |   |   |   |   | 1                    |   |   |   |   |   |   |   |   |   | 2            |   |   |   |   |   |   |   |   |   | 3               |   |  |  |  |  |  |  |  |  |
|----------------------|---|---|---|---|---|---|---|---|---|----------------------|---|---|---|---|---|---|---|---|---|--------------|---|---|---|---|---|---|---|---|---|-----------------|---|--|--|--|--|--|--|--|--|
| 0                    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0                    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0            | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0               | 1 |  |  |  |  |  |  |  |  |
| Type                 |   |   |   |   |   |   |   |   |   | Length               |   |   |   |   |   |   |   |   |   | Num. of Addr |   |   |   |   |   |   |   |   |   | Addr Entry Size |   |  |  |  |  |  |  |  |  |
| Lifetime             |   |   |   |   |   |   |   |   |   | Proxy Address 1      |   |   |   |   |   |   |   |   |   |              |   |   |   |   |   |   |   |   |   |                 |   |  |  |  |  |  |  |  |  |
| Proxy Address 1      |   |   |   |   |   |   |   |   |   | Address Preference 1 |   |   |   |   |   |   |   |   |   |              |   |   |   |   |   |   |   |   |   |                 |   |  |  |  |  |  |  |  |  |
| Address Preference 1 |   |   |   |   |   |   |   |   |   | Proxy Address 2      |   |   |   |   |   |   |   |   |   |              |   |   |   |   |   |   |   |   |   |                 |   |  |  |  |  |  |  |  |  |
| Proxy Address 2      |   |   |   |   |   |   |   |   |   | Address Preference 2 |   |   |   |   |   |   |   |   |   |              |   |   |   |   |   |   |   |   |   |                 |   |  |  |  |  |  |  |  |  |
| Address Preference 2 |   |   |   |   |   |   |   |   |   |                      |   |   |   |   |   |   |   |   |   | ...          |   |   |   |   |   |   |   |   |   |                 |   |  |  |  |  |  |  |  |  |

Figure 6: Proxy advertisement option

Figure 7 shows Option format for Sleep Request Sub-Type message. The message is unicasted to Proxy Server and it informs the client's entering to sleep mode. Hardware Address Type indicates hardware address type of client. Protocol Type contains protocol address type. H/W length means the length of hardware address. Finally, number of addresses indicates the number of hardware and protocol pairs.

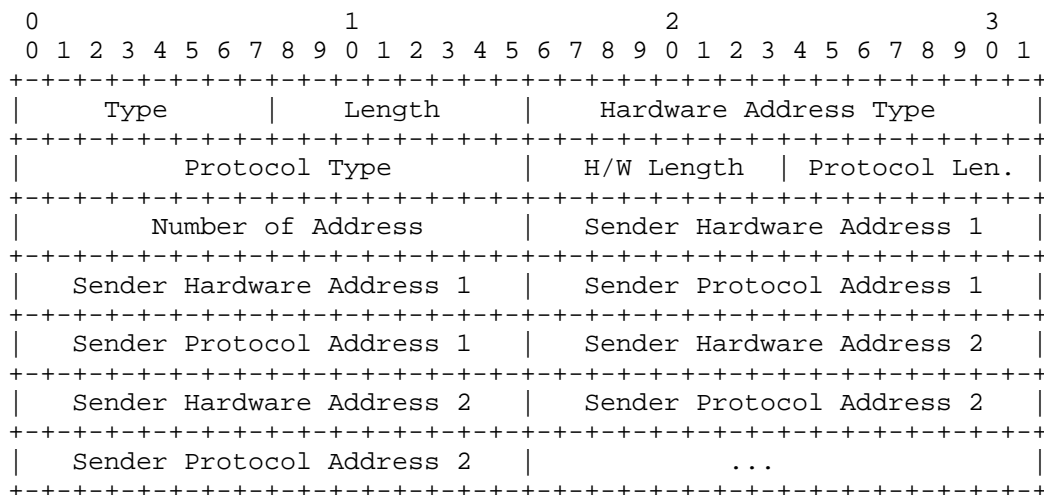


Figure 7: Sleep request option

Figure 8 describes Option format for Sleep Confirm Sub-Type message that is sent from a Proxy Server to Client as a response of Sleep Request message. Code indicates the result of Sleep Request operation. 0 indicates success and 1 indicates failure. Client Identifier is a unique ID for identifying Client and will be allocated by Proxy Server.

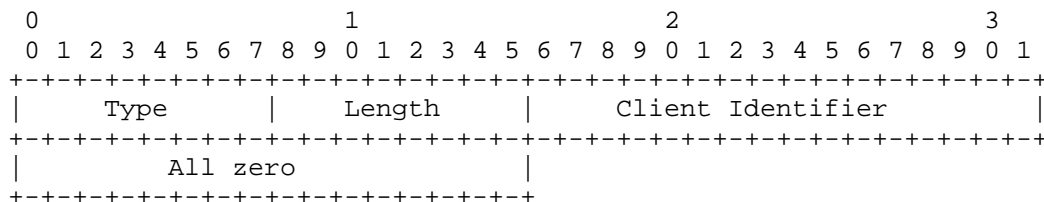


Figure 8: Sleep confirm option

Figure 9 depicts Option format for Wake-up report message. It is sent by a client to Proxy Server in order to notify the wake-up event of the client. It is unicasted to the Proxy Server. Client Identifier is the same Identifier assigned by Sleep Confirm message.



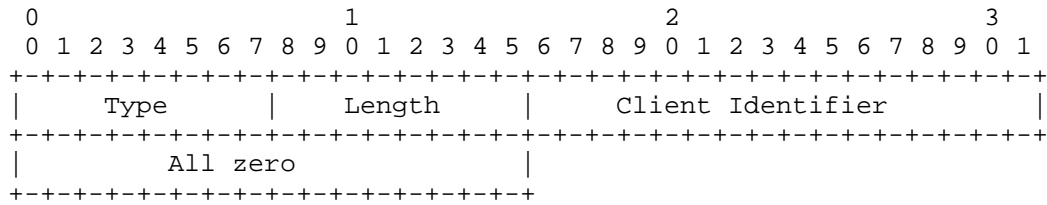


Figure 9: Wake-up report option

Figure 10 shows Option format for Wake-up Confirm message. It is unicasted to a Client as a reply of the Client's Wake-up Report message. Code 0 means success and 1 means failure. Client Identifier is the same Identifier assigned by Sleep Confirm message.

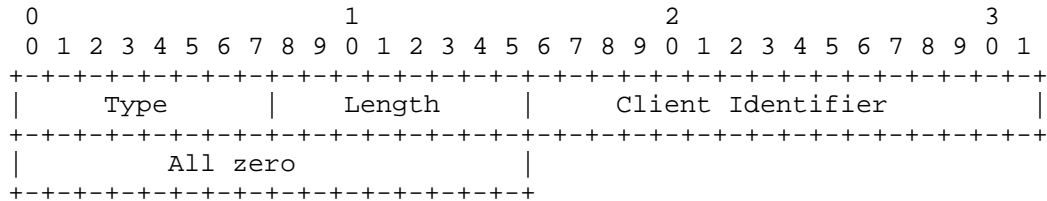


Figure 10: Wake-up confirm option

## 6. Security Considerations

[TBD]

## 7. IANA Considerations

[TBD]

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draft-suganuma-greenmib-01.txt

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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.

The feature of the GreenUsage-MIB is simple and easy to use and develop. The GreenUsage-MIB has essential functions to monitoring the power status of the devices. The GreenUsage-MIB is a simple structure and has only 6 Managed Objects (MOs). The file size of the GreenUsage-MIB is small, therefore the MIB can be developed on the limited computational resource such as a mobile device.

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 "201301080000Z" -- 8th January, 2013
 ORGANIZATION "PREDICT Working Group"
 CONTACT-INFO
 "
 Takuo Suganuma
 Postal: Tohoku University.
 2-1-1 Katahira
 Aoba-ku, Sendai, Japan 980-8577.
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E-mail: kohei@cysols.com

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 "201301080000Z" -- 8th January, 2013

## DESCRIPTION

"added gumDevUsageCreatedTimeStamp to usage table"

REVISION "201207070000Z" -- 7th July, 2012

## DESCRIPTION

"The initial version, published as draft-suganuma-greenmib-00.txt"

-- 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<br>device                |
| neighborDiscoverySensing | (2): neighbor discovery<br>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,
 gumDevUsageCreatedTimeStamp 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 }

gumDevUsageCreatedTimeStamp OBJECT-TYPE
SYNTAX TimeStamp
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "the time at which the entry of usage table created."
 ::= { gumDevUsageEntry 4 }

-- Units of conformance
gumGroups OBJECT IDENTIFIER ::= { gumConformance 1}
gumCompliances OBJECT IDENTIFIER ::= { gumConformance 2}

gumObjectsGroup OBJECT-GROUP
OBJECTS {
 gumDeviceName,
 gumDeviceMacAddress,
 gumDeviceType,
 gumDeviceLocation,
 gumDevUsageDetStatus,
 gumDevUsageDetTimeStamp,
 gumDevUsageCreatedTimeStamp
}
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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- [RFC2863] McCloghrie, K., and Kastenholz., F., The Interfaces Group MIB, RFC 2863, June 2000.

### 8.2 Informative References

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## 9. Acknowledgements

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