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Power and Energy Monitoring MIB
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Abstract

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

Conventions used in this document

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

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- . Do we need the pmIndex persistence?
Agreement among us: should be optional, like for ifIndex.
Option: the implementation might indicate it. Persistent or not might be shown in a OID, using the StorageType ::= TEXTUAL-CONVENTION. One OID that explains the persistence of all objects, not more granularity. This must also be covered in the architecture draft.
- . ACTION: change the pmPowerLevel to pmRequestedPowerLevel, and pmPowerActualLevel to pmPowerLevel? The 3 drafts need to be changed. DMTF uses "requestedLevel"
- . "Power Monitor Child" Feedback received: it's the object to be monitored, not the monitoring device. Power Monitoring/Monitored Child?
- . If [POWER-MON-ARCH] covers the notion of transition state, we must be covering this topic in this MIB module.

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 Power Management Architecture [POWER-MON-ARCH], which in turn, is based on the Power Monitoring Requirements [POWER-MON-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.

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 [POWER-MON-REQ]. The requirements in [POWER-MON-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 [POWER-MON-REQ]. Several scenarios that cover these broader use cases are presented later in Section 6 - Implementation Scenarios.

4. Terminology

The definitions of basic terms like Power Monitor, Power Monitor Parent, Power Monitor Child, Power Monitor Meter Domain, Power Level, and Manufacturer Power Level can be found in the Power Management Architecture [POWER-MON-ARCH].

5. Architecture Concepts Applied to the MIB Module

This section describes the concepts specified in the Power Monitor Architecture [POWER-MON-ARCH] 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 [POWER-MON-ARCH].

5.1 Power Monitor Information

Refer to the "Power Monitor Information" section in [POWER-MON-ARCH] for background information. An energy aware device is considered an instance of a power monitor as defined in the [POWER-MON-ARCH].

The Power Monitor information is specified in the MIB module primary table, i.e. the pmTable. Every Power Monitor SHOULD have a printable name pmName, and MUST HAVE a unique Power Monitor index pmIndex, as specified in [POWER-AWARE-MIB].

5.2 Power Monitor Levels

Refer to the "Power Monitor Levels" section in [POWER-MON-ARCH] for background information.

Power Levels, which represent universal states of power management of a Power Monitor, are specified by the pmPowerLevel MIB object.

Via the pmManufacturerActualPowerLevel MIB variable, the Manufacturer Power Levels might be read, in case the Power Levels specified in this document are not (yet) supported. The Manufacturer Power Level name can be read with the pmManufacturerActualPowerLevel Name MIB variable.

When a Power Monitor requires a mapping with the Manufacturer Power Level, the Power Monitor configuration is done via the Power Level settings, and not directly via the Manufacturer Power Levels, which are read-only. The actual Power Level is specified by the pmPowerActualLevel MIB object, while the pmPowerLevel MIB object specifies the Power Level requested for the Power Monitor. A difference in values between the pmPowerLevel and pmPowerActualLevel indicates that the Power

Monitor is busy going into the pmPowerLevel, at which point it will update the content of pmPowerActualLevel.

The MIB objects pmPowerLevel and pmManufacturerDefinedPowerLevel are contained in the pmTable MIB table.

The pmPowerLevelTable table enumerates the maximum power usage in watts, for every single supported Power Level of each Power Monitor.

The pmPowerLevelMappingTable table enumerates the maximum power usage in watts, for every single Manufacturer Power Level. Furthermore, this table maps the Manufacturer Power Levels to the Power Levels specified in this document (more specifically with the PowerMonitorLevel textual convention). Finally, this table returns the name of each Manufacturer Power Level.

5.3 Power Monitor Usage Measurement

Refer to the "Power Monitor Usage Measurement" section in [POWER-MON-ARCH] for background information.

For a Power Monitor, power usage is reported using pmPower. The magnitude of measurement is based on the pmPowerUnitMultiplier MIB variable, based on the UnitMultiplier Textual Convention (TC).

For example, if current power usage of a Power Monitor is 3, it could be 3 W, 3 mW, 3 KW, or 3 MW, depending on the value of pmPowerUnitMultiplier. Note that other measurements throughout the two MIB modules in this document use the same mechanism, including pmPowerLevelPowerUnitMultiplier, pmDemandIntervalEnergyUnitMultiplier, and pmACPwrQualityPowerUnitMultiplier.

In addition to knowing the usage and magnitude, it is useful to know how a pmPower measurement was obtained. An NMS can use this to account for the accuracy and nature of the reading between different implementations. For this pmPowerOrigin describes whether the measurements were made at the device itself or from a remote source. The pmPowerMeasurementCaliber describes the method that was used to measure the power and can distinguish actual or estimated values.

The nameplate power rating of a Power Monitor is specified in pmPowerNameplate MIB object.

5.4 Optional Power Usage Quality

Refer to the "Optional Power Usage Quality" section in [POWER-MON-ARCH] for background information.

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

The powerQualityMIB MIB module contains a primary table, the pmACPwrQualityTable table, that defines power quality measurements for supported pmIndex entities, as a sparse extension of the pmTable (with pmIndex as primary index). This pmACPwrQualityTable 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 pmACPwrQualityPhaseTable additional table is populated with power quality measurements per phase (so double indexed by the pmIndex and pmPhaseIndex). 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 pmACPwrQualityDelPhaseTable table describes the phase-to-phase power quality measurements, i.e., voltage and current.

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

5.5 Optional Energy Measurement

Refer to the "Optional Energy Measurement" section in [POWER-MON-ARCH] for background information.

It is relevant to measure the demand only when there are actual power measurements from a Power Monitor, and not when the power measurement is assumed or predicted as specified in the description clause of the object pmPowerMeasurementCaliber.

Two tables are introduced to characterize the energy demand: pmDemandEnergyTable and pmDemandEnergyParametersTable. The

pmDemandEnergyParametersTable table consists of parameters defining the duration of the demand intervals in seconds, (pmDemandEnergyParametersIntervalLength), the number of demand intervals kept in the pmDemandEnergyTable, (pmDemandEnergyParametersIntervalNumber), the type of demand intervals (pmDemandEnergyParametersIntervalMode), and a sample rate used to calculate the average (pmDemandEnergyParametersSampleRate). Judicious choice of the SamplingRate will ensure accurate measurement of power while not imposing an excessive polling burden.

There are three pmDemandEnergyParametersIntervalMode types used for energy measurement collection: period, sliding, and total. Note that multiple pmDemandEnergyParametersIntervalMode types MAY be configured simultaneously.

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

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

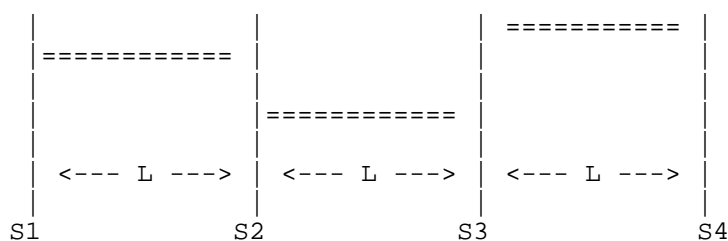


Figure 1 : Period pmDemandEnergyParametersIntervalMode

A pmDemandEnergyParametersIntervalMode type of 'period' specifies non-overlapping periodic measurements. Therefore, the next pmDemandEnergyIntervalStartTime is equal to the previous

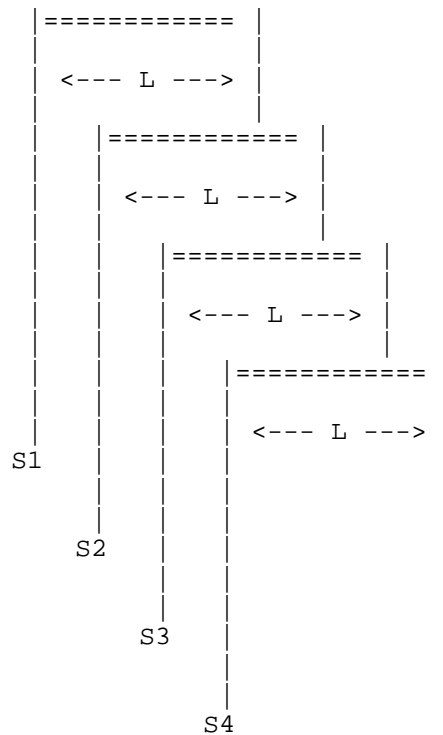


Figure 2 : Sliding pmDemandEnergyParametersIntervalMode

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

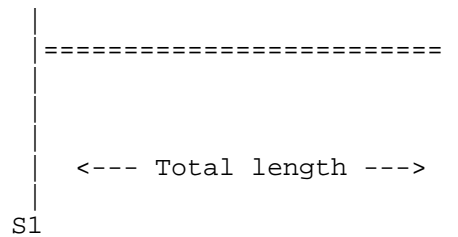


Figure 3 : Total pmDemandEnergyParametersIntervalMode

A `pmDemandEnergyParametersIntervalMode` type of 'total' specifies a continuous measurement since the last reset. The value of `pmDemandEnergyParametersIntervalNumber` should be (1) one and `pmDemandEnergyParametersIntervalLength` is ignored.

The `pmDemandEnergyParametersStatus` is useful to specify that the energy measurement is actual and thus to indicate if the `pmDemandEnergyTable` entries exist or not.

The `pmDemand` Table consists of energy measurements in `pmDemandIntervalEnergyUsed`, the scale of energy measured, `pmDemandIntervalEnergyUnitMultiplier`, and the maximum observed demand in a window - `pmDemandIntervalMax`.

The following example illustrates the `pmDemandEnergyTable` and `pmDemandEnergyParametersTable`:

First, in order to estimate demand, an interval to sample energy should be specified, i.e. `pmDemandEnergyParametersIntervalLength` can be "900 seconds" and the number of consecutive intervals over which the maximum demand is calculated (`pmDemandEnergyParametersIntervalNumber`) as "10". The sampling rate internal to the Power Monitor for measurement of power usage (`pmDemandEnergyParametersSampleRate`) can be "1000 milliseconds", as set by the Power Monitor as a reasonable value. Then, the `pmDemandEnergyParametersStatus` is set to active (value 1) to indicate that the Power Monitor should start monitoring the usage per the `pmDemandEnergyTable`.

The indices in the `pmDemandEnergyTable` are `pmIndex`, which identifies the Power Monitor, and `pmDemandIntervalStartTime`, which denotes the start time of the demand measurement interval based on `sysUpTime`. The value of `pmDemandIntervalEnergyUsed` is the measured energy consumption over the time interval specified (`pmDemandEnergyParametersIntervalLength`) based on the Power Monitor internal sampling rate (`pmDemandEnergyParametersSampleRate`). While choosing the values for the `pmDemandEnergyParametersIntervalLength` and `pmDemandEnergyParametersSampleRate`, 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 `pmDemandEnergyIntervalEnergyUsed`. The units are derived from `pmDemandIntervalPowerUnitMultiplier`. For example, `pmDemandIntervalPowerUsed` can be "100" with `pmDemandIntervalPowerUnits` equal to 0, the demand is 100 watt-hours. The `pmDemandIntervalMax` is the maximum demand observed and can be "150 watt-hours".

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

Here is a brief explanation of how the maximum demand can be calculated. The first observed demand measurement value is taken to be the initial maximum. With each subsequent measurement, based on numerical comparison, maximum demand 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 Optional Battery Information

EDITOR NOTE: Since a merge between this draft and [QUITTEK-POWER-MIB] seems to be the direction that the OPSAWG/EMAN IETF WG wants to go, one idea is to copy the battery MIB module from [QUITTEK-POWER-MIB].

6. Implementation Scenarios

The scope of power and energy monitoring consists of devices that consume power within and that are connected to a communications network. These devices include:

- Network devices and sub-components: Devices such as routers and switches and their sub-components.
- Network attached endpoints: Devices that use the communications network, such as endpoints, PCs, and facility gateways that proxy energy monitor and control for commercial buildings or home automation.
- Network attached meters or supplies: Devices that can monitor the electrical supply, such as smart meters or Universal Power Supplies (UPS) that meter and provide availability.

This section provides illustrative examples that model different scenarios for implementation of the Power Monitor, including Power Monitor Parent and Power Monitor Child relationships.

Consider a PoE IP phone connected to a switch, as displayed in Figure 4. The IP phone consumes power from the PoE switch. The switch has the following attributes, also illustrated in Figure 4: pmIndex "1", pmPhysicalEntity "2", and pmPowerMonitorId "UUID 1000". The power usage of the switch is "440 Watts". The switch does not have a Power Monitor Parent.

The PoE switch port has the following attributes: The switch port has pmIndex "3", pmPhysicalEntity is "12" and pmPowerMonitorId is "UUID 1003". The power metered at the POE switch port is "12 watts". Note that the PoE switch port doesn't consume any power, it meters the usage. When summing power usage for the Power Monitor Meter Domain, the PoE switch port meter usage should be kept separate from actual Power Monitor Children usage.

In this example, the POE switch port has the switch as the Power Monitor Parent, with its pmParentId of "1000".

The IP phone has the following attributes: the IP phone has pmIndex "31" and pmPowerMonitorId "UUID 2003", but does not have an entry for pmPhysicalEntity, as the ENTITY MIB is not supported on this device. The IP phone has a Power Monitor Parent: the switch whose pmPowerMonitorId is "UUID 1000". The power usage of the IP phone is metered at the POE switch port and the pmPower on the PoE IP phone reports 12.

Switch					
Switch pmIndex	Switch pmPhyIdx	Switch pmPowerMonId	Switch pmParentId	Switch pmPower	
1	2	UUID 1000	null	440	
SWITCH PORT					
Switch Port pmIndex	Switch Port pmPhyIdx	Switch Port pmPowerMonId	Switch Port pmParentId	Switch Port pmPower	
3	12	UUID 1003	UUID 1000	12	

^

POE IP PHONE				
=====				
IP phone	IP phone	IP phone	IP phone	IP phone
pmIndex	EntPhyIdx	pmPowerMonitorId	pmParentID	pmPower
=====				
31	0	UUID 2003	UUID 1000	12
=====				

Figure 4: Scenario 1

Scenario 2: Switch with PoE Endpoints with Further Connected Devices

Consider the same scenario as example 1 with an IP phone connected to PoE port of a switch. Now, in addition, a PC is daisy-chained from the IP phone for LAN connectivity. The phone draws power from the PoE port of the switch, while the PC draws power from the wall outlet.

The attributes of the switch, switch port and IP phone are the same as in Scenario 1. The attributes of the PC are given below. The PC does not have pmPhysicalEntity. The pmIndex of the PC is "57", the pmPowerMonitorId is "UUID 3003". The PC has a Power Monitor Parent, i.e. the switch whose pmPowerMonitorId is "UUID 1000". The power usage of the PC is "120 Watts" and is communicated to the switch port.

This example illustrates the important distinction between the Power Monitor 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 Power Monitor Parent sends power control messages to both the Power Monitor Children (IP phone and PC) and the Children react to those messages.

Switch				
=====				
Switch	Switch	Switch	Switch	Switch
pmIndex	pmPhyIdx	pmPowerMonId	pmParentId	pmPower
=====				
1	2	UUID 1000	null	440

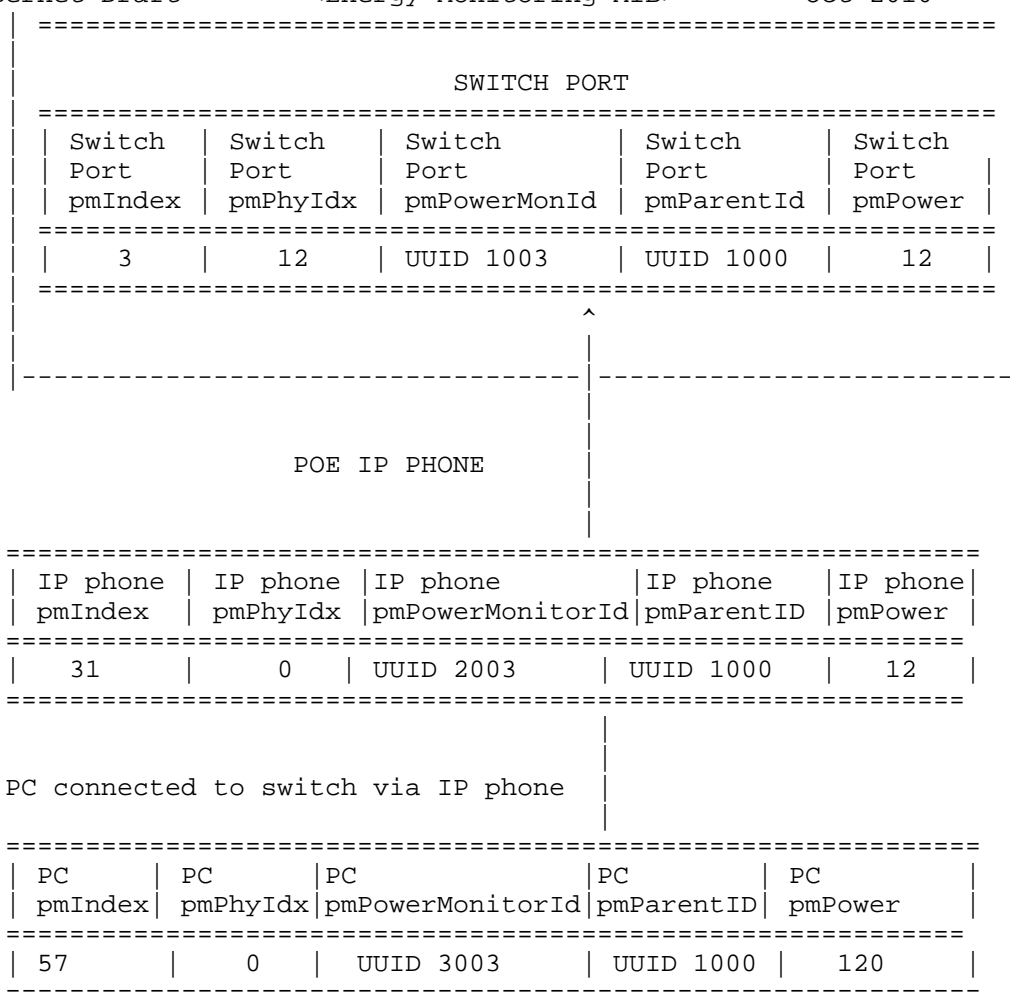


Figure 5: Scenario 2

Scenario 3: Switch with Wireless Access Points

Consider a Wireless Access Point connected to the PoE port of a switch. There are several PCs connected to the Wireless Access Point over Wireless protocols. All PCs draw power from the wall outlets.

The switch port is the Power Monitor Parent for the Wireless Access Point (WAP) and the PCs. There is a distinction between the Power Monitor Children, as the WAP draws power from the PoE port of the switch and the PCs draw power from the wall outlet.

The switch has pmIndex "1", pmPhysicalEntity is "2" and pmPowerMonitorId is "UUID 1000". The power usage of the switch is "440 Watts". The switch does not have a Power Monitor Parent.

The PoE switch port has the following attributes: The switch port has pmIndex "3", pmPhysicalEntity is "12" and pmPowerMonitorId is "UUID 1003". The power usage of the POE switch port is "20 watts". The POE switch port has the switch as the parent and the pmParentId is "UUID 1000".

The WAP has the following attributes: The WAP has no entry for pmPhysicalEntity, pmIndex "47", and pmPowerMonitorId "UUID 2004". The WAP has a parent: the switch whose pmPowerMonitorId is "UUID 1000". The power usage of the WAP is measured at the PoE switch port.

Neither of the two PCs - PC1 and PC2 - has pmPhysicalEntity.

The pmIndex of PC1 is "53" and the pmPowerMonitorId is "UUID 3". PC1 has a parent: the switch whose pmPowerMonitorId is "UUID 1000". The power usage of PC1 is "120 Watts" and is communicated to the switch port.

The pmIndex of PC2 is "58" and the pmPowerMonitorId is "UUID 5". PC2 has a parent: the switch whose pmPowerMonitorId is "UUID 1000". The power usage of the PC is "120 Watts" and is communicated to the switch port.

Switch				
Switch pmIndex	Switch pmPhyIdx	Switch pmPowerMonId	Switch pmParentId	Switch pmPower
1	2	UUID 1000	null	440
SWITCH PORT				
Switch Port pmIndex	Switch Port pmPhyIdx	Switch Port pmPowerMonId	Switch Port pmParentId	Switch Port pmPower

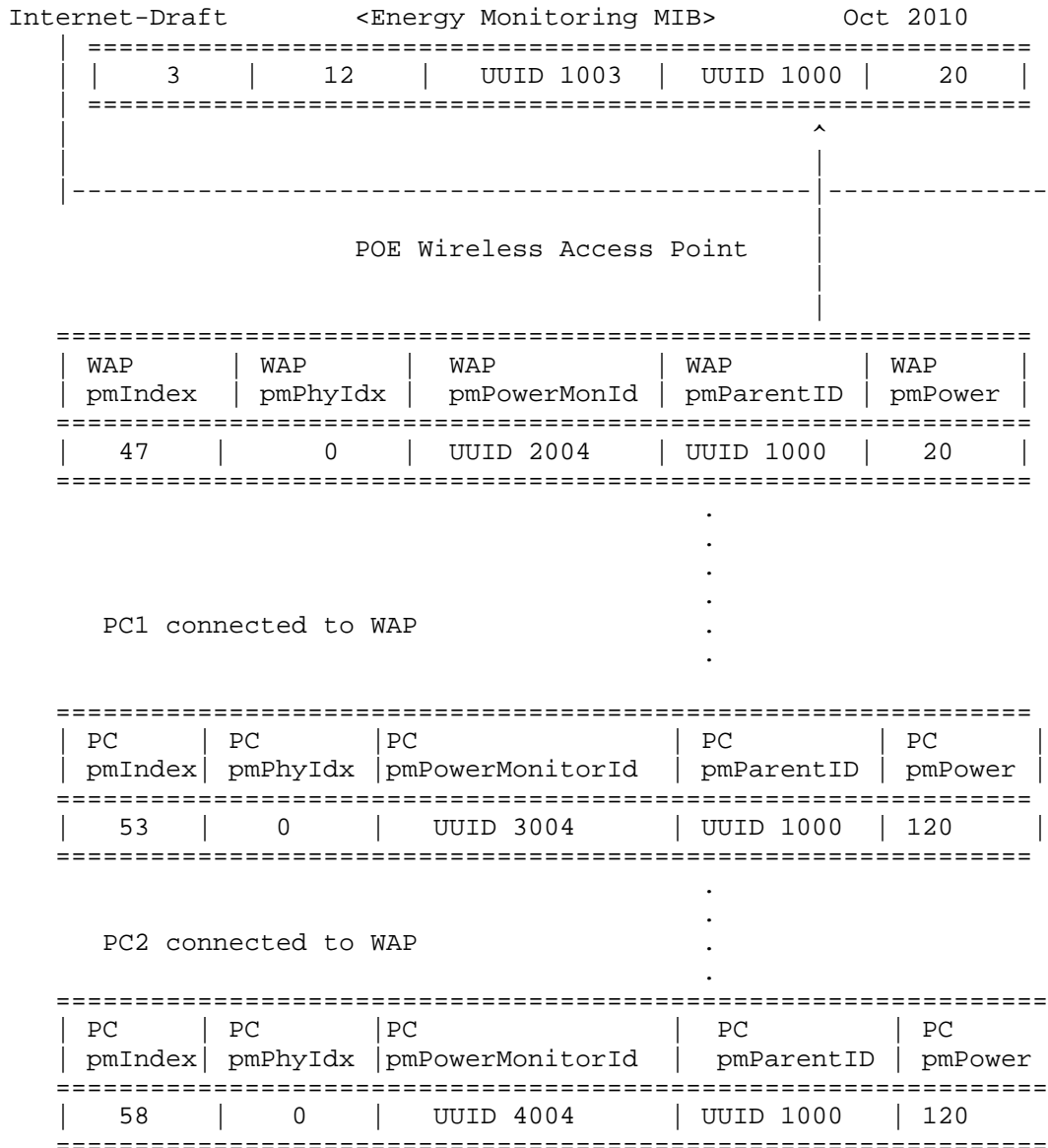


Figure 6: Scenario 3

Scenario 4: Network Connected Facilities Gateway

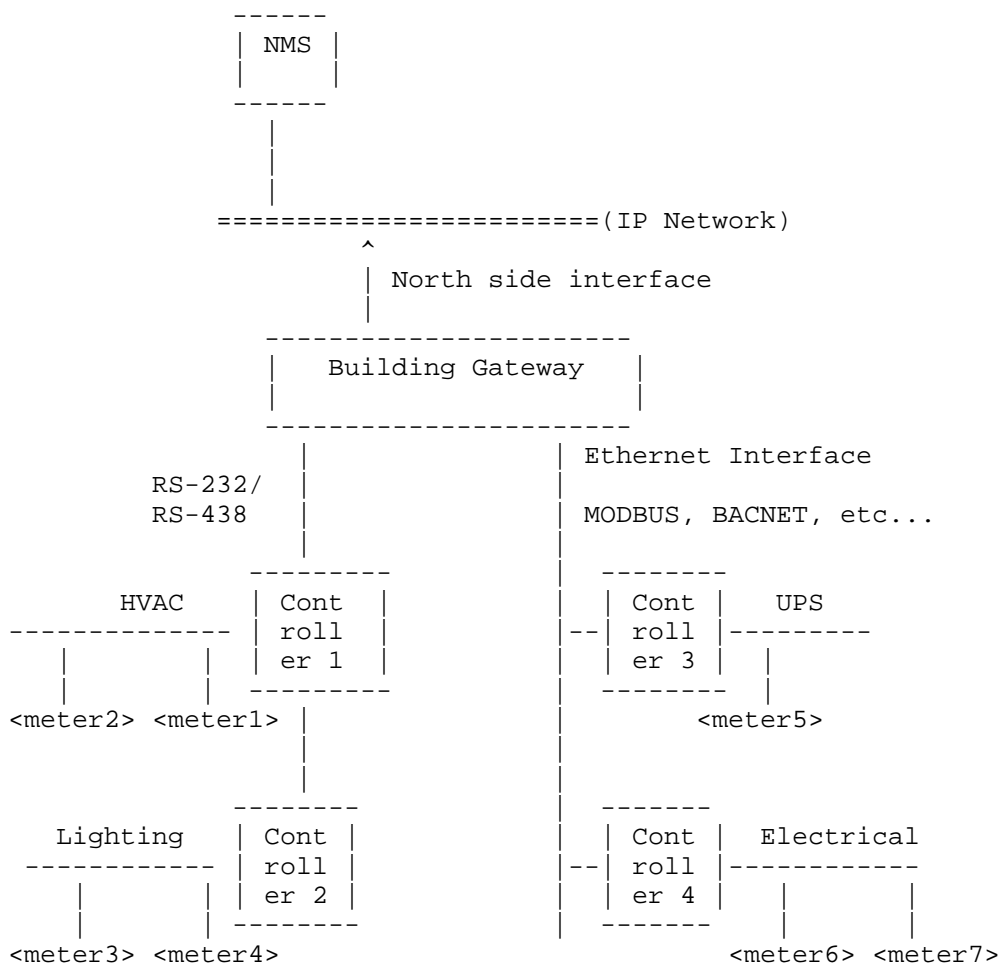


Figure 7: Scenario 4

A simplified illustration of the building gateway network is presented in Figure 7. At the top of the network hierarchy of a building network is a gateway device that can perform protocol conversion between many facility management devices. The south building gateway communicates to the controllers, via RS-232/RS-485 interfaces, ethernet interfaces, and building management protocols such as BACNET or MODBUS. Each controller is associated with a specific energy-consuming function, such as

HVAC, electrical or lighting. The controllers are in turn connected to the actual building energy management devices: meters, sub-meters, valves, actuators, etc. Controller 1 is associated with a meter for the HVAC system and controller 2 can be associated with a meter for the Lighting.

Assuming that the MIB is implemented on the gateway device, the building gateway can be considered as the Power Monitor Parent, and the controllers associated with the meters can be considered as Power Monitor Children. The power measurement collected is therefore at the granularity of a controller, which aggregates all the energy measurement collected from all the meters and sub-meters. However, if energy measurement needs to be collected at a meter level, then the MIB should be implemented at the controller level.

In building management, the EntPhysicalIndex usually is not defined for these Power Monitor Parents or Children, as the ENTITY MIB is generally not implemented for these devices. Hence the gateway, controller 1, and controller 2 all have pmPhysicalEntities of value zero.

The pmIndex of the gateway is "7", and the pmPowerMonitorId is "UUID 1000". The gateway does not have a Power Monitor Parent. The total power usage of the gateway and its children is "2000 Watts".

Controller 1 has pmIndex "707", and pmPowerMonitorId is "UUID 5007". Controller 1 will report a power usage of "2000 watts". Controller 1 has the gateway as the parent and its pmParentID is "UUID 1000".

Controller 2 has pmIndex "708", and pmPowerMonitorId is "UUID 5008". Controller 2 will report a power usage of "500 watts". Controller 2 has the gateway as the Power Monitor Parent and its pmParentID is "UUID 1007".

Building Gateway				
Mediat pmIndex	Mediat pmPhyIdx	Mediat pmPowerMonId	Mediat pmParentId	Mediat pmPower
7	None	UUID 1000	Null	2500

=> Controller 1				
=====				
Cntrl1 pmIndex	Cntrl1 pmPhyIdx	Cntrl1 pmPowerMonId	Cntrl1 pmParentID	Cntrl1 pmPower
=====				
707	0	UUID 5007	UUID 1000	2000
=====				
===>Controller 2				
=====				
Cntrl2 pmIndex	Cntrl2 pmPhyIdx	Cntrl2 pmPowerMonId	Cntrl2 pmParentID	Cntrl2 pmPower
=====				
708	0	UUID 5008	UUID 1000	500
=====				

Figure 8: Scenario 4

Scenario 5: Data Center Network

A typical data center network consists of a hierarchy of switches. At the bottom of the hierarchy are servers mounted on a rack, and these are connected to the top-of-the-rack switches. The top switches are connected to aggregation switches that are in turn connected to core switches. As an example, Server 1 and Server 2 are connected to different switch ports of the top switch, as shown in Figure 9.

The proposed MIB can be implemented on the switches. The switch can be considered as the Power Monitor Parent. The servers can be considered as the Power Monitor Children.

The switch has pmIndex "1", pmPhysicalEntity is "2", and the pmPowerMonitorId is "UUID 1000". The power usage of the switch is "440 Watts". The switch does not have a parent.

The switch ports are non-PoE and have the following attributes: Server 1 is connected to Switch port 1. Switch port 1 has pmIndex "3", pmPhysicalEntity is "12", and pmPowerMonitorId is "UUID 1003". Switch port 2 has pmIndex "4", pmPhysicalEntity is

"13", and pmPowerMonitorId is "UUID 1004". The power usage of the non-POE switch port cannot be measured. The switch ports have the switch as the Power Monitor Parent and its pmParentId is "1000".

Server 1 has a value of zero for pmPhysicalEntity. The pmIndex of Server 1 is "5", and the pmPowerMonitorId is "UUID 2006". Server 1 has a Power Monitor Parent: The switch whose pmPowerMonitorId is "1000". The power usage of Server 1 is "200 Watts" and is communicated to the switch port.

Server 2 has a value of zero for pmPhysicalEntity. The pmIndex of Server 2 is "6", and the pmPowerMonitorId is "UUID 3006". Server 1 has a parent: The switch whose pmPowerMonitorId is "1000". The power usage of the Server 2 is "140 Watts" and is communicated to the switch port.

Communication of power usage of Server1 and Server2 to the switch is out of scope of this document.

Switch				
Switch pmIndex	Switch pmPhyIdx	Switch pmPowerMonId	Switch pmParentId	Switch pmPower
1	2	UUID 1000	null	440
SWITCH PORT 1				
Switch Port1 pmIndex	Switch Port1 pmPhyIdx	Switch Port1 pmPowerMonId	Switch Port1 pmParentId	Switch Port1 pmPower
3	12	UUID 1003	UUID 1000	NULL
SWITCH PORT 2				
Switch Port2 pmIndex	Switch Port2 pmPhyIdx	Switch Port2 pmPowerMonId	Switch Port2 pmParentId	Switch Port2 pmPower
4	13	UUID 1004	UUID 1000	NULL

Server 1 connected to switch (Non-POE)					
=====					
Server 1	Server 1	Server 1	Server 1	Server 1	Server 1
pmIndex	pmPhyIdx	pmPowerMonitorId	pmParentID	pmPower	
=>=====					
5	0	UUID 2006	UUID 1000	200	
=====					
Server 2 connected to switch (Non-POE)					
=====					
Server 2	Server 2	Server 2	Server 2	Server 2	
pmIndex	pmPhyIdx	pmPowerMonitorId	pmParentID	pmPower	
=>=====					
6	0	UUID 3006	UUID 1000	140	
=====					

Figure 9: Scenario 5

Scenario 6: Switch with Power Distribution Units (PDU)

Consider Scenario 1 again, this time with two PDUs. The switch draws power from one of the PDUs, while the PDUs are plugged into the switch for LAN connectivity.

The attributes of the switch and switch ports are the same as in Scenario 1. The attributes of the PDUs are given in Figure 11.

The PDUs are network peers of the switch, with their own management agent and no pmPowerMonitor parent pmPowerMonitorId, as the PDUs are Power Monitor Parents themselves. The power usage of the PDUs are reporting 3000 watts and 12000 watts categorized as 'Meter'.

This example illustrates the distinction between power supply, metering, and LAN connectivity. The PDUs supply and meter power to the switch, while the PC has LAN connectivity from the phone, but is powered from the wall outlet. However, the Power Monitor Parent sends power control messages to both the Power Monitor Children (IP phone and PC) and the children react to those messages.

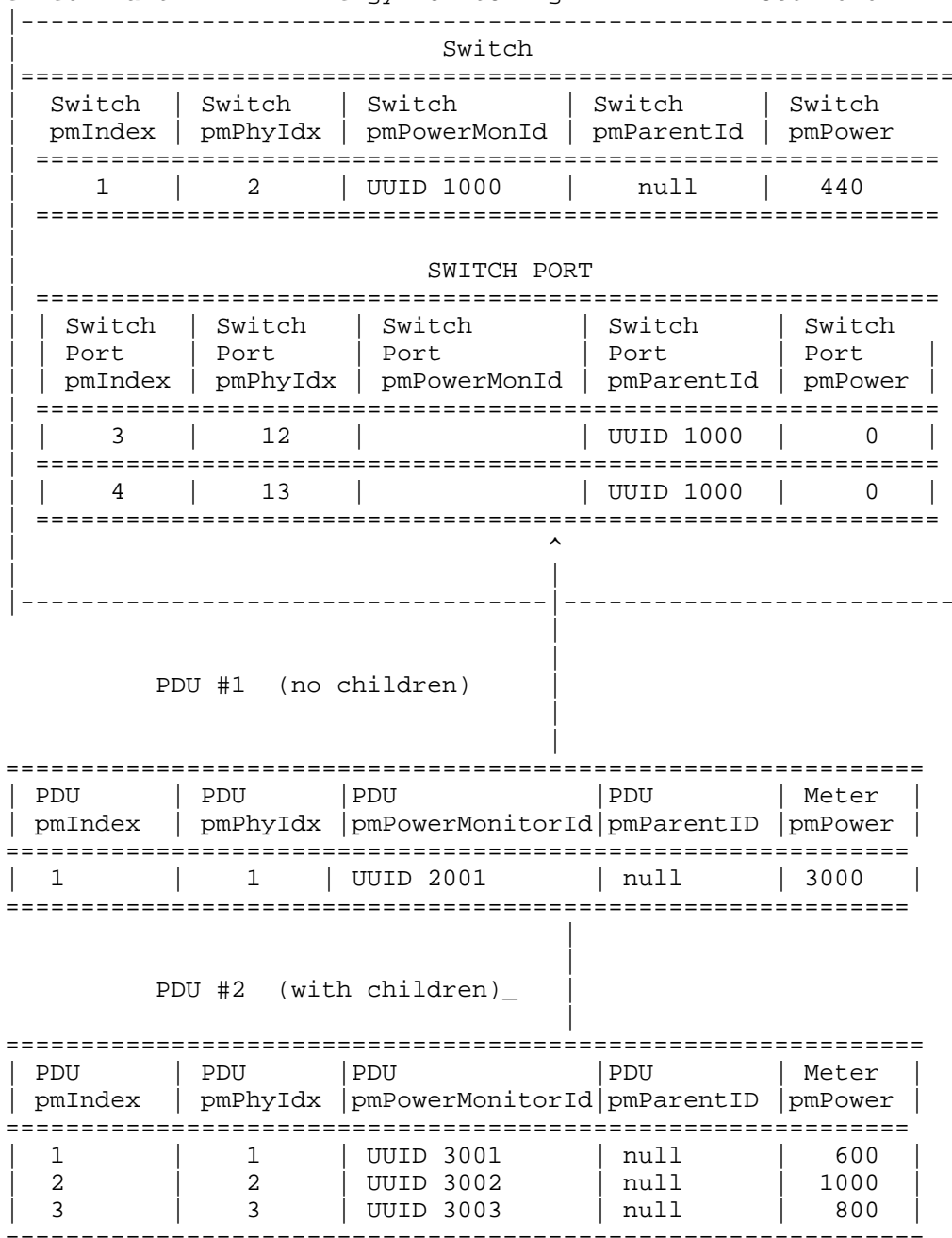


Figure 11: Scenario 6

Data centers and commercial buildings can have Uninterruptible Power Supplies (UPS) connected to the network. The Power Monitor can be used to model a UPS as a Power Monitor Parent with the connected devices as Power Monitor Children.

EDITOR'S NOTE: the example will be completed in the future.

Scenario 8: Power Consumption of Battery-Based Devices

As specified in [POWER-MON-REQ], battery-state monitoring is a requirement for the Power and Energy Monitoring MIB.

EDITOR NOTE: since a merge between this draft and [QUITTEK-POWER-MIB] seems to be the direction that the OPSAWG IETF WG wants to go, one idea is to copy the battery MIB module from [QUITTEK-POWER-MIB].

7. Link with the other IETF MIBs

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 level states of networking equipment, and functionality to configure the power level 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 Power

Monitors are modeled by the entPhysicalIndex through the pmPhysicalEntity MIB object specified in the pmTable.

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 pmPowerAccuracy MIB object models this accuracy. Note that pmPowerUnitMultiplier represents the scale factor per IEC 61850, 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 [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 Power Monitors 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 pmPhysicalEntity value contains the zero value, thanks to PhysicalIndexOrZero textual convention.

The pmIndex MIB object has been kept as the unique Power Monitor index. The pmPower is similar to entPhySensorValue [RFC3433] and the pmPowerUnitMultiplier 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 Levels are required, as

proposed in the Power and Energy Monitoring MIB module. Those Power Levels 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 Level "unknown", "ready", "standby", respectively, while the entStateStandby "providingService" could map to any "low" to "high" Power Level.

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 Power Monitors 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 pmethPortIndex and pmethPortGrpIndex values contain the zero value, thanks to new PethPsePortIndexOrZero and textual PethPsePortGroupIndexOrZero conventions.

However, if the Power-over-Ethernet MIB [RFC3621] is supported, the Power Monitor pmethPortIndex and pmethPortGrpIndex contain the pethPsePortIndex and pethPsePortGroupIndex, respectively.

As a consequence, the pmIndex MIB object has been kept as the unique Power Monitor 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.)
- 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, Amps and Watts. The units of power measurement are RMS volts and RMS Amps. They are not based on 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 Power Monitor Parent and any of the UPS meters or submeters are the Power Monitor 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 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 pmethPortIndex and pmethPortGrpIndex.

The lldpXMedLocXPoEPDPowerSource [LLDP-MED-MIB] is similar to pmPowerOrigin 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 pmPowerOrigin: lldpXMedLocXPoEPDPowerSource fromPSE(2) and local(3) can be mapped to remote(2) and self(1), respectively.

8. Structure of the MIB

The primary MIB object in this MIB module is the PowerMonitorMIBObject. The pmTable table of PowerMonitorMibObject describes an entity in the network that is a Power Monitor.

A Power Monitor contains information describing itself as an entity in the context of the network (such as its Power Monitor Meter Domain pmDomainName) and attributes for describing its business context (such as pmImportance, pmRoleDescription and pmKeywords).

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A Power Monitor contains information describing its power usage (pmPower) and its power state (pmPowerLevel). Along with the power usage is information describing how the power usage was determined (such as pmPowerMeasurementCaliber and pmPowerOrigin).

The pmPowerLevelMappingTable table enumerates the maximum power usage in watts for every Manufacturer Power Level. This table also maps the Manufacturer Power Levels to the Power Levels specified in this document (more specifically, to the PowerMonitorLevel textual convention). Finally, this table returns the name of each Manufacturer Power Level.

A Power Monitor may contain an optional pmPowerQuality table that describes the electrical characteristics associated with the current power state and usage.

A Power Monitor may contain an optional pmDemandEnergyTable to describe energy information over time.

A Power Monitor may also contain optional battery information associated with this entity.

EDITOR NOTE: since a merge between this draft and [QUITTEK-POWER-MIB] seems to be the direction that the OPSAWG IETF WG wants to go, one idea is to copy the battery MIB module from [QUITTEK-POWER-MIB].

9. MIB Definitions

```
-- *****  
--  
--  
-- This MIB is used to monitor power usage of network  
-- devices  
--  
-- *****  
  
POWER-MONITOR-MIB DEFINITIONS ::= BEGIN  
  
IMPORTS  
    MODULE-IDENTITY,  
    OBJECT-TYPE,  
    NOTIFICATION-TYPE,  
    mib-2,
```

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Integer32, TimeTicks
FROM SNMPv2-SMI
TEXTUAL-CONVENTION, DisplayString, RowStatus, TimeInterval
FROM SNMPv2-TC
MODULE-COMPLIANCE,
NOTIFICATION-GROUP,
OBJECT-GROUP
FROM SNMPv2-CONF
SnmpAdminString
FROM SNMP-FRAMEWORK-MIB

pmEntry, pmIndex
FROM ENERGY-AWARE-NETWORKS-AND-DEVICE-MIB;

powerMonitorMIB MODULE-IDENTITY
LAST-UPDATED "201010150000Z"
ORGANIZATION "Cisco Systems, Inc."
CONTACT-INFO
 "Cisco Systems
 Customer Service

 Postal: 170 W Tasman Drive
 San Jose, CA 95134
 USA

 Tel: +1 800 553-NETS

 E-mail: cs-snmp@cisco.com"

DESCRIPTION
 "This MIB is used to monitor power and energy in
 devices."
REVISION
 "201010150000Z"
DESCRIPTION
 "Initial version, published as RFC XXXX."

::= { mib-2 xxxxx }

powerMonitorMIBNotifs OBJECT IDENTIFIER
::= { powerMonitorMIB 0 }

```
powerMonitorMIBObjects OBJECT IDENTIFIER
    ::= { powerMonitorMIB 1 }
```

```
powerMonitorMIBConform OBJECT IDENTIFIER
    ::= { powerMonitorMIB 2 }
```

-- Textual Conventions

```
PowerMonitorLevel ::= TEXTUAL-CONVENTION
```

```
    STATUS          current
```

```
    DESCRIPTION
```

"An enumerated integer value that represents the value of the power policy level, a current power setting at which a Power Monitor uses power.

There are twelve power policy levels, divided into six operational states, and six non-operational states. The lowest non-operational state is 1 and the highest is six. Each non-operational state corresponds to an ACPI level [ACPI] corresponding to Global and System levels between G3 (hard-off) and G1 (sleeping). For operational levels, 6 is the lowest, and 12 the highest (full power). Each operational level represent a performance state, and may be mapped to ACPI states P0 (maximum performance & power) through P5 (minimum performance and minimum power).

An entity may have fewer power levels than twelve and would then map several policy levels to the same power state. Entities with more than twelve levels, would choose which twelve to represent as power policy levels.

Note that Power Monitor Parents MUST report some of the non-operational Power Levels of their Power Monitor Children who are unable to report their Power Level. For example: A phone may notify its Power Monitor Parent that it will go into a mechoff(1) or hibernate(3) state so that the Power Monitor Parent can report the phone's current state (such as zero or 1 watt). Conversely, a PC with Desktop and mobile Architecture for System Hardware [DASH] out-of-band management is an example where a Power Monitor Child can report its usage and level even when in a non-operational state.

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

- mechoff(1) : An off state where no entity features are available. The entity is unavailable. No energy is being consumed and the power connector can be removed. This corresponds to ACPI level G3.
- 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 level G2.
- 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 level 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 level 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 level 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 be quickly transitioned into an operational state. For example, processors are not executing, but processor context is maintained. This corresponds to level G1, S1 in ACPI.

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 levels 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.

Note that unknown(0) is not a Power Level as such, but simply an indication that the Power Level unavailable."

SYNTAX

INTEGER {
 unknown(0),

```
    mechoff(1),
    softoff(2),
    hibernate(3),
    sleep(4),
    standby(5),
    ready(6),
    lowMinus(7),
    low(8),
    mediumMinus(9),
    medium(10),
    highMinus(11),
    high(12)
}
```

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 pmPowerUnitMultiplier, -3 represents 10⁻³ 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), -- 10⁰
 kilo(3), -- 10³
 mega(6), -- 10⁶
 giga(9), -- 10⁹
 tera(12), -- 10¹²
 peta(15), -- 10¹⁵
 exa(18), -- 10¹⁸
 zetta(21), -- 10²¹
 yotta(24) -- 10²⁴
}

```
pmPowerTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF PmEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "This table lists Power Monitors."
    ::= { powerMonitorMIBObjects 1 }

pmPowerEntry OBJECT-TYPE
    SYNTAX          PmEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "An entry describes the power usage of a Power Monitor.
        This table augments the pmTable."
    AUGMENTS        { pmEntry }
    ::= { pmPowerTable 1 }

PmEntry ::= SEQUENCE {
    pmPower                Integer32,
    pmPowerNameplate       Integer32,
    pmPowerUnitMultiplier  UnitMultiplier,
    pmPowerAccuracy        Integer32,
    pmPowerMeasurementCaliber  INTEGER,
    pmCurrentType          INTEGER,
    pmPowerOrigin          INTEGER,
    pmPowerLevel           PowerMonitorLevel,
    pmPowerActualLevel     PowerMonitorLevel,
    pmManufacturerActualPowerLevel  Integer32,
    pmManufacturerMappingId Integer32
}

pmPower OBJECT-TYPE
    SYNTAX          Integer32
    UNITS           "Watts"
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION
        "This object indicates the 'instantaneous' RMS
        consumption for the Power Monitor. This value is
        specified in SI units of watts with the magnitude of
        watts (milliwatts, kilowatts, etc.) indicated separately
        in pmPowerUnitMultiplier. The accuracy of the measurement
```

is specified in pmPowerAccuracy. The direction of power flow is indicated by the sign on pmPower. If the Power Monitor is consuming power, the pmPower value will be positive. If the Power Monitor is producing power, the pmPower value will be negative.

The pmPower MUST be less than or equal to the maximum power that can be consumed at the power level specified by pmPowerLevel."

::= { pmPowerEntry 1 }

pmPowerNameplate OBJECT-TYPE

SYNTAX Integer32

UNITS "Watts"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the rated maximum consumption for the fully populated Power Monitor. The nameplate power requirements are the maximum power numbers and, in almost all cases, are well above the expected operational consumption. The pmPowerNameplate 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 pmPowerUnitMultiplier."

::= { pmPowerEntry 2 }

pmPowerUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The magnitude of watts for the usage value in pmPower and pmPowerNameplate."

::= { pmPowerEntry 3 }

pmPowerAccuracy 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 pmPower. For example: The value 1010 means the reported usage is accurate to +/- 10.1 percent. This

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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"
::= { pmPowerEntry 4 }

pmPowerMeasurementCaliber OBJECT-TYPE
SYNTAX INTEGER {
 unknown(1),
 actual(2) ,
 estimated(3),
 presumed(4)
 }
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "This object specifies how the usage value reported by
 pmPower was obtained:

 - unknown: 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).

 - actual: 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: 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: 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."
::= { pmPowerEntry 5 }

```

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pmCurrentType OBJECT-TYPE
    SYNTAX      INTEGER {
                    ac(1),
                    dc(2),
                    unknown(3)
                }
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "This object indicates whether the pmUsage for the Power
        Monitor reports alternative current AC(1), direct current
        DC(2), or that the current type is unknown(3)."
```

::= { pmPowerEntry 6 }

```

pmPowerOrigin 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
        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."
```

::= { pmPowerEntry 7 }

```

pmPowerLevel OBJECT-TYPE
    SYNTAX      PowerMonitorLevel
    MAX-ACCESS   read-write
    STATUS       current
    DESCRIPTION
        "This object specifies the Power Level (0..12) requested
        for the Power Monitor. The pmPowerLevel values increase
        with the power consumption.
        If the Power Monitor is unable to report its Power
        Level, it must report the value unknown(0). Note that
        unknown(0) is not a Power Level as such, but simply an
        indication that the Power Level is unknown."
```

::= { pmPowerEntry 8 }

```

pmPowerActualLevel OBJECT-TYPE
```

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```

SYNTAX          PowerMonitorLevel
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
    "This object specifies the current Power Level (0..12)
    for the Power Monitor. If the Power Monitor is unable to
    report its Power Level, it must report the value
    unknown(0). Note that unknown(0) is not a Power Level
    as such, but simply an indication that the Power Level
    is unknown."
 ::= { pmPowerEntry 9 }

```



```

pmManufacturerActualPowerLevel      OBJECT-TYPE
SYNTAX          Integer32 (0..1000)
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
    "This object is a positive integer which specifies the
    actual Manufacturer Power Level for the Power Monitor.
    If the Manufacturer Power Level is not defined, the
    pmManufacturerActualPowerLevel will report 0. If the
    Power Monitor is unable to report its Manufacturer Power
    Level, it must report the value 0."
 ::= { pmPowerEntry 10 }

```



```

pmManufacturerMappingId OBJECT-TYPE
SYNTAX          Integer32 (1..1000)
MAX-ACCESS      read-write
STATUS          current
DESCRIPTION
    "This object specifies the actual Manufacturer Power
    Level mapping ID for the Power Monitor. The
    pmManufacturerMappingId points to the
    pmPowerLevelMappingTable, which maps the Manufacturer
    Power Levels versus the standard ones specified in the
    PowerMonitorLevel textual convention. If the
    Manufacturer Power Level mapping is not defined, the
    pmManufacturerMappingId will report 0. If the Power
    Monitor is unable to report its Manufacturer Power
    Level mapping ID, it must report the value 0."
 ::= { pmPowerEntry 11 }

```



```

pmPowerLevelTable OBJECT-TYPE
SYNTAX          SEQUENCE OF PmPowerLevelEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION

```


"This table enumerates the maximum power usage, in watts, for every single supported Power Level of each Power Monitor.

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

```
::= { powerMonitorMIBObjects 2 }
```

pmPowerLevelEntry OBJECT-TYPE

SYNTAX PmPowerLevelEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"A pmPowerLevelEntry extends a corresponding pmEntry. This entry displays max usage values at every single possible Power Monitor Level supported by the Power Monitor.

For example, given the values of a Power Monitor corresponding to a maximum usage of 11W at the level 1 (off), 6 (low), 8 (medium), 12 (full):

Level	MaxUsage	Units
1	0	0
5	0	0
6	8	0
7	8	0
8	11	0
12	11	0"

```
INDEX {
    pmIndex,
    pmPowerLevelIndex
```

```
    }
::= { pmPowerLevelTable 1 }
```

PmPowerLevelEntry ::= SEQUENCE {

pmPowerLevelIndex

PowerMonitorLevel,

pmPowerLevelMaxPower

Integer32,

pmPowerLevelPowerUnitMultiplier

UnitMultiplier

}

pmPowerLevelIndex OBJECT-TYPE

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SYNTAX PowerMonitorLevel
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This object indicates the level for which this entry
 describes the power usage."
 ::= { pmPowerLevelEntry 1 }

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

 For Power Levels not enumerated, the value of
 pmPowerLevelMaxPower might be interpolated by using the
 next highest supported Power Level."
 ::= { pmPowerLevelEntry 2 }

pmPowerLevelPowerUnitMultiplier OBJECT-TYPE
 SYNTAX UnitMultiplier
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "The magnitude of watts for the usage value in
 pmPowerLevelMaxPower."
 ::= { pmPowerLevelEntry 3 }

pmPowerLevelMappingTable OBJECT-TYPE
 SYNTAX SEQUENCE OF PmPowerLevelMappingEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table enumerates the maximum power usage, in watts,
 for every single Manufacturer Power Level. This table
 also maps the Manufacturer Power Levels to the Power
 Levels specified in this document (more specifically, to
 the PowerMonitorLevel textual convention). Finally, this

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 table returns the name of each Manufacturer Power Level.
 For every different pmManufacturerMappingId in the
 pmTable, there is a corresponding entry in this table."
 ::= { powerMonitorMIBObjects 3 }

pmPowerLevelMappingEntry OBJECT-TYPE
 SYNTAX PmPowerLevelMappingEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "For every pmManufacturerMappingId, this entry displays
 the max usage value at every single possible Manufacturer
 Power Level supported by the Power Monitor, along with
 the mapping at the standardized Power Level
 For example, given the values of a Power Monitor
 corresponding to a maximum usage of 0, 3, 7, and 11W at
 the level 1 (off), 2 (low), 3 (medium), 4 (full), the
 mapping would be represent as follows:

Pow. Lev.	Manu. Pow. Lev./Name	maxUsage
1	1/off	0 W
2	1/off	0 W
3	1/off	0 W
4	1/off	0 W
5	1/off	0 W
6	2/low	3 W
7	2/low	3 W
8	3/medium	7 W
9	3/medium	7 W
10	3/medium	7 W
11	3/medium	7 W
12	4/full	11 W

In this example, the Manufacturer Power Levels map to the
 lowest applicable Power Levels, so that setting all Power
 Monitors to a Power Level would be conservative in terms
 of disabled functionality on the Power Monitor
 implementing the Manufacturer Power Levels."

 INDEX {
 pmManufacturerMappingId,
 pmPowerLevelIndex,
 pmManufacturerDefinedPowerLevel
 }
 ::= { pmPowerLevelMappingTable 1 }

PmPowerLevelMappingEntry ::= SEQUENCE {

```

    pmManufacturerDefinedPowerLevel Integer32,
    pmManufacturerPowerLevelMaxPower Integer32,
    pmManufacturerPowerLevelPowerUnitMultiplier
                                   UnitMultiplier,
    pmManufacturerPowerLevelName    DisplayString
}

```

```

pmManufacturerDefinedPowerLevel OBJECT-TYPE
    SYNTAX      Integer32 (0..10000)
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This object specifies the Manufacturer Power Levels for
        the specific pmManufacturerMappingId."
    ::= { pmPowerLevelMappingEntry 1 }

```

```

pmManufacturerPowerLevelMaxPower OBJECT-TYPE
    SYNTAX      Integer32
    UNITS       "Watts"
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "This object indicates the maximum power for the
        Manufacturer Power Level specified by the
        pmManufacturerDefinedPowerLevel index. This value is
        specified in SI units of watts with the magnitude of the
        units (milliwatts, kilowatts, etc.) indicated separately
        in pmManufacturerPowerLevelPowerUnitMultiplier. If the
        maximum power is not known for a certain Power Level,
        then the value is encoded as 0xFFFF.
        For Power Levels not enumerated, the value of
        pmManufacturerPowerLevelMaxPower might be interpolated by
        using the next highest supported Power Level."
    ::= { pmPowerLevelMappingEntry 2 }

```

```

pmManufacturerPowerLevelPowerUnitMultiplier OBJECT-TYPE
    SYNTAX      UnitMultiplier
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "The magnitude of watts for the usage value in
        pmManufacturerPowerLevelMaxPower ."
    ::= { pmPowerLevelMappingEntry 3 }

```

```

pmManufacturerPowerLevelName OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current

```

DESCRIPTION

"The textual name of the manufacturer name for the Power Level specified by the pmManufacturerDefinedPowerLevel index. If there is no local name, or this object is otherwise not applicable, then this object contains a zero-length string."

::= { pmPowerLevelMappingEntry 4 }

pmDemandEnergyParametersTable OBJECT-TYPE

SYNTAX SEQUENCE OF PmDemandEnergyParametersEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"Controls and configures the demand table

pmDemandEnergyTable."

::= { powerMonitorMIBObjects 4 }

pmDemandEnergyParametersEntry OBJECT-TYPE

SYNTAX PmDemandEnergyParametersEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry controls an energy measurement in

pmDemandEnergyTable."

INDEX { pmIndex }

::= { pmDemandEnergyParametersTable 1 }

PmDemandEnergyParametersEntry ::= SEQUENCE {

pmDemandEnergyParametersIntervalLength	TimeInterval,
pmDemandEnergyParametersIntervalNumber	Integer32,
pmDemandEnergyParametersIntervalMode	Integer32,
pmDemandEnergyParametersIntervalWindow	TimeInterval,
pmDemandEnergyParametersSampleRate	Integer32,
pmDemandEnergyParametersStatus	RowStatus

}

pmDemandEnergyParametersIntervalLength OBJECT-TYPE

SYNTAX TimeInterval

UNITS "Seconds"

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"This object indicates the length of time in seconds over which to compute the average pmDemandIntervalEnergyUsed measurement in the pmDemandEnergyTable table. The computation is based on the Power Monitor's internal sampling rate of power consumed or produced by the Power

Monitor. The sampling rate is the rate at which the power monitor can read the power usage and may differ based on device capabilities. The average energy consumption is then computed over the length of the demand interval."

DEFVAL { 900 }

::= { pmDemandEnergyParametersEntry 1 }

pmDemandEnergyParametersIntervalNumber OBJECT-TYPE

SYNTAX Integer32

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"The number of demand intervals maintained in the pmDemandEnergyTable table. Each interval is characterized by a specific pmDemandIntervalStartTime, used as an index in the the table pmDemandEnergyTable table pmDemandIntervalStartTime. Whenever the maximum number of entries is reached, the new demand interval replaces the oldest one, except if the oldest one is the pmDemandIntervalMax, in which case the next oldest interval is replaced."

DEFVAL { 10 }

::= { pmDemandEnergyParametersEntry 2 }

pmDemandEnergyParametersIntervalMode 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

pmDemandIntervalEnergyUsed measurement in the pmDemandEnergyTable table.

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 pmDemandEnergyParametersIntervalWindow.

A mode of total(3) specifies non-periodic measurement. In this mode only one interval is used as this is a

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continuous measurement since the last reset. The value of
pmDemandEnergyParametersIntervalNumber should be (1) one
and pmDemandEnergyParametersIntervalLength is ignored. "
::= { pmDemandEnergyParametersEntry 3 }

pmDemandEnergyParametersIntervalWindow OBJECT-TYPE

SYNTAX TimeInterval
UNITS "Seconds"
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
seconds, in order to compute the average
pmDemandIntervalEnergyUsed measurement in the
pmDemandEnergyTable table This is valid only when the
pmDemandEnergyParametersIntervalMode is sliding(2). The
pmDemandEnergyParametersIntervalWindow value should be a
multiple of pmDemandEnergyParametersSampleRate."

::= { pmDemandEnergyParametersEntry 4 }

pmDemandEnergyParametersSampleRate OBJECT-TYPE

SYNTAX Integer32
UNITS "Milliseconds"
MAX-ACCESS read-create
STATUS current

DESCRIPTION

"The sampling rate, in milliseconds, at which the Power
Monitor should poll power usage in order to compute the
average pmDemandIntervalEnergyUsed measurement in the
table pmDemandEnergyTable. The Power Monitor 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 Power Monitor performance by
requesting continuous polling. If the sampling rate is
unknown, the value 0 is reported. The sampling rate
should be selected so that

pmDemandEnergyParametersIntervalWindow is a multiple of
pmDemandEnergyParametersSampleRate."

DEFVAL { 1000 }

::= { pmDemandEnergyParametersEntry 5 }

pmDemandEnergyParametersStatus OBJECT-TYPE

SYNTAX RowStatus
MAX-ACCESS read-create
STATUS current

DESCRIPTION

"The status of this row. The pmDemandEnergyParametersStatus 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 pmDemandEnergyTable will be deleted. The data can be destroyed by setting up the pmDemandEnergyParametersStatus to destroy(2)."

::= { pmDemandEnergyParametersEntry 6 }

pmDemandEnergyTable OBJECT-TYPE

SYNTAX SEQUENCE OF PmDemandEnergyEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

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

::= { powerMonitorMIBObjects 5 }

pmDemandEnergyEntry OBJECT-TYPE

SYNTAX PmDemandEnergyEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry describing energy measurements."

INDEX { pmIndex, pmDemandEnergyParametersIntervalMode,
pmDemandEnergyIntervalStartTime }

::= { pmDemandEnergyTable 1 }

PmDemandEnergyEntry ::= SEQUENCE {

pmDemandEnergyIntervalStartTime	TimeTicks,
pmDemandEnergyIntervalEnergyUsed	Integer32,
pmDemandEnergyIntervalEnergyUnitMultiplier	UnitMultiplier,
pmDemandEnergyIntervalMax	Integer32

}

pmDemandEnergyIntervalStartTime OBJECT-TYPE

SYNTAX TimeTicks

UNITS "hundredths of seconds"

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MAX-ACCESS	not-accessible	
STATUS	current	
DESCRIPTION		
<p>"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 demand is measured."</p>		
::= { pmDemandEnergyEntry 1 }		

pmDemandEnergyIntervalEnergyUsed	OBJECT-TYPE
SYNTAX	Integer32
UNITS	"Watt-hours"
MAX-ACCESS	read-only
STATUS	current
DESCRIPTION	
<p>"This object indicates the energy used in units of watt-hours for the Power Monitor 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 pmDemandEnergyIntervalEnergyUnitMultiplier."</p>	
::= { pmDemandEnergyEntry 2 }	

pmDemandEnergyIntervalEnergyUnitMultiplier	OBJECT-TYPE
SYNTAX	UnitMultiplier
MAX-ACCESS	read-only
STATUS	current
DESCRIPTION	
<p>"This object is the magnitude of watt-hours for the energy field in pmDemandEnergyIntervalEnergyUsed."</p>	
::= { pmDemandEnergyEntry 3 }	

pmDemandEnergyIntervalMax	OBJECT-TYPE
SYNTAX	Integer32
UNITS	"Watt-hours"
MAX-ACCESS	read-only
STATUS	current
DESCRIPTION	
<p>"This object is the maximum demand ever observed in pmDemandEnergyIntervalEnergyUsed 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 pmDemandEnergyIntervalEnergyUnits."</p>	
::= { pmDemandEnergyEntry 4 }	

```
-- Notifications
```

```
pmPowerLevelChange NOTIFICATION-TYPE
```

```
    OBJECTS      {pmPowerLevel,pmManufacturerActualPowerLevel}
```

```
    STATUS      current
```

```
    DESCRIPTION
```

```
        "The SNMP entity generates the PmPowerLevelChange when
         the value(s) of pmPowerLevel and/or
         pmManufacturerActualPowerLevel has changed for the Power
         Monitor represented by the pmIndex."
```

```
 ::= { powerMonitorMIBNotifs 1 }
```

```
-- Conformance
```

```
powerMonitorMIBCompliances OBJECT IDENTIFIER
```

```
 ::= { powerMonitorMIB 3 }
```

```
powerMonitorMIBGroups OBJECT IDENTIFIER
```

```
 ::= { powerMonitorMIB 4 }
```

```
powerMonitorMIBFullCompliance 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      -- this module
```

```
    MANDATORY-GROUPS {
```

```
        powerMonitorMIBTableGroup,
        powerMonitorMIBLevelTableGroup,
        powerMonitorMIBLevelMappingTableGroup,
        powerMonitorMIBDemandEnergyTableGroup,
        powerMonitorMIBDemandEnergyParametersTableGroup,
        powerMonitorMIBNotifGroup
    }
```

```
 ::= { powerMonitorMIBCompliances 1 }
```

```
powerMonitorMIBReadOnlyCompliance 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 can not be configured
         with this MIB."
```

```
    MODULE      -- this module
```

```
MANDATORY-GROUPS {
    powerMonitorMIBTableGroup,
    powerMonitorMIBLevelTableGroup,
    powerMonitorMIBLevelMappingTableGroup,
    powerMonitorMIBNotifGroup
}

OBJECT      pmPowerLevel
MIN-ACCESS  read-only
DESCRIPTION
    "Write access is not required."

::= { powerMonitorMIBCompliances 2 }

-- Units of Conformance

powerMonitorMIBTableGroup OBJECT-GROUP
    OBJECTS      {
        pmPower,
        pmPowerNameplate,
        pmPowerUnitMultiplier,
        pmPowerAccuracy,
        pmPowerMeasurementCaliber,
        pmCurrentType,
        pmPowerOrigin,
        pmPowerCategory,
        pmPowerLevel,
        pmPowerActualLevel,
        pmManufacturerActualPowerLevel,
        pmManufacturerMappingId
    }
    STATUS      current
DESCRIPTION
    "This group contains the collection of all the objects
    related to the PowerMonitor."
::= { powerMonitorMIBGroups 1 }

powerMonitorMIBLevelTableGroup OBJECT-GROUP
    OBJECTS      {
        pmPowerLevelMaxPower,
        pmPowerLevelPowerUnitMultiplier
    }
    STATUS      current
DESCRIPTION
    "This group contains the collection of all the
    objects related to the Power Level. "
::= { powerMonitorMIBGroups 2 }
```

```

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    powerMonitorMIBLevelMappingTableGroup  OBJECT-GROUP
        OBJECTS
            {
                pmManufacturerPowerLevelMaxPower,
                pmManufacturerPowerLevelPowerUnitMultiplier,
                pmManufacturerPowerLevelName
            }
        STATUS          current
        DESCRIPTION
            "This table enumerates the maximum power usage
            in watts, for every single Manufacturer Power
            Level."
    ::= { powerMonitorMIBGroups 3 }

```

```

powerMonitorMIBDemandEnergyParametersTableGroup  OBJECT-GROUP
    OBJECTS
        {
            pmDemandEnergyParametersIntervalLength,
            pmDemandEnergyParametersIntervalNumber,
            pmDemandEnergyParametersIntervalMode,
            pmDemandEnergyParametersIntervalWindow,
            pmDemandEnergyParametersSampleRate,
            pmDemandEnergyParametersStatus
        }
    STATUS          current
    DESCRIPTION
        "This group contains the collection of all the objects
        related to the configuration of the Demand Table."
    ::= { powerMonitorMIBGroups 4 }

```

```

powerMonitorMIBDemandEnergyTableGroup  OBJECT-GROUP
    OBJECTS
        {
            -- Note that object
            -- pmDemandIntervalStartTime is not
            -- included since it is not-accessible

            pmDemandEnergyIntervalEnergyUsed,
            pmDemandEnergyIntervalEnergyUnitMultiplier,
            pmDemandEnergyIntervalMax
        }
    STATUS          current
    DESCRIPTION
        "This group contains the collection of all the objects
        related to the Demand Table."
    ::= { powerMonitorMIBGroups 5 }

```

```

powerMonitorMIBNotifGroup  NOTIFICATION-GROUP

```

```

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NOTIFICATIONS      {
                        pmPowerLevelChange
                    }
STATUS              current
DESCRIPTION
    "This group contains the notifications for the power and
    energy monitoring MIB Module."
 ::= { powerMonitorMIBGroups 6 }

```

END

```

-- *****
--
-- This MIB module is used to monitor power quality of networked
-- devices with measurements.
--
-- This MIB module is an extension of powerMonitorMIB module.
--
-- *****

```

POWER-QUALITY-MIB DEFINITIONS ::= BEGIN

```

IMPORTS
    MODULE-IDENTITY,
    OBJECT-TYPE,
    NOTIFICATION-TYPE,
    mib-2,
    Integer32
FROM SNMPv2-SMI
    MODULE-COMPLIANCE,
    NOTIFICATION-GROUP,
    OBJECT-GROUP
    FROM SNMPv2-CONF
TEXTUAL-CONVENTION
    FROM SNMPv2-TC
    UnitMultiplier, pmPowerTable , pmIndex
FROM POWER-MONITOR-MIB
;

```

```

powerQualityMIB MODULE-IDENTITY
    LAST-UPDATED      "201005300000Z"
    ORGANIZATION      "Cisco Systems, Inc."
    CONTACT-INFO
        "Cisco Systems
        Customer Service

        Postal: 170 W Tasman Drive

```

San Jose, CA 95134
USA

Tel: +1 800 553-NETS

E-mail: cs-snmp@cisco.com"

DESCRIPTION

"This MIB is used to report AC power quality in devices. The table is a sparse augmentation of the pmTable table from the powerMonitorMIB module. Both three-phase and single-phase power configurations are supported."

REVISION

"201005300000Z"

DESCRIPTION

"Initial version, published as RFC XXXX."

::= { mib-2 yyyyyy }

powerQualityMIBConform OBJECT IDENTIFIER

::= { powerQualityMIB 0 }

powerQualityMIBObjects OBJECT IDENTIFIER

::= { powerQualityMIB 1 }

-- Objects

pmACPwrQualityTable OBJECT-TYPE

SYNTAX SEQUENCE OF PmACPwrQualityEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table defines power quality measurements for supported pmIndex entities. It is a sparse extension of the pmTable."

::= { powerQualityMIBObjects 1 }

pmACPwrQualityEntry OBJECT-TYPE

SYNTAX PmACPwrQualityEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This is a sparse extension of the pmTable with entries for power quality measurements or configuration. Each measured value corresponds to an attribute in IEC

```
INDEX { pmIndex }
 ::= { pmACPwrQualityTable 1 }
```

```
PmACPwrQualityEntry ::= SEQUENCE {
    pmACPwrQualityConfiguration      INTEGER,
    pmACPwrQualityAvgVoltage         Integer32,
    pmACPwrQualityAvgCurrent         Integer32,
    pmACPwrQualityFrequency          Integer32,
    pmACPwrQualityPowerUnitMultiplier UnitMultiplier,
    pmACPwrQualityPowerAccuracy      Integer32,
    pmACPwrQualityTotalActivePower   Integer32,
    pmACPwrQualityTotalReactivePower Integer32,
    pmACPwrQualityTotalApparentPower Integer32,
    pmACPwrQualityTotalPowerFactor   Integer32,
    pmACPwrQualityThdAmperes         Integer32,
    pmACPwrQualityThdVoltage         Integer32
}
```

pmACPwrQualityConfiguration 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."

```
::= { pmACPwrQualityEntry 1 }
```

pmACPwrQualityAvgVoltage OBJECT-TYPE

```
SYNTAX                Integer32
```

```
UNITS                 "0.1 Volt AC"
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"A measured value for average 'instantaneous' RMS line voltage. For a 3-phase system, this is the average voltage $(V1+V2+V3)/3$. IEC 61850-7-4 measured value attribute 'Vol'"

::= { pmACPwrQualityEntry 2 }

pmACPwrQualityAvgCurrent 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'"

::= { pmACPwrQualityEntry 3 }

pmACPwrQualityFrequency 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'."

::= { pmACPwrQualityEntry 4 }

pmACPwrQualityPowerUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The magnitude of watts for the usage value in pmACPwrQualityTotalActivePower, pmACPwrQualityTotalReactivePower and pmACPwrQualityTotalApparentPower measurements. For 3-phase power systems, this will also include pmACPwrQualityPhaseActivePower, pmACPwrQualityPhaseReactivePower and pmACPwrQualityPhaseApparentPower"

::= { pmACPwrQualityEntry 5 }

pmACPwrQualityPowerAccuracy OBJECT-TYPE

SYNTAX Integer32 (0..10000)

UNITS "hundredths of percent"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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"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"

```
 ::= { pmACPwrQualityEntry 6 }
```

pmACPwrQualityTotalActivePower OBJECT-TYPE

```
SYNTAX          Integer32
UNITS           "RMS 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'."
 ::= { pmACPwrQualityEntry 7 }
```

pmACPwrQualityTotalReactivePower 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'."
 ::= { pmACPwrQualityEntry 8 }
```

pmACPwrQualityTotalApparentPower OBJECT-TYPE

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



```
 ::= { pmACPwrQualityEntry 9 }
```



pmACPwrQualityTotalPowerFactor OBJECT-TYPE


```

```

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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'."
 ::= { pmACPwrQualityEntry 10 }

pmACPwrQualityThdAmperes 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'."
 ::= { pmACPwrQualityEntry 11 }

pmACPwrQualityThdVoltage 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'."
 ::= { pmACPwrQualityEntry 12 }

pmACPwrQualityPhaseTable OBJECT-TYPE
SYNTAX                  SEQUENCE OF PmACPwrQualityPhaseEntry
MAX-ACCESS              not-accessible
STATUS                  current
DESCRIPTION
    "This table describes 3-phase power quality
    measurements. It is a sparse extension of the
    pmACPwrQualityTable."
 ::= { powerQualityMIBObjects 2 }

pmACPwrQualityPhaseEntry OBJECT-TYPE

```

```

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SYNTAX                  PmACPwrQualityPhaseEntry
MAX-ACCESS              not-accessible
STATUS                  current
DESCRIPTION
    "An entry describes common 3-phase power quality
    measurements.

    This optional table describes 3-phase power quality
    measurements, with three entries for each supported
    pmIndex 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
    pmACPwrQualityTable.

    These attributes correspond to IEC 61850-7.4 MMXU phase
    measurements."
INDEX { pmIndex, pmPhaseIndex }
 ::= { pmACPwrQualityPhaseTable 1 }

PmACPwrQualityPhaseEntry ::= SEQUENCE {
    pmPhaseIndex          Integer32,
    pmACPwrQualityPhaseAvgCurrent    Integer32,
    pmACPwrQualityPhaseActivePower   Integer32,
    pmACPwrQualityPhaseReactivePower Integer32,
    pmACPwrQualityPhaseApparentPower Integer32,
    pmACPwrQualityPhasePowerFactor   Integer32,
    pmACPwrQualityPhaseImpedance     Integer32
}

pmPhaseIndex OBJECT-TYPE
    SYNTAX          Integer32 (0..359)
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION
        "A phase angle typically corresponding to 0, 120, 240."
        ::= { pmACPwrQualityPhaseEntry 1 }

pmACPwrQualityPhaseAvgCurrent 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'"

```

```
::= { pmACPwrQualityPhaseEntry 2 }
```

```
pmACPwrQualityPhaseActivePower OBJECT-TYPE
```

```
SYNTAX Integer32
```

```
UNITS "RMS 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'."

```
::= { pmACPwrQualityPhaseEntry 3 }
```

```
pmACPwrQualityPhaseReactivePower 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'."

```
::= { pmACPwrQualityPhaseEntry 4 }
```

```
pmACPwrQualityPhaseApparentPower 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'."

```
::= { pmACPwrQualityPhaseEntry 5 }
```

```
pmACPwrQualityPhasePowerFactor 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 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."

```
::= { pmACPwrQualityPhaseEntry 6 }
```

```

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pmACPwrQualityPhaseImpedance 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'."
        ::= { pmACPwrQualityPhaseEntry 7 }

pmACPwrQualityDelPhaseTable OBJECT-TYPE
    SYNTAX                SEQUENCE OF PmACPwrQualityDelPhaseEntry
    MAX-ACCESS             not-accessible
    STATUS                 current
    DESCRIPTION
        "This table describes DEL configuration phase-to-phase
        power quality measurements.  This is a sparse extension
        of the pmACPwrQualityPhaseTable."
        ::= { powerQualityMIBObjects 3 }

pmACPwrQualityDelPhaseEntry OBJECT-TYPE
    SYNTAX                PmACPwrQualityDelPhaseEntry
    MAX-ACCESS             not-accessible
    STATUS                 current
    DESCRIPTION
        "An entry describes quality 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.

        For phase-to-phase measurements, the pmPhaseIndex is
        compared against the following phase at +120 degrees.
        Thus, the possible values are:

                pmPhaseIndex      Next Phase Angle
                0                  120
                120                240
                240                0

        "
        INDEX { pmIndex, pmPhaseIndex}
        ::= { pmACPwrQualityDelPhaseTable 1}

PmACPwrQualityDelPhaseEntry ::= SEQUENCE {
    pmACPwrQualityDelPhaseToNextPhaseVoltage  Integer32,
    pmACPwrQualityDelThdPhaseToNextPhaseVoltage Integer32,

```

```

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                        pmACPwrQualityDelThdCurrent        Integer32
                    }

pmACPwrQualityDelPhaseToNextPhaseVoltage 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'."
        ::= { pmACPwrQualityDelPhaseEntry 2 }

pmACPwrQualityDelThdPhaseToNextPhaseVoltage 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 for phase to next phase. Method of calculation
         is not specified. IEC 61850-7-4 attribute 'ThdPPV'."
        ::= { pmACPwrQualityDelPhaseEntry 3 }

pmACPwrQualityDelThdCurrent 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) for phase to phase. Method of
         calculation is not specified.
         IEC 61850-7-4 attribute 'ThdPPV'."
        ::= { pmACPwrQualityDelPhaseEntry 4 }

pmACPwrQualityWyePhaseTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF PmACPwrQualityWyePhaseEntry
    MAX-ACCESS      not-accessible
    STATUS           current
    DESCRIPTION
        "This table describes WYE configuration phase-to-neutral
         power quality measurements. This is a sparse extension
         of the pmACPwrQualityPhaseTable."
        ::= { powerQualityMIBObjects 4 }

pmACPwrQualityWyePhaseEntry OBJECT-TYPE
    SYNTAX          PmACPwrQualityWyePhaseEntry

```

```

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MAX-ACCESS              not-accessible
STATUS                  current
DESCRIPTION
    "This table describes measurements of WYE configuration
    with phase to neutral power quality attributes. Three
    entries are required for each supported pmIndex entry.
    Voltage measurements are relative to neutral.

    This is a sparse extension of the
    pmACPwrQualityPhaseTable.

    Each entry describes quality 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 { pmIndex, pmPhaseIndex }
 ::= { pmACPwrQualityWyePhaseTable 1}

PmACPwrQualityWyePhaseEntry ::= SEQUENCE {
    pmACPwrQualityWyePhaseToNeutralVoltage      Integer32,
    pmACPwrQualityWyePhaseCurrent               Integer32,
    pmACPwrQualityWyeThdPhaseToNeutralVoltage   Integer32
}

pmACPwrQualityWyePhaseToNeutralVoltage 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'."
 ::= { pmACPwrQualityWyePhaseEntry 1 }

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

pmACPwrQualityWyeThdPhaseToNeutralVoltage OBJECT-TYPE
SYNTAX      Integer32 (0..10000)
UNITS       "hundredths of percent"

```

```

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    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'."
    ::= { pmACPwrQualityWyePhaseEntry 3 }

-- Conformance

powerQualityMIBCompliances OBJECT IDENTIFIER
    ::= { powerQualityMIB 2 }

powerQualityMIBGroups OBJECT IDENTIFIER
    ::= { powerQualityMIB 3 }

powerQualityMIBFullCompliance 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              -- this module
    MANDATORY-GROUPS {
        powerACPwrQualityMIBTableGroup,
        powerACPwrQualityPhaseMIBTableGroup
    }

    GROUP              powerACPwrQualityDelPhaseMIBTableGroup
    DESCRIPTION
        "This group must only be implemented for a DEL phase
        configuration."

    GROUP              powerACPwrQualityWyePhaseMIBTableGroup
    DESCRIPTION
        "This group must only be implemented for a WYE phase
        configuration."
    ::= { powerQualityMIBCompliances 1 }

-- Units of Conformance

powerACPwrQualityMIBTableGroup OBJECT-GROUP
    OBJECTS             {
        -- Note that object pmIndex is NOT
        -- included since it is not-accessible
        pmACPwrQualityConfiguration,

```

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```

        pmACPwrQualityAvgVoltage,
        pmACPwrQualityAvgCurrent,
        pmACPwrQualityFrequency,
        pmACPwrQualityPowerUnitMultiplier,
        pmACPwrQualityPowerAccuracy,
        pmACPwrQualityTotalActivePower,
        pmACPwrQualityTotalReactivePower,
        pmACPwrQualityTotalApparentPower,
        pmACPwrQualityTotalPowerFactor,
        pmACPwrQualityThdAmpheres,
        pmACPwrQualityThdVoltage
    }      STATUS      current
DESCRIPTION
    "This group contains the collection of all the power
    quality objects related to the Power Monitor."
    ::= { powerQualityMIBGroups 1 }

```

```

powerACPwrQualityPhaseMIBTableGroup OBJECT-GROUP
    OBJECTS      {
        -- Note that object pmIndex is NOT
        -- included since it is not-accessible
        pmACPwrQualityPhaseAvgCurrent,
        pmACPwrQualityPhaseActivePower,
        pmACPwrQualityPhaseReactivePower,
        pmACPwrQualityPhaseApparentPower,
        pmACPwrQualityPhasePowerFactor,
        pmACPwrQualityPhaseImpedance
    }
    STATUS      current
DESCRIPTION
    "This group contains the collection of all 3-phase power
    quality objects related to the Power Level."
    ::= { powerQualityMIBGroups 2 }

```

```

powerACPwrQualityDelPhaseMIBTableGroup OBJECT-GROUP
    OBJECTS      {
        -- Note that object pmIndex and
        -- pmPhaseIndex are NOT included
        -- since they are not-accessible
        pmACPwrQualityDelPhaseToNextPhaseVoltage ,
        pmACPwrQualityDelThdPhaseToNextPhaseVoltage,
        pmACPwrQualityDelThdCurrent
    }
    STATUS      current
DESCRIPTION
    "This group contains the collection of all quality
    attributes of a phase in a DEL 3-phase power system."

```

```
powerACPwrQualityWyePhaseMIBTableGroup OBJECT-GROUP
    OBJECTS {
        -- Note that object pmIndex and
        -- pmPhaseIndex are NOT included
        -- since they are not-accessible
        pmACPwrQualityWyePhaseToNeutralVoltage,
        pmACPwrQualityWyePhaseCurrent,
        pmACPwrQualityWyeThdPhaseToNeutralVoltage
    }
    STATUS current
    DESCRIPTION
        "This group contains the collection of all WYE
        configuration phase-to-neutral power quality
        measurements."
    ::= { powerQualityMIBGroups 4 }
```

END

10. 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 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 pmPowerLevel MAY disrupt the power settings of the different Power Monitors, and therefore the level of functionality of the respective Power Monitors.
- . Unauthorized changes to the pmDemandControlTable MAY disrupt energy measurement in the pmDemandEnergyTable 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.

11. 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
-----	-----
PowerMonitorMIB	{ 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.

12. Acknowledgment

The authors would like to thank Shamita Pisal for her prototype of this MIB module, and her valuable feedback. The authors would like to Michael Brown for improving the text dramatically.

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Power Management Architecture
draft-claise-power-management-arch-02

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Expires April 20 2011

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Abstract

This document defines the power management architecture.

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- Question for the Working Group: Should the WG consider IPFIX in this architecture?
- Question for the Working Group: How to specify the notion of child capabilities, i.e. the capabilities that the Power Monitor Parents have with Power Monitor Children.
For Example:
 1. Monitoring (only reporting)
 2. Configuration power state
 3. Configuration: powerExample: on a PC, we can set power level without knowing the power. A solution must be specified in this draft.
- Question for the Working Group: Should transition states be tracked when setting a level. Example: The configured level is set to Off from High. The Actual level will take time to update as the device powers down. Should there be transitions shown or will the two variables suffice to track the device state.
- Question for working group: Should implementation scenarios be incorporated in the architecture draft
- We should have a similar section, for all the drafts, which includes an overview of all EMAN documents.

1. Introduction

Network management is typically divided into the five main network management areas defined in the ISO Telecommunications Management Network model: Fault, Configuration, Accounting, Performance, and Security Management. Absent from this model is any consideration of energy management, which is now becoming a critical area of concern worldwide.

This document defines an architecture for power management for devices within or connected to communication networks. This architecture includes monitoring for power state and energy consumption of networked elements, covering the requirements specified in [POWER-MON-REQ]. It also goes a step further in defining some elements of configuration.

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 gateway, hosts and servers, sensor proxies, etc.

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.

2. Use Cases & Requirements

Requirements for power and energy monitoring for networking devices are specified in [POWER-MON-REQ]. The requirements in [POWER-MON-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, this architecture, the scope is broader than that specified in [POWER-MON-REQ]. Several scenarios that cover these broader use cases are presented later in Section 11. - Implementation Scenarios.

3. Terminology

This section contains definitions of important terms used throughout this specification.

IPFIX-specific terminology used in this document is defined in section 2 of [RFC5101]. For example: Flow Record, Collector , etc... As in [RFC5101], these IPFIX-specific terms have the first letter of a word capitalized.

Power Monitor

A Power Monitor is a component within a system of components that provides power, draws power, or reports energy consumption on behalf of another Power Monitor. It can be independently

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managed from a power-monitoring and power-state configuration point of view. Examples of Power Monitors are: a router line card, a motherboard with a CPU, an IP phone connected with a switch, etc.

Power Monitor Parent

A Power Monitor Parent is a Power Monitor that is the root of one or more subtending Power Monitors, called Power Monitor Children. The Power Monitor Parent is able to collect data about or report on the power state and energy consumption of its Power Monitor Children.

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 is the source of power for the attached device, so the Power Monitor Parent is the switch, and the Power Monitor Child is the device attached to the switch.

The Power Monitor Parent may report data or implement actions on behalf of the Power Monitor Child. These capabilities must be enumerated by the Power Monitor Parent.

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.

Power Monitor Child

A Power Monitor Child is a Power Monitor associated with a Power Monitor Parent, and which reports its power usage and power state to its Power Monitor Parent. The Power Monitor Child may or may not draw power from its Power Monitor Parent. .

Power Monitor Meter Domain

A Power Monitor Meter Domain is a name or name space that logically groups Power Monitors into a zone of manageable power usage. Typically, this zone will have as members all Power Monitors that are powered from the same electrical panel or panels for which there is a meter or sub meter. For example: All Power Monitors receiving power from the same distribution panel of a building, or all Power Monitors in a building for

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 which there is one main meter, would comprise a Power Monitor
 Meter Doman. From the standpoint of power-use monitoring, it is
 useful to report the total power usage as the sum of power
 consumed by all the Power Monitors within a Power Monitor Meter
 Domain and then correlate that value with the metered usage.

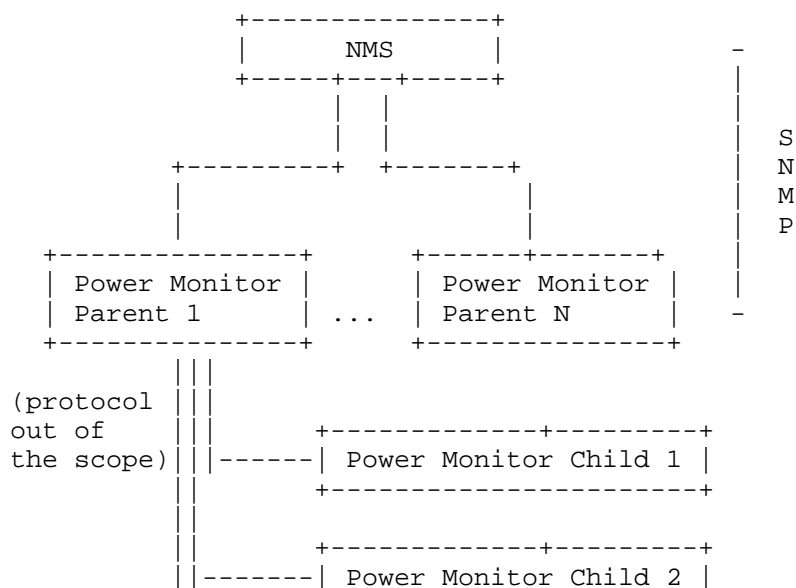
Power Level

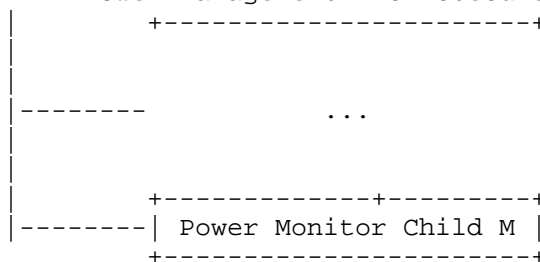
A Power Level is a uniform way to classify power settings on a
 Power Monitor (e.g., shut, hibernate, sleep, high). Power
 Levels can be viewed as an interface for the underlying device-
 implemented power settings.

Manufacturer Power Level

A Manufacturer Power Level is a device-specific way to classify
 power settings implemented on a Power Monitor. For cases where
 the implemented power settings cannot be directly mapped to
 Power Levels, we can use the Manufacturer Power Levels to
 enumerate and show the relationship between the implemented
 power settings and the Power Level interface.

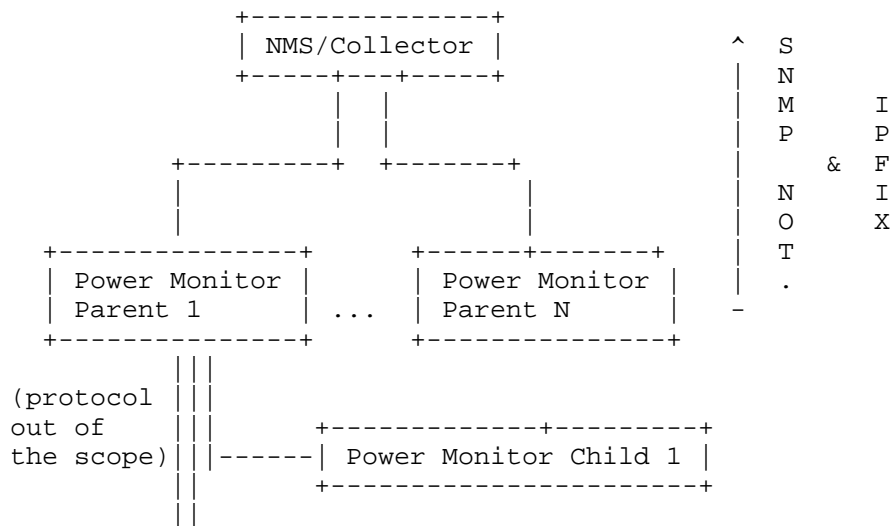
4. Energy Management Reference Model





In this architecture a Network Management Station (NMS) will poll MIB variables on a Power Monitors via SNMP. The Power Monitor returns information for itself and for any Power Monitor Children if applicable. The information returned will contain business context, energy usage, power quality and other information as described further.

The protocol between the Power Monitor Parent and Power Monitor Children is out of scope of this document. The Power Monitor Parent may speak to a Power Monitor Child using a manufacturer selected protocol. This protocol may or may not be based on IP. In this way, a Power Monitor Parent acts as a PROXY for protocol translation between the Power Monitor Parent and Child. The Power Monitor Parent also acts as an aggregation point for other subtended Power Monitor Children.



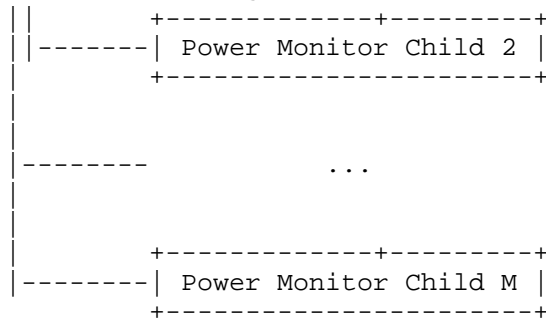


Figure 2: Energy Management PUSH Reference Model

The Power Monitor Parents may send SNMP notifications regarding their own state or the state of their Power Monitor Children. The Power Monitor Children do not send SNMP notifications on their own.

As discussed in [POWER-MON-REQ], the Power Monitor Parents may export IPFIX Flow Records [RFC5101] to a Collector. The IPFIX protocol is well suited for regular time series export of similar information, such as the energy consumed by the Power Monitor Children.

EDITOR'S NOTE: at this point in time, there is no draft specifying the IPFIX Flow Records.

5. Architecture High Level Concepts and Scope

The scope of this architecture is to enable networking and network-attached devices to be managed with respect to their energy consumption or production. The goal is to make devices energy-aware.

The architecture describes how to make a device aware of its consumption or production of energy expressed as usage in watts. This does not include:

- Manufacturing costs in currency or environmental units
- Embedded carbon or environmental equivalences of the device itself
- Cost in currency or environmental impact to dismantle or recycle the device
- Relationship to an electrical or smart grid
- Supply chain analysis

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- 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 remainder of this section describes the basic concepts of the architecture. Each concept is examined in detail in subsequent sections.

Examples are provided in a later section to show how these concepts can be implemented.

The basic concepts are:

The Power Monitor will have basic naming and informational descriptors to identify it in the network.

A Power Monitor can be part of a Power Monitor Meter Domain. A Power Monitor Meter Domain is a manageable set of devices that has a meter or sub-meter attached and typically corresponds to a power distribution point or panel.

A Power Monitor can be a parent (Power Monitor Parent) or child (Power Monitor Child) of another Power Monitor. This allows for Power Monitor Parent to aggregate power reporting and control of power information.

Each Power Monitor can have information to allow it to be described in the context of the business or ultimate use. This is in addition to its networked information. This allows for tagging, grouping, and differentiation between Power Monitors for NMS.

For control and universal monitoring, each Power Monitor implements or declares a set of known Power Levels. The Power Levels are mapped to Manufacturer Power Levels that indicate the specific power settings for the device implementing the Power Monitor.

When the Power Level is set, a Power Monitor may be busy at the request time. The Power Monitor will set the desired level and then update the actual Power Level when the priority task is finished. This mechanism implies two different Power Level variables: actual versus desired.

EDITOR'S NOTE: The transition state will have to be specified.

Each Power Monitor will have usage information that describes the power information along with how that usage was obtained or derived.

Optionally, a Power Monitor can further describe the power information with power quality information reflecting the electrical characteristics of the measurement.

Optionally, a Power Monitor can provide power usage over time to describe energy consumption

If a Power Monitor has one or more batteries, it can provide optional battery information as well.

5.1. Power Monitor Information

Every Power Monitor should have a unique printable name, and must have a unique Power Monitor index.

Possible naming conventions are: textual DNS name, MAC-address of the device, interface ifName, or a text string uniquely identifying the Power Monitor. As an example, in the case of IP phones, the Power Monitor name can be the device DNS name.

5.2. Power Monitor Meter Domain

Each Power Monitor must be a member of a Power Monitor Meter Domain. The Power Monitor Meter Domain should map 1-1 with a metered or sub-metered portion of the site. The Power Monitor Meter Domain must be configured on the Power Monitor Parent. The Power Monitor Children may inherit their domain values from the Power Monitor Parent or the Power Monitor Meter Domain may be configured directly in a Power Monitor Child.

5.3. Power Monitor Parent and Child

A Power Monitor Child reports its power usage to its Power Monitor Parent. A Power Monitor Child has one and only one Power Monitor Parent. If a Power Monitor had two parents there would be a risk of double-reporting the power usage in the Power Monitor Meter Domain. Therefore, a Power Monitor cannot be both a Power Monitor Parent and a Power Monitor Child at the same time.

A Power Monitor Child can be fully dependent on the Power Monitor Parent for its power or independent from the parent (such as a PC connected to a switch). In the dependently powered case, the Power Monitor Parent provides power for the Power Monitor Child (as in the case of Power Over Ethernet devices). In the independently powered case, the Power Monitor Child draws power from another source (typically a wall outlet). Since the Power Monitor Parent is not the source of power supply, the power usage cannot be measured at the Power Monitor Parent. However, an independent Power Monitor Child reports Power Monitor information to the Power Monitor Parent. The Power Monitor Child may listen to the power control settings from a Power Monitor Parent and could react to the control messages. However, note that the communication between the Power Monitor Parent and Power Monitor Child is out of scope for this document.

A mechanism, outside of the scope of this document, should be in place to verify the connectivity between the Power Monitor Parent and its Power Monitor Children. If a Power Monitor Child is unavailable, the Power Monitor Parent must follow some rules to determine how long it should wait before removing the Power Monitor Child entry, along with all associated statistics, from its database. In some situations, such as a connected building in which the Power Monitor Children are somewhat static, this removal-delay period may be long, and persistence across a Power Monitor Parent reload may make sense. However, in a networking environment, where endpoints can come and go, there is not much sense in configuring a long removal timer. In all cases, the removal timer or persistence must be clearly specified.

Further examples of Power Monitor Parent and Child implementations are provided in the Implementation Scenarios section 11.

5.4. Power Monitor Context

Monitored power data will ultimately be collected by and reported from an NMS. In order to aid in reporting and in differentiation between Power Monitors, each Power Monitor will contain information establishing its business or site context. A Power Monitor can provide an importance value in the range of 1 to 100 to help differentiate 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 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

A Power Monitor can provide a set of keywords. These keywords are a list of tags that can be used for grouping and summary reporting within or between Power Monitor Meter Domains. All alphanumeric characters and symbols, 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. In such cases, the keywords are separated by commas and no spaces between keywords are allowed. For example, "HR,Bldg1,Private".

Additionally, a Power Monitor can provide a "role description" string that indicates the purpose the Power Monitor serves in the network or for the site/business. This could be a string describing the context the device fulfills in deployment. For example, a lighting fixture in a kitchen area could have a role of "Hospitality Lighting" to provide context for the use of the device.

5.5. Power Monitor Levels

Power Levels represent universal states of power management of a Power Monitor. Each Power Level corresponds to a global, system, and performance state in the ACPI model [ACPI].

Level	ACPI Global/System State	Power Level Name
-------	-----------------------------	---------------------

1	G3, S5	Mech Off
2	G2, S5	Soft Off
3	G1, S4	Hibernate
4	G1, S3	Sleep
5	G1, S2	Standby
6	G1, S1	Ready

Operational states:

7	G0, S0, P5	LowMinus
8	G0, S0, P4	Low
9	G0, S0, P3	MediumMinus
10	G0, S0, P2	Medium
11	G0, S0, P1	HighMinus
12	G0, S0, P0	High

Figure 3: ACPI / Power Level Mapping

For example, a Power Monitor with a Power Level of 9 would indicate an operational state with MediumMinus Power Level.

The Power Levels can be considered as guidelines in order to promote interoperability across device types. Realistically, each specific feature requiring Power Levels will require a complete recommendation of its own. For example, designing IP phones with consistent Power Levels across vendors requires a specification for IP phone design, along with the Power Levels mapping.

Manufacturer Power Levels are required in some situations, such as when no mappings with the existing Power Levels are possible, or when more than the twelve specified Power Levels are required.

A first example would be an imaginary device type, with only five levels: "none", "short", "tall", "grande", and "venti".

Manufacturer Power Level	Respective Name
0	none
1	short
2	tall
3	grande
4	venti

Figure 4: Mapping Example 1

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 In the unlikely event that there is no possible mapping between these Manufacturer Power Levels and the proposed Power Monitor Power Levels, the Power Level will remain 0 throughout the MIB module, as displayed below.

Power Level / Name	Manufacturer Power Level / Name
0 / unknown	0 / none
0 / unknown	1 / short
0 / unknown	2 / tall
0 / unknown	3 / grande
0 / unknown	4 / venti

Figure 5: Mapping Example 2

If a mapping between the Manufacturer Power Levels and the Power Monitor Power Levels is achievable, both series of levels must exist in the MIB module in the Power Monitor Parent, allowing the NMS to understand the mapping between them by correlating the Power Level with the Manufacturer Power Levels.

Power Level / Name	Manufacturer Power Level / Name
1 / Mech Off	0 / none
2 / Soft Off	0 / none
3 / Hibernate	0 / none
4 / Sleep, Save-to-RAM	0 / none
5 / Standby	0 / none
6 / Ready	1 / short
7 / LowMinus	1 / short
8 / Low	1 / short
9 / MediumMinus	2 / tall
10 / Medium	2 / tall
11 / HighMinus	3 / grande
12 / High	4 / venti

Figure 6: Mapping Example 3

How the Power Monitor Levels are then mapped is an implementation choice. However, it is recommended that the Manufacturer Power Levels map to the lowest applicable Power Levels, so that setting all Power Monitors to a Power Level would be conservative in terms of disabled functionality on the Power Monitor.

A second example would be a device type, such as a dimmer or a motor, with a high number of operational levels. For the sake of the example, 100 operational states are assumed.

Power Level / Name	Manufacturer Power Level / Name
1 / Mech Off	0 / off
2 / Soft Off	0 / off
3 / Hibernate	0 / off
4 / Sleep, Save-to-RAM	0 / off
5 / Standby	1 / off
6 / Ready	2 / off
7 / LowMinus	11 / 1%
7 / LowMinus	12 / 2%
7 / LowMinus	13 / 3%
.	.
.	.
.	.
8 / Low	15 / 15%
8 / Low	16 / 16%
8 / Low	17 / 17%
.	.
.	.
.	.
9 / MediumMinus	30 / 30%
9 / MediumMinus	31 / 31%
9 / MediumMinus	32 / 32%
.	.
.	.
.	.
10 / Medium	45 / 45%
10 / Medium	46 / 46%
10 / Medium	47 / 47%
.	.
.	.
.	.
etc...	.

Figure 7: Mapping Example 4

As specified in section 6, this architecture allows the configuration of the Power Level, while configuring the Manufacturer Power Level from the MIB directly is not possible.

5.6. Power Monitor Usage Measurement

The usage or production or power must be qualified as more than a value alone. A measurement should be qualified with the units, magnitude, direction of power flow, and by what means the measurement was made (ex: Root Mean Square versus Nameplate) .

In addition, the Power Monitor should describe how it intends to measure usage as one of consumer, producer or meter of usage. Given the intent any readings can be correctly summarized or analyzed by an NMS. 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 NMS.

The power usage measurement should conform to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure. The power usage measurement is considered an instantaneous usage value and does not include the usage over time.

Measured values are represented in SI units obtained by $\text{BaseValue} * 10$ raised to the power of the scale. For example, if current power usage of a Power Monitor is 3, it could be 3 W, 3 mW, 3 KW, or 3 MW, depending on the value of the scaling factor

In addition to knowing the usage and magnitude, it is useful to know how a Power Monitor 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 NMS can use this information to account for the accuracy and nature of the reading between different implementations.

In addition to the power usage, the nameplate power rating of a Power Monitor is typically specified by the vendor as the capacity required to power the device. Often this label is a conservative number and is the worst-case power draw. While the actual utilization of an entity can be lower, the nameplate power is important for provisioning, capacity planning and billing.

5.7. Optional Power Usage Quality

Given a power measurement of a Power Monitor, it may in certain circumstances be desirable to know the power quality associated with that measurement. The information model must adhere to the IEC 61850 7-2 standard for describing AC measurements. In some

5.8. Optional Energy Measurement

In addition to reporting the Power Level, an approach to characterizing the energy demand is required. It is well known in commercial electrical utility rates that demand charges can be on par with actual power charges, so it is useful to characterize the demand. The demand can be described as the average energy of an Power Monitor over a time window called a demand interval (typically 15 minutes). The highest peak energy demand measured over a time horizon, such as 1 month or 1 year, is often the basis for usage 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 a Power Monitor, and not when the power measurement is assumed or predicted.

Several efficiency metrics can be derived and tracked with the demand usage data. For example:

- . Per-packet power costs for a networking device (router or switch) can be calculated by an NMS. The packet count can be determined from the traffic usage in the ifTable [RFC2863], from the forwarding plane figure, or from the platform specifications.
- . Watt-hour power can be combined with utility energy sources to estimate carbon footprint and other emission statistics.

5.9. Optional Battery Information

Some Power Monitors may be running on batteries. Therefore information such as the battery status (charging or discharging), remaining capacity, and so on, must be available.

6. Power Monitor Children Discovery

There are multiple ways that the Power Monitor Parent can discover its Power Monitor Children, if they are not present on the same physical network element:

- . In case of PoE, the Power Monitor Parent automatically discovers a Power Monitor Child when the Child requests power.
- . The Power Monitor Parent and Children may run the Link Layer Discovery Protocol [LLDP], or any other discovery protocol, such as Cisco Discovery Protocol (CDP). The Power Monitor Parent might even support the LLDP-MED MIB [LLDP-MED-MIB], which returns extra information on the Power Monitor Children.
- . The Power Monitor Parent may reside on a network connected 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.

When a Power Monitor Child supports only its own Manufacturer Power Levels, the Power Monitor Parent will have to discover those Manufacturer Power Levels. Note that the communication specifications between the Power Monitor Parent and Children is out of the scope of this document. This includes the Manufacturer Power Levels discovery, which is protocol-specific.

7. Configuration

This power management architecture allows the configuration of the following key parameters:

- . Power Monitor name: A unique printable name for the Power Monitor.
- . Power Monitor Role: An administratively assigned name to indicate the purpose a Power Monitor serves in the network.
- . Power Monitor Importance: A ranking of how important the Power Monitor is, on a scale of 1 to 100, compared with other Power Monitors in the same Power Monitor Meter Domain.
- . Power Monitor Keywords: A list of keywords that can be used to group Power Monitors for reporting or searching.
- . Power Monitor Domain: Specifies the name of a Power Monitor Meter Domain for the Power Monitor.
- . The Power Monitor Level: Specifies the current Power Level (0..12) for the Power Monitor.
- . The energy demand parameters: For example, which interval length to report the energy on, the number of intervals to keep, etc.

When a Power Monitor requires a mapping with the Manufacturer Power Level, the Power Monitor configuration is done via the

Power Level settings, and not directly via the Manufacturer Power Levels, which are read-only. Taking into account Figure 8, where the LowMinus Power Level corresponds to three different Manufacturer Power Levels (11 for 1%, 12 for 2%, and 13 for 3%), the implication is that this architecture will not set the Manufacturer Power Level to one percent granularity without communicating over or configuring the proprietary protocol for this Power Monitor.

This architecture uses a Power Level MIB object to set up the Power Level for a specific Power Monitor. However, the Power Monitor might be busy executing an important task that requires the current Power Level for some more time. For example, a PC might have to finish a backup first, or an IP phone might be busy with a current phone call. Therefore a second MIB object contains the actual Power Level. A difference in values between the two objects indicates that the Power Monitor is currently in Power Level transition.

Interactions with established open protocols, such as Wake-up-on-Lan (WoL) and DASH [DASH], may require configuration in the Power Monitor as well, facilitating the communication between Power Monitor Parent and remote Power Monitor Children.

Note that the communication specifications between the Power Monitor Parent and Children is out of the scope of this document. This includes communication of power settings and configuration information, such as the Power Monitor Domain.

8. Fault Management

[POWER-MON-REQ] specifies some requirements about power states such as "the current state - the time of the last change", "the total time spent in each state", "the number of transitions to each state", etc. Such requirements are fulfilled via the pmPowerLevelChange NOTIFICATION-TYPE [POWER-MON-MIB]. This SNMP notification is generated when the value(s) of Power Level has changed for the Power Monitor.

9. IPFIX

A push-based mechanism, such as IPFIX [RFC5101], might be required to export high-volume time series of energy consumption values, as mentioned in [POWER-MON-REQ].

10. Relationship with Other Standards Development Organizations

10.1. Information Modeling

This power management architecture should, as much as possible, reuse existing standards efforts, especially with respect to information modeling and data modeling [RFC3444].

The data model for power, energy related objects is based on IEC 61850.

Specific examples include:

- . The scaling factor, which represents Power Monitor usage magnitude, conforms to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure.
- . The power accuracy model 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 powerQualityMIB MIB module adheres closely to the IEC 61850 7-2 standard for describing AC measurements.

10.2. Power Levels

There are twelve Power Monitor Levels. They are subdivided into six operational states, and six non-operational states. The lowest non-operational state is 1 and the highest is six. Each non-operational state corresponds to an ACPI level [ACPI].

The scope of power and energy monitoring consists of devices that consume power within and that are connected to a communications network. These devices include:

- Network devices and sub-components: Devices such as routers and switches and their sub-components.
- Network attached endpoints: Devices that use the communications network, such as endpoints, PCs, and facility gateways that proxy energy monitor and control for commercial buildings or home automation.
- Network attached meters or supplies: Devices that can monitor the electrical supply, such as smart meters or Universal Power Supplies (UPS) that meter and provide availability.

-
This section provides illustrative examples that model different scenarios for implementation of the Power Monitor, including Power Monitor Parent and Power Monitor Child relationships.

Each of the scenarios below is explained in more detail in the Power Monitor MIB document [POWER-MON-MIB], with a mapping to the MIB Objects.

Scenario 1: Switch with PoE endpoints

Consider a PoE IP phone connected to a switch. The IP phone draws power from the PoE switch.

Scenario 2: Switch with PoE endpoints with further connected device(s)

Consider the same example as in Scenario 1, but with a PC daisy-chained from the IP phone for LAN connectivity. The phone draws power from the PoE port of the switch, while the PC draws power from the wall outlet.

Scenario 3: A switch with Wireless Access Points

Consider a WAP (Wireless Access Point) connected to the PoE port of a switch. There are several PCs connected to the Wireless Access Point over Wireless protocols. All PCs draw power from the wall outlets.

The switch port is the Power Monitor Parent for the Wireless Access Point (WAP) and all the PCs. But there is a distinction among the Power Monitor Children, as the WAP draws power from the PoE port of the switch and the PCs draw power from the wall outlet.

Scenario 4: Network connected facilities gateway

At the top of the network hierarchy of a building network is a gateway device that can perform protocol conversion between many facility management devices, such as BACNET, MODBUS, DALI, LON, etc. There are power meters associated with power-consuming entities (Heating Ventilation & Air Conditioning - HVAC, lighting, electrical, fire control, elevators, etc). The proposed MIB can be implemented on the gateway device. The gateway can be considered as the Power Monitor Parent, while the power meters associated with the energy consuming entities can be considered as its Power Monitor Children.

Scenario 5: Data center network

A typical data center network consists of a hierarchy of switches. At the bottom of the hierarchy there are servers mounted on a rack, and these are connected to the top-of-the-rack switches. The top switches are connected to aggregation switches that are in turn connected to core switches. As an example, Server 1 and Server 2 are connected to different switch ports of the top switch.

The proposed MIB can be implemented on the switches. The switch can be considered as the Power Monitor Parent. The servers can be considered as the Power Monitor Children.

Scenario 6: Building gateway device

Similar scenario as the scenario 4.

Scenario 7: Power consumption of UPS

Data centers and commercial buildings can have Uninterruptible Power Supplies (UPS) connected to the network. The Power Monitor can be used to model a UPS as a Power Monitor Parent with the connected devices as Power Monitor Children.

A PC is a typical example of a battery-based device.

12. Security Considerations

Regarding the data attributes specified here, some or all may be considered sensitive or vulnerable in some network environments. Reading or writing these attributes without proper protection such as encryption or access authorization may have negative effects on the network capabilities.

12.1. Security Considerations for SNMP

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

The support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations. For example:

- . Unauthorized changes to the Power Domain or business context of a Power Monitor may result in misreporting or interruption of power.
- . Unauthorized changes to a power level may disrupt the power settings of the different Power Monitors, and therefore the level of functionality of the respective Power Monitors.
- . 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).

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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.

12.2. Security Considerations for IPFIX

EDITOR'S NOTE: to be completed if IPFIX is discussed in this document

13. IANA Considerations

This document has no actions for IANA.

14. Acknowledgments

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Considerations for Power and Energy Management
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Abstract

With rising cost and an increasing awareness of the environmental impact of energy consumption, a desirable feature of networked devices is to be able to assess their power state and energy consumption at will. With this data available, one can build sophisticated applications such as monitoring applications or even active energy management systems. These systems themselves are out of scope of this memo, as it discusses only considerations for the monitored devices. Implementation specifics such as the definition of a Management Information Base are also outside the scope of this document.

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1. Requirements notation

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].

2. Overview/Goals

This document aims at framing discussions on power and energy management within the IETF and recording their results. It clarifies terminology that is routinely used to have multiple contrary meanings, which results in unnecessary confusion. The document further describes how energy and power reporting differs from other reporting tasks that have been defined by the IETF and the resulting implications for mechanisms the IETF will define. This document is intended to be a living document that also captures why certain decisions were made in the process of defining power and energy management mechanisms.

3. Settled topics

The following are topics that seem settled in eman discussions, recognizing that this draft has no authority on that point.

3.1. Scope of Devices

All energy-using devices that have a network connection are in scope. The eman mechanisms also provide for non-IP devices that are supplied with power or that have power metered by an IP device, or are brought into the eman context by a gateway/proxy.

While first adopters will surely be devices such as switches, routers, and servers (some of which already report power levels and power state through proprietary means), in the future networked electronic devices, appliances, and even lights will also need such capability. These devices may have different ways of accomplishing discovery and management for functional purposes, but will share the common energy and power reporting capability. While some devices will directly measure power, other devices will not be able to measure their power, but may be able to reliably estimate it. These devices are still in scope.

3.2. Identity

Some universal mechanisms for identity are needed so that the NMS knows what the devices are that are using energy. The nature of these mechanisms, whether they are existing ones to be referenced or new ones to be created (almost certainly some of both) has not yet been determined.

3.3. Power Levels

The power level of a device is its current electricity demand. It is an important complement to power mode, providing articulation of power level within the basic mode. It also avoids the need for a large number of named modes. Basic modes are distinguished by important functional differences or power levels. Core power modes are an abstraction from individual implementations.

3.4. Devices

The organizing unit for power is a single device with one or more power sources. The term "product" is sometimes used as a synonym, and also covers the case in which a device proxies network presence including power reporting for a second device.

3.5. Intervals

A common feature of energy monitoring is to track energy use over time. Recording of energy use for intervals of time is the responsibility of a network management system (or whatever entity requests data via the eman protocol), not the monitored device itself. The monitored device always reports accumulated energy use with an associated timestamp.

3.6. Presentation to non-IETF audiences

Many people and organizations who have not in the past understood or interacted with the IETF will be interested in eman results. They need to be provided with easily understandable explanations of what eman does and why. How this presentation will be accomplished is still to be determined.

3.7. Functions vs. Entities

Eman is concerned with exposing information to Network Management Systems (NMSs). Providing information is a function. The various functions may be implemented by a single device, or distributed among several devices.

3.8. Simple and Complex Devices

We will support both. Simple devices want to avoid complexity that burdens both implementation on the monitored device, and the monitoring system. Complex devices need to have access to additional data fields and capabilities.

4. Topics under discussion

4.1. Power States

We synonymously use the terms Power Mode and Power State; named modes are general categories only ("buckets"), not individual states with highly-specific meaning.

Discussions about energy consumptions and device power states are often confusing as different products define states such as "standby" quite differently. Even the same class of devices often implement named states differently. Named power states are intrinsically difficult to define consistently as they imply not only something about a device's energy consumption but also something about the device's capabilities in that state, and are implementation-dependent. All of this makes highly-specific named modes unsuitable for use in a general context. The term with by far the most different definitions is "standby" and so we therefore do not refer to standby in this document and believe it unsuitable for use in eman.

We believe that the three named power state categories, on, off and sleep, are broadly understood. These mode categories may each contain a large set of power sub-states. A fourth basic power state of 'ready' may be more appropriate for some devices, particularly appliances.

In general, devices that are asleep will be able to wake quickly and will retain network connectivity. Devices that are off usually take much more time to turn on than the wake time and usually lack network connectivity. Devices that are on are fully functional but potentially with reduced performance.

A critical feature of the set of basic power states is that they should be universally applicable to any device eman is applied to. This does not mean that each device has every state, but that the model is sufficiently general that it can be applied to all. When the level of detail rises, the set of states usually is then applicable to only certain types of products, and/or to specific implementations. In addition, these detailed states generally embody specific functional characteristics of the state, and so are better embodied in other variables (that may be delivered by an energy management protocol).

5. Energy Manangement

First and foremost, the task of power and energy management is reporting. While a more active role in energy management is conceivable by e.g. putting devices into power states based on policies or other predefined schemes at a network management system (NMS).

5.1. Control

There should not be an assumption that power state management of devices is done externally/centrally. Ideally most devices will manage their own power state, implementing distributed intelligence. The control function is accomplished separately from power reporting. A core mechanism many devices will use to manage power consumption is a price (and price forecast) for electricity.

5.2. Identity

All devices on a network need to expose identity to others. While some protocols accomplish this for particular applications or contexts, it is desirable to have a simple universal mechanism. This is particularly true for devices that may have a fairly limited degree of participation in the network, such as appliances.

For energy management purposes, the it is important to know "what" a device is, and "who" it is. Each of these has two parts as follows:

- o "Species". This is the fundamental classification that a device is a member of due to its design and capabilities. This property is determined by the manufacturer before it is sold. Examples are server, router, notebook PC, display, TV, refrigerator, light, etc.
- o "Origin". The brand and model of the device. Primarily a method to find out more information about a device, such as its specifications for requirements and capabilities. It would be advantageous to include a URL for detailed information from the manufacturer. An example of this is the "Universal Product Code" on many products.
- o Name: A human-readable name, locally specified when the device is configured or installed.
- o Network ID: A globally unique identifier for the NMS to use to recognize a device. This should be based on one or more existing IETF mechanisms.

An energy management application could then obtain current energy use for a device like a refrigerator, and compare it to what it is expected to use under normal operation, and alert the building manager if it is significantly out of range. This also can be used to quickly inventory energy-using products in a building, and to summarize by product type where energy is being used.

5.3. NMS Considerations

A Network Management System is an entity which collects energy and power reporting data and uses it for advanced applications. One such application correlates energy consumption with other metrics to display efficiency metrics (like watthours/bit). An NMS can also set device policies to control larger networked systems such as a data center.

An NMS will query energy MIB data on a periodic basis, with that period dictated by its needs, possibly being dynamic. MIBs should provide an energy "meter reading" to allow computing of energy use for any period. Thus, the NMS does most of the work to generate time series energy data, and this minimizes burden on the host and the complexity of the Power MIB.

The core function of power monitoring is to maintain meters of energy use and of time in different power states (and through summing, total energy and time). The second is to be able to report current power consumption and power state.

5.4. MIB Considerations

The MIB should be generic as there are a large number of devices yet to come and power states are and will become more diverse.

The MIB should be structured so that the smallest possible set of values/information is applicable to a large range of devices, can be implemented efficiently and is extensible to accommodate additional information objects. As an example, many devices will not be battery powered but it should be easy to add battery monitoring to the basic set of energy-related information.

The proposed MIB structures enable reporting on components of products (e.g. linecards in a chassis) in addition to entire products. Doing this is not part of the eman charter, so while there is no reason to preclude the capability, it should not be a distraction to completing the chartered eman scope.

5.5. Power Considerations

Reporting should cover both AC and DC power sources. However, other types should be provided for, and the type of energy is one of the reported values. Standard low-voltage DC (e.g. USB, Power over Ethernet, eMerge) is immediately useful. A core set of values should be available from any device that implements the Power MIB at all so that an NMS can quickly obtain and aggregate uniform data for all devices.

There is a fundamental distinction between supplied power from a device And input power to a device, notably losses that occur in transmission, as well as other (possibly unknown) devices that are also using the power. The effect of internal batteries is not revealed by the MIB, as it only reports on net power into or out of a device.

5.6. Incomplete data

Energy reporting will cover a wide variety of information about a device, its status, and energy usage. Sometimes, particularly for legacy or non-IP products, this will be incomplete. It is critical that the fact that some data are missing does not undermine the ability to report the data that are present.

5.7. Time reporting

At the core of energy reporting is data from energy meters that are meter readings associated with timestamps. A variety of issues arise on the meaning of that time.

Without strong synchronization, the NMS and the devices it queries will have different absolute times. However, the NMS knows when it asked for each meter reading so can account for this difference.

For some devices, when they are off they will be unable to accumulate their energy consumption. The fact that some consumption may be missing needs to be communicated to the NMS. One possibility is to record the last time that a period of missing energy occurred, and report that to the NMS.

5.8. Portable devices

Devices that are routinely moved from one building to another (or even within a building) pose special challenges for energy reporting. The question arises whether it is the energy into the device, or from the building, which is dominant. It may be important to record the time a device most recently changed power domain to ensure that a NMS

can correctly account only for energy consumed on its premises.

5.9. Beyond energy

The charter references "energy" but virtually all discussion has been limited to electricity. Other forms of energy should be included at some point; we should discuss whether this is readily feasible now, or needs to be postponed to future work.

5.10. Power State Monitoring

For the device power state, the following information is considered to be relevant:

- o the current state
- o the time of (or time since) the last change
- o the current real power (energy consumption rate)
- o accumulated energy consumption

5.11. Power Distribution

Wired networks enable power distribution that is co-incident with network Communication. However, many devices will not communicate on the same Medium that they are powered on, or may lack connectivity entirely (though with the power provider knowing of their identity). Devices can report power for another device only if they are the entity providing the power.

6. Use Context and Use Cases

The following are some use contexts that this facility is intended for. These are not necessarily mutually exclusive, and a device can report the same data regardless of the context.

- o A data center, with a NMS which is integrated with application functionality, and also manages energy use.
- o A commercial building, in which the energy reporting is separate from any management of devices, and more as background to help understand building operation (including occupancy) and identify inefficiencies or equipment failures.
- o A house, which shares some of the commercial building characteristics, but with different management approach and security concerns.
- o A vehicle, which uses the reporting only for automatic management, not for reporting to the user.

Use cases include a facility manager or an NMS in an automated fashion:

- o Understand costs for billing purposes.
- o Assess savings potentials.
- o Identify possible device malfunctions.
- o Reveal unexpected usage patterns.
- o Plan for future capacity needs.
- o Understand heat production in a building or space.
- o A NMS which deals with draws on current power use to deal with an actual or potential shortfall in power supply.

7. Future Directions

The current effort to create a protocol for energy management is unlikely to be the last word on the topic. In fact, there are many directions that need to be explored for potential addition to the features enabled by this mechanism or others. These include:

- o other energy media such as wireless power, non-electric energy (e.g. natural gas, steam, hot/cold water).
- o more features for control.
- o other energy-relevant quantities (e.g. temperatures, flow rates).
- o other resources (e.g. water).

8. Security Considerations

None.

9. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

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October 16, 2010

Energy-aware Networks and Devices MIB
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Status of this Memo

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

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<Parello, Claise>

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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", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

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- . The roles/capabilities that the Power Monitor Parent have with Power Monitor Child(ren) are described in [POWER-MON-ARCH]:

1. Monitoring (only reporting)
2. Configuration power state
3. Configuration: power

Example: on a PC, we can set power level without knowing the power. A solution must be specified in this draft. We have to find a way to model this role in this MIB module. Bitmap is just one example.

1. Introduction

This document defines a subset of the Management Information Base (MIB) for use with network management protocols for power and energy monitoring of network devices and devices attached to the network, as specified in the Power Management Architecture [POWER-MON-ARCH], which in turn, is based on the Power Monitoring Requirements [POWER-MON-REQ] .

This module's special focus is on monitoring energy-aware networks and devices. The module addresses device identification, context information, and potential relationships between reporting devices, remote devices, and monitoring probes.

Devices and their sub-components may be characterized by the power-related attributes of a physical entity present in the ENTITY MIB, even though 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

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(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. Use Cases

Requirements for power and energy monitoring for networking devices are specified in [POWER-MON-REQ]. The requirements in [POWER-MON-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 [POWER-MON-REQ].

4. Terminology

The definitions of basic terms like Power Monitor, Power Monitor Parent, Power Monitor Child, Power Monitor Meter Domain, Power Level, and Manufacturer Power Level can be found in the Power Management Architecture [POWER-MON-ARCH].

5. Architecture Concepts Applied to the MIB Module

This section describes the basic concepts specified in the Power Monitor Architecture [POWER-MON-ARCH], 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 [POWER-MON-ARCH].

5.1 Power Monitor Information

Refer to the "Power Monitor Information" section in [POWER-MON-ARCH] for background information. An energy aware device is considered an instance of a power monitor as defined in the [POWER-MON-ARCH].

The Power Monitor information is specified in the MIB module primary table, i.e. the pmTable. Every Power Monitor SHOULD

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have a printable name pmName, and MUST HAVE a unique Power
Monitor index pmIndex.

The pmIndex is a unique index greater than zero for each Power Monitor. It is recommended that values be assigned sequentially starting from 1. The value for each pmIndex must remain constant at least from one re-initialization of the entity's network management system to the next re-initialization. In addition, the Power Monitor can potentially have an entityPhysicalIndex from the ENTITY MIB [RFC4133] in the pmPhysicalEntity, if supported by the Power Monitor. In case of Power over Ethernet (if the Power over Ethernet MIB is supported on the Power Monitor), the Power Monitor pmethPortIndex and pmethPortGrpIndex must contain the values of pethPsePortIndex and pethPsePortGroupIndex, respectively. In case of LLDP-MED (if the LLDP-MED MIB is supported on the Power Monitor), the Power Monitor pmLldpPortNumber must contain the lldpLocPortNum from the LLDP MIB.

Possible pmName conventions are: textual DNS name, MAC-address of the device, interface ifName, or a text string uniquely identifying the Power Monitor. However, if entPhysicalName is present for the respective pmPhysicalEntity (i.e. if the ENTITY-MIB is supported), then the pmName SHOULD be identical to the entPhysicalName. The pmName SHOULD be unique. As an example, in the case of IP phones, pmName can be the device DNS name, while in the case of router/switch line cards, the pmName should contain the entPhysicalName.

To distinguish if a Power Monitor is considered producing, consuming or metering power, the pmPowerCategory MIB object must be implemented.

5.2 Power Monitor Meter Domain

Refer to the "Power Monitor Meter Domain" section in [POWER-MON-ARCH] for background information.

Each Power Monitor MUST be a member of a Power Monitor Meter Domain, specified by the pmDomainName MIB Object. The pmDomainName, which is part of the pmTable, is a read-write MIB object.

5.3 Power Monitor Parent and Child

Refer to the "Power Monitor Parent and Child" section in [POWER-MON-ARCH] for background information. In order to link the Power Monitor Child and the Power Monitor Parent, the pmParentId is introduced.

5.4 Power Monitor Context

Refer to the "Power Monitor Context" section in [POWER-MON-ARCH] for background information.

A Power Monitor can provide a pmImportance value in the range of 1..100 to help differentiate the 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.

A Power Monitor can provide a set of pmKeywords. These keywords are a list of tags that can be used for grouping and summary reporting within or between Power Monitor Meter Domains.

Additionally, a Power Monitor can provide a pmRoleDescription string that indicates the purpose the Power Monitor serves in the network or for the site/business.

6. Structure of the MIB

The primary MIB object in this MIB module is the EnergyAwareDeviceMIBObject. The pmTable table of EnergyAwareDeviceMIBObject describes an entity in the network that is a Power Monitor according the [POWER-MON-ARCH].

A Power Monitor that implements the EnergyAwareDeviceMIB contains information describing itself as an entity in the context of the network (such as its Power Monitor Meter Domain pmDomainName) and attributes for describing its business context (such as pmImportance, pmRoleDescription and pmKeywords).

The information in this MIB describes the device itself so that the device is aware of its context in a communication network with respect to power. The actual power usage, which is described in [POWER-MON-ARCH], is specified in [POWER-MON-MIB].

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

ENERGY-AWARE-MIB DEFINITIONS ::= BEGIN

IMPORTS

```
    MODULE-IDENTITY,
    OBJECT-TYPE,
    mib-2,
    Integer32
        FROM SNMPv2-SMI
    TEXTUAL-CONVENTION
        FROM SNMPv2-TC
    MODULE-COMPLIANCE,
    OBJECT-GROUP
        FROM SNMPv2-CONF
    SnmpAdminString
        FROM SNMP-FRAMEWORK-MIB
    PhysicalIndexOrZero
        FROM ENTITY-MIB;
```

```
energyAwareMIB MODULE-IDENTITY
    LAST-UPDATED      "201010150000Z"
    ORGANIZATION      "Cisco Systems, Inc."
    CONTACT-INFO
        "Cisco Systems
        Customer Service

        Postal: 170 W Tasman Drive
        San Jose, CA  95134
        USA

        Tel: +1 800 553-NETS

        E-mail: cs-snmp@cisco.com"
```

DESCRIPTION

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

REVISION

"201010150000Z"

DESCRIPTION

"Initial version, published as RFC XXXX."

::= { mib-2 xxxxx }

energyAwareMIBNotifs OBJECT IDENTIFIER

::= { energyAwareMIB 0 }

energyAwareMIBObjects OBJECT IDENTIFIER

::= { energyAwareMIB 1 }

energyAwareMIBConform OBJECT IDENTIFIER

::= { energyAwareMIB 2 }

-- Textual Conventions

PowerMonitorId ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"This object indicates the Power Monitor Universally Unique Identifier."

REFERENCE

"IETF RFC 4122"

SYNTAX OCTET STRING (SIZE (16))

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, 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 this extension are situations where none or all physical entities need to be referenced."

SYNTAX Integer32(0..4096)

PowerMonitorKeywordList ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"A list of keywords that can be used to group Power Monitors for reporting or searching. If multiple keywords are present, then this string will contain all the keywords separated by the ',' character. For example, if a Power Monitor were to be tagged with the keyword values

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 'hospitality' and 'guest', then the keyword list will be
 'hospitality,guest'."
 SYNTAX OCTET STRING (SIZE (0..255))

-- Objects

pmTable OBJECT-TYPE
 SYNTAX SEQUENCE OF PmEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "This table lists Power Monitors."
 ::= { energyAwareMIBObjects 1 }

pmEntry OBJECT-TYPE
 SYNTAX PmEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "An entry describes the attributes of a Power Monitor.
 Whenever a new Power Monitor is added or deleted a row in
 the pmTable is added or deleted."
 INDEX { pmIndex }
 ::= { pmTable 1 }

PmEntry ::= SEQUENCE {
 pmIndex Integer32,
 pmPowerMonitorId PowerMonitorId,
 pmPhysicalEntity PhysicalIndexOrZero,
 pmEthPortIndex PethPsePortIndexOrZero,
 pmEthPortGrpIndex PethPsePortGroupIndexOrZero,
 pmLldpPortNumber LldpPortNumberOrZero,
 pmName SnmpAdminString,
 pmDomainName SnmpAdminString,
 pmRoleDescription SnmpAdminString,
 pmKeywords PowerMonitorKeywordList,
 pmImportance Integer32,
 pmPowerCategory INTEGER,
 pmParentId PowerMonitorId
 }

pmIndex OBJECT-TYPE
 SYNTAX Integer32 (1..2147483647)

MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
"A unique value, greater than zero, for each Power Monitor. It is recommended that values be assigned sequentially starting from 1. The value for each pmIndex must remain constant at least from one re-initialization of the entity's network management system to the next re-initialization."
 ::= { pmEntry 1 }

pmPowerMonitorId OBJECT-TYPE
SYNTAX PowerMonitorId
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object indicates the Power Monitor UUID identifier."
 ::= { pmEntry 2 }

pmPhysicalEntity OBJECT-TYPE
SYNTAX PhysicalIndexOrZero
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object contains the index of a physical entity in the ENTITY MIB. This physical entity is the given observation point. If such a physical entity cannot be specified or is not known then the object is zero."
 ::= { pmEntry 3 }

pmEthPortIndex 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]. If such a power Ethernet port cannot be specified or is not known then the object is zero."
 ::= { pmEntry 4 }

pmEthPortGrpIndex 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]. If such a group cannot be specified or is not known then the object is zero."
 ::= { pmEntry 5 }

pmLldpPortNumber 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]. If such a port number cannot be specified or is not known then the object is zero."
 ::= { pmEntry 6 }

pmName OBJECT-TYPE
SYNTAX SnmpAdminString
MAX-ACCESS read-write
STATUS current
DESCRIPTION
"This object specifies a printable name, a text string, for the Power Monitor. The pmName SHOULD be unique. If pmPhysicalName is present for the respective pmPhysicalEntity (i.e. if the ENTITY-MIB is supported), then the pmName SHOULD be identical to the pmPhysicalName. If pmPhysicalName is not present, the process to assign the pmName can be implementation specific. Example: DNS Name, MAC address in canonical form, ifName, etc.
However, if pmPhysicalName is present for the respective pmPhysicalEntity (i.e. if the ENTITY-MIB is supported), then the pmName should be identical to the pmPhysicalName."
 ::= { pmEntry 7 }

pmDomainName OBJECT-TYPE
SYNTAX SnmpAdminString
MAX-ACCESS read-write
STATUS current
DESCRIPTION
"This object specifies the name of a Power Monitor Meter Domain for the Power Monitor. This object specifies a null string if no Power Monitor Domain name is configured. The value of pmDomainName must remain constant at least from one re-initialization of the

entity's network management system to the next re-initialization."
 ::= { pmEntry 8 }

pmRoleDescription OBJECT-TYPE

SYNTAX SnmpAdminString
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"This object specifies an administratively assigned name to indicate the purpose a Power Monitor serves in the network.

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

This object specifies a null string if no role description is configured."

::= { pmEntry 9 }

pmKeywords OBJECT-TYPE

SYNTAX PowerMonitorKeywordList
MAX-ACCESS read-write
STATUS current
DESCRIPTION

"This object specifies a list of keywords that can be used to group Power Monitors for reporting or searching. This object specifies the null string if no keywords have been configured. If multiple keywords are present, then this string will contain all the keywords separated by the ',' character. For example, if a Power Monitor 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 pmKeywords 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."

::= { pmEntry 10 }

pmImportance OBJECT-TYPE

SYNTAX Integer32 (1..100)
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object specifies a ranking of how important the Power Monitor is (on a scale of 1 to 100) compared with other Power Monitors in the same Power Monitor Meter Domain. The ranking should provide a business or operational context for the Power Monitor as compared to other similar Power Monitors. 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"

DEFVAL { 1 }
::= { pmEntry 11 }

pmPowerCategory OBJECT-TYPE

SYNTAX INTEGER {
consumer(0),
provider(1),
meter(2)
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object describes the Power Monitor and indicates the expected power usage of the Power Monitor. A Power Monitor could be designed or manufactured to be a provider(1), consumer(0) or meter(2) of power.

The actual power direction is indicated by the sign of pmPower, with positive representing consumption and negative representing production, and may or may not match the expected value of pmPowerCategory. In these cases the two objects can be used to detect unexpected conditions of the Power Monitor.

For example a generator with a category of provider(1) that is malfunctioning and is consuming power as indicated by a positive pmPower value."

::= { pmEntry 12 }

```
pmParentId OBJECT-TYPE
    SYNTAX      PowerMonitorId
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "If the current Power Monitor has a Power Monitor Parent,
         then its Power Monitor Id value is set in pmParentId.
         Otherwise, the pmParentId value is the null string."
    ::= { pmEntry 13 }
```

-- Conformance

```
energyAwareMIBCompliances OBJECT IDENTIFIER
    ::= { energyAwareMIBObjects 3 }
```

```
energyAwareMIBGroups OBJECT IDENTIFIER
    ::= { energyAwareMIBObjects 4 }
```

```
energyAwareMIBFullCompliance 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       -- this module
    MANDATORY-GROUPS {
        energyAwareMIBTableGroup
    }

    ::= { energyAwareMIBCompliances 1 }
```

```
energyAwareMIBReadOnlyCompliance 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 can not be configured
         with this MIB."
    MODULE       -- this module
    MANDATORY-GROUPS {
        energyAwareMIBTableGroup
    }
```

```

OBJECT      pmName
MIN-ACCESS  read-only
DESCRIPTION
    "Write access is not required."

```

```

OBJECT      pmDomainName
MIN-ACCESS  read-only
DESCRIPTION
    "Write access is not required."

```

```

OBJECT      pmRoleDescription
MIN-ACCESS  read-only
DESCRIPTION
    "Write access is not required."

```

```

OBJECT      pmKeywords
MIN-ACCESS  read-only
DESCRIPTION
    "Write access is not required."

```

```

OBJECT      pmImportance
MIN-ACCESS  read-only
DESCRIPTION
    "Write access is not required."

```

```
 ::= { energyAwareMIBCompliances 2 }
```

```
-- Units of Conformance
```

```

energyAwareMIBTableGroup OBJECT-GROUP
    OBJECTS      {
        -- Note that object pmIndex is NOT
        -- included since it is not-accessible
        pmPowerMonitorId,
        pmPhysicalEntity,
        pmEthPortIndex,
        pmEthPortGrpIndex,
        pmLldpPortNumber,
        pmName,
        pmDomainName,
        pmRoleDescription,
        pmKeywords,
        pmImportance,
        pmPowerCategory,
        pmParentId
    }
    STATUS        current
DESCRIPTION

```

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"This group contains the collection of all the objects
related to the PowerMonitor."
::= { energyAwareMIBGroups 1 }

END

8. 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 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 pmDomainName, pmName, pmRoleDescription, pmKeywords, and/or pmImportance 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

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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

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.

10. References

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September 2010.

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October 25, 2010

Definition of Managed Objects for Energy Management
draft-quittek-power-mib-02.txt

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 providing information about the energy consumption, the power states, and the battery status of managed devices and their components.

Status of this Memo

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

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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 MIB modules 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. Introduction

Energy management in communication networks is a topic that has been neglected for many years when energy was cheap and global warming not recognized. This has changed recently. Energy management is becoming a significant component of network planning, operations and management and new energy management strategies are currently being explored.

An essential requirement for energy management is collecting information on energy consumption and energy storage at managed devices.

An elementary step into this direction is monitoring power states. A power state defines a limitations of services provided by a device and implicitly limits energy consumption. Examples for commonly implemented power states include 'on', 'full power', 'low power', 'sleep', 'stand-by', and 'off'. There is no commonly agreed convention for power states naming and semantics. Therefore power states with the same names may have different semantics and different names may be in use for the same power state.

But the actual energy consumption of a device depends on more than just its power state. Also the current load, the kind of load, and many other factors influence energy consumption. If instrumentation is available, it is very helpful to receive information on the actual energy consumption of a device and its component. Providing this information requires much more effort than reporting power states, because a probe that measures (electrical) power is required. Typically this means not just adding several lines of software to a device, but also adding costly sensor hardware to it.

A third aspect to be considered for energy management is energy storage in batteries. It is helpful, for example, to monitor which device is running on batteries and which is charging its battery. Fortunately, the problem of instrumentation is often an easy one for devices with rechargeable batteries. Controlling the charging cycles needs instrumentation anyway and this instrumentation can also be used for providing battery status information.

This document defines a portion of the Management Information Base (MIB) that serves the three purposes sketched above:

- o monitoring power states of managed entities,
- o monitoring energy consumption of managed entities,
- o monitoring the status of batteries contained in or controlled by managed devices.

Supporting all three monitoring task will not make sense for every device. Many networked devices do not have batteries to be monitored and thus it would not make sense for them to implement managed objects for this purpose.

As mentioned above, instrumentation for measuring actual energy consumption is relatively expensive and it will not make sense for every managed device to provide sufficient instrumentation. In such a case it would not be appropriate to still implement managed objects for energy consumption monitoring.

This leads to the conclusion that the portions of the MIB for the three monitoring tasks listed above should be rather independent of each other and not combined in a single one. This document contains three MIB modules called Power State MIB, Energy MIB, and Battery MIB. The Energy MIB module uses an object defined in the Power State MIB module, but beyond that there is no dependency between the three modules. Obviously, any combination of the three modules is possible.

The definitions in this document are based on the requirements outlined in [I-D.quittek-power-monitoring-requirements].

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].

3. Identifying Monitored Devices and Components

As argued in [I-D.quittek-power-monitoring-requirements] it is often required or at least desirable to not just monitor energy consumption and power state of an entire devices, but also of its contained

individual components. Furthermore it is argued in [I-D.quittek-power-monitoring-requirements] that there are cases where it is required that a managed device reports about energy consumption of one or more other, potentially remote devices. An example is a power strip reporting actual power and accumulated energy consumption of devices plugged into it.

It is not the purpose of MIB modules in this document to solve the problem of identifying components of the managed device that implements these modules or of components remote to this managed device. The task of identifying the entity that is subject of monitoring is left to other MIB modules, such as the ENERGY AWARE MIB module [I-D.pareello-eman-energy-aware-mib], and the Entity MIB module [RFC4133].

As an open and flexible way of identifying the monitored entity, the MIB modules in this document use an OID as index that points into a MIB module used for identifying the monitored entity. For simplifying the trivial case that the monitored entity is identical with the device that implements the MIB module, an empty OID may be used.

4. Power State MIB

A number of devices today can operate in a number of different power states by reducing performance or going into standby mode or sleep mode. The Power State MIB module can be used for monitoring these states. Typically, not much instrumentation is needed for supporting the power state MIB module, because most devices with different power states are already equipped with means for controlling their these.

The Power State MIB module is structured into two tables, the powerCurrentStateTable reporting the current power state per entity and the powerStateTable providing statistics per power state. In addition, the Power State MIB module defines a notification that can be sent for informing the receiver about a change of an entity's current power state. For identifying the entity for which power state information is provided, OIDs are used, as explained in the previous section. Both tables use such an OID as their first index.

4.1. Current Power State Table

For basic monitoring of the actual power state of an entity, there is already a MIB module available: the Entity State MIB [RFC4268]. It reports the power state of an entity in object entStateStandby. It can have four different values: unknown(0), off(1), nonOperational(2), operational(3), see ENTITY-STATE-TC-MIB in

[RFC4268].

If this was considered to be sufficient, there would be no need for replicating this object in the power state MIB module. However, there is a concern that the three "known" states are too few for reflecting the variety of power saving states available today. For PCs, for example, there are several more states defined for the Advanced Configuration & Power Interface (ACPI). It might be useful to support several or all of these power states as suggested by [I-D.claise-energy-monitoring-mib].

The powerCurrentStateTable contains just a two objects per row:

```
powerStateTable(1)
+--powerStateEntry(1) [powerStateEnergyConsumerId]
  +-- --- Integer32      powerStateEnergyConsumerId(1)
  +-- --- ObjectIdentifier powerStateEnergyConsumerOid(2)
  +-- r-n SnmpAdminString powerStateOperationalState(3)
  +-- rwn SnmpAdminString powerStateAdminState(4)
```

Object powerStateOperationalState reports the actual power state of an entity at the time the object's value is retrieved. Object powerStateAdminState indicates a desired power state that the entity has been requested to enter, for example, by a network management system.

4.2. Power State Table

The second table called powerStateTable provides more detailed statistics for each power state. For this purpose it uses the power state name as another index object next to the entity index. This way, statistics can be reported per entity and per power state. The second index has the syntax of a SnmpAdminString and can be defined by the manufacturer of the device or MIB. In this way the index can fit many devices because the characteristics of the power state can be defined per device. The characteristics of the power state SHOULD be described as closely as possible in the object powerStateDescription.

```
powerStateAllStatesTable(2)
+--powerStateAllStatesEntry(1)
  [powerStateEnergyConsumerId,powerStateName]
  +-- --- SnmpAdminString powerStateName(1)
  +-- r-n Enumeration      powerStateType(2)
  +-- r-n SnmpAdminString powerStateDescription(3)
  +-- r-n Integer32        powerStateAveragePower(4)
  +-- r-n Integer32        powerStateMaximumPower(5)
  +-- r-n TimeTicks        powerStateTotalTime(6)
  +-- r-n TimeStamp        powerStateLastEnterTime(7)
  +-- r-n SnmpAdminString powerStateLastEnterReason(8)
  +-- r-n Counter64        powerStateEnterCount(9)
```

The offered statistics include the total time that the entity spent in a certain power state (`powerStateTotalTime`), the last time at which the entity entered a power state (`powerStateLastEnterTime`), the reason for entering it at the last time (`powerStateLastEnterReason`), the number of times a certain state has been entered (`powerStateEnterCount`), the average power consumed by the entity (`powerStateAveragePower`) and the maximum power consumed by the entity (`powerStateMaximumPower`).

5. Energy MIB

Devices that have instrumentation for measuring electrical energy consumption of entities can implement the Energy MIB module. Entities for which energy consumption is reported can be the entire devices, a component thereof or even an external entity for which the reporting devices observes the energy consumption.

The Energy MIB module defines two tables, the `energyTable` and the `energyPerStateTable`. The first one provides information on the instrumentations and on measured energy consumption of the entity. The second one provides energy consumption information for each individual power state.

5.1. Energy Consumption Table

The first set of managed objects in the `energyTable` are needed to help interpreting the energy consumption readings. These include the power supply type and voltage.


```

energyTable(1)
+--energyEntry(1) [energyConsumerId]
+-- --- Integer32          energyConsumerId(1)
+-- --- ObjectIdentifier   energyConsumerOid(2)
+-- r-n EntitySensorStatus energySensorOperStatus(3)
+-- r-n Unsigned32         energyNominalSupplyVoltage(4)
+-- r-n Enumeration        energyElectricSupplyType(5)
+-- r-n Unsigned32         energyTotalEnergy(6)
+-- r-n UnitMultiplier     energyEnergyUnitMultiplier(7)
+-- r-n Integer32          energyEnergyPrecision(8)
+-- r-n Enumeration        energyMeasurementMethod(9)
+-- r-n TimeStamp          energyDiscontinuityTime(10)
+-- r-n Unsigned32         energySampleInterval(11)
+-- r-n Unsigned32         energyMaxHistory(12)
+-- r-n UnitMultiplier     energyPowerUnitMultiplier(13)
+-- r-n Integer32          energyPowerPrecision(14)
+-- r-n Unsigned32         energyRealPower(15)
+-- r-n Unsigned32         energyPeakRealPower(16)
+-- r-n Unsigned32         energyReactivePower(17)
+-- r-n Unsigned32         energyApparentPower(18)
+-- r-n Integer32          energyPhaseAngle(19)
+-- r-n Integer32          energyPhaseAnglePrecision(20)

```

The main measured values provided by the table are the total energy consumed by the device and the current power (energy consumption rate). For entities supplied with alternating current (AC) there are also objects defined for reporting apparent power, reactive power and phase angle.

Provided energy and power values need to be multiplied by a unit multiplier given by a corresponding unit multiplier object in order to determine a measured value.

Measurements of the total energy consumed by an entity may suffer from interruptions in the continuous measurement of the current energy consumption. In order to indicate such interruptions, object `energyDiscontinuityTime` is provided for indicating the time of the last interruption of total energy measurement.

Time series of energy consumption values for past points in time are stored in the `energyHistoryTable`. Objects `energySampleInterval` and `energyMaxHistory` control the generation of entries in this table, see below.

5.2. Energy Consumption Per Power State Table

The second table in this module is called `energyPerStateTable` and it provides values of total energy consumption per power state in a way

similar to the powerStateTable in the Power State MIB module.

```
energyPerStateTable(2)
+--energyPerStateEntry(1) [energyConsumerId,powerStateName]
+-- r-n Unsigned32 energyPerStateTotalEnergy(1)
```

5.3. Power History Table

The third table in this module is the energyHistoryTable. It stores total energy consumption values for past points in time.

```
energyHistoryTable(3)
+--energyHistoryEntry(1) [energyConsumerId,energyHistoryIndex]
+-- --- Unsigned32 energyHistoryIndex(1)
+-- r-n TimeStamp energyHistoryTimestamp(2)
+-- r-n Unsigned32 energyHistoryTotalEnergy(3)
```

Creation of entries in this table is controlled by the values of corresponding objects energySampleInterval and energyMaxHistory in the energyTable.

Entries are indexed by the the entity (energyConsumerId) and by energyHistoryIndex. The first entry created for a certain entity in the table always has an energyHistoryIndex with a value of 1. Further entries for the same entity get increasing consecutive indices until the maximum index value given by object energyMaxHistory is reached. Then, no further indices will be used, but the entry with the oldest timestamp will be overwritten each time a new entry needs to be created.

A new entry is created with a time difference given by object energySampleInterval after creation of the previous entry. Hence, the difference between timestamps energyHistoryTimestamp of two consecutive entries SHOULD be equal to the value of object energySampleInterval.

6. Battery MIB

Editor's note: The Battery MIB module still uses the entPhysicalIndex from the ENTITY MIB. This will be changed in the next revision.

The third MIB module defined in this document defines objects for reporting information about batteries. The batteryTable contained in the Batter MIB module is again a sparse augment of the Entity MIB module [RFC4133]. It uses one row per battery and require that every battery for which information is provided has its own entry in the entPhysicalTable of the Entity MIB module.

The kind of entity in the entPhysicalTable 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 describes the battery in more detail than the generic objects in the entPhysicalTable. The second group of objects report 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) [entPhysicalIndex]
  +-- r-n Enumeration batteryType(1)
  +-- r-n Enumeration batteryTechnology(2)
  +-- r-n Unsigned32 batteryNominalVoltage(3)
  +-- r-n Unsigned32 batteryNumberOfCells(4)
  +-- r-n Unsigned32 batteryNominalCapacity(5)
  +-- r-n Unsigned32 batteryRemainingCapacity(6)
  +-- r-n Counter32 batteryChargingCycleCount(7)
  +-- r-n DateAndTime batteryLastChargingCycleTime(8)
  +-- r-n Enumeration batteryState(9)
  +-- r-n Unsigned32 batteryCurrentCharge(10)
  +-- r-n Unsigned32 batteryCurrentChargePercentage(11)
  +-- r-n Unsigned32 batteryCurrentVoltage(12)
  +-- r-n Integer32 batteryCurrentCurrent(13)
  +-- r-n Unsigned32 batteryLowAlarmPercentage(14)
  +-- r-n Unsigned32 batteryLowAlarmVoltage(15)
  +-- r-n Unsigned32 batteryReplacementAlarmCapacity(16)
  +-- r-n Unsigned32 batteryReplacementAlarmCycles(17)
```

The third group of objects in this table 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 two notifications, one indicating a low battery charging state and one indicating an aged battery that may need to be replaced.

7. Relationship to Other MIB Modules

The three MIB modules described above relate to a number of existing standard MIB modules and complements them where necessary.

This section needs to be revised.

8. Definitions

8.1. Power State MIB

```
POWER-STATE-MIB DEFINITIONS ::= BEGIN
```

```
IMPORTS
```

```
    MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,  
    mib-2, Integer32, Counter64, TimeTicks  
        FROM SNMPv2-SMI -- RFC2578  
    TimeStamp  
        FROM SNMPv2-TC -- RFC2579  
    MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP  
        FROM SNMPv2-CONF -- RFC2580  
    SnmpAdminString  
        FROM SNMP-FRAMEWORK-MIB; -- RFC3411
```

```
powerStateMIB MODULE-IDENTITY
```

```
    LAST-UPDATED "201010231200Z" -- 23 October 2010  
    ORGANIZATION "IETF OPSAWG Working Group"  
    CONTACT-INFO  
        "General Discussion: opsawg@ietf.org  
        To Subscribe: https://www.ietf.org/mailman/listinfo/opsawg  
        Archive: http://www.ietf.org/mail-archive/web/opsawg
```

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```

```
DESCRIPTION
```

```
    "This MIB module defines a set of objects for monitoring  
    the power state of managed entitites."
```

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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 "201010231200Z" -- 23 October 2010
DESCRIPTION

"Initial version, published as RFC yyyy."

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

::= { mib-2 9991 }

-- xxx to be assigned by IANA.

-- *****
-- Top Level Structure of the MIB module
-- *****

powerStateNotifications OBJECT IDENTIFIER ::= { powerStateMIB 0 }
powerStateObjects OBJECT IDENTIFIER ::= { powerStateMIB 1 }
powerStateConformance OBJECT IDENTIFIER ::= { powerStateMIB 2 }

=====
-- 1. Object Definitions
=====

-- 1.1. Actual Power State Table

powerStateTable OBJECT-TYPE
SYNTAX SEQUENCE OF PowerStateEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
"This table provides information on the current power state of managed entities.

The table is indexed by an ID of the entity on which power

state information is provided. IDs can be provided by another MIB module, such as the ENERGY AWARE MIB module or the ENTITY MIB module. If not ID provisioning from other MIB modules is available, the table can only have one entry for reporting the local power state of the device that tuns an instance of this table."

::= { powerStateObjects 1 }

powerStateEntry OBJECT-TYPE

SYNTAX PowerStateEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry providing information on the current power state of an entity."

INDEX { powerStateEnergyConsumerId }

::= { powerStateTable 1 }

PowerStateEntry ::=

SEQUENCE {

powerStateEnergyConsumerId Integer32,

powerStateEnergyConsumerOid OBJECT IDENTIFIER,

powerStateOperationalState SnmpAdminString,

powerStateAdminState SnmpAdminString

}

powerStateEnergyConsumerId OBJECT-TYPE

SYNTAX Integer32 (0..2147483647)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An integer that identifies an entity that is subject of power state monitoring. Index values MUST be locally unique for each identified entity."

If an implementation of the ENERGY AWARE MIB module is available in the local SNMP context, then the same index of an entity MUST be chosen as assigned to the entity by object pmIndex in the ENERGY AWARE MIB module. In this case, entities without an assigned value for pmIndex cannot be indexed by the powerCurrentStateTable.

If there is no implementation of the ENERGY AWARE MIB module but one of the ENTITY MIB module is available in the local SNMP context, then the same index of an entity MUST be chosen as assigned to the entity by object entPhysicalIndex in the ENTITY MIB module. In this case, entities without an assigned value for pmIndex cannot be indexed by the

powerCurrentStateTable.

If neither the ENERGY AWARE MIB module nor of the ENTITY MIB module is available in the local SNMP context, then this MIB module may choose identity values from a further MIB module providing entity identities. In this case the value for each pmIndex must remain constant at least from one re-initialization of the entity's network management system to the next re-initialization.

In case that no other MIB module has been chosen for providing entity identities, power state can be reported exclusively for the local device on which this table is instantiated. Then this table will have a single entry only and an index value of 0 MUST be used.

The identity provisioning method that has been chosen can be retrieved by reading the value of powerStateEnergyConsumerOid. In case of identities provided by the ENERGY AWARE MIB module, this OID points to an existing instance of pmIndex, in case of the ENTITY MIB, the object points to a valid instance of entPhysicalIndex, and in a similar way, it points to a value of another MIB module if this is used for identifying entities. If no other MIB module has been chosen for providing entity identities, then the value of powerStateEnergyConsumerOid MUST be 0.0 (zeroDotZero)."

::= { powerStateEntry 1 }

powerStateEnergyConsumerOid OBJECT-TYPE

SYNTAX OBJECT IDENTIFIER

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An OID that identifies an entity that is subject of power state monitoring. The value MUST be an OID that points to an existing managed object or 0.0 (zeroDotZero)."

If another MIB module is chosen for providing identities for managed entities, then the value of this object points to an existing instance of an entity identifier, such as an instance of pmIndex in the ENERGY AWARE MIB or an instance of entPhysicalIndex in the ENTITY MIB module.

If power state information is provided only for the local device on which this table is instantiated, then the value of this object MUST be 0.0 (zeroDotZero)."

::= { powerStateEntry 2 }

```
powerStateOperationalState OBJECT-TYPE
    SYNTAX      SnmpAdminString (SIZE(1..32))
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION
        "This object indicates the current power state of the
        entity. The given SnmpAdminString MUST match the
        powerStateName object of an entry in the
        powerStateAllStatesTable."
    ::= { powerStateEntry 3 }

powerStateAdminState OBJECT-TYPE
    SYNTAX      SnmpAdminString (SIZE(0..32))
    MAX-ACCESS   read-write
    STATUS       current
    DESCRIPTION
        "This object indicates the desired power state of the
        entity. This object may be set by a network management
        system in order to request changing the actual power state
        to the desired one.

        If this object has not been set by an administrative action
        requesting a certain power state, then its value is an
        empty string of length 0."
    ::= { powerStateEntry 4 }

-----
-- 1.2. All Power States Table
-----

powerStateAllStatesTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF PowerStateAllStatesEntry
    MAX-ACCESS   not-accessible
    STATUS       current
    DESCRIPTION
        "This table provides information on all available power
        states of managed entities.

        The table extends the powerStateTable by sharing the first
        index. The first index serves for identifying an entity for
        which power state information is provided. The second index
        identifies a single power state by its name."
    ::= { powerStateObjects 2 }

powerStateAllStatesEntry OBJECT-TYPE
    SYNTAX      PowerStateAllStatesEntry
    MAX-ACCESS   not-accessible
    STATUS       current
```


DESCRIPTION

"Power state information about this physical entity."

INDEX { powerStateEnergyConsumerId, powerStateName }
 ::= { powerStateAllStatesTable 1 }

PowerStateAllStatesEntry ::=

```
SEQUENCE {
    powerStateName          SnmpAdminString,
    powerStateType          INTEGER,
    powerStateDescription   SnmpAdminString,
    powerStateAveragePower  Integer32,
    powerStateMaximumPower  Integer32,
    powerStateTotalTime     TimeTicks,
    powerStateLastEnterTime TimeStamp,
    powerStateLastEnterReason SnmpAdminString,
    powerStateEnterCount    Counter64
}
```

powerStateName OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE(1..32))

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This index should only be created for power states that are actually implemented by the entity that is identified by the first index powerStateEnergyConsumerOid.

This index is the name of the power state and is limited to 32 characters.

If possible the name SHOULD already give a rough idea of the characteristic of this power state."

::= { powerStateAllStatesEntry 1 }

powerStateType OBJECT-TYPE

```
SYNTAX INTEGER {
    unknown(0),
    off(1),
    nonOperational(2),
    operational(3)
}
```

 -- Open issue: Shall we replace the syntax by textual convention
 -- PowerMonitorLevel from draft-claise-energy-monitoring-mib?

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"Object classifies the power state. It helps to clearly distinguish non-operational power states (sleep, standby, etc.) from operational ones. In a nonOperational(2) state an entity provides non of its primary services except for bringing it into operational(3) states or off(1) states.

A device in state off(1) cannot report its state on its own. But state off(1) may be reported by managed devices reporting on the power state of other managed devices."

::= { powerStateAllStatesEntry 2 }

powerStateDescription OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"Power states are identified by their names. However, semantics of power states may vary between different entities. Reasons for variations can be different hardware and software architectures of managed devices.

Object powerStateDescription SHOULD describe the power state and its characteristics as closely as possible."

::= { powerStateAllStatesEntry 3 }

powerStateAveragePower OBJECT-TYPE

SYNTAX Integer32

UNITS "milliwatt"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the average power (energy consumption rate) in milliwatt at the electrical power supply of the entity in the power state indicated by powerStateName.

A value of -1 indicates that the average power in this state is unknown."

::= { powerStateAllStatesEntry 4 }

powerStateMaximumPower OBJECT-TYPE

SYNTAX Integer32

UNITS "milliwatt"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the maximum power (energy consumption rate) in milliwatt at the electrical power supply of the

entity in the power state indicated by powerStateName.

A value of -1 indicates that the maximum power in this state is unknown."

::= { powerStateAllStatesEntry 5 }

powerStateTotalTime OBJECT-TYPE

SYNTAX TimeTicks

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the total time in hundreds of seconds that the entity has been in the state indicated by index powerStateName."

::= { powerStateAllStatesEntry 6 }

-- Open issue: Shall we use DateAndTime instead of timeTicks?

powerStateLastEnterTime OBJECT-TYPE

SYNTAX TimeStamp

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This time stamp object indicates the last time a which the entity entered the state indicated by index powerStateName."

::= { powerStateAllStatesEntry 7 }

powerStateLastEnterReason OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This string object describes the reason for the last power state transition into the power state indicated by index powerStateName."

::= { powerStateAllStatesEntry 8 }

powerStateEnterCount OBJECT-TYPE

SYNTAX Counter64

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates how often the entity indicated by index entPhysicalIndex entered the power state indicated by index powerStateName."

::= { powerStateAllStatesEntry 9 }

```
=====
-- 2. Notifications
=====

powerStateChangeEvent NOTIFICATION-TYPE
  OBJECTS      { powerStateLastEnterReason }
  STATUS       current
  DESCRIPTION
    "This notification can be generated when the power state of
    an entity changes.

    Note that the state that has been entered is indicated by
    the OID of object powerStateLastEnterReason."
  ::= { powerStateNotifications 1 }

=====
-- 3. Conformance Information
=====

powerStateCompliances OBJECT IDENTIFIER
  ::= { powerStateConformance 1 }
powerStateGroups      OBJECT IDENTIFIER
  ::= { powerStateConformance 2 }

-----
-- 3.1. Compliance Statements
-----

powerCompliance 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 group powerRequiredGroup."
  MODULE -- this module
  MANDATORY-GROUPS { powerStateRequiredGroup }
  GROUP powerStateNotificationsGroup
  DESCRIPTION
    "A compliant implementation does not have to implement
    the powerNotificationsGroup."
  ::= { powerStateCompliances 1 }

-----
-- 3.2. MIB Grouping
-----
```

```
powerStateRequiredGroup OBJECT-GROUP
    OBJECTS {
        powerStateOperationalState,
        powerStateAdminState,
        powerStateType,
        powerStateDescription,
        powerStateTotalTime,
        powerStateLastEnterTime,
        powerStateLastEnterReason,
        powerStateEnterCount,
        powerStateAveragePower,
        powerStateMaximumPower
    }
    STATUS      current
    DESCRIPTION
        "A compliant implementation MUST implement the objects
        contained in this group."
    ::= { powerStateGroups 1 }

powerStateNotificationsGroup NOTIFICATION-GROUP
    NOTIFICATIONS { powerStateChangeEvent }
    STATUS      current
    DESCRIPTION
        "A compliant implementation does not have to implement the
        notification contained in this group."
    ::= { powerStateGroups 2 }
END
```

8.2. Energy MIB

```
ENERGY-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY, OBJECT-TYPE, mib-2,
    Unsigned32, Integer32
        FROM SNMPv2-SMI
        -- RFC2578
    TimeStamp
        FROM SNMPv2-TC
        -- RFC2579
    MODULE-COMPLIANCE, OBJECT-GROUP
        FROM SNMPv2-CONF
        -- RFC2580
    EntitySensorStatus
        FROM ENTITY-SENSOR-MIB
        -- RFC3433
    powerStateName
        FROM POWER-STATE-MIB
    UnitMultiplier
        FROM POWER-MONITOR-MIB;

energyMIB MODULE-IDENTITY
```

LAST-UPDATED "201010231200Z" -- 23 October 2010
ORGANIZATION "IETF OPSAWG Working Group"
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"General Discussion: opsawg@ietf.org
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DESCRIPTION

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

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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      "201010231200Z"          -- 23 October 2010
    DESCRIPTION
        "Initial version, published as RFC yyyy."
-- replace yyyy with actual RFC number & remove this notice

    ::= { mib-2 9992 }
-- yyy to be assigned by IANA.

--*****
-- Top Level Structure of the MIB module
--*****

energyObjects      OBJECT IDENTIFIER ::= { energyMIB 1 }
energyConformance  OBJECT IDENTIFIER ::= { energyMIB 2 }

=====
-- 1. Object Definitions
=====

-----
-- 1.1. Energy Consumption Table
-----

energyTable  OBJECT-TYPE
    SYNTAX      SEQUENCE OF EnergyEntry
    MAX-ACCESS   not-accessible
    STATUS      current
    DESCRIPTION
        "This table provides information on the current and
        accumulated energy consumption of entities.

        The table is indexed by an ID of the entity on which
        energy information is provided. IDs can be provided by
        another MIB module, such as the ENERGY AWARE MIB module
        or the ENTITY MIB module. If not ID provisioning from
        other MIB modules is available, the table can only have
        one entry for reporting the local power state of the
        device that runs an instance of this table."
    ::= { energyObjects 1 }

energyEntry  OBJECT-TYPE
    SYNTAX      EnergyEntry
    MAX-ACCESS   not-accessible
    STATUS      current
    DESCRIPTION
        "An entry providing information on the energy consumption
        of a physical entity."
    INDEX       { energyConsumerId }
    ::= { energyTable 1 }

```

```

EnergyEntry ::=
  SEQUENCE {
    energyConsumerId          Integer32,
    energyConsumerOid         OBJECT IDENTIFIER,
    energySensorOperStatus    EntitySensorStatus,
    energyNominalSupplyVoltage Unsigned32,
    energyElectricSupplyType  INTEGER,
    energyTotalEnergy         Unsigned32,
    energyEnergyUnitMultiplier UnitMultiplier,
    energyEnergyPrecision     Integer32,
    energyMeasurementMethod   INTEGER,
    energyDiscontinuityTime   TimeStamp,
    energySampleInterval      Unsigned32,
    energyMaxHistory          Unsigned32,
    energyPowerUnitMultiplier UnitMultiplier,
    energyPowerPrecision      Integer32,
    energyRealPower           Unsigned32,
    energyPeakRealPower       Unsigned32,
    energyReactivePower       Unsigned32,
    energyApparentPower       Unsigned32,
    energyPhaseAngle          Integer32,
    energyPhaseAnglePrecision Integer32
  }

```

energyConsumerId OBJECT-TYPE

SYNTAX Integer32 (0..2147483647)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An integer that identifies an entity that is subject of energy monitoring. Index values MUST be locally unique for each identified entity.

If an implementation of the ENERGY AWARE MIB module is available in the local SNMP context, then the same index of an entity MUST be chosen as assigned to the entity by object pmIndex in the ENERGY AWARE MIB module. In this case, entities without an assigned value for pmIndex cannot be indexed by the powerCurrentStateTable.

If there is no implementation of the ENERGY AWARE MIB module but one of the ENTITY MIB module is available in the local SNMP context, then the same index of an entity MUST be chosen as assigned to the entity by object entPhysicalIndex in the ENTITY MIB module. In this case, entities without an assigned value for pmIndex cannot be indexed by the powerCurrentStateTable.

If neither the ENERGY AWARE MIB module nor of the ENTITY MIB module is available in the local SNMP context, then this MIB module may choose identity values from a further MIB module providing entity identities. In this case the value for each pmIndex must remain constant at least from one re-initialization of the entity's network management system to the next re-initialization.

In case that no other MIB module has been chosen for providing entity identities, power state can be reported exclusively for the local device on which this table is instantiated. Then this table will have a single entry only and an index value of 0 MUST be used.

The identity provisioning method that has been chosen can be retrieved by reading the value of object powerStateEnergyConsumerOid. In case of identities provided by the ENERGY AWARE MIB module, this OID points to an existing instance of pmIndex, in case of the ENTITY MIB, the object points to a valid instance of entPhysicalIndex, and in a similar way, it points to a value of another MIB module if this is used for identifying entities. If no other MIB module has been chosen for providing entity identities, then the value of powerStateEnergyConsumerOid MUST be 0.0 (zeroDotZero)."

```
::= { energyEntry 1 }
```

energyConsumerOid OBJECT-TYPE

SYNTAX OBJECT IDENTIFIER

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An OID that identifies an entity that is subject of energy monitoring. The value MUST be an OID that points to an existing managed object or 0.0 (zeroDotZero)."

If another MIB module is chosen for providing identities for managed entities, then the value of this object points to an existing instance of an entity identifier, such as an instance of pmIndex in the ENERGY AWARE MIB or an instance of entPhysicalIndex in the ENTITY MIB module.

If power state information is provided only for the local device on which this table is instantiated, then the value of this object MUST be 0.0 (zeroDotZero)."

```
::= { energyEntry 2 }
```

energySensorOperStatus OBJECT-TYPE

```
SYNTAX      EntitySensorStatus
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "This object provides the operational status of the
    sensor that is used for measuring the energy consumption
    of the entity indicated by energyConsumerId."
 ::= { energyEntry 3 }
```

energyNominalSupplyVoltage OBJECT-TYPE

```
SYNTAX      Unsigned32
UNITS       "millivolt"
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "This object provides the nominal voltage of the power
    supply of the entity. It is provided in units of
    millivolt (mV).

    The nominal voltage actual of an entity is assumed to be
    fixed, while the actual power supply voltage may vary over
    time, for example, caused by changing load conditions.

    A value of 0 indicates that the nominal supply voltage
    is unknown."
 ::= { energyEntry 4 }
```

energyElectricSupplyType OBJECT-TYPE

```
SYNTAX      INTEGER {
                    alternatingCurrent(1),
                    directCurrent(2),
                    unknown(3)
                }
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "This object indicates the type of electrical power
    supply for the entity. It is used for distinguishing
    between alternating current (AC) supply and direct
    current (DC) supply."
 ::= { energyEntry 5 }
```

energyTotalEnergy OBJECT-TYPE

```
SYNTAX      Unsigned32
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
    "This object indicates the total consumed energy measured
```

at the electrical power supply of the entity.

In order to determine the measured value in watt hours, the value of this object needs to be multiplied by a unit multiplier given by the value of object `energyEnergyUnitMultiplier`.

Discontinuities in the value of this counter can occur at re-initialization of the management system, and at other times as indicated by the value of `energyDiscontinuityTime`."

::= { energyEntry 6 }

`energyEnergyUnitMultiplier` OBJECT-TYPE

SYNTAX UnitMultiplier

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides unit multiplier for measured energy values. Reported values need to be multiplied with this multiplier in order to determine the measured value in watt hours.

This object serves as unit multiplier for objects `energyTotalEnergy`, `energyPSTotalEnergy`,

..."

::= { energyEntry 7 }

`energyEnergyPrecision` OBJECT-TYPE

SYNTAX Integer32 (0..10000)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates a the precision of a measured energy value. The precision is indicated as a percentage value, in 100ths of a percent. A value of 0 indicates that the precision is unknown or not applicable to the measured value.

This object serves precision indicator for the values provided by objects `energyTotalEnergy`, `energyPSTotalEnergy`, ..."

::= { energyEntry 8 }

`energyMeasurementMethod` OBJECT-TYPE

SYNTAX INTEGER {
 directEnergyMeasurement(1),
 powerOversampling(2),

```

        powerSampling(3),
        loadBasedEstimation(4),
        deviceBasedEstimation(5),
        unknown(6)
    }
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION
    "This object indicates the method used for measuring energy
    consumption. A device may not be equipped with capabilities
    to measure its energy consumption directly, but rather
    relies on other input in order to conduct more or less
    precise estimations of its power consumption.

    The measurement methods concerns values of objects
    energyTotalEnergy, energyPSTotalEnergy, and
    energyPowerHistoryAverageValue.

    Five different measurement methods are specified.

    - directEnergyMeasurement(1) indicates that the entity is
      instrumented to directly measure its energy consumption.

    - powerOversampling(2) indicates that energy is measured
      by sampling power values more frequently than indicated
      by the value of object energySampleInterval.

    - powerSampling(3) indicates that energy is measured
      by sampling power values according to the value of object
      energySampleInterval.

    - loadBasedEstimation(4) indicates that power is estimated
      based on measurements of the load of the entity.

    - deviceBasedEstimation(5) indicates that power is estimated
      based on static properties of the entity. In this case,
      reported power only depends on the power state of the
      devices as indicated by object powerCurrentState in the
      powerCurrentStateTable of the Power State MIB module."
 ::= { energyEntry 9 }

```

energyDiscontinuityTime OBJECT-TYPE

```

SYNTAX        TimeStamp
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION

```

"The value of sysUpTime on the most recent occasion at which
any one or more of this entity's energy consumption counters

suffered a discontinuity. The relevant counters are energyTotalEnergy and energyPerStateTotalEnergy. If no such discontinuities have occurred since the last re-initialization of the local management subsystem, then this object contains a zero value."

```
::= { energyEntry 10 }
```

energySampleInterval OBJECT-TYPE

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

"This object indicates is the difference of time stamps between two consecutive entries in the energyHistoryTable for this entity.

The interval lenght provided by this object indicates the or maximum interval length (or minimal sampling rate) at which the power sensor measures values of the current power. Implementations of the Energy MIB module may choose higher sampling rates (or shorter sampling intervals) in order to provide higher precision of the measurement. Preferably, shorter intervals may be chosen such that the sampling interval indicated by this object is a multiple of the actual sampling interval.

The sampling interval is provided in units of microseconds.

A value of 0 indicates that the sampling interval applied by the sensor is unknown or not constant."

```
::= { energyEntry 11 }
```

energyMaxHistory OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates is the maximum number of corresponding entries in the energyPowerHistoryTable. An entry in the energyHistoryTable is corresponding if it has the same value for object energyConsumerId as index.

An implementation of the Energy MIB module will remove the oldest correaponding entry in the energyHistoryTable to allow the addition of a new entry once the number of corresponding entries in the energyHistoryTable

reaches this value.

Entries are added to the energyHistoryTable until energyMaxHistory is reached before entries begin to be removed.

A value of 0 for this object disables creation of corresponding energyHistoryTable entries."

DEFVAL { 0 }
::= { energyEntry 12 }

energyPowerUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides unit multiplier for measured energy values. Reported values need to be multiplied with this multiplier in order to determine the measured value in watt hours.

This object serves as unit multiplier for the values provided by objects energyRealPower, energyPeakRealPower, energyReactivePower, and energyApparentPower."

::= { energyEntry 13 }

energyPowerPrecision OBJECT-TYPE

SYNTAX Integer32 (0..10000)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates a the precision of a measured power value. The precision is indicated as a percentage value, in 100ths of a percent. A value of 0 indicates that the precision is unknown or not applicable to the measured value.

This object serves precision indicator for the values provided by objects energyRealPower, energyPeakRealPower, energyReactivePower, and energyApparentPower."

::= { energyEntry 14 }

energyRealPower OBJECT-TYPE

SYNTAX Unsigned32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current real power value

at the electrical supply of the entity indicated by index energyConsumerId.

In order to determine the measured value in watts, the value of this object needs to be multiplied by a unit multiplier given by the value of object energyEnergyUnitMultiplier.

Measured values of this object are stored in the energyPowerTable with a rate determined by object energySampleInterval."

::= { energyEntry 15 }

energyPeakRealPower OBJECT-TYPE

SYNTAX Unsigned32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the highest observed value for object energyRealPower since the last re-initialization of the management system.

In order to determine the measured value in watts, the value of this object needs to be multiplied by a unit multiplier given by the value of object energyEnergyUnitMultiplier."

::= { energyEntry 16 }

energyReactivePower OBJECT-TYPE

SYNTAX Unsigned32

UNITS "volt-amperes reactive"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current reactive power value at the electrical supply of the entity indicated by index energyConsumerId.

In order to determine the measured value in volt-amperes (var), the value of this object needs to be multiplied by a unit multiplier given by the value of object energyEnergyUnitMultiplier.

The value provided by this object is only useful if the value of object energySupplyType is alternatingCurrent(1). In this case it is RECOMMENDED that at least one of the three values energyReactivePower, energyApparentPowerScale, and energyPhaseAngle

are provided.

If object `energyElectricSupplyType` of this row has a value other than `alternatingCurrent(1)`, then the value of this object MUST be 0.

If object `energyElectricSupplyType` of this row has the value `alternatingCurrent(1)` and if no value for the current reactive power is provided, then the value of this object MUST be 0xFFFF."

::= { energyEntry 17 }

`energyApparentPower` OBJECT-TYPE

SYNTAX Unsigned32

UNITS "volt-amperes"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current apparent power value measured in volt-ampere (VA) at the electrical supply of the entity for a time interval indicated by object `energySampleInterval`.

The value provided by this object is only useful if the value of object `energySupplyType` is `alternatingCurrent(1)`. In this case it is RECOMMENDED that at least one of the three values `energyReactivePower`, `energyApparentPowerScale`, and `energyPhaseAngle` are provided.

Scale and precision of the value are indicated by objects `energyPowerScale` and `energyPowerPrecision`.

If object `energyElectricSupplyType` of this row has a value other than `alternatingCurrent(1)`, then the value of this object MUST be equal to the value of object `energyRealPower`.

If object `energyElectricSupplyType` of this row has the value `alternatingCurrent(1)` and if no value for the current apparent power is provided, then the value of this object MUST be -10000000000."

::= { energyEntry 18 }

`energyPhaseAngle` OBJECT-TYPE

SYNTAX Integer32 (-1..360000)

UNITS "millidegrees"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current phase angle value measured at the electrical supply of the entity for a time interval indicated by object energySampleInterval.

The value provided by this object is only useful if the value of object energySupplyType is alternatingCurrent(1). In this case it is RECOMMENDED that at least one of the three values energyReactivePower, energyApparentPowerScale, and energyPhaseAngle are provided.

The value is provided in units of millidegree (one thousands of a degree. This is equivalent to an associated object of type EntitySensorDataScale with the value of milli(8) and an associated object of type EntitySensorPrecision with a value of 0.

The minimum value for this object when indicating an actual angle is 0, the maximum value is 360000.

The maximum error of of the value is indicated by object energyPhaseAngleMaxError.

If object energyElectricSupplyType of this row has a value other than alternatingCurrent(1), then the value of this object MUST be 0.

If object energyElectricSupplyType of this row has the value alternatingCurrent(1) and if no value for the phase angle is provided, then the value of this object MUST be -1."

::= { energyEntry 19 }

energyPhaseAnglePrecision OBJECT-TYPE

SYNTAX Integer32 (0..10000)

UNITS "millidegrees"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates a the precision of a measured phase angle value. The precision is indicated as a percentage value, in 100ths of a percent. A value of 0 indicates that the precision is unknown or not applicable to the measured value.

This object serves precision indicator for the values

```

        provided by object energyPhaseAngle."
 ::= { energyEntry 20 }

```

```

-----
-- 1.2. Energy Consumption Per Power State Table
-----

```

```

energyPerStateTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF EnergyPerStateEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This table provides information on the accumulated energy
        consumption of an entity.

        This table extends the energyTable by sharing the
        first index. The first index serves for identifying an
        entity for which energy information is provided. The second
        index identifies a single power state by its name."
    ::= { energyObjects 2 }

```

```

energyPerStateEntry OBJECT-TYPE
    SYNTAX      EnergyPerStateEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "Energy consumption information per power state for a
        physical entity."
    INDEX { energyConsumerId, powerStateName }
    ::= { energyPerStateTable 1 }

```

```

EnergyPerStateEntry ::=
    SEQUENCE {
        energyPerStateTotalEnergy      Unsigned32
    }

```

```

energyPerStateTotalEnergy OBJECT-TYPE
    SYNTAX      Unsigned32
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "This object indicates the total consumed energy value
        at the electrical supply of the entity indicated by index
        energyConsumerId while being in a specific power state
        indicated by index powerStateName.

        In order to determine the measured value in watts, the value
        of this object needs to be multiplied by a unit multiplier

```

given by the value of object
energyEnergyUnitMultiplier of table
energyTable.

Discontinuities in the value of this counter can occur at
re-initialization of the management system, and at other
times as indicated by the value of
energyDiscontinuityTime."
 ::= { energyPerStateEntry 1 }

-- 1.3. Energy Power History Table

energyHistoryTable OBJECT-TYPE
SYNTAX SEQUENCE OF EnergyHistoryEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
"This table stores results of energy consumption
measurements for multiple entities.

This table extends the energyTable by sharing the
first index. The first index serves for identifying an
entity for which energy information is provided. The second
index energyHistoryIndex identifies a single measurement
consisting of an energy consumption value and a timestamp.

Creation of entries in this row is controlled individually
for each entity by two parameters: energyMaxHistory and
energySamplingInterval.

The energySamplingInterval controls the difference in time
between the creation of two consecutive entries in this
table. Object energyMaxHistory limits the number of entries
in this table that can be created for the corresponding
entity.

An implementation of the Energy MIB module will remove the
oldest entry for an entity in the energyHistoryTable to
allow the addition of a new entry once the number of
entries for this entity reaches the value indicated by
object energyMaxHistory.

Entries for a specific entity are added to this table
until energyMaxHistory is reached before
entries begin to be removed.

Entries for the same entity are indexed by energyHistoryIndex. The first entry for an entity MUST have an index value of 1. Further new entries MUST be indexed by consecutive numbers in the order in which they are created until the value of energyMaxHistory is reached. Then no further new indices will be assigned, but existing ones will be re-used."

::= { energyObjects 3 }

energyHistoryEntry OBJECT-TYPE

SYNTAX EnergyHistoryEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry indicating consumed energy for an entity at a certain point in time."

INDEX { energyConsumerId, energyHistoryIndex }

::= { energyHistoryTable 1 }

EnergyHistoryEntry ::=

SEQUENCE {

energyHistoryIndex Unsigned32,

energyHistoryTimestamp TimeStamp,

energyHistoryTotalEnergy Unsigned32

}

energyHistoryIndex OBJECT-TYPE

SYNTAX Unsigned32 (1..4294967295)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"The index for this entry per entity.

Values of this index MUST be unique per entity used as first index."

::= { energyHistoryEntry 1 }

energyHistoryTimestamp OBJECT-TYPE

SYNTAX TimeStamp

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the time at which the energy consumption value provided by object energyHistoryTotalEnergy was measured."

::= { energyHistoryEntry 2 }

energyHistoryTotalEnergy OBJECT-TYPE

SYNTAX Unsigned32

```
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION
    "This object indicates the total consumed energy measured
    at the electrical power supply of the entity.

    In order to determine the measured value in watt hours,
    the value of this object needs to be multiplied by a unit
    multiplier given by the value of object
    energyEnergyUnitMultiplier in the corresponding entry
    for this entity in table energyTable.

    Discontinuities in the value of this counter can occur at
    re-initialization of the management system, and at other
    times as indicated by the value of
    energyDiscontinuityTime in the corresponding entry
    for this entity in table energyTable."
 ::= { energyHistoryEntry 3 }
```

```
=====
-- 2. Conformance Information
=====
```

```
energyCompliances OBJECT IDENTIFIER ::= { energyConformance 1 }
energyGroups       OBJECT IDENTIFIER ::= { energyConformance 2 }
```

```
-----
-- 2.1. Compliance Statements
-----
```

```
energyCompliance MODULE-COMPLIANCE
    STATUS        current
    DESCRIPTION
        "The compliance statement for implementations of the
        ENERGY-MIB module.

        A compliant implementation MUST implement the objects
        defined in the mandatory group energyRequiredGroup.

        If one of the entities for which energy consumption is
        reported are supplied by alternating current (AC) then it
        is recommended that not just real power is reported
        (REQUIRED) but it is also RECOMMENDED that at least one
        of three other related values (reactive power, apparent
        power, and phase angle) is reported by implementing at least
        one of the three groups energyReactivePowerGroup,
        energyApparentPowerGroup, and energyPhaseAngleGroup."
```

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

GROUP energyPowerHistoryGroup
DESCRIPTION
    "This group is only needed for implementations that
    support storing time series of measured power values
    in the energyPowerHistoryTable."

GROUP energyACGroup
DESCRIPTION
    "This group is only needed for implementations that report
    consumption of electric energy provided by alternating
    current (AC) supply.

    Implementations for devices supplied with direct current (DC)
    only and implementations that do only report real power
    reporting for alternative current do not need to implement
    objects in this group."

GROUP energyReactivePowerGroup
DESCRIPTION
    "Information provided by elements in this group is redundant
    to information provided by elements in the
    energyApparentPowerGroup and the energyPhaseAngleGroup.

    For compliant implementations that report consumption of
    electric energy provided by alternating current (AC) supply
    it is RECOMMENDED to at least one of the three groups
    energyReactivePowerGroup, energyApparentPowerGroup, and
    energyPhaseAngleGroup."

GROUP energyApparentPowerGroup
DESCRIPTION
    "Information provided by elements in this group is redundant
    to information provided by elements in the
    energyReactivePowerGroup and the energyPhaseAngleGroup.

    For compliant implementations that report consumption of
    electric energy provided by alternating current (AC) supply
    it is RECOMMENDED to at least one of the three groups
    energyReactivePowerGroup, energyApparentPowerGroup, and
    energyPhaseAngleGroup."

GROUP energyPhaseAngleGroup
DESCRIPTION
    "Information provided by elements in this group is redundant
    to information provided by elements in the
```

energyReactivePowerGroup and the energyApparentPowerGroup.

For compliant implementations that report consumption of electric energy provided by alternating current (AC) supply it is RECOMMENDED to at least one of the three groups energyReactivePowerGroup, energyApparentPowerGroup, and energyPhaseAngleGroup."

::= { energyCompliances 1 }

-- 2.2. Object Grouping

energyRequiredGroup OBJECT-GROUP

OBJECTS {
 energySensorOperStatus,
 energyNominalSupplyVoltage,
 energyElectricSupplyType,
 energyTotalEnergy,
 energyEnergyUnitMultiplier,
 energyEnergyPrecision,
 energyMeasurementMethod,
 energyDiscontinuityTime,
 energyPowerUnitMultiplier,
 energyPowerPrecision,
 energyRealPower,
 energyPeakRealPower,
 energyPerStateTotalEnergy
}

STATUS current

DESCRIPTION

"A compliant implementation MUST implement the objects contained in this group."

::= { energyGroups 1 }

energyPowerHistoryGroup OBJECT-GROUP

OBJECTS {
 energySampleInterval,
 energyMaxHistory,
 energyHistoryTimestamp,
 energyHistoryTotalEnergy
}

STATUS current

DESCRIPTION

"The group of object for reporting details of AC power measurement."

::= { energyGroups 2 }

```
energyACGroup OBJECT-GROUP
  OBJECTS {
    energyReactivePower,
    energyApparentPower,
    energyPhaseAngle,
    energyPhaseAnglePrecision
  }
  STATUS      current
  DESCRIPTION
    "The group of object for reporting details of
    AC power measurement."
  ::= { energyGroups 3 }

energyReactivePowerGroup OBJECT-GROUP
  OBJECTS {
    energyReactivePower
  }
  STATUS      current
  DESCRIPTION
    "The group of object for reporting the reactive power
    measured for AC supply."
  ::= { energyGroups 4 }

energyApparentPowerGroup OBJECT-GROUP
  OBJECTS {
    energyApparentPower
  }
  STATUS      current
  DESCRIPTION
    "The group of object for reporting the apparent power
    measured for AC supply."
  ::= { energyGroups 5 }

energyPhaseAngleGroup OBJECT-GROUP
  OBJECTS {
    energyPhaseAngle,
    energyPhaseAnglePrecision
  }
  STATUS      current
  DESCRIPTION
    "The group of object for reporting the phase angler
    measured for AC supply."
  ::= { energyGroups 6 }

END
```

8.3. Battery MIB


```
BATTERY-MIB DEFINITIONS ::= BEGIN
```

```
IMPORTS
```

```
    MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,  
    mib-2, Integer32, Unsigned32, Counter32  
        FROM SNMPv2-SMI                                -- RFC2578  
    DateAndTime  
        FROM SNMPv2-TC                                -- RFC2579  
    MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP  
        FROM SNMPv2-CONF                                -- RFC2580  
    entPhysicalIndex  
        FROM ENTITY-MIB;                                -- RFC4133
```

```
batteryMIB MODULE-IDENTITY
```

```
    LAST-UPDATED "201001291200Z"                        -- 29 January 2010  
    ORGANIZATION "IETF OPSAWG Working Group"  
    CONTACT-INFO  
        "General Discussion: opsawg@ietf.org  
        To Subscribe: https://www.ietf.org/mailman/listinfo/opsawg  
        Archive: http://www.ietf.org/mail-archive/web/opsawg
```

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```

```
DESCRIPTION
```

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

```
    Copyright (c) 2010 IETF Trust and the persons identified as  
    authors of the code. All rights reserved.
```

Redistribution and use in source and binary forms, with or without modification, is permitted pursuant to, and subject to the license terms contained in, the Simplified BSD License set forth in Section 4.c of the IETF Trust's Legal Provisions Relating to IETF Documents (<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 "201001291200Z" -- 29 January 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 in networked devices. It is designed as a sparse augment of the entPhysicalTable defined in the ENTITY-MIB module and assumes that each battery is represented by an individual row in the entPhysicalTable with an individual value for the index entPhysicalIndex.

Entries appear in this table only for entities that represent a battery. An entry in this table SHOULD be created at the same time as the associated entPhysicalEntry. An entry SHOULD be destroyed if the associated entPhysicalEntry is destroyed."

```
::= { batteryObjects 1 }
```

```
batteryEntry OBJECT-TYPE
```

```
SYNTAX      BatteryEntry
```

```
MAX-ACCESS  not-accessible
```

```
STATUS      current
```

```
DESCRIPTION
```

```
"An entry providing information on a battery."
```

```
INDEX { entPhysicalIndex } -- SPARSE-AUGMENTS
```

```
::= { batteryTable 1 }
```

```
BatteryEntry ::=
```

```
SEQUENCE {
```

batteryType	INTEGER,
batteryTechnology	INTEGER,
batteryNominalVoltage	Unsigned32,
batteryNumberOfCells	Unsigned32,
batteryNominalCapacity	Unsigned32,
batteryRemainingCapacity	Unsigned32,
batteryChargingCycleCount	Counter32,
batteryLastChargingCycleTime	DateAndTime,
batteryState	INTEGER,
batteryCurrentCharge	Unsigned32,
batteryCurrentChargePercentage	Unsigned32,
batteryCurrentVoltage	Unsigned32,
batteryCurrentCurrent	Integer32,
batteryLowAlarmPercentage	Unsigned32,
batteryLowAlarmVoltage	Unsigned32,
batteryReplacementAlarmCapacity	Unsigned32,
batteryReplacementAlarmCycles	Unsigned32

```
}
```

```
batteryType OBJECT-TYPE
```

```
SYNTAX      INTEGER {
                    primary(1),
                    rechargeable(2),
                    capacitor(3),
                    other(4),
                    unknown(5)
                }
```

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

```
STATUS      current
```

```
DESCRIPTION
```

"This object indicates the type of battery. It distinguishes between one-way primary batteries, rechargeable secondary batteries and capacitors which are not really batteries but often used in the same way as a battery.

The value other(4) can be used if the battery type is known but none of the ones above. Value unknown(5) is to be used if the type of battery cannot be determined."

```
::= { batteryEntry 1 }
```

batteryTechnology OBJECT-TYPE

```
SYNTAX      INTEGER {
                zincCarbon(1),
                zincChloride(2),
                oxyNickelHydroxide(3),
                lithiumCopper(4),
                lithiumIron(5),
                lithiumManganese(6),
                zincAir(7),
                silverOxide(8),
                alkaline(9),
                leadAcid(10),
                nickelCadmium(12),
                nickelMetalHybride(13),
                nickelZinc(14),
                lithiumIon(15),
                lithiumPolymer(16),
                doubleLayerCapacitor(17),
                other(18),
                unknown(19)
            }
```

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

```
STATUS      current
```

DESCRIPTION

"This object indicates the technology used by the battery. Values 1-8 are primary battery technologies, values 10-16 are rechargeable battery technologies and value alkaline(9) is used for primary batteries as well as for rechargeable batteries.

The value other(18) can be used if the battery type is known but none of the ones above. Value unknown(19) is to be used if the type of battery cannot be determined."

```
::= { batteryEntry 2 }
```

batteryNominalVoltage OBJECT-TYPE

```
SYNTAX      Unsigned32
```

```
UNITS       "millivolt"
```

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

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

 A value of 0 indicates that the nominal voltage is unknown."
 ::= { batteryEntry 3 }

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 4 }

batteryNominalCapacity OBJECT-TYPE
SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "This object provides the nominal capacity of the battery
 in units of milliampere hours (mAh).

 Note that the nominal capacity is a constant value and
 typically different from the actual capacity of the battery.

 A value of 0 indicates that the nominal capacity is unknown."
 ::= { batteryEntry 5 }

batteryRemainingCapacity OBJECT-TYPE
SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "This object provides the ACTUAL REMAINING capacity of the
 battery in units of milliampere hours (mAh).

 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 6 }

batteryChargingCycleCount OBJECT-TYPE

SYNTAX Counter32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the number of charging cycles that that the battery underwent. Please note that the precise definition of a recharge cycle varies for different kinds of batteries and of devices containing batteries.

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 7 }

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 8 }

batteryState OBJECT-TYPE

SYNTAX INTEGER {
 full(1),
 partiallyCharged(2),
 empty(3),
 charging(4),
 discharging(5),
 unknown(6)
}

MAX-ACCESS read-only

STATUS current
DESCRIPTION
"This object indicates the current state of the battery.
Value full(1) indicates a full battery with a capacity
given by object batteryRemainingCapacity. Value empty(3)
indicates a battery that cannot be used for providing
electric power before charging it. Value partiallyCharged(2)
is provided if the battery is neither empty nor full and if
no charging or discharging is in progress. Charging or
discharging of the battery is indicated by values charging(3)
or discharging(4), respectively.

Value unknown(6) is to be used if the state of the battery
cannot be determined."
 ::= { batteryEntry 9 }

batteryCurrentCharge OBJECT-TYPE
SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object provides the current charge of the battery
in units of milliampere hours (mAh).

Note that the current 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 current charge
cannot be determined."
 ::= { batteryEntry 10 }

batteryCurrentChargePercentage OBJECT-TYPE
SYNTAX Unsigned32 (0..10000)
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object provides the current charge of the battery
relative to the nominal capacity in units of a hundreds
of a percent.

-- Open issue:
-- Should it be the percentage of the nominal capacity
-- or of the current capacity?

Note that this value 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 relative current charge cannot be determined."

::= { batteryEntry 11 }

batteryCurrentVoltage OBJECT-TYPE

SYNTAX Unsigned32

UNITS "millivolt"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the current voltage of the battery in units of millivolt (mV).

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

::= { batteryEntry 12 }

batteryCurrentCurrent OBJECT-TYPE

SYNTAX Integer32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the current charging or discharging current of the battery in units of milliampere (mA). Charging current is indicated by positive values, discharging current is indicated by negative values.

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

::= { batteryEntry 13 }

batteryLowAlarmPercentage OBJECT-TYPE

SYNTAX Unsigned32 (0..10000)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the lower threshold value for object batteryCurrentChargePercentage. If the value of object batteryCurrentChargePercentage 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 the no alarm will be raised for

any value of object batteryCurrentChargePercentage."
 ::= { batteryEntry 14 }

batteryLowAlarmVoltage OBJECT-TYPE

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

DESCRIPTION

"This object provides the lower threshold value for object batteryCurrentVoltage. If the value of object batteryCurrentVoltage 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 the no alarm will be raised for any value of object batteryCurrentVoltage."

::= { batteryEntry 15 }

batteryReplacementAlarmCapacity OBJECT-TYPE

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

DESCRIPTION

"This object provides the lower threshold value for object batteryRemainingCapacity. If the value of object batteryRemainingCapacity 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 the no alarm will be raised for any value of object batteryRemainingCapacity."

::= { batteryEntry 16 }

batteryReplacementAlarmCycles OBJECT-TYPE

SYNTAX Unsigned32
UNITS "milliampere hours"
MAX-ACCESS read-only
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 the no alarm will be raised for

```
any value of object batteryChargingCycleCount."
 ::= { batteryEntry 17 }
```

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

```
batteryLowNotification NOTIFICATION-TYPE
```

```
  OBJECTS      {
    batteryCurrentChargePercentage,
    batteryCurrentVoltage
  }
```

```
  STATUS      current
```

```
  DESCRIPTION
```

```
    "This notification can be generated when the current charge
    (batteryCurrentChargePercentage) or the current voltage
    (batteryCurrentVoltage) of the battery falls below a
    threshold defined by object batteryLowAlarmPercentage or
    object batteryLowAlarmVoltage, respectively."
```

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

```
batteryAgingNotification NOTIFICATION-TYPE
```

```
  OBJECTS      {
    batteryRemainingCapacity,
    batteryChargingCycleCount
  }
```

```
  STATUS      current
```

```
  DESCRIPTION
```

```
    "This notification can be generated when the remaining
    capacity (batteryRemainingCapacity) falls below a threshold
    defined by object batteryReplacementAlarmCapacity
    or when the charging cycle count of the battery
    (batteryChargingCycleCount) exceeds the threshold defined
    by object batteryLowAlarmPercentage."
```

```
 ::= { batteryNotifications 2 }
```

```
-----
-- 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 group psmRequiredGroup."
  MODULE -- this module
  MANDATORY-GROUPS {
    batteryDescriptionGroup,
    batteryStatusGroup,
    batteryAlarmThresholdsGroup
  }
  GROUP      batteryNotificationsGroup
  DESCRIPTION
    "A compliant implementation does not have to implement
    the psmNotificationsGroup."
  ::= { batteryCompliances 1 }
```

```
-----
-- 3.2. MIB Grouping
-----
```

```
batteryDescriptionGroup OBJECT-GROUP
  OBJECTS {
    batteryType,
    batteryTechnology,
    batteryNominalVoltage,
    batteryNumberOfCells,
    batteryNominalCapacity
  }
  STATUS      current
  DESCRIPTION
    "A compliant implementation MUST implement the objects
    contained in this group."
  ::= { batteryGroups 1 }
```

```
batteryStatusGroup OBJECT-GROUP
  OBJECTS {
    batteryRemainingCapacity,
    batteryChargingCycleCount,
    batteryLastChargingCycleTime,
    batteryState,
    batteryCurrentCharge,
    batteryCurrentChargePercentage,
    batteryCurrentVoltage,
    batteryCurrentCurrent
```

```
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation MUST implement the objects
        contained in this group."
    ::= { batteryGroups 2 }

batteryAlarmThresholdsGroup OBJECT-GROUP
    OBJECTS {
        batteryLowAlarmPercentage,
        batteryLowAlarmVoltage,
        batteryReplacementAlarmCapacity,
        batteryReplacementAlarmCycles
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation MUST implement the objects
        contained in this group."
    ::= { batteryGroups 3 }

batteryNotificationsGroup NOTIFICATION-GROUP
    NOTIFICATIONS {
        batteryLowNotification,
        batteryAgingNotification
    }
    STATUS          current
    DESCRIPTION
        "A compliant implementation does not have to implement the
        notification contained in this group."
    ::= { batteryGroups 4 }
END
```

9. Security Considerations

There are no management objects defined in this MIB module that have a MAX-ACCESS clause of read-write and/or read-create. So, if this MIB module is implemented correctly, then there is no risk that an intruder can alter or create any management objects of this MIB module via direct SNMP SET operations.

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:

- o This list is still to be done.

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.

10. IANA Considerations

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

Descriptor	OBJECT IDENTIFIER value
-----	-----
powerStateMIB	{ mib-2 xxx }
energyMIB	{ mib-2 yyy }
batteryMIB	{ mib-2 zzz }

Other than that this document does not impose any IANA considerations.

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Requirements for Power Monitoring
draft-quittek-power-monitoring-requirements-02

Abstract

This memo discusses requirements for energy management, particularly for monitoring energy consumption and controlling power states of managed devices. This memo further shows that existing IETF standards are not sufficient for energy management and that energy management requires architectural considerations that are different from common other management functions.

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1. Introduction

With rising energy cost and with an increasing awareness of the ecological impact of running IT and networking equipment, energy management is becoming an additional basic requirement for network management frameworks and systems.

Different to other typical network management functions, energy management often extends its scope beyond devices with IP network interfaces. Requirements in this document do not fully cover all these networks, but they cover means for opening IP network management towards them.

In general, IETF Standards for energy management should be defined in such a way that they can be applied to several areas including

- o Communication networks and IT systems
- o Building networks
- o Home networks
- o Smart (power) grids

1.1. Energy management functions

The basic objective of energy management is operating communication networks and other equipment with a minimal amount of energy. An energy management system should provide means for reducing the power consumption of individual components of a network as well as of the whole network.

One approach to achieve this goal is setting all components to an operational state that results in lower energy consumption but still meets service level performance objectives. The sufficient performance level may vary over time and can depend on several factors. In principle, there are four basic types of power states for a component or for a whole system:

- o full power state
- o reduced power states (lower clock rate for processor, lower data rate on a link, etc.)
- o stand-by/sleep state (not functional, but immediately available)
- o power-off state (requiring significant time for becoming operational)

In actual implementations the number of power states and their properties vary a lot. Very simple devices may just have a full power and a power off state, while other devices may have a high number of different reduced power and sleep states.

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 consumption without the consequence of a

potential performance degradation. Then a trade-off needs to be dealt with between service level objectives and energy efficiency. In other cases a reduction of energy consumption can easily be achieved while still maintaining sufficient service level performance, for example, by switching components to lower power states when higher performance is not needed.

Network management systems can control such situations by implementing policies to achieve a certain degree of energy efficiency. In order to make policy decisions properly, information about the energy consumption of network components and sub-components in different power states is required. Often this information is acquired best through monitoring.

Monitoring operational power states and energy consumption is also useful for other energy management purposes including but not limited to

- o investigating power saving potential
- o evaluating the effectiveness of energy saving policies and measures
- o deriving, implementing, and testing power management strategies
- o accounting the total power consumption of a network element, a network, a service, or subcomponents of those

From the considerations described above the following basic management functions appear to be required for energy management:

- o monitoring power states of network elements and their subcomponents
- o monitoring actual power (energy consumption rate) of network elements and their subcomponents
- o monitoring (accumulated) energy consumption of network elements and their subcomponents
- o setting power states of network elements and their subcomponents
- o setting and enforcing power saving policies

Editorial note: With the extension to power state control and policy enforcement, the title of the draft does not anymore match the scope well. The name of the draft will be updated in a future revision.

It should be noted that monitoring energy consumption and power states itself is obviously not in itself a means to reduce the energy consumption of a device. In fact, it is likely to increase the power consumption of a device slightly. However, the acquired energy consumption and power state information is essential for defining energy saving policies and can be used as input to power state control loops that in total can lead to energy savings.

It should further be noted that active power control is complementary

(but essential) to other energy savings measures such as low power electronics, energy saving protocols (e.g. IEEE 802.3az), and energy-efficient device design (for example, stand-by and low-power modes for individual components of a device), and energy-efficient network architectures. Measurement of energy consumption may also provide input for developing these technologies.

1.2. Specific aspects of energy management

There are two aspects of energy management that make it different from other common network management functions. The first difference is that energy consumption is often measured remotely to the device under consideration. A reason for this is that today very few devices are instrumented with the hardware and software for measuring their own current power and accumulated energy consumption. Often power and energy for such devices is measured by other devices.

A common example is a Power over Ethernet (PoE) sourcing device that provides means for measuring provided power per port. If the device connected to a port is known, power and energy measurements for that device can be conducted by the PoE sourcing device. Another example is a smart power strip. Again, if it is known which devices are plugged into which outlets of the smart power strip, then the power strip can provide measured values for these devices.

The second difference is that often it is desirable to apply energy management also to networks and devices that do not communicate via IP, for example, in building networks where besides IP several other communication protocols are used. In these networks, it may be desirable that devices with IP interfaces report energy and power values for other devices. Reports may be based on measurements at the reporting device, similar to the PoE sourcing device and the smart strip. But reports may also be just relayed from non-IP communication to IP communication.

2. Scenarios and target devices

This section describes a selection of scenarios for the application of energy management. For each scenario a list of target devices is given in the headline, for which IETF energy management standards are needed.

2.1. Scenario 1: Routers, switches, middleboxes, and hosts

Power management of network devices is considered as a fundamental (basic first step) requirement. The devices listed in this scenario are some of the components of a communication network. For these

network devices, the chassis draws power from an outlet and feeds all its internal sub-components.

2.2. Scenario 2: PoE sourcing equipment and PoE powered devices

This scenario covers devices using Power over Ethernet (PoE). A PoE Power Sourcing Equipment (PSE), for example, a PoE switch, provides power to a PoE Powered Device (PD), for example, a PoE desktop phone. Here, the PSE provides means for controlling power supply (switching it on and off) and for monitoring actual power provided at a port to a specific PD.

2.3. Scenario 3: Power probes and Smart meters

Today, very few devices are equipped with sufficient instrumentation to measure their own actual power and accumulated energy consumption. Often external probes are connected to the power supply for measuring these properties for a single device or for a set of devices.

Homes, buildings, and data centers have smart meters that monitor and report accumulated power consumption of an entire home, a set of offices or a set of devices in data centers.

Power Distribution Unit (PDUs) attached to racks in data center and other smart power strips are evolving with smart meters and remote controllable power switches embedded for each socket.

2.4. Scenario 4: Mid-level managers

Sometimes it is useful to have mid-level managers that provide energy management functions not just for themselves but also for a set of associated devices. For example, a switch can provide energy management functions for all devices connected to its ports, even if these devices are not PoE PDs, but have their own power supply as, for example, PCs connected to the switch.

2.5. Scenario 5: Gateways to building networks

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 network Heating Ventilating Air Conditioning (HVAC), lighting, electrical, fire and emergency systems, elevators etc. The gateway device provides power monitoring and control function for other devices in the building network.

2.6. Scenario 6: Home energy gateways

Home energy gateway can be used for energy management of a home. This gateway can manage the appliances (refrigerator, heating/cooling, washing machine etc.) and interface with the electrical grid. The gateway can implement policies based on demand and energy pricing from the grid.

2.7. Scenario 7: Data center devices

Energy efficiency of data centers has become a fundamental challenges of data center operation. Energy management is conducted on different aggregation levels, such as network level, Power Distribution Unit (PDU) level, and server level.

2.8. Scenario 8: Battery powered devices

Some devices have a battery as a back-up source of power. Given the finite capacity and lifetime of a battery, means for reporting the actual charge, age, and state of a battery are required.

3. Monitoring Requirements

3.1. Granularity of monitoring and control

Often it is desirable to switch off individual components of a device but not the entire device. The switch may need to continue serving a few ports (for example, the ports serving an email server or needed for server backup), but most other ports could be entirely switched off under some policies (for example at night or the weekend in an office).

As illustrated by this example, it is often desirable to monitor power state and energy consumption on a granularity level that is finer than just the device level. Monitoring should be available for individual components of devices, such as line cards, processor cards, hard drives, etc. For example, for IP routers the following list of views of a router gives an idea of components that potentially could be monitored and controlled individually:

- o Physical view: chassis (or stack), central control engine, line cards, service cards, etc.
- o Component view: CPU, ASICs, fans, power supply, ports (single ports and port groups), storage and memory
- o Feature view: L2 forwarding, L3 routing, security features, load balancing features, network management, etc.

- o Logical view: system, data-plane, control-plane, etc.
- o Relationship view: line cards, ports and the correlation between transmission speed and power consumption, relationship of system load and total power consumption

Instrumentation for measuring energy consumption of a device is typically more expensive than instrumentation for retrieving the devices power state. It may be a reasonable compromise in many cases to provide power state information for all individually switchable components of a device separately, while the energy consumption is only measured for the entire device.

3.2. Remote and Aggregated Monitoring

There are several ways power and energy consumption can be measured and reported. Measurements can be performed locally at the device that consumes energy or remotely by a device that has access to the power supply of another device.

Instrumentation for power and energy measurements at a device requires additional hardware. A cost-efficient alternative is measuring power and energy consumption aggregated for a set of devices, for example a PoE PSE reporting these values per port group instead of per port, or a power distribution unit that reports the values for all connected devices instead of per socket.

If aggregated measurement is conducted, it is obvious that reporting provides aggregated values. but aggregated reporting can also be combined with local measurements. A managed node may act as mid-level manager or protocol converter for several devices that measure power consumption by themselves, for example a home gateway or a gateway to building networks. In this case, the reporting node may choose to report for each device individual values or aggregated values from groups of devices that transmitted their power and energy consumption values to the reporting node.

Often it is sufficient and more cost efficient having a single device measuring and providing power state and energy consumption information not just for itself but also for several further devices that are in some way attached to it. If the measuring and reporting device has access to individual power supply lines for each device, then it can measure energy consumption per device. If it only has access to a joint power supply for several devices, then it will measure aggregated values.

One example for the first case is a switch acting as power sourcing equipment for several IP phones using Power over Ethernet (PoE). The switch can measure the power consumption for each phone individually

at the port the phone is connected to or it measures aggregated values per port group for a set of devices.. The phones do not need to provide means for energy consumption measurement and reporting by themselves.

Another example is a smart meter that just measures and reports the energy transmitted through attached electric cables. Such a smart meter can be used to monitor energy consumption of an individual device if connected to the devices' individual power supply. But in many common cases it measures the aggregated energy consumption of several devices, for example, as part of an uninterruptible power supply (UPS) that serves several devices at a single power cord, or as a smart electric meter for a set of machines in a rack, in an office building or at a residence.

3.3. Accuracy

Depending on how power and energy consumption values are obtained the confidence in the reported value and its accuracy may vary. Managed nodes reporting values concerning themselves or other devices should qualify the confidence in reported values and quantify the accuracy of measurements. For accuracy reporting, the accuracy classes specified in IEC 61850 should be considered.

3.4. Required Information

This section lists requirements for information to be retrieved. Because of the different nature of power state monitoring and energy consumption monitoring, these are discussed separately. In addition, a section on battery monitoring is included which again comes with a set of very different requirements.

Not all of the individual requirements listed in subsections below are equally relevant. A classification into 'required' and 'optional' is still in progress.

3.4.1. Power State Monitoring

The power state of a device or component typically can only have a small number of discrete values such as, for example, full power, low power, standby, hibernating, off. However, some of these states may have one or more sub-states or state parameters. For example, in low power state, a reduced clock rate may be set to a large number of different values. For the device power state, the following information is considered to be relevant:

- o the current state - the time of the last change
- o the cause for the last transition
- o time to transit from one stage to another
- o the total time spent in each state
- o the duration of the last period spent in each state
- o the number of transitions to each state
- o the current power source

For some network management tasks it may be desirable to receive notifications from devices when components or the entire device change their power state.

3.4.2. Energy Consumption Monitoring

Independent of the power state, energy consumption of a device or a device's component is a quantity for which the value may change continuously. Therefore, the information that needs to be retrieved concerning this quantity is quite different:

- o the current real power (energy consumption rate) averaged over a short time interval
- o total energy consumption
- o energy consumption since the last report or for the last configured time interval
- o total energy consumption per power state
- o energy consumption per power state since the last report

For some network management tasks it may be desirable to receive notifications from devices when the current power consumption of a component or of the entire device exceeds or falls below certain thresholds.

Energy consumption of a device or a device's component is a quantity for which the value may change continuously. For some network management tasks it is required to measure the power over time with a relatively high time resolution. In such a case not just single values for the current power of a component is needed, but a series of power values reporting on consecutive time intervals.

In order to put measured data into perspective, the precision of the measured data, i.e. the potential error in the measured data, needs to be known as well.

3.4.3. Power Quality

In addition to the quantity of power or energy, also power quality should be reported according to IEC 62053-22 and IEC 60044-1.

3.4.4. Battery State Monitoring

An increasing number of networked devices are expected to be battery powered. This includes e.g. smart meters that report meter readings and are installed in places where external power supply is not always possible or costly. But also other devices might have internal/external batteries to power devices for short periods of time when the main power fails, to power parts of the device when the main device is switches off etc. Knowing the state of these batteries is important for the operation of these devices and includes information such as:

- o the current charge of the battery
- o the age of the battery
- o the state of the battery (e.g. being re-charged)
- o last usage of the battery
- o maximum energy provided by the battery

It is possible for devices that are only battery-powered 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 for the age of a battery.

4. Monitoring Models

Monitoring of power states and energy consumption can be performed in pull mode (for example, SNMP GET [RFC3410]) or in push mode (for example SNMP notification [RFC3410], Syslog [RFC5424], or IPFIX [RFC5101]).

Pull mode monitoring is often easier to handle for a network management systems, because it can determine when it gets certain information from a certain device. However, the overhead of pull model monitoring is typically higher than for push model monitoring, particularly when large numbers of values are to be collected, such as time series of power values.

In such cases, push model monitoring may be preferable with a device sending a data stream of values without explicit request for each value from the network management system. For notifications on events, only the push model is considered to be appropriate.

Applying these considerations to the required information leads to the conclusion that most of the information can appropriately be reported using the pull model. The only exceptions are notifications on power state changes and high volume time series of energy consumption values.

5. Control Requirements

To realize the envisioned benefits of energy savings, just monitoring power states and energy consumption would not be sufficient. Energy efficiency can be realized only by setting the network entities or components to energy saving power states when appropriate.

With means for power state control, energy saving policies and control loops can be realized. Policies may, for example, define different power state settings based on the time-of-day. Control loops may, for example, change power states based on actual network load.

Trivially, all entities being subject of energy management should have at least two power states, such as "on" and "off" or "on" and "sleep" to be set. In many cases, it may be desirable to have more operational ("on" mode) and non-operational ("off"/"sleep" mode) power states. This applies particularly to devices with a lot of configuration parameters that influence their energy consumption. Examples for specifications of power states of managed devices can be found in the Advanced Configuration and Power Interface (ACPI) [ACPI.R30b] or the DMTF Power State Management Profile [DMTF.DSP1027].

6. Existing Standards

This section analyzes existing standards for energy consumption and power state monitoring. It shows that there are already several standards that cover some part of the requirements listed above, but even all together they do not cover all of the requirements for energy management.

6.1. Existing IETF Standards

There are already RFCs available that address a subset of the requirements.

6.1.1. ENTITY STATE MIB

RFC 4268 [RFC4268] defines the ENTITY STATE MIB module. Implementations of this module provide information on entities including the standby status (hotStandby, coldStandby, providingService), the operational status (disabled, enabled, testing), the alarm status (underRepair, critical, major, minor, warning), and the usage status (idle, active, busy). This information is already useful as input to policy decisions and for other network monitoring tasks. However, the number of states would

cover only a small subset of the requirements for power state monitoring and it does not provide means for energy consumption monitoring. For associating the provided information to specific components of a device, the ENTITY STATE MIB module makes use of the means provided by the ENTITY MIB module [RFC4133]. Particularly, it uses the entPhysicalIndex for identifying entities.

The standby status provided by the ENTITY STATE MIB module is related to power states required for energy management, but the number of states is too restricted for meeting all energy management requirements. For energy management several more power states are required, such as different sleep and operational states as defined by the Advanced Configuration and Power Interface (ACPI) [ACPI.R30b] or the DMTF Power State Management Profile [DMTF.DSP1027].

6.1.2. ENTITY SENSOR MIB

RFC 3433 [RFC3433] defines the ENTITY SENSOR MIB module. Implementations of this module offer a generic way to provide data collected by a sensor. A sensor could be an energy consumption meter delivering measured values in Watt. This could be used for reporting current power of a device and its components. Furthermore, the ENTITY SENSOR MIB can be used to retrieve the precision of the used power meter.

Similar to the ENTITY STATE MIB module, the ENTITY SENSOR MIB module makes use of the means provided by the ENTITY MIB module [RFC4133] for relating provided information to components of a device.

However, there is no unit available for reporting energy quantities, such as, for example, watt seconds or kilowatt hours, and the ENTITY SENSOR MIB module does not support reporting accuracy of measurements according to the IEC / ANSI accuracy classes, which are commonly in use for electric power and energy measurements. The ENTITY SENSOR MIB modules only provides a coarse-grained method for indicating accuracy by stating the number of correct digits of fixed point values.

6.1.3. UPS MIB

RFC 1628 [RFC1628] defines the UPS MIB module. Implementations of this module provide information on the current real power of devices attached to an uninterruptible power supply (UPS) device. This application would require identifying which device is attached to which port of the UPS device.

UPS MIB provides information on the state of the UPS network. The MIB module contains several variables identify the UPS entity (name,

model,...), the battery state, to characterize the input load to the UPS, to characterize the output from the UPS, to indicate the various alarm events. The measurements of power in UPS MIB are in Volts, Amperes and Watts. The units of power measurement are RMS volts, RMS Amperes and are not based on Entity-Sensor MIB [RFC3433].

6.1.4. POWER ETHERNET MIB

Similar to the UPS MIB, implementations of the POWER ETHERNET MIB module defined in RFC3621 [RFC3621] provide information on the current energy consumption of the devices that receive Power over Ethernet (PoE). This information can be retrieved at the power sourcing equipment. Analogous to the UPS MIB, it is required to identify which devices are attached to which port of the power sourcing equipment.

The POWER ETHERNET MIB does not report power and energy consumption on a per port basis, but can report aggregated values for groups of ports. It does not use objects of the ENTITY MIB module for identifying entities, although this module existed already when the POWER ETHERNET MIB modules was standardized.

6.1.5. LLDP MED MIB

The Link Layer Discovery Protocol (LLDP) defined in IEEE 802.1ab is a data link layer protocol used by network devices for advertising of their identities, capabilities, and interconnections on a LAN network. The Media Endpoint Discovery (MED) (ANSI/TIA-1057) is an enhancement of LLDP known as LLDP-MED. The LLDP-MED enhancements specifically address voice applications. LLDP-MED covers 6 basic areas: capabilities discovery, LAN speed and duplex discovery, network policy discovery, location identification discovery, inventory discovery, and power discovery.

6.2. Existing standards of other bodies

6.2.1. DMTF

The DMTF has defined a power state management profile [DMTF.DSP1027] that is targeted at computer systems. It is based on the DMTF's Common Information Model (CIM) and rather a device profile than an actual energy consumption monitoring standard.

The power state management profile is used to describe and to manage the power state of computer systems. This includes e.g. means to change the power state of a device (e.g. to shutdown the device) which is an aspect of but not sufficient for active energy management.

7. Suggested Actions

Based on the analysis of requirements in Section 3 and the discussion of monitoring models in Section 4 this memo proposes to develop a standard for pull-based monitoring of power states, energy consumption, and battery states. The analysis of existing MIB modules in the previous section shows that they are not sufficient to meet the requirements discussed in Section 3.

As a consequence, it suggested to develop one or more MIB modules for this purpose. Such MIB modules could also cover push-based reporting of power state changes using SNMP notifications. The only aspect that would not be covered well by a MIB/SNMP solution is the reporting of large time series of energy consumption values. For this purpose SNMP does not appear to be an optimal choice. Particularly for supporting smart meter functionality, a push-based protocol appears to be more appropriate. Within the IP protocol family the Syslog and IPFIX protocols seem to be the most suitable candidates. There are more standard protocols with the capability to transfer measurement series, for example, DIAMETER, but these protocols are designed and well suited for other application areas than network monitoring.

Comparing the two candidates (Syslog and IPFIX), IPFIX seems to be the better suited one. While Syslog is optimized for the transmission of text messages, IPFIX is better equipped for transmitting sequences of numerical values. Encoding numerical values into syslog is well feasible, see, for example, the mapping of SNMP notifications to Syslog messages in [RFC5675], but IPFIX provides better means. With the extensible IPFIX information model [RFC5102] no protocol extension would be required for transmitting energy consumption information. Only a set of new information elements would need to be registered at IANA. However, this memo suggests that the definition of such information elements should be conducted within the IETF and they should be documented in a standards track RFC.

8. Acknowledgements

The authors would like to thank Ralf Wolter, for his first essay on this draft.

9. Security Considerations

This memo currently does not impose any security considerations.

10. IANA Considerations

This memo has no actions for IANA..

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Abstract

The Energy Management (EMAN) framework will work on the management of energy-aware devices. In this document we describe the applicability of the EMAN framework for a variety of applications. We show how network elements and applications can use EMAN, describe the relevant information elements (IEs) for those applications and present opportunities and limitations. We furthermore describe relations of the EMAN framework to other architectures and frameworks.

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1. Introduction

The EMAN framework defines how Energy information can be retrieved, controlled and monitored from IP-enabled consumers. EMAN is to be need as a generic method of accessing this information, as traditional methods such as SNMP have proved not be sufficient.

In this document, we describe typical applications of the EMAN framework, we will show opportunities and limitations of the framework. Furthermore, we describe other standards that are close to EMAN but addresses different needs or users. Applications of EMAN

EMAN will enable heterogeneous energy consumers to report their own consumption, and will enable external system to control them. There are multiple scenarios where this is desirable, particularly today considering the increased importance of limiting our own carbon footprint and reducing operational expenses.

1.1. Energy Measurement

Over time, more and more devices will be able to report their own energy consumption. Smart power strips and some Power-over-Ethernet switches are already able to consumption of the connected devices (proxies). Unfortunately, alone, this information is not really useful and will be better leveraged on a global system where the global power can be metered properly, in real time.

One aspect of EMAN is to enable this reporting by providing a standard framework applicable to various devices, consumers or proxy devices.

Being able to know who's consuming what, when and how at any time by leveraging existing networks, and across various equipment is one pillar of the EMAN framework.

1.2. Energy Control

There are many cases where reducing energy consumption is desirable, such as when the demand is already high, when there's no one using the resource, and so on.

In some cases, you can't simply turn it off. For instance you cannot turn off all phones, because some still need to be available in case of emergency. You can't turn cooling off totally, but you can reduce the comfort level, and so on.

In other cases, there are intermediate power levels between off and on, such as standby, sleep or deep sleep mode.

The EMAN framework will provide a control mechanism that is generic for all devices, power states, and allows for fine-grained priority control, and emergency function.

1.3. Examples

1.3.1. Building Networks

Buildings are big energy consumers, and companies are looking into ways to reduce their energy consumption, as well as to react positively in case of emergency, such as a risk of blackout.

The EMAN framework will enable building owners to control their own consumption and, unlike a meter, to break it down to who's consuming what and when.

Laptops, air conditioning, phone, desktops, lighting and so on will all be metered and controlled using the EMAN framework. EMAN can, for instance, act as a communication protocol between a presence system to deactivate the cooling and phones when there's no one on the floor.

1.3.2. Home Energy Gateways

Home Energy Gateways are devices with remote metering capabilities, and will let service providers and utility companies respond to demand by varying pricing according to time of usage.

Within a home network, it is desirable to schedule tasks that can wait to a later time, provided it will be cheaper. For instance, it really does not matter when the dishwasher runs as long as it is done for the next day at the cheapest price.

Using the EMAN framework, the HEG will know that some appliances are waiting to be activated and based on pricing or other indicators may take the decision to trigger those appliances.

1.3.3. Datacenters

Datacenters too are big energy consumers. All that equipment generates heat, and heat needs to be evacuated through a HVAC system. Reducing the datacenter consumption means slowing down or turning off equipment and cooling.

Most organizations will target datacenter initially because the problem is centralized logically and physically, and a lot of money is involved in such projects. Some don't because datacenters are usually operated 24/7 and mission-critical.

A data center spend 50% of its energy on cooling, 37% on IT infrastructure, 10% on electrical conversion loss, and 3% on lighting. [PARELLO]

Within the IT infrastructure, energy consumption breakdown for datacenter is 45% for computing, 40% for storage and 15% for networking. [PARELLO]

The EMAN framework will enable that level of control by providing a unified means of communication between heterogeneous devices over a network.

1.3.4. Smart Power Strips

Smart Power Strips are power strips with communication capability to remotely enable / disable a particular plug, and sometimes to measure power consumption.

Those strips are currently supporting either their own proprietary protocol, or at best SNMP, but EMAN will provide a framework that has been specifically designed for this purpose.

2. Relation of EMAN to Other Frameworks and Technologies

EMAN as a framework is tied with other standards and efforts in the area. We will try to re-use existing standards as much as possible, as well as providing control to adjacent technologies such as Smart Grid.

We have listed most of them with a brief description of what is their objective and the current state.

2.1. IEC

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

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

This set of standards is oriented to the substation. An electrical substation is a subsidiary station of an electricity generation, transmission and distribution system where voltage is transformed from high to low or the reverse using transformers. While the domain of 61850 is substation automation, the extensive model that resulted has been widely used in other areas, including Energy Management Systems (EMS) and forms the core of many Smart Grid standards.

2.2. ISO

The ISO is developing an Energy Management framework called ISO 50001. The intent of the framework is to facilitate the creation of energy management programs for industrial, commercial and other entities. The standard defines a process for energy management at a an organization level. It is not expected to define the way in which devices report energy and consume energy. The IETF effort would be complementary.

"The future ISO 50001 standard for energy management was recently approved as a Draft International Standard (DIS).

ISO 50001 will establish a framework for industrial plants, commercial facilities or entire organizations to manage energy. Targeting broad applicability across national economic sectors, it is estimated that the standard could influence up to 60% of the world's energy use.

The document is based on the common elements found in all of ISO's management system standards, assuring a high level of compatibility with ISO 9001 (quality management) and ISO 14001 (environmental management). ISO 50001 will provide the following benefits:

- A framework for integrating energy efficiency into management practices
- Making better use of existing energy-consuming assets
- Benchmarking, measuring, documenting, and reporting energy intensity improvements and their projected impact on reductions in greenhouse gas (GHG) emissions
- Transparency and communication on the management of energy resources
- Energy management best practices and good energy management behaviors
- Evaluating and prioritizing the implementation of new energy-efficient technologies
- A framework for promoting energy efficiency throughout the supply chain
- Energy management improvements in the context of GHG emission reduction projects.

ISO 50001 is being developed by ISO project committee ISO/PC 242, Energy management. The secretariat of ISO/PC 242 is provided by the partnership of the ISO members for the USA (ANSI) and Brazil (ABNT). Forty-two ISO member countries are participating in its development, with another 10 as observers.

Now that ISO 50001 has advanced to the DIS stage, national member bodies of ISO have been invited to vote and comment on the text of the standard during the five-month balloting period.

If the outcome of the DIS voting is positive, the modified document will then be circulated to the ISO members as a Final Draft International Standard (FDIS). If that vote is positive, ISO 50001 is expected to be published as an International Standard by early 2011."

<http://www.iso.org/iso/pressrelease.htm?refid=Ref1337>

2.3. 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), measurement accuracy (C12.20). European equivalent standards are provided by the IEC.

ANSI C12.20 defines accuracy classes for watt-hour meters. Typical accuracy classes are class 0.5, class 1, and class 3; which correspond to +/- 0.5%, +/- 1% and +/- 3% accuracy thresholds.

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

2.4. EnergyStar US EPA

The US Environmental Protection Agency and US Department of Energy jointly sponsor the Energy Star program. The program promotes the development of energy efficient products and practices.

Energy Star approved appliances in the home or business must meet specific energy efficiency targets set by the EPA and US Department of Energy. The Energy Star program also provides planning tools and technical documentation to help homeowners design more energy efficient homes. Energy Star is a program; it's 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. The rating system can be used for benchmarking against other buildings.

http://www.energystar.gov/index.cfm?c=about.ab_history

2.5. DMTF

The DMTF continues to develop and enhance its standardized management solutions that include full power-state configuration and management of any heterogeneous managed environment.

Currently there are two primary specifications that would address or benefit EMAN-like behavior, they are listed below. Both specifications are fully extensible to meet any existing physical, logical or virtual system management requirements specific to power-state control.

Through various Working Group efforts these specifications continue to evolve and advance in features and functionalities. Both specifications can be found at the DMTF web site:

<http://www.dmtf.org>

The DMTF uses CIM-based (Common Information Model) 'Profiles' that extend the management capabilities of referencing profiles and managers to represent and manage power utilization and configuration of any managed element.

The key 'Profile' is titled and labeled 'Power Utilization Management Profile' DSP 1085.

The Profile defines via configuration of the Power Managed Element power utilization modes, capping values and levels, among other features.

Included in the Profile is the power management service that represents the behavior of the power utilization management modes and related classes of a Power Managed Element. Systems that support power management modes are capable of operating at, and being controlled at, different rates of power consumption. This management profile allows full span of control for this behavior.

Power capping functions of any managed element is also included behavior and is part of the active management capabilities that is based on dynamic and static configuration features for system operation.

2.5.1. Desktop And Mobile Architecture for System Hardware (DASH)

The DMTF has addressed the challenges of managing heterogeneous desktop and mobile systems (including power) via in-band and out-of-band environments.

The DMTF has produced the DASH (Desktop and Mobile Architecture for System Hardware) specifications as a solution.

Based on the DMTF's WS-Management and CIM (Common Information Model) the solution provides for a standardized and comprehensive framework

that delivers the syntax and semantics necessary to manage and control (among other things) configuration and consumption of managed elements like power, CPU etc.

Through the use of the common syntax and semantics the creation of an API / Interface set is realized.

The DASH specification is DSP0232.

Both in service and out-of-service systems can be managed with the DASH specification in a fully secured remote environment.

Full power-state management is afforded by DASH including full 'remote control' of the state of any managed device through a full power lifecycle.

2.6. SmartGrid

The Smart Grid standards efforts underway in the United States are overseen by the US National Institute of Standards and Technology [NIST]. NIST was given the charter to oversee the development of smart grid related standards by the Energy Independence and Security Act of 2007. NIST is responsible for coordinating a public-private partnership with key energy and consumer stakeholders in order to facilitate the development of smart grid standards.

The smart grid standards activity (sponsored and hosted by NIST) is monitored and facilitated by the SGIP (Smart Grid Interoperability Panel). This group has several sub groups called working groups. These teams examine smaller parts of the smart grid. They include B2G, I2G, and H2G and others (Building to Grid; Industrial to Grid and Home to Grid).

<http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/SGIPWorkingGroupsAndCommittees>

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). The PAP is a private-public partnership with a charter to close a specific gap. There are currently 17 Priority Action Plans (PAP).

PAP 10 Addresses "Standard Energy Usage Information".

According to the PAP website, "Customers will benefit from standardized energy usage information that enables them to make better decisions and take other actions consistent with the goals of

Sections 1301 and 1305 of EISA. An understanding of energy usage informs better decisions about energy use and conservation, and is the basis for performance feedback on the operation of customer owned energy management systems and understanding device energy usage and management.

Some states have already mandated customer access to meter-based usage information. As part of this action plan a limited set of requirements are driving a specification.

Subsequent work will drive a standardized information model for broader exchange of usage information. This model for cross-domain interaction needs the characteristics of integration models as described elsewhere in this document."

2.7. NAESB, ASHRAE and NEMA

As an output of the PAP10's work on the standard information model, multiple stakeholders agreed to work on a utility centric model in NAESB (North American Electric Standards Board) and the building side information model in a joint effort by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and National Electrical Manufacturers Association (NEMA).

The NAESB effort is a NAESB REQ/WEQ.
http://www.naesb.org/smart_grid_PAP10.asp

The ASHRAE effort is SPC201. <http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP17Information>

The output of both ANSI approved SDO's is an information model. It is not a device level monitoring protocol.

After the ASHRAE SPC201 group formed as a result of initial work done by the PAP 10, the SGIP added PAP17 in order to focus specifically on in-building standards for energy using devices.

PAP 17 "will lead to development of a data model standard to enable energy consuming devices and control systems in the customer premises to manage electrical loads and generation sources in response to communication with the Smart Grid. It will be possible to communicate information about those electrical loads to utilities, other electrical service providers, and market operators.

The term "Facility Smart Grid Information" is intended to convey the nature of critical information originating from the customer

operated "facility" which deals with the representation and dynamics of loads including prediction, measurement and shedding. It also helps to distinguish between this PAP and that of PAP10 which deals exclusively with the representation of energy usage.

This data model standard will complement the flow, aggregation, summary, and forecasting of energy usage information being standardized by NAESB in PAP10 through the definition of additional distinct model components. While the NAESB standard is focusing on "a single limited-scope information model" that "will not cover all interactions associated with energy in the home or commercial space" including, for example, load management ("Report to the SGIP Governing Board: PAP10 plan," June 15, 2010), these new components will address load modeling and behavior necessary to manage on-site generation, demand response, electrical storage, peak demand management, load shedding capability estimation, and responsive energy load control."

<http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP17FacilitySmartGridInformationStandard>

2.8. ZigBee

The "Zigbee Smart Energy 2.0 effort" currently focuses on wireless communication to smart home appliances. It is intended to enable home energy management and direct load control by utilities.

ZigBee protocols are intended for use in embedded applications requiring low data rates and low power consumption. ZigBee's current focus is to define 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.

It is not known if the Zigbee Alliance plans to extend support of SEP 2.0 to business class devices. There also does not appear to be a plan for context aware marking.

Zigbee is currently not an ANSI recognized SDO-but they are working toward formal recognition.

3. Limitations

EMAN will address the needs of the network operators both in term of measurement and control over IP networks. Other protocols may

already exists (ModBus), but are not designed initially to work on IP, even if in some cases it is possible to transport them over IP with some limitations.

The EMAN framework does not aim to address questions regarding Smartgrid, Electricity producers, distributors even if there is obvious link between them.

4. Security Considerations

The whole context of energy management has brought a lot of attention from the security experts, particularly since SmartGrid is often depicted as a big security risk.

To a more limited extent, the EMAN framework may suffer the same security risk, more specifically when the notion of "control" is being used. No one wants to jeopardize the service's stability by letting hacker shut down critical equipment.

Multiple mechanisms and solutions can be envisioned, and this is what others have been doing in this area:

4.1. SmartGrid

Even if discussing SmartGrid security is not the scope of this document, NIST has found at least five standards that are directly related to smart grid security. That includes standards from NERC, IEEE, AMI System Security Requirements, UtilityAMI Home Area Network System Requirements and IEC standards.

The SmartGrid security issue is more difficult being actually an open network, spawning entire territories and devices from smart meters, secondary and primary sub stations, etc...

EDITOR'S NODE: TO BE EXPANDED

4.2. Cisco EnergyWise

EnergyWise security uses secret shared secret in a layer fashion. Devices within a layer share the same password, and devices talking to upper / lower layers also know the password. The password can be made more resistant against replay and man-in-the-middle attacks by incorporating a time-of-day component as part of it.

5. IANA Considerations

This memo includes no request to IANA.

6. References

6.1. Normative References

6.2. Informative References

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[NIST] <http://www.nist.gov/smartgrid/>

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