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M. Chandramouli
Cisco Systems, Inc.
B. Schoening
Independent Consultant
J. Quittek
T. Dietz
NEC Europe Ltd.
B. Claise
Cisco Systems, Inc.

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Power and Energy Monitoring MIB
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Status of this Memo

Abstract

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

Conventions used in this document

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

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OPEN ISSUES:

. The UUID is per box, not per port. So, for example, n the figure 5, the switch port should have pmPowerMonId of 1000, and not 1003 as displayed in the draft. This is a problem. The UUID must be unique within the component inside box.

```
| ============================================================|
|                                                             |
|                          SWITCH PORT                        |
| =========================================================== |
| | Switch   | Switch    | Switch         | Switch      | Switch    |
| | Port     | Port      | Port           | Port        | Port    | |
| | pmPIndex| pmPhyIdx | pmPowerMonId | pmParentId | pmPower| |
| =========================================================== |
| |    3     |    12     | UUID 1003      | UUID 1000   |    12   | |
| =========================================================== |
|                                   ^                         |
|                                   |                         |
|-----------------------------------|-------------------------|
```

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 [EMAN-FRAMEWORK], which in turn, is based on the Power Monitoring Requirements [EMAN-REQ] .

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

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

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

2. The Internet-Standard Management Framework

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

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

3. Use Cases

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

5. Architecture Concepts Applied to the MIB Module

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

5.1 Power Monitor Information

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

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 States

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

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

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

When a Power Monitor requires a mapping with the Manufacturer Power State, the Power Monitor configuration is done via the Power State settings, and not directly via the Manufacturer

Power States, which are read-only. The actual Power State is specified by the pmPowerActualState MIB object, while the pmPowerState MIB object specifies the Power State requested for the Power Monitor. A difference in values between the pmPowerState and pmPowerActualState indicates that the Power Monitor is busy going into the pmPowerState, at which point it will update the content of pmPowerActualState.

The MIB object pmPowerState and pmPowerManufacturerMappingId are contained in the pmTable MIB table.

The pmPowerStateTable table enumerates the maximum power usage in watts, for every single supported Power State of each Power Monitor. In addition, PowerStateTable provides additional statistics: powerStateEnterCount, the number of times an entity has visited a particular power state, and powerStateTotalTime , the total time spent in a particular power state.

The pmPowerStateMappingTable table enumerates the maximum power usage in watts, for every single Manufacturer Power State. Furthermore, this table maps the Manufacturer Power States to the Power States specified in this document (more specifically with the PowerMonitorState textual convention). Finally, this table returns the name of each Manufacturer Power State. In addition, the possible reason for change in power state (due to NMS or CLI) is reported in pmPowerStateEnterReason.

5.3 Power Monitor Usage Measurement

Refer to the "Power Monitor Usage Measurement" section in [EMAN-FRAMEWORK] 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 pmPowerStatePowerUnitMultiplier, 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. There may be devices in the network, which may not be able to measure or report power consumption. For those devices, the object pmPowerMeasurementCaliber shall report that measurement mechanism is "unavailable" and the pmPower measurement shall be "0".

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 [EMAN-FRAMEWORK] 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 pmPowerIndex 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 pmPowerIndex 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 [EMAN-FRAMEWORK] 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: pmEnergyTable and pmEnergyParametersTable. The pmEnergyParametersTable table consists of parameters defining the duration of the demand intervals in seconds, (pmEnergyParametersIntervalLength), the number of demand intervals kept in the pmEnergyTable, (pmEnergyParametersIntervalNumber), the type of demand intervals (pmEnergyParametersIntervalMode), and a sample rate used to calculate the average (pmEnergyParametersSampleRate). Judicious choice of the SamplingRate will ensure accurate measurement of power while not imposing an excessive polling burden.

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

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

- The horizontal axis represents the current time, with the symbol <--- L ---> expressing the pmEnergyParametersIntervalLength, and the pmEnergyIntervalStartTime is represented by S1, S2, S3, S4, ..., Sx where x is the value of pmEnergyParametersIntervalNumber.

- The vertical axis represents the time interval of sampling and the value of pmEnergyIntervalEnergyUsed can be obtained at the end of the sampling period. The symbol =========== denotes the duration of the sampling period.

```
         |             |             | =========== |
         |============ |             |             |
         |             |             |             |
         |             |============ |             |
         |             |             |             |
         | <--- L ---> | <--- L ---> | <--- L ---> |
         |             |             |             |
        S1            S2            S3             S4
```

Figure 1 : Period pmEnergyParametersIntervalMode

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

```
                  |============ |
                  |             |
                  | <--- L ---> |
                  |             |
                  |   |============ |
                  |   |             |
                  |   | <--- L ---> |
                  |   |             |
                  |   |   |============ |
                  |   |   |             |
                  |   |   | <--- L ---> |
                  |   |   |             |
                  |   |   |   |============ |
                  |   |   |   |             |
                  |   |   |   | <--- L ---> |
                 S1   |   |   |             |
                      |   |   |             |
                      |   |   |             |
                     S2   |   |             |
                          |   |             |
                          |   |             |
                         S3   |             |
                              |             |
                              |             |
                             S4
```

Figure 2 : Sliding pmEnergyParametersIntervalMode

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

```
                     |                           |
                     |========================== |
                     |                           |
                     |                           |
                     |                           |
                     |  <--- Total length --->   |
                     |                           |
                   S1
```

Figure 3 : Total pmEnergyParametersIntervalMode

A pmEnergyParametersIntervalMode type of 'total' specifies a continuous measurement since the last reset. The value of pmEnergyParametersIntervalNumber should be (1) one and pmEnergyParametersIntervalLength is ignored.

The pmEnergyParametersStatus is useful to specify that the energy measurement is actual and thus to indicate if the pmEnergyTable 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.

Measurements of the total energy consumed by an Power Monitor may suffer from interruptions in the continuous measurement of the current energy consumption. In order to indicate such interruptions, object pmEnergyIntervalDiscontinuityTime is provided for indicating the time of the last interruption of total energy measurement. pmEnergyIntervalDiscontinuityTime shall indicate the sysUpTime when the device was reset.

The following example illustrates the pmEnergyTable and pmEnergyParametersTable:

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

The indices in the pmEnergyTable are pmPowerIndex, 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 (pmEnergyParametersIntervalLength) based on the Power Monitor internal sampling rate (pmEnergyParametersSampleRate). While choosing the values for the pmEnergyParametersIntervalLength and pmEnergyParametersSampleRate, 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 pmEnergyIntervalEnergyUsed. 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 pmEnergyTable has a buffer to retain a certain number of intervals, as defined by pmEnergyParametersIntervalNumber. If the default value of "10" is kept, then the pmEnergyTable 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

RFC’EDITOR NOTE: Power consumption of battery enabled devices can be obtained from ... (draft to be posted by Juergen Quittek).

5.7 Fault Management

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

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.

Scenario 1: Switch with PoE Endpoints

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: pmPowerIndex "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 pmPowerIndex "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 pmPowerIndex "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   | Switch    | Switch         | Switch      | Switch   | |
| |pmPIndex| pmPhyIdx | pmPowerMonId | pmParentId | pmPower  | |
| ============================================================ |
| |   1    |     2     | UUID 1000    |    null    |   440    | |
| ============================================================ |
|                                                               |
|                            SWITCH PORT                        |
| ============================================================ |
| | Switch   | Switch    | Switch        | Switch      | Switch   | |
| | Port     | Port      | Port          | Port        | Port     | |
| | pmPIndex| pmPhyIdx | pmPowerMonId | pmParentId | pmPower | |
| ============================================================ |
| |    3     |    12     | UUID 1003    | UUID 1000  |    12    | |
| ============================================================ |
|                               ^                               |
|                               |                               |
|-------------------------------|---------------------------- |
                                |
                                |
                  POE IP PHONE  |
                                |
==============================================================
| IP phone| IP phone | IP phone          | IP phone  | IP phone|
| pmPIndex| 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 pmPowerIndex (pmPIndex) 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  |
| pmPIndex  | pmPhyIdx  | pmPowerMonId  | pmParentId  | pmPower |
| ============================================================= |
|     1     |    2      | UUID 1000     |    null     |   440   |
| ============================================================= |
|                                                               |
|                            SWITCH PORT                        |
| ============================================================= |
| | Switch   | Switch     | Switch        | Switch      | Switch   |
| | Port     | Port       | Port          | Port        | Port   | |
| | pmPIndex| pmPhyIdx  | pmPowerMonId  | pmParentId  | pmPower  | |
| ============================================================= |
| |    3     |    12      | UUID 1003     | UUID 1000   |    12  | |
| ============================================================= |
|                                    ^                          |
|                                    |                          |
|-----------------------------------|--------------------------|
                                    |
                                    |
                  POE IP PHONE      |
                                    |
```

```
                                       |
   =============================================================
   | IP phone | IP phone |IP phone        |IP phone   |IP phone|
   | pmPIndex  | pmPhyIdx |pmPowerMonitorId|pmParentID |pmPower |
   ============================================================
   |   31     |     0   | UUID 2003     | UUID 1000   |   12   |
   ============================================================
                                        |
                                        |
   PC connected to switch via IP phone  |
                                        |
   =============================================================
   | PC      | PC       |PC               |PC         | PC         |
   |pmPIndex| pmPhyIdx|pmPowerMonitorId|pmParentID| pmPower    |
   ============================================================
   | 57      |    0   |  UUID 3003     | UUID 1000 |   120      |
   =============================================================
```

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 pmPowerIndex "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 pmPowerIndex "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, pmPowerIndex "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 pmPowerIndex 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 pmPowerIndex 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  | Switch    | Switch         | Switch      | Switch  |
|  pmPIndex| pmPhyIdx  | pmPowerMonId   | pmParentId  | pmPower |
| ============================================================  |
|     1    |     2     |   UUID 1000    |    null     |   440   |
| ============================================================  |
|                                                               |
|                             SWITCH PORT                       |
| ============================================================  |
| | Switch   | Switch    | Switch         | Switch      | Switch  | |
| | Port     | Port      | Port           | Port        | Port    | |
| | pmPIndex| pmPhyIdx | pmPowerMonId | pmParentId | pmPower | |
| ============================================================  |
| |    3     |    12     |   UUID 1003    |  UUID 1000 |    20   | |
| ============================================================  |
|                                                ^              |
|                                                |              |
|-----------------------------------------------|--------------|
                                                 |
                  POE Wireless Access Point      |
                                                 |
                                                 |
==============================================================
| WAP      | WAP      |  WAP           | WAP         | WAP     |
| pmPIndex | pmPhyIdx |  pmPowerMonId  | pmParentID  | pmPower |
==============================================================
|   47     |     0    |  UUID 2004     | UUID 1000   |   20    |
==============================================================
                                        .
```

```
                                            .
                                            .
                                            .
      PC1 connected to WAP                  .
                                            .
```

PC pmPIndex	PC pmPhyIdx	PC pmPowerMonitorId	PC pmParentID	PC pmPower
53	0	UUID 3004	UUID 1000	120

```
                                            .
                                            .
      PC2 connected to WAP                  .
                                            .
```

PC pmPIndex	PC pmPhyIdx	PC pmPowerMonitorId	PC pmParentID	PC pmPower
58	0	UUID 4004	UUID 1000	120

Figure 6: Scenario 3

Scenario 4: Network Connected Facilities Gateway

```
              ------
              | NMS |
              |     |
              ------
                |
                |
                |
             ========================(IP Network)
                      ^
                      | North side interface
                      |
                ----------------------
                |   Building Gateway   |
                |                      |
```

```
                ----------------------
                  |               | Ethernet Interface
         RS-232/  |               |
         RS-438   |               | MODBUS, BACNET, etc...
                  |               |
               ---------          |  --------
       HVAC    | Cont  |          |  | Cont |   UPS
-------------- | roll  |          |--| roll |---------
   |        |  | er 1  |          |  | er 3 |  |
   |        |  ---------          |  --------  |
<meter2> <meter1> |               |        <meter5>
                  |               |
                  |               |
              --------            |  -------
   Lighting   | Cont |            |  | Cont |  Electrical
 ------------ | roll |            |--| roll |------------
    |       | | er 2 |            |  | er 4 |   |       |
    |       | --------            |  -------    |       |
<meter3> <meter4>                            <meter6> <meter7>
```

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. Tthe power measurement collected is therfore 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 state, then the MIB should be implemented at the controller state.

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 pmPowerIndex 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 pmPowerIndex "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 pmPowerIndex "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   | Mediat    | Mediat         | Mediat    | Mediat  |
| pmPIndex | pmPhyIdx  | pmPowerMonId   | pmParentId|pmPower |
|========================================================= |
|    7     |    None   | UUID 1000      |    Null   | 2500  |
|========================================================= |
                                                       |
  -------------------------------------------------------
  |
  |
  |=> Controller 1
  ==========================================================
  | Cntrl1  | Cntrl1    | Cntrl1      | Cntrl1       | Cntrl1  |
  | pmPIndex| pmPhyIdx  |pmPowerMonId|pmParentID     | pmPower |
  |=========================================================|
  |   707   |    0      |  UUID 5007 | UUID 1000     | 2000    |
  |==========================================================
  |
  |
  |===>Controller 2
  ==========================================================
```

Cntrl2 pmPIndex	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 pmPowerIndex "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 pmPowerIndex "3", pmPhysicalEntity is "12", and pmPowerMonitorId is "UUID 1003". Switch port 2 has pmPowerIndex "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 pmPowerIndex 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 pmPowerIndex 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  | Switch   | Switch        | Switch      | Switch   | |
| |pmPIndex| pmPhyIdx | pmPowerMonId  | pmParentId  | pmPower  | |
| ============================================================= |
| |   1    |    2     | UUID 1000     |    null     |   440    | |
| ============================================================= |
|                                                               |
|                                                               |
|                           SWITCH PORT 1                       |
| ============================================================= |
| | Switch   | Switch    | Switch        | Switch      | Switch |
| | Port1    | Port1     | Port1         | Port1       | Port1  |
| | pmPIndex| pmPhyIdx  | pmPowerMonId  | pmParentId  | pmPower |
| ============================================================= |
| |   3      |    12     | UUID 1003     | UUID 1000   |   NULL ||
| ============================================================= |
|                                                               |
|                           SWITCH PORT 2                       |
| ============================================================= |
| | Switch   | Switch    | Switch        | Switch      | Switch |
| | Port2    | Port2     | Port2         | Port2       | Port2  |
| | pmPIndex| pmPhyIdx  | pmPowerMonId  | pmParentId  | 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 |
|  | pmPIndex| 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 |
      | pmPIndex| 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.

```
   |---------------------------------------------------------------|
   |                            Switch                             |
   |===============================================================|
   |  Switch   | Switch    | Switch        | Switch      | Switch   |
   |  pmPIndex| pmPhyIdx  | pmPowerMonId  | pmParentId  | pmPower  |
   | ============================================================= |
   |     1    |     2     | UUID 1000     |    null     |   440    |
   | ============================================================= |
   |                                                               |
   |                         SWITCH PORT                           |
   | ============================================================= |
   | | Switch   | Switch    | Switch        | Switch      | Switch   |
   | | Port     | Port      | Port          | Port        | Port    | |
   | | pmPIndex| pmPhyIdx  | pmPowerMonId  | pmParentId  | pmPower | |
   | ============================================================= |
```

```
   | |    3    |    12    |               | UUID 1000  |     0   | |
   | ============================================================== |
   | |    4    |    13    |               | UUID 1000  |     0   | |
   | ============================================================== |
   |                                  ^                             |
   |                                  |                             |
   |----------------------------------|-----------------------------|
                                      |
                                      |
             PDU #1  (no children)    |
                                      |
                                      |
   ==============================================================
   | PDU      | PDU      |PDU             |PDU         | Meter  |
   | pmPIndex | pmPhyIdx |pmPowerMonitorId|pmParentID  |pmPower |
   =============================================================
   |  1       |    1    | UUID 2001       | null       | 3000   |
   =============================================================
                                       |
                                       |
             PDU #2  (with children)_  |
                                       |
   ==============================================================
   | PDU      | PDU      |PDU             |PDU         | Meter  |
   | pmPIndex | pmPhyIdx |pmPowerMonitorId|pmParentID  |pmPower |
   =============================================================
   |  1       |    1     | UUID 3001      | null       |   600  |
   |  2       |    2     | UUID 3002      | null       |  1000  |
   |  3       |    3     | UUID 3003      | null       |   800  |
   ==============================================================
```

Figure 11: Scenario 6

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.

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

Scenario 8: Power Consumption of Battery-Based Devices

RFC’EDITOR NOTE: Power consumption of battery enabled devices can be obtained from ... (draft to be posted by Juergen Quittek).

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 state states of networking equipment, and functionality to configure the power state states.

When this MIB module is used to monitor the power usage of devices like routers and switches, the ENTITY MIB and ENTITY-SENSOR MIB SHOULD be implemented. In such cases, the 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 pmPowerUnitMultipler 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 pmPowerIndex MIB object has been kept as the unique Power Monitor index. The pmPower is similar to entPhySensorValue [RFC3433] and the pmPowerUnitMultipler is similar to entPhySensorScale.

7.2. Link with the ENTITY-STATE MIB

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

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

7.3. Link with the POWER-OVER-ETHERNET MIB

Power-over-Ethernet MIB [RFC3621] provides an energy monitoring and configuration framework for power over Ethernet devices.

The RFC introduces a concept of a port group on a switch to define power monitoring and management policy and does not use the entPhysicalIndex as the index. Indeed, the pethMainPseConsumptionPower is indexed by the pethMainPseGroupIndex, which has no mapping with the entPhysicalIndex.

One cannot assume that the Power-over-Ethernet MIB is implemented for all 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 pmPowerIndex 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).

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

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

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 pmEnergyTable to describe energy information over time.

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

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,
    Integer32, Counter64, TimeTicks
        FROM SNMPv2-SMI
    TEXTUAL-CONVENTION, DisplayString, RowStatus, TimeInterval
      FROM SNMPv2-TC
    MODULE-COMPLIANCE, NOTIFICATION-GROUP, OBJECT-GROUP
        FROM SNMPv2-CONF
    OwnerString
        FROM RMON-MIB;

powerMonitorMIB MODULE-IDENTITY
    LAST-UPDATED    "201103140000Z"
    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
            "201103140000Z"
        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


   PowerMonitorState ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
   "An enumerated integer value that represents the value of the
   power policy state, a current power setting at which a Power
   Monitor uses power.

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

   An entity may have fewer power states than twelve and would then
   map several policy states to the same power state.  Entities
```

with more than twelve states, would choose which twelve to represent as power policy states.

Note that Power Monitor Parents MUST report some of the nonoperational Power States of their Power Monitor Children who are unable to report their Power State. 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 state even when in a non-operational state.

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

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 state 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 state 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 state G1, S4 in ACPI.

sleep(4) : No entity features are available, except for out-of-band management, for example wake-up mechanisms. The time for

```
                       availability is longer than standby(5).
                       An example for state sleep(4) is a save-
                       to-RAM state, where DRAM context is
                       maintained.  Typically, energy
                       consumption is close to zero. This
                       corresponds to state G1, S3 in ACPI.

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

         ready(6)    : No entity features are available, except
                       for out-of-band management, for example
                       wake-up mechanisms. This mode is
                       analogous to hot-standby.  The entity can
                       be quickly transitioned into an
                       operational state.  For example,
                       processors are not executing, but
                       processor context is maintained. This
                       corresponds to state G1, S1 in ACPI.

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

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

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

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

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



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

           Note that unknown(0) is not a Power State as such, but
           simply an indication that the Power State 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),     -- 10^0
           kilo(3),      -- 10^3
           mega(6),      -- 10^6
           giga(9),      -- 10^9
           tera(12),     -- 10^12
           peta(15),     -- 10^15
           exa(18),      -- 10^18
           zetta(21),    -- 10^21
           yotta(24)     -- 10^24
       }

   -- Objects


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


   pmPowerEntry OBJECT-TYPE
       SYNTAX          PmPowerEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "An entry describes the power usage of a Power Monitor."
       INDEX           { pmPowerIndex }
       ::= { pmPowerTable  1 }

  PmPowerEntry ::= SEQUENCE {
           pmPowerIndex                    Integer32,
           pmPower                         Integer32,
           pmPowerNameplate                Integer32,
           pmPowerUnitMultiplier           UnitMultiplier,
           pmPowerAccuracy                 Integer32,
           pmPowerMeasurementCaliber       INTEGER,
           pmPowerCurrentType              INTEGER,
           pmPowerOrigin                   INTEGER,
           pmPowerState                    PowerMonitorState,
           pmPowerActualState              PowerMonitorState,
```

```
           pmPowerManufacturerActualPowerState    Integer32,
           pmPowerManufacturerMappingId           Integer32,
           pmPowerStateEnterReason         OwnerString
     }

   pmPowerIndex OBJECT-TYPE
       SYNTAX          Integer32 (0..2147483647)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION

         "A unique value, for each Power Monitor.
         If an implementation of the ENERGY AWARE MIB module is
         available in the local SNMP context, then the same index
         as the one in the ENERGY AWARE MIB MUST be assigned for
         the identical Power Monitor. In this case, entities
         without an assigned value for pmIndex cannot be indexed
         by the pmPowerStateTable.

         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 entPhysicalIndex
         cannot be indexed by the pmPowerStateTable.

         If neither the ENERGY AWARE MIB module nor of the ENTITY
         MIB module are 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 pmPowerIndex 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 modules have been chosen for
         providing entity identities, Power States 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."

       ::= { pmPowerEntry 1 }

   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 specfied 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 state specified
          by pmPowerState.

          The pmPowerMeasurementCaliber object specifies how the
          usage value reported by pmPower was obtained. The pmPower
          value must report 0 if the pmPowerMeasurementCaliber is
          'unavailable'.  For devices that can not measure or
          report power, this option can be used."
       ::= { pmPowerEntry 2 }


   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 3 }

   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 4 }

   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
          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 5 }


   pmPowerMeasurementCaliber   OBJECT-TYPE
       SYNTAX          INTEGER  {
                           unavailable(1) ,
                           unknown(2),
                           actual(3) ,
                           estimated(4),
                           presumed(5)                   }
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object specifies how the usage value reported by
          pmPower was obtained:

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

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

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

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

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

     ::= { pmPowerEntry 6 }

   pmPowerCurrentType 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 7 }

   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 8 }

   pmPowerState OBJECT-TYPE
       SYNTAX          PowerMonitorState
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION
           "This object specifies the Power State (0..12) requested
           for the Power Monitor.  The pmPowerState values increase
           with the power consumption.
           If the Power Monitor is unable to report its Power
           State, it must report the value unknown(0).  Note that
           unknown(0) is not a Power State as such, but simply an
           indication that the Power State is unknown."
       ::= { pmPowerEntry 9  }

   pmPowerActualState OBJECT-TYPE
       SYNTAX          PowerMonitorState
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object specifies the current Power State (0..12)
           for the Power Monitor. If the Power Monitor is unable to
           report its Power State, it must report the value
           unknown(0).  Note that unknown(0) is not a Power State
           as such, but simply an indication that the Power State
           is unknown."
       ::= { pmPowerEntry 10  }

   pmPowerManufacturerActualPowerState     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 State for the Power Monitor.
           If the Manufacturer Power State is not defined, the
           pmPowerManufacturerActualPowerState will report 0. If
           the Power Monitor is unable to report its Manufacturer
           Power State, it must report the value 0."
    ::= { pmPowerEntry 11   }

    pmPowerManufacturerMappingId OBJECT-TYPE
```

```
       SYNTAX          Integer32 (1..1000)
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION
           "This object specifies the actual Manufacturer Power
           State mapping ID for the Power Monitor. The
           pmPowerManufacturerMappingId points to the
           pmPowerStateMappingTable, which maps the Manufacturer
           Power States versus the standard ones specified in the
           PowerMonitorState textual convention.  If the
           Manufacturer Power State mapping is not defined, the
           pmPowerManufacturerMappingId will report 0. If the
           Power Monitor is unable to report its Manufacturer
           Power State mapping ID, it must report the value 0."
       ::= { pmPowerEntry 12   }

   pmPowerStateEnterReason OBJECT-TYPE
        SYNTAX     OwnerString
        MAX-ACCESS read-create
        STATUS     current
        DESCRIPTION
           "This string object describes the reason for the last
           power state transition into this power state.
           Alternatively, this string may contain with the entity
           that configured this Power Monitor to this Power
           State."
        DEFVAL { "" }
        ::= { pmPowerEntry 13 }


   pmPowerStateTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF PmPowerStateEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table enumerates the maximum power usage, in watts,
          for every single supported Power State of each Power
          Monitor.

          This table has an expansion-dependent relationship on the
          pmTable, containing rows describing each Power State for
          the corresponding Power Monitor. For every Power Monitor
          in the pmTable, there is a corresponding entry in this
          table."
       ::= { powerMonitorMIBObjects 2 }


   pmPowerStateEntry OBJECT-TYPE
```

```
       SYNTAX          PmPowerStateEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "A pmPowerStateEntry extends a corresponding
          pmPowerEntry.  This entry displays max usage values at
          every single possible Power Monitor State supported by
          the Power Monitor.
          For example, given the values of a Power Monitor
          corresponding to a maximum usage of 11W at the
          state 1 (off), 6 (low), 8 (medium), 12 (full):

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

                   INDEX   {
                             pmPowerIndex,
                             pmPowerStateIndex


                           }
       ::= { pmPowerStateTable 1 }

   PmPowerStateEntry ::= SEQUENCE {
           pmPowerStateIndex                  PowerMonitorState,
           pmPowerStateMaxPower               Integer32,
           pmPowerStatePowerUnitMultiplier    UnitMultiplier,
           pmPowerStateTotalTime              TimeTicks,
           pmPowerStateEnterCount             Counter64

   }

   pmPowerStateIndex OBJECT-TYPE
       SYNTAX          PowerMonitorState
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This object indicates the state for which this entry
          describes the power usage."
       ::= { pmPowerStateEntry 1 }


   pmPowerStateMaxPower 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 State. This value is
          specified in SI units of watts with the magnitude of the
          units (milliwatts, kilowatts, etc.) indicated separately
          in pmPowerStatePowerUnitMultiplier. If the maximum power
          is not known for a certain Power State, then the value is
          encoded as 0xFFFF.

          For Power States not enumerated, the value of
          pmPowerStateMaxPower might be interpolated by using the
          next highest supported Power State."
       ::= { pmPowerStateEntry 2 }


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

   pmPowerStateTotalTime OBJECT-TYPE
       SYNTAX      TimeTicks
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
         "This object indicates the total time in hundreds
         of seconds that the Power Monitor has been in this power
         state since the last reset, as specified in the
         sysUpTime."
       ::= { pmPowerStateEntry 4 }


   pmPowerStateEnterCount OBJECT-TYPE
      SYNTAX      Counter64
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
         "This object indicates how often the Power Monitor has
         entered this power state, since the last reset of the
         device as specified in the sysUpTime."
```

```
      ::= { pmPowerStateEntry 5  }


   pmPowerStateMappingTable  OBJECT-TYPE
       SYNTAX          SEQUENCE OF PmPowerStateMappingEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table enumerates the maximum power usage, in watts,
          for every single Manufacturer Power State. This table
          also maps the Manufacturer Power States to the Power
          States specified in this document (more specifically, to
          the PowerMonitorState textual convention). Finally, this
          table returns the name of each Manufacturer Power State.
          For every different pmPowerManufacturerMappingId in the
          pmTable, there is a corresponding entry in this table."
       ::= { powerMonitorMIBObjects 3 }

   pmPowerStateMappingEntry  OBJECT-TYPE
       SYNTAX          PmPowerStateMappingEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "For every pmPowerManufacturerMappingId, this entry
          displays the max usage value at every single possible
          Manufacturer Power State supported by the Power Monitor,
          along with the mapping at the standardized Power State
          For example, given the values of a Power Monitor
          corresponding to a maximum usage of 0, 3, 7, and 11W at
          the state 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 States map to the
          lowest applicable Power States, so that setting all Power
```

```
          Monitors to a Power State would be conservative in terms
          of disabled functionality on the Power Monitor
          implementing the Manufacturer Power States."

            INDEX   {
                      pmPowerManufacturerMappingId,
                      pmPowerStateIndex,
                      pmManufacturerPowerState
                    }
        ::= { pmPowerStateMappingTable  1 }

   PmPowerStateMappingEntry  ::= SEQUENCE {
           pmManufacturerPowerState   Integer32,
           pmManufacturerPowerStateMaxPower  Integer32,
           pmManufacturerPowerStatePowerUnitMultiplier
                                             UnitMultiplier,
           pmManufacturerPowerStateName      DisplayString
   }

   pmManufacturerPowerState   OBJECT-TYPE
       SYNTAX          Integer32 (0..10000)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the Manufacturer Power States for
           the specific pmPowerManufacturerMappingId."
       ::= { pmPowerStateMappingEntry 1 }

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

   pmManufacturerPowerStatePowerUnitMultiplier  OBJECT-TYPE
```

```
       SYNTAX          UnitMultiplier
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "The magnitude of watts for the usage value in
          pmManufacturerPowerStateMaxPower ."
       ::= { pmPowerStateMappingEntry 3 }

   pmManufacturerPowerStateName   OBJECT-TYPE
       SYNTAX          DisplayString
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION
          "The textual name of the manufacturer name for the Power
          State specified by the pmManufacturerPowerState index. If
          there is no local name, or this object is otherwise not
          applicable, then this object contains a zero-length
          string."
       ::= { pmPowerStateMappingEntry 4 }

   pmEnergyParametersTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF PmEnergyParametersEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
      "Controls and configures the demand table
           pmEnergyTable."
       ::= { powerMonitorMIBObjects 4 }

   pmEnergyParametersEntry OBJECT-TYPE
       SYNTAX          PmEnergyParametersEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "An entry controls an energy measurement in
          pmEnergyTable."
       INDEX  { pmPowerIndex }
       ::= { pmEnergyParametersTable 1 }

   PmEnergyParametersEntry ::= SEQUENCE {
           pmEnergyParametersIntervalLength     TimeInterval,
           pmEnergyParametersIntervalNumber     Integer32,
           pmEnergyParametersIntervalMode       Integer32,
           pmEnergyParametersIntervalWindow     TimeInterval,
           pmEnergyParametersSampleRate         Integer32,
           pmEnergyParametersStatus             RowStatus
   }
```

```
   pmEnergyParametersIntervalLength 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 pmEnergyTable 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 }
       ::= { pmEnergyParametersEntry 1 }

   pmEnergyParametersIntervalNumber OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
          "The number of demand intervals maintained in the
          pmEnergyTable table. Each interval is characterized by a
          specific pmDemandIntervalStartTime, used as an index in
          the the table pmEnergyTable 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 }
     ::= { pmEnergyParametersEntry 2 }

   pmEnergyParametersIntervalMode 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 pmEnergyTable
       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 pmEnergyParametersIntervalWindow.

         A mode of total(3) specifies non-periodic measurement.  In
         this mode only one interval is used as this is a
         continuous measurement since the last reset. The value of
         pmEnergyParametersIntervalNumber should be (1) one and
         pmEnergyParametersIntervalLength is ignored. "
      ::= { pmEnergyParametersEntry 3 }

   pmEnergyParametersIntervalWindow 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 pmEnergyTable
        table  This is valid only when the
        pmEnergyParametersIntervalMode is sliding(2). The
        pmEnergyParametersIntervalWindow value should be a multiple
        of pmEnergyParametersSampleRate."
          ::= { pmEnergyParametersEntry 4 }

   pmEnergyParametersSampleRate 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 pmEnergyTable.  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 pmEnergyParametersIntervalWindow is a multiple of
          pmEnergyParametersSampleRate."
        DEFVAL { 1000 }
       ::= { pmEnergyParametersEntry 5 }

   pmEnergyParametersStatus OBJECT-TYPE
       SYNTAX          RowStatus
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
         "The status of this row. The pmEnergyParametersStatus 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 pmEnergyTable will be deleted. The data can be
         destroyed by setting up the pmEnergyParametersStatus to
         destroy(2)."

       ::= {pmEnergyParametersEntry 6 }

   pmEnergyTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF PmEnergyIntervalEntry
       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 }

   pmEnergyIntervalEntry OBJECT-TYPE
       SYNTAX          PmEnergyIntervalEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "An entry describing energy measurements."

       INDEX  { pmPowerIndex, pmEnergyParametersIntervalMode,
   pmEnergyIntervalStartTime }

       ::= { pmEnergyTable 1 }

   PmEnergyIntervalEntry ::= SEQUENCE {
        pmEnergyIntervalStartTime            TimeTicks,
```

```
        pmEnergyIntervalEnergyUsed           Integer32,
        pmEnergyIntervalEnergyUnitMultiplier UnitMultiplier,
        pmEnergyIntervalMax                  Integer32,
        pmEnergyIntervalDiscontinuityTime    TimeTicks
   }

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

   pmEnergyIntervalEnergyUsed OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Watt-hours"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "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
          pmEnergyIntervalEnergyUnitMultiplier."
       ::= { pmEnergyIntervalEntry 2 }

   pmEnergyIntervalEnergyUnitMultiplier OBJECT-TYPE
       SYNTAX          UnitMultiplier
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object is the magnitude of watt-hours for the
          energy field in pmEnergyIntervalEnergyUsed."
       ::= { pmEnergyIntervalEntry 3 }

   pmEnergyIntervalMax OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Watt-hours"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
```

```
          "This object is the maximum demand ever observed in
          pmEnergyIntervalEnergyUsed 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
          pmEnergyIntervalEnergyUnits."
       ::= { pmEnergyIntervalEntry 4 }


    pmEnergyIntervalDiscontinuityTime OBJECT-TYPE
       SYNTAX      TimeTicks
       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. If no such
         discontinuities have occurred since the last re-
         initialization of the local management subsystem, then
         this object contains a zero value."
       ::= { pmEnergyIntervalEntry 5 }

   -- Notifications

   pmPowerStateChange NOTIFICATION-TYPE
       OBJECTS
   {pmPowerState,pmPowerManufacturerActualPowerState,
   pmPowerStateEnterReason}
       STATUS        current
       DESCRIPTION
           "The SNMP entity generates the PmPowerStateChange when
           the value(s) of pmPowerState and/or
          pmPowerManufacturerActualPowerState has changed for the
          Power Monitor represented by the pmPowerIndex."
      ::= { 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,
                   powerMonitorMIBStateTableGroup,
                   powerMonitorMIBStateMappingTableGroup,
                   powerMonitorMIBEnergyTableGroup,
                   powerMonitorMIBEnergyParametersTableGroup,
                   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,
                           powerMonitorMIBStateTableGroup,
                           powerMonitorMIBStateMappingTableGroup,
                           powerMonitorMIBNotifGroup
                       }

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

       ::= { powerMonitorMIBCompliances 2 }

   -- Units of Conformance

   powerMonitorMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                           pmPower,
                           pmPowerNameplate,
                           pmPowerUnitMultiplier,
                           pmPowerAccuracy,
                           pmPowerMeasurementCaliber,
                           pmPoweCurrentType,
```

```
                           pmPowerOrigin,
                           pmPowerState,
                           pmPowerActualState,
                           pmPowerManufacturerActualPowerState,
                           pmPowerManufacturerMappingId,
                           pmPowerStateEnterReason
                       }
               STATUS          current
       DESCRIPTION
           "This group contains the collection of all the objects
           related to the PowerMonitor."
       ::= { powerMonitorMIBGroups 1 }

      powerMonitorMIBStateTableGroup OBJECT-GROUP
               OBJECTS         {
                                   pmPowerStateMaxPower,

   pmPowerStatePowerUnitMultiplier,
        pmPowerStateTotalTime,
        pmPowerStateEnterCount
                               }
               STATUS          current
               DESCRIPTION
                   "This group contains the collection of all the
                   objects related to the Power State."
               ::= { powerMonitorMIBGroups 2 }


     powerMonitorMIBStateMappingTableGroup  OBJECT-GROUP
               OBJECTS         {
                      pmManufacturerPowerStateMaxPower,
                      pmManufacturerPowerStatePowerUnitMultiplier,
                      pmManufacturerPowerStateName
                       }
               STATUS          current
               DESCRIPTION
                    "This table enumerates the maximum power usage
                    in watts, for every single Manufacturer Power
                    State."
              ::= { powerMonitorMIBGroups 3 }


   powerMonitorMIBEnergyParametersTableGroup OBJECT-GROUP
       OBJECTS         {
                           pmEnergyParametersIntervalLength,
                           pmEnergyParametersIntervalNumber,
                           pmEnergyParametersIntervalMode,
                           pmEnergyParametersIntervalWindow,
```

```
                            pmEnergyParametersSampleRate,
                            pmEnergyParametersStatus
                        }
        STATUS          current
        DESCRIPTION
            "This group contains the collection of all the objects
            related to the configuration of the Demand Table."
        ::= { powerMonitorMIBGroups 4 }

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

                         pmEnergyIntervalEnergyUsed,
                         pmEnergyIntervalEnergyUnitMultiplier,
                         pmEnergyIntervalMax,
                         pmEnergyIntervalDiscontinuityTime
                        }
        STATUS          current
        DESCRIPTION
            "This group contains the collection of all the objects
            related to the Demand Table."
        ::= { powerMonitorMIBGroups 5 }

   powerMonitorMIBNotifGroup NOTIFICATION-GROUP
       NOTIFICATIONS    {
                            pmPowerStateChange
                        }
        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,
       mib-2,
       Integer32
          FROM SNMPv2-SMI
       MODULE-COMPLIANCE,
       OBJECT-GROUP
           FROM SNMPv2-CONF
       UnitMultiplier, pmPowerIndex
           FROM POWER-MONITOR-MIB
       OwnerString
           FROM RMON-MIB;

   powerQualityMIB MODULE-IDENTITY
       LAST-UPDATED    "201103140000Z"
       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
           "201103140000Z"
     DESCRIPTION
          "Initial version, published as RFC XXXX."

      ::= { mib-2 yyyyy }

   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 pmPowerIndex entities. It is a sparse
           extension of the pmPowerTable."
       ::= { 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
           61850-7-4 for non-phase measurements within the object
           MMUX."
       INDEX { pmPowerIndex }
       ::= { pmACPwrQualityTable 1 }

   PmACPwrQualityEntry ::= SEQUENCE {
       pmACPwrQualityConfiguration       INTEGER,
       pmACPwrQualityAvgVoltage          Integer32,
       pmACPwrQualityAvgCurrent          Integer32,
       pmACPwrQualityFrequency           Integer32,
       pmACPwrQualityPowerUnitMultiplier UnitMultiplier,
       pmACPwrQualityPowerAccuracy       Integer32,
       pmACPwrQualityTotalActivePower    Integer32,
       pmACPwrQualityTotalReactivePower  Integer32,
       pmACPwrQualityTotalApparentPower  Integer32,
       pmACPwrQualityTotalPowerFactor    Integer32,
       pmACPwrQualityThdAmpheres         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           "Ampheres"
       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
            "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 mesured 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-ampheres are equivalent units and
           may be combined.  IEC 61850-7-4 attribute 'TotVA'."
       ::= { pmACPwrQualityEntry 9 }

   pmACPwrQualityTotalPowerFactor OBJECT-TYPE
       SYNTAX          Integer32 (-10000..10000)
       UNITS           "hundredths of percent"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "A measured value ratio of the real power flowing to
           the load versus the apparent power. It is dimensionless
           and expressed here as a percentage value in 100ths of a
           percent. A power factor of 100% indicates there is no
           inductance load and thus no reactive power. Power
           Factor can be positive or negative, where the sign
           should be in lead/lag (IEEE) form.  IEC 61850-7-4
           attribute 'TotPF'."
       ::= { pmACPwrQualityEntry 10 }

   pmACPwrQualityThdAmpheres 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
        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
            pmPowerIndex 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 { pmPowerIndex, 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           "Ampheres"
       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 powwer.

           Note: Watts and volt-ampheres 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 }

   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 { pmPowerIndex, pmPhaseIndex}
       ::= { pmACPwrQualityDelPhaseTable 1}

   PmACPwrQualityDelPhaseEntry ::= SEQUENCE {
       pmACPwrQualityDelPhaseToNextPhaseVoltage      Integer32,
       pmACPwrQualityDelThdPhaseToNextPhaseVoltage   Integer32,
       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
          disortion 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
          disortion (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
       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 pmPowerIndex
          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 { pmPowerIndex, 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 ampheres 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"
       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 pmPowerIndex is NOT
                           -- included since it is not-accessible
                           pmACPwrQualityConfiguration,
                           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 pmPowerIndex 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 State."
       ::= { powerQualityMIBGroups  2 }

   powerACPwrQualityDelPhaseMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                       -- Note that object pmPowerIndex 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."
       ::= { powerQualityMIBGroups  3 }

   powerACPwrQualityWyePhaseMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                          -- Note that object pmPowerIndex 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 pmPowerState MAY disrupt the power settings of the different Power Monitors, and therefore the state of functionality of the respective Power Monitors.
- Unauthorized changes to the pmDemandControlTable MAY disrupt energy measurement in the pmEnergyTable 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. Contributors

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

John Parello

Rolf Winter

Dominique Dudkowski

13. 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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Authors' Addresses

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

Phone: +91 80 4426 3947
Email: moulchan@cisco.com

John Parello
Cisco Systems, Inc.
3550 Cisco Way
San Jose, California 95134
US

Phone: +1 408 525 2339

Email: jparello@cisco.com

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

Email: brad@bradschoening.com

Juergen Quittek (editor)
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-115
Email: quittek@neclab.eu

Thomas Dietz
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-128
Email: Thomas.Dietz@neclab.eu

Benoit Claise
Cisco Systems, Inc.
De Kleetlaan 6a b1
Diegem 1813
BE

Phone: +32 2 704 5622
Email: bclaise@cisco.com

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J. Parello
B. Claise
Cisco Systems, Inc.
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Energy-aware Networks and Devices MIB
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Status of this Memo

Abstract

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

Conventions used in this document

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

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OPEN ISSUES:

1. Length and format of PowerMonitorId. The pmPowerMonitorID should be a unique id that identfies the device in the universe. A UUID using RFC 4122 seems to suffice. However an x.509 certificate conforming to RFC 5280 could also be appropriate. We have specified the field as variable 16 bytes but would like feedback and consensus on the format that is appropriate.
2. Do we want separate tables, as depicted in figure 1, as opposed to a single pmTable?
3. Should the pmMgmtMacAddress, pmMgmtAddress, pmMgmtAddressType, and pmMgmtDNSName also be implemented for Power Monitor Parent?

1. Introduction

The EMAN standards provides network administrators with energy management. 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 [EMAN-FMWK], which in turn, is based on the Power Monitoring Requirements [EMAN-REQ].

This module's special focus is on monitoring energy-aware networks and devices. The module addresses device identification, context information, and 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 [RFC4133], even though ENTITY MIB compliance is not a requirement due to the variety and broad base of devices concerned with energy management.

1.1. Energy Management Document Overview

This document, which specifies the Energy-aware Networks and Devices MIB document is based on the Energy Management Framework [EMAN-FMWK], per the Energy Management requirements specified in [EMAN-REQ], which allows networks and devices to become energy aware.

The Power and Energy Monitoring MIB [EMAN-MON-MIB] contains the managed objects for monitoring of power states and energy consumption/production. The monitoring of power states includes: retrieving power states, properties of power states, current power state, power state transitions, and power state statistics. This MIB provides the detailed properties of the actual energy rate (power) and of accumulated energy, along with the power quality.

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

EDITOR’S NOTE: [EMAN-MON-MIB] and [EMAN-AS] are not EMAN working group documents. Hence, these references will be changed in the future.

2. The Internet-Standard Management Framework

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

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

3. Use Cases

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

4. Terminology

The definitions of basic terms like Energy Management, Energy Monitoring, "Power, Energy, and Energy Consumption", Power Monitor, Power Monitor Parent, Power Monitor Child, Power Monitor Meter Domain, Power Level, and Manufacturer Power Level, Nameplate Power, Power Proxy, Power Aggregator, Power Distributor can be found in the Power Management Architecture [EMAN-FMWK].

EDITOR’S NOTE: not sure if all terms will be used in the final version of the draft

EDITOR’S NOTE: [EMAN-FMWK] is an informational non normative reference. Is this fine?

5. Architecture Concepts Applied to the MIB Module

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

The following diagram shows the relationship of the identifying information.

```
                                 +-------------------------+
                                 | _Child Specific Info __ |
   +-------------------------+   |                         |
   |    Context Information  |   |  pmParentId             |
   | _______________________ |   |  pmParentProxyAbilities |
   |  pmRoleDescription      |   | _pmMgmtMacAddress       |
   |  pmKeywords             |   |  pmMgmtAddress          |
   |  pmImportance           |   |  pmMgmtAddressType      |
   |  pmCategory             |   |  pmMgmtDNSName          |
   +-------------------------+   +-------------------------+
             |                            |
             |                            |
             |                            |
             v                            v
     +-----------------------------------------+
     |  Power Monitor Information              |
     |_______________________________________  |
     | pmIndex                                 |
     | pmPowerMonitorId                        |
     | pmName                                  |
     | pmDomainName                            |
     | pmAlternateKey                          |
     +-----------------------------------------+
             ^
             |
             |
             |
   +-------------------------+
   |    Links to other MIBs  |
   | _______________________ |
   |  pmPhysicalEntity (*)   |
   |  pmEthPortIndex (**)    |
   |  pmEthPortGrpIndex (**) |
   |  pmLldpPortNumber (***) |
   +-------------------------+

     (*)   Link with the ENTITY MIB [RFC4133]
     (**)  Link with the Power over Ethernet MIB [RFC3621]
     (***) Link with LLDP MIBs [LLDP-MIB] [LLDP-MED-MIB]
```

Figure 1: MIB Objects Grouping

As displayed in figure 1, there are four different types of MIB objects in the ENERGY-AWARE-MIB module:

1) The Power Monitor Information. See Section 5.1 Power Monitor Information

2) The links to other MIB modules. See Section 5.2 Links to other MIB Modules
3) The Power Monitor Child specific information. See Section 5.3 Power Monitor Parent and Child
4) The Context Information. See Section 5.4 Power Monitor Context

5.1 Power Monitor Information

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

The Power Monitor information is specified in the MIB module pmTable table. Every Power Monitor 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 pmIndex is completed by the Power Monitor Universally Unique Identifier [RFC4122] in the pmPowerMonitorId MIB object.

5.1.1. Power Monitor Name

Every Power Monitor SHOULD have a printable name pmName. 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 [RFC4133] is supported), then the pmName SHOULD be identical to the entPhysicalName. The pmName SHOULD be unique in the Power Monitor Meter Domain. 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.

5.1.2. Power Monitor Meter Domain

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

When a Power Monitor Parent acts as a Power Aggregator or a Power Proxy, the Power Monitor Parent and its Power Monitor Child/Children MUST be a member of Power Monitor Meter Domain, specified by the pmDomainName MIB Object. The pmDomainName, which is part of the pmTable, is a read-write MIB object. Note that the Power Monitor MUST belong to a single 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.

5.1.3. Alternate Key

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

5.1.4. Persistence

In some situations, the Power Monitor information should be persistent across a reload. For example, in a static setup where a switch monitors a series of connected PoE phones, there is a clear benefit for the NMS if the pmIndex and all associated information persist, as it saves a network discovery. However, in other situations, such as a wireless access point monitoring the mobile user PCs, there is not much advantage to persist the Power Monitor Information. Therefore, a specific MIB object, the pmTablePersistence, enables and disables the persistence globally for all Power Monitors information in the ENERGY-AWARE-MIB MIB module.

5.2 Links to other MIB Modules

The Power Monitor MUST contain the 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 [RFC3621] 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 [LLDP-MIB].

5.3 Power Monitor Parent and Child

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

The pmParentId, pmParentProxyAbilities, pmMgmtMacAddress, pmMgmtAddress, pmMgmtAddressType, and pmMgmtDNSName MIB objects are specific to Power Monitor Children.

The Power Monitor Child MUST set the pmParentId content to its Power Monitor Parent pmIndex. In the case of Power Monitor Parent, the pmParentId MUST be set to the null string

The Power Monitor Child can indicate that it wants its Power Monitor Parent to proxy capabilities such as, energy reporting, power state configurations, non physical wake capabilities (such as WoL)), or any combination of capabilities. These capalities are indicated in the pmPArentProxyAbilities object. In the case of Power Monitor Parent, the pmParentProxyAbilities MUST be set to "none" (0).

Since the communication between the Power Monitor Parent and Power Monitor Child is out of the scope, a Power Monitor Child can have additional objects used for easier identification by the NMS: IP Address and DNS name. The MAC address is also provided as a way to identify the Power Monitor Child: this information is required, among other use case, by the wake on lan feature.

5.4 Power Monitor Context

Refer to the "Power Monitor Context" section in [EMAN-FMWK] 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 of the device. 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 [EMAN-FMWK].

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 [EMAN-FMWK], is specified in [EMAN-MON-MIB].

7. MIB Definitions

```
-- ************************************************************
--
--
-- 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, MacAddress, TruthValue
        FROM SNMPv2-TC
    MODULE-COMPLIANCE,
    OBJECT-GROUP
        FROM SNMPv2-CONF
    SnmpAdminString
        FROM SNMP-FRAMEWORK-MIB
    InetAddressType, InetAddress
       FROM INET-ADDRESS-MIB
    PhysicalIndexOrZero
       FROM ENTITY-MIB;



energyAwareMIB MODULE-IDENTITY
    LAST-UPDATED    "201103050000Z"
    ORGANIZATION    "IETF EMAN Working Group"
    CONTACT-INFO
       "WG Charter:
        http://datatracker.ietf.org/wg/eman/charter/

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

       Editors:
          John Parello
          Cisco Systems, Inc.
          3550 Cisco Way
          San Jose, California 95134
          US
          Phone: +1 408 525 2339
          Email: jparello@cisco.com
```

```
             Benoit Claise
             Cisco Systems, Inc.
             De Kleetlaan 6a b1
             Degem 1831
             Belgium
             Phone:  +32 2 704 5622
             Email: bclaise@cisco.com"

       DESCRIPTION
          "This MIB is used to monitor power and energy in
          devices."
       REVISION
           "201103050000Z"
       DESCRIPTION
          "Initial version, published as RFC XXXX."


      ::= { mib-2 xxxxx }

   energyAwareMIBNotifs OBJECT IDENTIFIER
       ::= { energyAwareMIB 0 }

   energyAwareMIBObjects OBJECT IDENTIFIER
       ::= { energyAwareMIB 2 }

   energyAwareMIBConform  OBJECT IDENTIFIER
       ::= { energyAwareMIB 3 }


   -- Textual Conventions

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

   -- Objects

   pmTablePersistence OBJECT-TYPE
       SYNTAX          TruthValue
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION
          "This object enables/disables persistence for
          all entries in the pmTable. A value of True enables the
          persistence, while a value of False disables the
          persistence."
       ::= { energyAwareMIBObjects 1 }


   pmTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF PmEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table lists Power Monitors."
       ::= { energyAwareMIBObjects 2 }


   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,
           pmMgmtMacAddress             MacAddress,
           pmMgmtAddressType            InetAddressType,
           pmMgmtAddress                InetAddress,
           pmMgmtDNSName                SnmpAdminString,
           pmAlternateKey               SnmpAdminString,
           pmKeywords                   PowerMonitorKeywordList,
           pmImportance                 Integer32,
           pmPowerCategory              INTEGER,
           pmParentId                   PowerMonitorId,
           pmParentProxyAbilities       BITS
   }

   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 [RFC4133].  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 [RFC4133] 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 [RFC4133] 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 }

   pmMgmtMacAddress OBJECT-TYPE
       SYNTAX          MacAddress
       MAX-ACCESS      read-only
```

```
       STATUS          current
       DESCRIPTION
          "This object specifies a MAC address of the Power
          Monitor. This object only applies to Power Monitor
          Children. For a Power Monitor Parent, the value SHOULD be
          set to the null string."
       ::= { pmEntry 10 }



   pmMgmtAddressType OBJECT-TYPE
       SYNTAX          InetAddressType
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
         "This object specifies the pmMgmtAddress type, i.e. an
         IPv4 address or an IPv6 address. This object only applies
         to a Power Monitor Children. For a Power Monitor only
         Parent, the value SHOULD be set to unknown(0)."
       ::= { pmEntry 11 }

   pmMgmtAddress OBJECT-TYPE
       SYNTAX          InetAddress
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object specifies the management address as an IPv4
          address or IPv6 address of Power Monitor. The IP address
          type, i.e. IPv4 or IPv6, is determined by the
          pmMgmtAddressType value. This object only applies to a
          Power Monitor Children. For a Power Monitor, the value
          SHOULD be set to the null string."
       ::= { pmEntry 12 }

   pmMgmtDNSName OBJECT-TYPE
       SYNTAX          SnmpAdminString
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object specifies the DNS name of the pmMgmtAddress.
          This object only applies to a Power Monitor Children. For
          a Power Monitor Parent, the value SHOULD be set to the
          null string."
       ::= { pmEntry 13 }

   pmAlternateKey OBJECT-TYPE
       SYNTAX          SnmpAdminString
```

```
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION
          "This object specifies a manufacturer defined string that
          can be used to identify the Power Monitor. Since Element
          Management Systems (EMS) and Network Management Systems
          (NMS) may need to correlate objects across management
          systems, this alternate key is provided to provide such a
          link. This optional value is intended as a foreign key or
          alternate identifier for a manufacturer or EMS/NMS to use
          to correlate the unique Power Monitor Id in other systems
          or namespaces. If an alternate key is not available or is
          not applicable then NULL should be returned."
       ::= { pmEntry 14 }

   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 15 }

   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 16 }

   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 17 }

   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.
          This object only applies to Power Monitor Children. When
          the Power Monitor is a Power Monitor Parent, the
          pmParentId value MUST be set to the null string.
          "
       ::= { pmEntry 18 }

   pmParentProxyAbilities OBJECT-TYPE
       SYNTAX          BITS {
                           none(0),
                           report(1),
                           configuration(2),
                           wakeonlan(3)
                       }
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object describes the capabilities of the Power
          Monitor Parent (represented by the pmParentId) for the
          Power Monitor Child, represented by the pmIndex. This
          object only applies to a Power Monitor Child.
          None (0) MUST be used when the Power Monitor represented
          by the pmIndex is a Power Monitor Parent, and no other
          bit can be set.
          Report(1) indicates that the Power Monitor Parent reports
          the usage for the Power Monitor Child.
          Configuration(2) indicates that the Power Monitor Parent
          can configure the Power Level for the Power Monitor
          Child.
          Wakeonlan(3) indicates that the Power Monitor Parent can
          wake up the Power Monitor Child, whatever the mechanism."
       ::= { pmEntry 19 }


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

        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
                            pmTablePersistence,
                            pmPowerMonitorId,
                            pmPhysicalEntity,
                            pmEthPortIndex,
                            pmEthPortGrpIndex,
                            pmLldpPortNumber,
                            pmName,
                            pmDomainName,
                            pmRoleDescription,
                            pmMgmtMacAddress,
                            pmMgmtAddressType,
                            pmMgmtAddress,
                            pmMgmtDNSName,
                            pmAlternateKey,
                            pmKeywords,
                            pmImportance,
                            pmPowerCategory,
                            pmParentId,
                            pmParentProxyAbilities
                        }
        STATUS          current
        DESCRIPTION
            "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 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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Authors' Addresses

Benoit Claise
Cisco Systems, Inc.
De Kleetlaan 6a b1
Diegem 1813
BE

Phone: +32 2 704 5622
Email: bclaise@cisco.com

John Parello
Cisco Systems, Inc.
3550 Cisco Way
San Jose, California 95134
US

Phone: +1 408 525 2339
Email: jparello@cisco.com

Network Working Group B. Claise
Internet-Draft J. Parello
Intended Status: Informational Cisco Systems, Inc.
Expires: September 14, 2011 B. Schoening
Independent Consultant
J. Quittek
NEC Europe Ltd.
March 14, 2011

Energy Management Framework
draft-ietf-eman-framework-01

Status of this Memo

Copyright Notice

Abstract

This document defines an energy management framework.

Table of Contents

OPEN ISSUES

- Agree on the terminology (Power Monitor agreed on the mailing list)
- How to model the battery in PC? What are the requirements?
- ENTITY-MIB:
  - o 1. could we solve the problems specified in draft-ietf-eman-requirements with the ENTITY-MIB?
    2. if yes, do we chose to do so?
- How many operational power states (series) do we need? If any?
- At some paces in this I-D there is support for devices producing power. However, this is not done consistently. Is a generator of electricity a power monitor? If we want to support generation, then we must check the entire document for consistency. The same applies if we just focus on consumption (usage). I tend to exclude generation, but include storage, such as batteries. Must wait for a definite requirements draft.
- Should implementation scenarios be incorporated in the framework draft or in the MIB module?
- Do we agree that the units should W, A, Wh, Ah, V, and not Joule and Coulombs? Proposal: the MIB variable uses W, A, Wh, Ah, V, and explain, if appropriate, how to convert into Joule/Coulomb.
- Identity table: If the UUID is per box, then we have an issue as we need it per port.

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

There is a need to apply Energy Management to all devices in communication networks. Target devices for this specification include (but are not limited to): hosts, servers, routers, switches, Power over Ethernet (PoE) endpoints, protocol gateways for building management systems, intelligent meters, home energy gateway, 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 powered devices or a power distribution unit with attached powered devices.

1.1. Energy Management Document Overview

The EMAN standards provides network administrators with energy management. This document specifies the framework, per the Energy Management requirements specified in [EMAN-REQ], which allow networks and devices to become energy aware.

Energy-aware Networks and Devices MIB document [EMAN-AWARE-MIB] allows the monitoring of energy-aware networks and devices, by addressing devices identification, context information, and relationship between reporting devices, remote devices, and monitoring probes.

The Power and Energy Monitoring MIB [EMAN-MON-MIB] contains the managed objects for monitoring of power states and energy consumption/production. The monitoring of power states includes: retrieving power states, properties of power states, current power state, power state transitions, and power state statistics. This MIB provides the detailed properties of the actual energy rate (power) and of accumulated energy, along with the power quality.

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

EDITOR'S NOTE: [EMAN-MON-MIB] and [EMAN-AS] are not EMAN working group documents. Hence, these references will be changed in the futureg.

2. Use Cases & Requirements

Requirements for power and energy monitoring for networking devices are specified in [EMAN-REQ]. The requirements in [EMAN-REQ] cover devices typically found in communications networks, such as switches, routers, and various connected endpoints. For a power monitoring framework 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 framework, the scope is broader than that specified in [EMAN-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.

Energy Management

Energy Management deals with assessing and influencing the consumption of energy in a network of powered devices. A typical objective of energy management is reducing the energy consumption in the network. This objective may conflict with other objectives of a general network management system, for example, with service level objectives.

Energy Monitoring

Energy Monitoring is a part of Energy Management. It deals with monitoring only and does not include influencing the consumption of energy.

Power, Energy, and Energy Consumption

Power is a rate of energy conversion. In scenarios relevant to energy management electrical energy is delivered to a device that "consumes" it by converting the energy.

Power and consumed energy are essential quantities for network management. Power can be an instantaneous value of the current energy conversion rate or an average value of instantaneous power over a time interval. Consumed energy, is the total energy converted by a powered device during a time interval.

The term 'Energy Consumption' is commonly used for both, for referring to the amount of consumed energy and also for referring to the process of consuming energy. In the first case it addresses consumed energy, in the second one it addresses power, typically an average power. In this document we use this ambiguous term for addressing both, power and consumed energy.

Power Monitor

A power monitor has access to energy-related information concerning powered devices and is able to report this information to energy management systems.

The power monitor may also provide information on identities and properties of powered devices to the management system.

A power monitor may store energy-related information and process it, for example, for aggregating information or for extracting statistics that are provided to the management system.

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 aggregate 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 aggregate data or proxy actions on behalf of the Power Monitor Child.

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 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 State

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

Manufacturer Power State

A Manufacturer Power State 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 States, we can use the Manufacturer Power States to enumerate and show the relationship between the implemented power settings and the Power State interface.

Nameplate Power

The Nameplate Power is the maximal electrical capacity that a component can support under electrical load testing. It is 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.
EDITOR’S NOTE: we should be referring to another SDO/reference.

3.1. Functional Entities

Power Proxy

A Power Proxy is a Power Monitor Parent that reports the power information on behalf of its Power Monitor Children. For example, because the Power Monitor Children are non IP devices, because they can’t report the power information themselves, or simply for scalability reasons.

Power Aggregator

A Power Aggregator is a Power Monitor Parent that aggregates the power information of its Power Monitor Children.

Power Distributor

A Power Aggregator supplies power to Power Monitors. Only in rare examples such as PoE is the Power Distributor a Power Monitor Parent.

4. Energy Management Reference Model

As displayed in the figure 1, the most basic energy reference model is composed of a Energy Management Systems (EMS) that manages, via SNMP, the power and energy information from Power Monitors. The Power Monitor returns information about the power consumption, the power states, the power quality, the energy usage, potentially the business context, and other information as described further.

```
                  +---------------+
                  |      EMS      |            -
                  +-----+---+-----+            |
                        |   |                  |
                        |   |                  |  S
              +---------+   +----------+       |  N
              |                        |       |  M
              |                        |       |  P
     +-----------------+     +--------+--------+  |
     | Power Monitor 1 |  ...| Power Monitor N |  |
     +-----------------+     +-----------------+  -
```

Figure 1: Basic Energy Management Model

As displayed in the figure 2, the advanced energy reference model manages the Power Monitor Parents. The Power Monitor Parents returns information for themselves and for any attached Power Monitor Children. The information returned is the same as in the basic energy management, plus some extra information about the relationship between Power Monitor Child and Power Monitor Parent.

```
                +---------------+
                |      EMS      |            -
                +-----+--+------+            |
                      |  |                   |
                      |  |                   |  S
         +------------+  +---------+         |  N
         |                         |         |  M
         |                         |         |  P
 +------------------+     +------+-----------+  |
 | Power Monitor    |     | Power Monitor    |  |
 | Parent 1         | ... | Parent N         |  -
 | Power Proxy      | ... | Power Proxy      |
 |(Power Aggregator)| ... |(Power Aggregator)|
 +------------------+     +------------------+
```

```
                   |||                    |
        (protocol  |||                    |
        out of     |||       +-------------+---------+
        the scope)|||------| Power Monitor Child 1 |
                   ||        +-----------------------+
                   ||
                   ||        +-------------+---------+
                   ||-------| Power Monitor Child 2 |
                   |         +-----------------------+
                   |
                   |
                   |--------           ...
                   |
                   |
                   |         +-------------+---------+
                   |--------| Power Monitor Child M |
                             +-----------------------+
```

Figure 2: Advanced Energy Management Model

This advanced energy management model is required when the scalability of managing all Power Monitor Children becomes an issue. In such as case, the Power Monitor Parent also acts as a Power Aggregator, i.e. an aggregation point for other subtended Power Monitor Children.
The advanced energy management model is also required when the Power Monitor Child doesn't speak the IP protocol. Indeed, the Power Monitor Parent may speak to a Power Monitor Child using a manufacturer selected protocol. In such a case, the Power Monitor Parent acts as a Power Proxy for protocol translation between the Power Monitor Parent and Child. Therefore, the protocol between the Power Monitor Parent and Power Monitor Children is out of scope of this document.

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 [EMAN-REQ], the Power Monitor Parents may export IPFIX Flow Records [RFC5101] to a Collector. However, the framework doesn't mandate it.

While both the basic and advanced energy management models (figure 1 and 2) contain a EMS, this architecture doesn't impose any requirements regarding the control, which could be centralized from the EMS, or distributing in the network.

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 IP devices energy-aware. If those devices don't support IP, then a Power Proxy acting as a protocol translation can be used.

The architecture makes the Energy Management System aware of power usage. . 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
- 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. In building management, the meter refers to the meter provided by the utility used for billing or rationing power to the entire building or unit in a building, while a sub-meter refers to a customer or user installed meter that is not used by the utility to bill but instead used to get readings from sub portions of a building.

Examples consists of building with a meter form utility with submeters installed for data center, HVAC and common areas.

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 the EMS.

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

When the Power State is set, a Power Monitor may be busy at the request time. The Power Monitor will set the desired state and then update the actual Power State when the priority task is finished. This mechanism implies two different Power State 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 Topologies: Metering versus Control versus Power Distribution

In a simple Power Proxy scenario, the Power Monitor Parent, which reports on the power state and power consumption of its Power Monitor Children, would also be controlling the Power States for its Power Monitor Children and would provide the power to the Power Monitor Children. A typical example is the PoE case, where a switch meters the power consumption, controls the power state, and also provides the power for the connected device. In this PoE case, the metering, control and power distribution topologies are overlapping. This case offers an extra advantage if the Power Monitor Child sends its own power consumption metering value to the Power Monitor Parent, as the Power Monitor Parent can compare two values and deduce the discrepancy such as line loss.

However, this ideal case is not the only situation.

In most cases, the Power Monitor Children communicates his power consumption to the Power Monitor Parent, while it receives its energy from a different source. A very simple example is a PC connected to a switch port, which receives his power from the outlet, or from its battery. Another example is the introduction of smart PDU in a datacenter, where the power distribution is a key aspect. In such cases, metering and power distribution are two distinct topologies. Note that the power distribution topology is also known as the power distribution tree. If the Power Monitor Child communicates its power consumption, it should have one and only Power Monitor Parent, so that there is no double counting in the Power Monitor Metering Domain.

In other cases, sub-meters may exist in a building or data center. These meters monitor the power consumption of one or more end devices. Since these meters are layered on an existing infrastructure, they subdivide the domain and might overlap. They are also distinct from the network control topology. An example would be a smart PDU metering the power consumption of a server in a data center, while the server applications could be moved to a different data center.

To summarize, all combinations of distinct or overlapping topologies exist: metering, configuration, and power source. The Power Monitor Metering Domain reflects the metering topology.

5.3. Power Monitor Meter Domain

When a Power Monitor Parent acts as a Power Aggregator or a Power Proxy, the Power Monitor Parent and its Power Monitor Child/Children must be a member of 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. The Power Monitor must belong to a single Power Monitor Meter Domain.

5.4. Power Monitor Parent and Child

When a Power Monitor Parent acts as a Power Aggregator or a Power Proxy, 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 in the Power Monitor Metering Domain. If a Power Monitor had two parents in the same Power Monitor Metering Domain, there would be a risk of double-reporting the power usage. 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.

5.5. Power Monitor Context

Monitored power data will ultimately be collected by and reported from an EMS. In order to aid in reporting and in differentiation between Power Monitors, each Power Monitor optionally contains information establishing its business or site context.

Importance Description

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

Keywords Description

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".

Another keyword use case is the virtual grouping of Power Monitors. For example, a Power Distribution Unit (PDU) that allows physical entities like outlets to be "ganged" together as a logical entity for simplified management purposes. This is particularly useful for servers with multiple power supplies, where each power supply is connected to a different physical outlet. Other implementations allow "gangs" to be created based on common ownership of outlets, such as business units or load shed priority or other non-physical relationships. For example, current PDU implementations allow for an "M-to-N" mapping between outlet "gangs" and physical outlets:

```
Outlet 1             (physical entity)
Outlet 2             (physical entity)
Outlet 3             (physical entity)
Outlet 4             (physical entity)
Outlet Gang A        (virtual entity)
Outlet Gang B        (virtual entity)

Gang A -> Outlets 1, 2 and 3
Gang B -> Outlets 3 and 4
```

Note the allowed overlap on Outlet 3, where Outlet 3 belongs to both "gangs." The keywords concept for this specific example would be used as such:

```
Outlet 1        Power Monitor 1, keywords: gangA
```

```
        Outlet 2        Power Monitor 2, keywords: gangA
        Outlet 3        Power Monitor 3, keywords: gangA, gangB
        Outlet 4        Power Monitor 4, keywords: gangB
```

Each "Outlet Gang" virtual entity, aggregated based on the value of the keywords, reports the aggregated data from the individual outlet entities that comprise it. The same concept enables a single point of control for all the individual outlet entities. For example, turning "Outlet Gang A" to the "off" state would turn outlets 1, 2, and 3 "off" in some implementations. Note that the impact of this action on "Outlet Gang B" is out of scope of this document.

Role Description

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.

5.6. Power Monitor States

Power States represent universal states of power management of a Power Monitor. Existing power state models can be roughly divided into operational and non-operational states. Examples of operational power state models include PoE power classes and Windows Power Polices. PoE negotiation may select a power level from one of four power classes: Very Low power (1), Low power (2), Mid power (3), and High power (4). Windows default power policy settings define three states: ’Power Saver’, ’Balanced’, and ’High Performance’. Windows allows user defined states, so many more states are possible. Some new devices starts to have several operational Power States: an IP phone with an High Power State and a lower operational Power State for the ability to only dial 911, IP surveillance cameras with different Power States depending on the image definition and sampling rate, etc...
It is foreseen that, with the goal to save energy, this trend will continue and many more devices will contain Power States.

ACPI and the DMTF Power State models define non-operational states for when a system is inactive. In our model, each Power State corresponds to a global, system, and performance state in the ACPI model [ACPI] and DMTF models.

State	DMTF Power State	ACPI State	MIB Power State Name
Non-operational states:			
1	Off-Hard	G3, S5	Mech Off
2	Off-Soft	G2, S5	Soft Off
3	Hibernate	G1, S4	Hibernate
4	Sleep-Deep	G1, S3	Sleep
5	Sleep-Light	G1, S2	Standby
6	Sleep-Light	G1, S1	Ready
Operational states:			
7	On	G0, S0, P5	LowMinus
8	On	G0, S0, P4	Low
9	On	G0, S0, P3	MediumMinus
10	On	G0, S0, P2	Medium
11	On	G0, S0, P1	HighMinus
12	On	G0, S0, P0	High

Figure 3: DMTF / ACPI Power State Mapping

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

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

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

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

Manufacturer Power State	Respective Name
0	none
1	short
2	tall
3	grande

4 venti

Figure 4: Mapping Example 1

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

Power State / Name	Manufacturer Power State / 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 States and the Power Monitor Power States is achievable, both series of states must exist in the MIB module in the Power Monitor Parent, allowing the EMS to understand the mapping between them by correlating the Power State with the Manufacturer Power States.

Power State / Name	Manufacturer Power State / 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 States are then mapped is an implementation choice. However, it is recommended that the Manufacturer Power States map to the lowest applicable Power States, so that setting all Power Monitors to a Power State 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 states. For the sake of the example, 100 operational states are assumed.

```
Power State / Name       Manufacturer Power State / 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 State, while configuring the Manufacturer Power State from the MIB directly is not possible.

5.7. Power Monitor Usage Measurement

A power measurement must 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 EMS. 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 EMS.

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 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. Electric energy is often billed in kilowatt-hours instead of megajoules from the SI units. Similarly, battery charge is often measured as miliamperes-hour (mAh) instead of coulombs from the SI units. The units used in this framework are: W, A, Wh, Ah, V. An conversion from Wh to Joule and from Ah to Coulombs is obviously possible, and can be described if required.

In addition to knowing the usage and magnitude, it is useful to know how 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 EMS can use this information to account for the accuracy and nature of the reading between different implementations.
The EMS can use the Nameplate Power for provisioning, capacity planning and potentially billing.

5.8. 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 Power Monitor Domains, the power quality may not be needed, available, or relevant to the Power Monitor.

5.9. Optional Energy Measurement

In addition to reporting the Power State, 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 a 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 EMS. 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.

5.10. Optional Battery Information

Some Power Monitors may use batteries for storing energy and for receiving power supply. These Power Monitors should report their current power supply (battery, power line, etc.) and the battery status for each contained battery. Battery-specific information to be reported should include the number of batteries contained in the device and per battery

- . battery type
- . nominal and remaining capacity
- . current charge
- . current state (charging, discharging, not in use, etc.)
- . number of charging cycles
- . expected remaining time that the battery can serve as power supply
- . expected remaining lifetime of the battery

Beyond that a device containing a battery should be able to generate alarms when the battery charge falls below a given threshold and when the battery needs to be replaced.

6. Structure of the Information Model: UML Representation

The following basic UML represents an information model expression of the concepts in this framework. This information model, provided as a reference for implementers, is represented as an MIB in the different related IETF Energy Monitoring documents. However, other programming structure with different data models could be used as well.

Notation is a shorthand UML with lowercase types considered platform or atomic types (i.e. int, string, collection). Uppercase types denote classes described further. Collections and cardinality are expressed via qualifier notation. Attributes labeled static are considered class variables and global to the class. Algorithms for class variable initialization, constructors or destructors are not shown

```
              POWER MONITOR RELATIONSHIPS AND CONTEXT

                                +-----------------------------+
                                | _Child Specific Info __     |
+---------------------------+   |                             |
|    Context Information    |   |  parentId : UUID            |
| _______________________   |   |  parentProxyAbilities       |
|                           |   |           : bitmap          |
|  roleDescription : string|    | _mgmtMacAddress : octets    |
|  keywords[0..n] : string |    |  mgmtAddress : inetaddress  |
|  importance : int         |   |  mgmtAddressType : enum     |
|  category :  enum         |   |  mgmtDNSName : inetaddress  |
+---------------------------+   +-----------------------------+
          |                             |
```

```
             |                             |
             |                             |
             v                             v
        +-----------------------------------------+
        |  Power Monitor Information              |
        |_______________________________________  |
        | index : int                             |
        | powerMonitorId | UUID                   |
        | name : string                           |
        | meterDomainName | string                |
        | alternateKey | string                   |
        +-----------------------------------------+
             ^
             |
             |
             |
      +-------------------------+
      |    Links Object         |
      | _______________________ |
      |  physicalEntity : int   |
      |  ethPortIndex : int     |
      |  ethPortGrpIndex : int  |
      |  lldpPortNumber : int   |
      +-------------------------+
```

POWER MONITOR AND MEASUREMENTS

```
      +---------------------------------------------+
      |            Power Monitor                    |
      | ___________________________________________ |
      |  nameplate : Measurement                    |
      |  battery[0..n]: Battery                     |
      |  measurements[0..n]: Measurement            |
      | ------------------------------------------- |
      | Measurement instantaneousUsage()            |
      | DemandMeasurement historicalUsage()         |
      +---------------------------------------------+
        +-----------------------------------+
        |  Measurements                     |
        | __________________________________|
        |                                   |
        +-----------------------------------+
                       ^
                       |
                       |
                       |
```

```
+-------------------+---------------------------+
|         PowerMeasurement                      |
| --------------------------------------------  |
| value : long                                  |
| rate : enum {0,millisecond,seconds,           |
|              minutes,hours,...}               |
| multiplier : enum {-24..24}                   |
| units : "watts"                               |
| caliber : enum { actual, estimated,           |
|                  trusted, assumed...}         |
| accuracy : enum { 0..10000}                   |
| current :  enum {AC, DC}                      |
| origin : enum { self, remote }                |
| time : timestamp                              |
| quality : MeasurementQuality                  |
+-----------------------------------------------+

+-----------------------------------------------+
|         TimeMeasurement                       |
| --------------------------------------------  |
| startTime : timestamp                         |
| usage : Measurement                           |
| maxUsage : Measurment                         |
+-----------------------------------------------+

+----------------------------------------+
|        TimeInterval                    |
|--------------------------------------- |
|value : long                            |
|units : enum { seconds, miliseconds..}  |
|                                        |
+----------------------------------------+

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

QUALITY

```
    +----------------------------------------+
    |       MeasurementQuality               |
    |----------------------------------------|
    |                                        |
    +----------------------------------------+
                       ^
                       |
                       |
    +------------------+--------------------+
    |         ACQuality                     |
    | --------------------------------------|
    | acConfiguration : enum {SNGL, DEL,WYE}|
    | avgVoltage   : long                   |
    | avgCurrent   : long                   |
    | frequency    : long                   |
    | unitMultiplier  : int                 |
    | accuracy  : int                       |
    | totalActivePower  : long              |
    | totalReactivePower : long             |
    | totalApparentPower : long             |
    | totalPowerFactor : long               |
    +---------+-----------------------------+
              | 1
              |
              |
              |
              |        +------------------------------------+
              |        |         ACPhase                    |
              |        | -----------------------------------|
              |     *  |                                    |
              +--------+ phaseIndex : long                  |
                       | avgCurrent : long                  |
                       | activePower : long                 |
                       | reactivePower : long               |
                       | apparentPower : long               |
                       | powerFactor : long                 |
                       +------------------------------------+
                                   ^           ^
                                   |           |
                                   |           |
                                   |           |
                                   |           |
   +-------------------------------+---+       |
   |        DelPhase                   |       |
   |--------------------------------   |       |
   |phaseToNextPhaseVoltage  : long    |       |
```

```
   |thdVoltage : long                  |       |
   |thdCurrent : long                  |       |
   |                                   |       |
   +-----------------------------------+       |
                                               |
                        +------------------+-----------+
                        |        WYEPhase              |
                        |----------------------------- |
                        |phaseToNeutralVoltage : long  |
                        |thdCurrent : long             |
                        |thdVoltage : long             |
                        |                              |
                        +------------------------------+
```

POWER MONITOR & STATES

```
      +----------------------------------------------+
      |         Power Monitor                        |
      |----------------------------------------------|
      | currentLevel : int                           |
      | configuredLevel : int                        |
      | configuredTime : timestamp                   |
      | reason: string                               |
      | manufacturerLevels[0..n]: State              |
      | emanLevels[0..11] : State                    |
      | levelMappings[0..n] : LevelMapping           |
      |                                              |
      +----------------------------------------------+

       +-------------------------------+
       |        State                  |
       | ------------------------------|
       | name : string                 |
       | cardinality : int             |
       | maxUsage : Measurement        |
       +-------------------------------+

      +-----------------------------------------------+
      |         Level Mapping                         |
      |-----------------------------------------------|
      | emanLevelIndex: int                           |
      | manufacturerLevelIndex : int                  |
      +-----------------------------------------------+
```

7. 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.
- Power Monitor Parent/Power Monitor Child relationships may be set by manual or automatic network configuration functions.

When a Power Monitor Child supports only its own Manufacturer Power States, the Power Monitor Parent will have to discover those Manufacturer Power States. 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 States discovery, which is protocol-specific.

8. 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 State: Specifies the current Power State (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.
- . Assigning a Power Monitor Parent to a Power Monitor Child
- . Assigning a Power Monitor Child to a Power Monitor Parent.

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

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

Other, already well established means for setting Power States, such as DASH [DASH], already exist. Such a protocol may be implemented between the Power Monitor Parent and the Power Monitor Child, when the Power Monitor Parent acts as a Power Proxy. Note that the Wake-up-on-Lan (WoL) mechanism allows to transition a device out of the Off Power State.

When a Power Monitor Parent is a Power Proxy, , the Power Monitor Parent should enumerate the capabilities it is providing for the Power Monitor Child. The child would express that it wants its parent to proxy capabilities such as, energy reporting, power state configurations, non physical wake capabilities (such as WoL)), or any combination of capabilities.

Note that for the communication between the Power Monitor Parent and Children the MIB modules and other communication means defined for this architecture may be used, but as well other proprietary protocols may be applied. This includes communication of power settings and configuration information, such as the Power Monitor Domain.

9. Fault Management

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

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.

- The power state definitions are based on the DMTF Power State Profile and ACPI models, with operational state extensions.

10.2. Power States

There are twelve Power Monitor States. 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 state [ACPI].

11. 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.

Each of the scenarios below is explained in more detail in the Power Monitor MIB document [EMAN-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 is supplied with 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 is supplied with 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.

Scenario 8: Power consumption of battery-based devices

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 state may disrupt the power settings of the different Power Monitors, and therefore the state 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).

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

13. IANA Considerations

This document has no actions for IANA.

14. Acknowledgments

The authors would like to Michael Brown for improving the text dramatically, and Bruce Nordman for his excellent feedback.

15. References

Normative References

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Authors' Addresses

Benoit Claise
Cisco Systems, Inc.
De Kleetlaan 6a b1
Diegem 1813
BE

Phone: +32 2 704 5622
Email: bclaise@cisco.com

John Parello
Cisco Systems, Inc.
3550 Cisco Way
San Jose, California 95134
US

Phone: +1 408 525 2339
Email: jparello@cisco.com

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

Phone:
Email: brad@bradschoening.com

Juergen Quittek
NEC Europe Ltd., Network Laboratories
Kurfuersten-Anlage 36
69115 Heidelberg
Germany

Phone: +49 6221 90511 15
EMail: quittek@netlab.nec.de

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J. Quittek, Ed.
R. Winter
T. Dietz
NEC Europe Ltd.
B. Claise
M. Chandramouli
Cisco Systems, Inc.
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Requirements for Energy Management
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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 but not limited to

- 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 or capacity 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

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 PoW 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.

2.9. Scenario 9: Ganged outlets on a smart power strip

Some PDUs allow physical entities like outlets to be "ganged" together as a logical entity for simplified management purposes. This is particularly useful for servers with multiple power supplies, where each power supply is connected to a different physical outlet. Other implementations allow "gangs" to be created based on common ownership of outlets, such as business units or load shed priority or other non-physical relationships.

Current implementations allow for an "M-to-N" mapping between outlet "gangs" and physical outlets. An example of this mapping includes the following:

```
Outlet 1             (physical entity)
Outlet 2             (physical entity)
Outlet 3             (physical entity)
Outlet 4             (physical entity)
Outlet Gang A        (virtual entity)
Outlet Gang B        (virtual entity)

Gang A -> Outlets 1, 2 and 3
Gang B -> Outlets 3 and 4
```

Note the allowed overlap on Outlet 3, where Outlet 3 belongs to both "gangs."

Each "Outlet Gang" entity reports the aggregated data from the individual outlet entities that comprise it and enables a single point of control for all the individual outlet entities. For example, turning "Outlet Gang A" to the "off" state would turn outlets 1, 2, and 3 "off" in some implementations. (The impact of this action on "Outlet Gang B" is to be defined by the equipment manufacturer.).

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 accuracy 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.

An open issue is modeling power states of devices that contain batteries. These devices can consume energy when turned off or to sleep mode, because in these modes they still can charge their batteries. Also thaey can be turned on without consuming any energy when running on battery. How to model these cases is currently under discussion in the eman working group. Anyway, it should be avoided that energy is accounted twice, once when the battery is charged and once when the device runs on battery.

3.4.5. Multiple Power Sources

Most devices have a single source of power only. But there are several devices, for example, highly reliable servers, that have two or more power sources. Dual power supply servers often receive power from two different PDUs in two different power distribution trees.

Some devices with multiple power sources use only one source at a time, while others make use of all sources at the same time. In any case, the total power of the device is given by the sum of power values at all supply lines of a device. However, in some scenarios individual reporting per power inlet is required.

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]).

The protocol choice for energy monitoring often depends on the characteristics and requirements of the network management application. It is important to note that no specific protocol mechanism has been explicitly mandated as a requirement for energy monitoring. A discussion of some of the use cases, and possible protocol candidates that can be considered for monitoring in those situations are presented.

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. Discovery

In order to measure and monitor the energy consumption of a network it is important to discover the network elements, the components of the network elements and the devices attached to the network. Since the required discovery protocol depends on the environment (full IP end-to-end devices, 6lowpan environments, non IP end devices, etc...), the discovery protocol is out of the scope of this requirement document. Note that there many well-known and widely deployed protocol options for network discovery for IP networks such as LLDP. Upon discovery, it must possible to measure the energy consumption of the entire network, a breakdown of the energy consumption of the components of the network elements and the energy consumption of the devices attached to the network.

5.1. Identification

Upon discovery of an entity within the network or attached to the network, it is important to identify the discovered entity uniquely. As an energy monitoring requirement, the identity of the discovered device should be unique within a management domain so that the correct device is monitored and possibly controlled. In addition to an unique ID, descriptive tags about the entity can be associated with the device. It is useful that this unique ID of the device is linked to the well-deployed MIBs if there exists an index for the device and the MIB has been implemented on the device. For example, the linking the unique with the index of the Entity MIB index or the Power over Ethernet MIB or the LLDP MIB would be useful.

6. 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].

7. 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.

7.1. Existing IETF Standards

There are already RFCs available that address a subset of the requirements.

7.1.1. ENTITY MIB

The ENTITY-MIB module defined in [RFC4133] was designed to model physical and logical entities of a managed system. A physical entity is an identifiable physical component. A logical entity can use one or more physical entities. From an energy monitoring perspective of a managed system, the ENTITY-MIB modeling framework can be reused and whenever RFC 4133 [RFC4133] has been implemented. The entPhysicalIndex from entPhysicalTable can be used to identify an entity/component. However, there are use cases of energy monitoring, where the application of the ENTITY-MIB does not seem readily apparent and some of those entities could be beyond the original scope and intent of the ENTITY-MIB.

Consider the case of remote devices attached to the network, and the network device could collect the energy measurement and report on behalf of such attached devices. Some of the remote devices such as PoE phones attached to a switch port have been considered in the Power-over-Ethernet MIB module [RFC3621]. However, there are many other devices such as a computer, which draw power from a wall outlet or building HVAC devices which seem to be beyond the original scope of the ENTITY-MIB.

Yet another example, is smart-PDUs, which can report the energy consumption of the device attached to the power outlet of the PDU. In some cases, the device can be attached to multiple to power outlets. Thus, the energy measured at multiple outlets need to be aggregated to determine the consumption of a single device. From mapping perspective, between the PDU outlets and the device this is a many-to-one mapping. It is not clear if such a many-to-one mapping is feasible within the ENTITY-MIB framework.

7.1.2. ENTITY STATE MIB

RFC 4268 [RFC4268] defines the ENTITY STATE MIB module. Implementations of this module provide information on entities including the standby status (hotStandby, coldStandby, providingService), the operational status (disabled, enabled, testing), the alarm status (underRepair, critical, major, minor, warning), and the usage status (idle, active, busy). This information is already useful as input 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].

7.1.3. ENTITY SENSOR MIB

RFC 3433 [RFC3433] defines the ENTITY SENSOR MIB module. Implementations of this module offer a generic way to provide data collected by a sensor. A sensor could be an energy 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 accuracy of the used power meter.

Similar to the ENTITY STATE MIB module, the ENTITY SENSOR MIB module makes use of the means provided by the ENTITY MIB module [RFC4133] for relating provided information to components of a device.

However, there is no unit available for reporting energy quantities, such as, for example, watt seconds or kilowatt hours, and the ENTITY SENSOR MIB module does not support reporting accuracy of measurements according to the IEC / ANSI accuracy classes, which are commonly in use for electric power and energy measurements. The ENTITY SENSOR MIB modules only provides a coarse-grained method for indicating accuracy by stating the number of correct digits of fixed point values.

7.1.4. 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].

7.1.5. POWER ETHERNET MIB

Similar to the UPS MIB, implementations of the POWER ETHERNET MIB module defined in RFC3621 [RFC3621] provide information on the current 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.

7.1.6. LLDP MED MIB

The Link Layer Discovery Protocol (LLDP) defined in IEEE 802.1ab is a data link layer protocol used by network devices for advertising of their identities, capabilities, and interconnections on a LAN network. The Media Endpoint Discovery (MED) (ANSI/TIA-1057) is an enhancement of LLDP known as LLDP-MED. The LLDP-MED enhancements specifically address voice applications. LLDP-MED covers 6 basic areas: capabilities discovery, LAN speed and duplex discovery, network policy discovery, location identification discovery, inventory discovery, and power discovery.

7.2. Existing standards of other bodies

7.2.1. 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.

8. Acknowledgements

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9. Security Considerations

The typical security threats for the management protocol for energy monitoring are similar to the ones specified in the SNMP security framework. In other words, from an energy monitoring point of view, no additional security requirements have been imposed.

Link layer discovery mechanisms need to ensure that only the trusted entities shall be discovered during discovery and detect/discard devices without a trusted relationship to be included among the devices for energy monitoring.

In terms of monitoring, considering that there can be some network entities which shall be entitled to collect the measured data on behalf of other devices, then it is important to authenticate and/or authorize such devices. In addition, in the case of control of other devices, it would be highly desirable to have some form of an authentication mechanism to ensure that only the designated devices shall control the devices within its control domain. It should be possible to prevent designated devices contolling devices not present in its control domain/purview. Secondly, it should be possible to prevent malicious network devices exercising control over network devices.

10. IANA Considerations

This memo has no actions for IANA..

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Authors' Addresses

Juergen Quittek (editor)
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-115
Email: quittek@neclab.eu

Rolf Winter
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-121
Email: Rolf.Winter@neclab.eu

Thomas Dietz
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-128
Email: Thomas.Dietz@neclab.eu

Benoit Claise
Cisco Systems, Inc.
De Kleetlaan 6a b1
Degem 1831
BE

Phone: +32 2 704 5622
Email: bclaise@cisco.com

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

Phone: +91 80 4426 3947
Email: moulchan@cisco.com

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B. Nordman
Lawrence Berkeley National Laboratory
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Energy perspective on applicability
draft-nordman-eman-energy-perspective-01

Abstract

This memo discusses applicability for energy management features to various types of devices and buildings. It describes the variety of applications that can use the EMAN energy framework and associated MIB modules. P otential examples are building networks, home energy gateway, etc. Finally, the document will also discuss relationships of the framework to other architectures and frameworks (such as smartgrid). The applicability statement will explain the relationship between the work in this WG and the other existing standards such as those from the IEC, ANSI, DMTF, and others.

Status of this Memo

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1. Introduction

The EMAN framework describes functionality for reporting of energy information in an Internet Protocol network. Monitoring is a critical first step towards energy management more generally, including control. Other Internet Drafts describe the requirements, framework, and implementation of this system. This document reviews how it is expected to be used, and how it relates to other activities regarding energy and information technology.

This document is intended to be useful to a wide set of audiences, including those with energy as a primary interest (who do not necessarily have any background in networking), the more usual network-centric audience in the IETF (who may have not connection to energy issues), and many whose knowledge and interest is intermediate.

1.1. Eman overview

The most basic example of energy management is a single device reporting only basic information about its own energy status; these "simple devices". The information is reported directly to a Network Management System (NMS).

The framework also provides additional features for collecting information from devices intermediate between the NMS and end-use devices. These intermediate devices ("complex devices") may have capabilities for monitoring or control, may serve to collect information from many devices for more efficient data transfer, may process the data (e.g. by summing across many devices), or any combination of these. The same protocol is used whether the NMS is communicating with an intermediate or end use device. The same protocol may be used between an intermediate and end use device.

This protocol does not define anything about the network management system, but only identifies it as the recipient of information. The NMS will commonly have an entire single building as its scope, though in some cases will cover only a part of a building, or multiple buildings. Usually the NMS will be scoped to match the reach of the local area network it is part of.

All devices are in scope, whether they are traditional IT products like computers or network equipment, or other energy-using devices that are only now beginning to get IP connections, such as appliances, lighting, and climate control systems. (Devices that are only ever powered by batteries, such as sensor nodes, could use this protocol, but are not a target).

The other eman documents are authoritative for specific technical content.

1.2. Usage overview

The basic usage of the eman protocol is a building operator installing software for collecting eman informatin on an existing device in the building, e.g. a personal computer, a server, or piece of network equipment. This software is the Network Management System (NMS) for eman; it can be implemented by extending an existing NMS that performs other functions, or by software that only deals with energy issues.

The NMS begins by probing the local area network to discover devices that respond to eman queries. It first discovers what devices are on the network at all, then determines the subset that implement eman. It then requests all information from each eman reporting device; much of which is static so does not need to be requested again.

The NMS then determines how often to query each device for updates to the energy information. This will likely vary by building type and device type, and the period could range from monthly to once per minute. The frequency of interrogation is entirely up to the NMS and can change dynamically as the NMS deems necessary. Only a small amount of data needs to be provided for the periodic reporting.

Some devices will fail to report some of the time, either because they are in a low-power state which does not include the ability to do eman reporting, or because they are portable and only sometimes in the building (e.g. a notebook computer). Occasionally, a device will leave the building permanently.

The NMS needs to periodically scan for new eman devices, and query for all devices for characteristics that could in principle change, but do so infrequently or never.

Finally, the NMS will digest the reported information into forms readily understood by people. Esxample include summaries by type of device ("energy end uses") based on the reported identity information, or by location within the building. Also, a NMS may detect suspected or known anomalous energy usage and highlight that, in case it represents equipment malfunction or inefficient or insufficient operation. Electricity pricing is becoming increasingly dynamic, so that the simple translation from quantity of energy to economic cost is becoming more complex. The ability of eman to enable tracking energy use over time provides for incorporating the time dimension of electricity use into both monitoring and control.

2. Terminology

This section reviews select terms used in this draft.

2.1. Building Network

Traditional IT local networks are made up of entities that provide information services. Future Building Networks will not be separate from the IT network, but will incorporate many devices whose primary function is not information, such as those that provide light, regulate temperature or ventilation, and appliances. A building network is IP-based and enables full inter-operation of IT and non-IT devices.

Traditional building control systems were developed before IP networking, often have limited scope in the services they address, and are often based on proprietary technologies.

2.2. Network Management System

A Network Management System (NMS) is the entity which requests information from energy-using devices. It may be a system which also implements other network management functions, or one that only deals with energy. It may be limited to monitoring energy use, or it may implement control functions (based on eman, other protocols, or both).

2.3. Energy

At present, the eman framework only addresses electricity use. It is plausible, and likely, that a future version of it will extend to other forms of energy (e.g. methane, steam, and hot/cold water), and even to non-energy quantities (e.g. temperature and flow).

3. Use Contexts

This section reviews the applications that the framework is intended to be suitable for. These vary according to the nature of devices involved, and the institutional environment (building type, management approach, and purpose). The other documents specify nothing about the network management system (NMS).

3.1. Management context

Buildings vary in scale from those with thousands of occupants, down to those with few or even none, with similar ranges in relevant floor areas. Some of these buildings have people with a job function that specifically covers energy management, and in others, no one actively pays attention to the topic.

3.1.1. Highly managed

Some network environments are closely monitored for what devices are introduced to it, their characteristics and capabilities, and the functions they provide; many data centers are managed this way. These are more likely to use advanced features of energy management technology, including accounting for multiple power supplies for products, use of power control, and more attention to power distribution. They also are more likely to be concerned with power quality characteristics.

The NMS in these contexts may be integrated with systems for functional control of devices. For a data center, the primary focus is the IT equipment it contains, though the devices that provide power (reliability, conditioning, distribution, and/or control) and those that do space conditioning are also likely to be monitored through the NMS. Monitoring data may be obtained frequently to closely track a dynamic usage environment.

3.1.2. Loosely managed

Other environments are not actively managed at all. Devices enter or leave the network on their own terms, and are fundamentally autonomous. Power control is not utilized at all, and the goal of the energy management facility is to simply understand what is going on, not to actively manage it. Most residential buildings are an example of this type of network, where there is no personnel or procedures for active network management. Power quality and capacity are essentially never a concern.

The NMS in a loosely managed environment should be as automatic as possible, so that the user can get useful information with little or no effort. No functional control is involved. Such environments will have a mixture of devices that can report power information as well as many that cannot. The NMS is principally tracking long-term trends and so information gathering is usually not frequent.

3.1.3. Hybrids

Most network environments have elements of these two extremes, both sets of devices of each sort, as well as devices that are managed in an intermediate form. Commercial buildings are commonly of this form, with some devices being highly managed, and others only loosely tracked.

The NMS for a hybrid must be able to accomodate a diverse set of devices and is likely to track some closely, and others much less so.

3.2. Building types

The EMAN facility is designed to be used in any building type (though the specific needs of industrial buildings have not yet been considered). Core building types are residential, commercial, and vehicle. In the United States, buildings account for just over 70% of electricity use, with this split almost evenly between residential and commercial.

The cases of multi-tenant buildings (residential and commercial) noted below raise the possibility of a device reporting to more than one NMS.

3.2.1. Residential

Residential buildings usually have no existing infrastructure for reporting energy use of devices within them. There are products available that can monitor and track whole-building use, either from added hardware, or by leveraging a communicating meter. However, this gives no visibilty to how much electricity is being consumed by each device. There are expensive systems available for houses that integrate control of many systems (e.g. climate control, lighting, security, entertainment) that can incorporate tracking of usage times and so well approximate energy use, but these are generally proprietary and not IP-based.

Residential buildings that incorporate multiple units are best dealt with as each unit being a separate building for NMS purposes. Privacy and security both preclude sharing much information outside the NMS, except for services that are centrally provided (e.g. hot water or space conditioning). Such buildings also have energy used in common areas and for common functions.

The term Home Energy Gateway is sometimes used to denote a demarcation point between devices in a building and the outside world. These gateways can also perform some active monitoring and control functions. There is no need for the architecture of a building network to be different in houses from other building types so that this is really just a specific example of a building network gateway.

3.2.2. Commercial

Commercial buildings vary enormously in scale, with some smaller than a typical house, to entire campuses of multi-story buildings.

Smaller buildings share many characteristics with houses in terms of technology and management styles. Larger buildings usually have some sorts of building control systems, though usually there are several systems for individual types of functions, and most are not IP-based. Thus, while some energy information can usually be extracted digitally, it is usually not comprehensive, and often derived from proprietary systems. With increasing building size, it is more likely that someone has energy management as an explicit job function.

Some commercial buildings have the multi-tenant character of some residential buildings, though the degree to which services are the responsibility of the building owner is usually greater than with residential.

3.2.3. Data Centers

A data center is technically an industrial building, but for eman purposes it has special interest and so is treated separately. These are highly managed environments and are most likely to use the most advanced and complex features of eman, and have more sophisticated mechanisms for power distribution and control, including use of power distribution units. They are also likely to see the quickest uptake of the protocol. Thus, their importance for eman is out of scale with their portion of global electricity use (a few percent).

3.2.4. Other industrial buildings

Industrial buildings in general use electricity for both process and non-process loads. Non-process loads are similar to those in other building types. Process loads have not yet been considered in the eman process.

3.2.5. Vehicles

While it may initially seem curious to treat automobiles, airplanes, and boats as types of buildings, for purposes of energy management, it is quite appropriate. They are generally self-contained structures with electricity distribution for a variety of uses (some infrastructure and some occupant oriented). Electricity is typically more expensive in energy and carbon terms than for fixed buildings and may have constrained capacity, so the reason to be concerned with energy management is even greater with vehicles. Many vehicles can connect to the electricity grid when stationary.

3.3. Device types

The EMAN facility is designed to be used for any device type. Its design and usage specifically takes account of two primary types: electronic devices, and all others.

3.3.1. Information technology

For many years, the only devices on IP networks were computers and network equipment. To these were added other types of information technology devices, such as printers and storage. These devices are at the core of EMAN and will see the widest initial use of EMAN reporting.

3.3.2. Other electronic devices

Information technology is a specific subset of the general category of "electronic" devices - those which have information as their primary function. Even televisions have a primary purpose of displaying information, and thus the traditional category of entertainment consumer electronics can be logically grouped under information technology. These devices are seeing rapid uptake of IP connectivity, and the distinction between IT and other electronic devices blurring.

3.3.3. Non-electronic devices

"Electronics" are devices whose primary function is information so that "non-electronics" is everything else in buildings, such as lighting, appliances, and equipment for space conditioning. This term does not imply that they have no electronic components.

4. Other topics

This section explores other topics relevant to energy management and eman.

4.1. Power distribution

An aspect of energy reporting that may not be initially apparent is how it can support understanding of power distribution systems. That is, different collections of devices in a building may be in different ’domains’ of electricity distribution, with a common fate (e.g. downstream of a circuit breaker), or under the same electricity meter. This is accomplished two ways: via reporting by products which have a power distribution function themselves (e.g. a Power Distribution Unit or an Ethernet switch that supports Power over

Ethernet), or by products self-identifying the domain they are a part of (usually by manual configuration).

In the past, few buildings had complex power distribution, with most simply a tree of circuit breakers, and just a few levels of AC power utilized. Today, an increasing number have additional features, such as uninterruptable power supplies, low-voltage DC powered devices, local generation, and storage. Power reporting mechanisms such as eman will need to have some understanding of these features.

4.2. Discovery

A Network Management System requires some method of collecting a list of the entities on the network that it needs to be cognizant of, both when it initially begins operation, and maintaining this on an ongoing basis as the population of devices evolves. There are three basic methods: protocol, manual, and opportunistic. A NMS can utilize more than one method.

In the protocol approach, the NMS periodically broadcasts a request for any EMAN reporting entity to identify itself to the NMS. For each entity that replies, the NMS queries it for the specific information it has.

In the manual approach, the identity of each device to be managed is provided to the NMS. Usually, additional information will also be provided, such as functional relationships among devices, policies to be employed (e.g. prioritization of the importance of each device), and control strategies (e.g. under what conditions a device should be have its power supply removed or reinstated).

In the opportunistic approach, the NMS observes the network to notice when a new device appears, then queries it for EMAN capabilities.

A NMS may also participate in one or more service discovery protocols to determine when a new device appears, though as none of these protocols are universal, this will always be an incomplete method. A NMS also has to deal with the fact that some devices will eventually disappear from the network and need to be expired from its databases. Also, some devices will be only intermittently on the network, either from being physically absent some of the time, or powered down to a low-power state in which they can’t respond to EMAN queries.

4.3. Identity

Eman needs to report basic characteristics of the "identity" of a device for the NMS to know how to interpret the information. That is, while the IP and MAC addresses of a device are essential to know, they are by no means sufficient. Other aspects of identity include what a device is (a general category as a person would describe it), its brand and model, and a locally determined name useful for building occupants.

5. Related Standards and Activities

This section reviews related standards and other activities that have some relationship to the EMAN protocol. A key point is that eman reports data on individual devices. Many standards are oriented to entire buildings or other large entities.

5.1. Standards that inform measurement

There are many energy test procedures for specific products. These generally are for tests conducted in laboratory conditions in specified configurations to assess energy performance for comparison to other models or criteria levels. However, EMAN measurements are not conducted in a laboratory, not under such specified conditions, and need to be universal across all products, so a "horizontal" test procedure is more relevant. The most widely used of these is IEC 62301 [IEC-62301] on measurement of standby power . While 62301 was created by a committee with a mandate on household appliances, it has been designed to be universal for any product commonly found in residential or commercial buildings, and is referenced in test procedures for appliances, electronics, and other devices. It was originally published in 2005, with a second edition finalized in 2011.

5.2. Standards that inform reporting

Energy reporting over networks is a relatively new service. Few devices had the hardware ability to measure power, and few of the rest made an attempt to estimate it. Further, for power state, devices could only report when they were fully on, so never could report themselves when in a low power state. Finally, the ability to remotely apply or remove power from a device has been confined to very specific usage environments.

5.2.1. DMTF

The Distributed Management Task Force (DMTF) has specified communication of power state information.

The DMTF Common Information Model (CIM) includes information about power states.

5.2.2. Ecma SDC

The Ecma International committee on Smart Data Centre (TC38-SDC [Ecma-SDC]) is in the process of defining semantics for management of entities in a data center such as servers, storage, network equipment, etc. It covers energy as one of many functional resources or attributes of systems for measurement and/or control. It only defines terms and variables, and does not reference any specific protocol. Its goal is to enable interoperability of such protocols by ensuring a common semantic model across them.

The SDC process is still underway, with a timeframe similar to EMAN. There seems to be no fundamental barrier to the two efforts to harmonize on aspects they have in common. These include identity, power states, power levels, accumulated energy use, and tracking of time.

5.3. Other Standards and Activities

While manufacturers may implement EMAN capabilities in their products, their are other organizations that may also do this. Future standards may reference EMAN as functionality that more comprehensive systems rely on (e.g. using reported power state for functional purposes). They may also define extensions to or particular uses of the EMAN facility.

In future, energy standards, both voluntary and mandatory, may reward or require use of EMAN capabilities. For example, the Energy Star program already references other specific network technologies in a variety of its specifications. In fact, the initial framework document for revising the Energy Star Computer specification [ESTAR] references the IETF eman activity . The most likely use of EMAN would be simply for a device to be able to report on its own basic status as defined by EMAN, such as identity, power state, power level, and accumulated energy.

5.3.1. Smart Grid

There are many definitions of what constitutes the "Smart Grid". In the most general sense, it is the application of information technology to our electricity system, so that the EMAN framework is an excellent example of that. Alternatively, it can describe using information technology to improve the electricity grid, from the power plant through transmission and distribution systems and ending at the meter. In this case, the EMAN framework has no connection to the Smart Grid. The most common definitions of the Smart Grid acknowledge that what occurs in buildings is different from the utility-managed grid, but specify some communication directly between the grid and end-use devices. The EMAN framework does not anticipate communication with entities outside the building, but rather only with a local NMS. The NMS could communicate with the grid, but that is well outside the EMAN scope and framework. End-use devices can still coordinate with the grid through other protocols, either in one-way communication (receiving demand response or direct price signals from the grid), or in two-way communication with the grid.

6. Security Considerations

The energy management facilities discussed here raise a number of security considerations. While not a part of the current drafts, the ability of one device to control the power state of a second connected device can be a problem if they do not share the same management goal. This can be either the act of powering down a device (e.g. from on to sleep or off), rendering it unable to perform ordinary services it might otherwise accomplish, or powering the device up, and consequently using energy resources not otherwise desired. Beyond control, simple information about the current or historic energy use of a device can indicate details of occupancy of the main person using the device, or of applications running on the device.

The capabilities described in this document do not introduce any new capabilities for security. Rather, any device that implements them must use existing security intrastructure and policies.

7. IANA Considerations

This memo creates several possible actions for IANA. First is a single canonical listing of "identity" of a device, in terms of what it is. Second is possible enumeration of power states, and/or functional states.

8. Acknowledgements

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Author’s Address

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

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

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B. Nordman
Lawrence Berkeley National Laboratory
R. Winter
NEC Labs Europe

March 15, 2011

Considerations for Power and Energy Management
draft-norwin-energy-consider-02

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.

Status of this Memo

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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:

- "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.

- "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.

- Name: A human-readable name, locally specified when the device is configured or installed.

- 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 syncronization, 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:

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

Authors' Addresses

Bruce Nordman
Lawrence Berkeley National Laboratory

Email: bnordman@lbl.gov

Rolf Winter
NEC Labs Europe

Email: rolf.winter@neclab.eu

Network Working Group J. Quittek
Internet-Draft R. Winter
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February 28, 2011

Definiton of Managed Objects for Battery Monitoring
draft-quittek-eman-battery-mib-00.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 defines managed objects that provide information on the status of batteries in managed devices.

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction

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

In addition to this, there is a need to monitor battery status of these devices by network management systems. This document defines a portion of the Management Information Base (MIB) that meets the requirements for monitoring the status of batteries described in [I-D.ietf-eman-requirements]. Managed objects defined in Section 4 serve for monitoring

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

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

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

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

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

2. The Internet-Standard Management Framework

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

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies MIB modules that 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].

3. Structure of the Battery MIB module

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

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

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

The batteryTable contains three groups of objects. The first group (OIDs ending with 2-6) provides information on static properties of the battery. The second group of objects (OIDs ending with 7-14) provides information on the current battery state, if it is charging or discharging, how much it is charged, its remaining capacity, the number of experienced charging cycles, etc.

```
batteryTable(1)
+--batteryEntry(1) [batteryIndex]
   +-- --- Unsigned32  batteryIndex(1)
   +-- r-n Enumeration batteryType(2)
   +-- r-n Enumeration batteryTechnology(3)
   +-- r-n Unsigned32  batteryNominalVoltage(4)
   +-- r-n Unsigned32  batteryNumberOfCells(5)
   +-- r-n Unsigned32  batteryNominalCapacity(6)
   +-- r-n Unsigned32  batteryRemainingCapacity(7)
   +-- r-n Counter32   batteryChargingCycleCount(8)
   +-- r-n DateAndTime batteryLastChargingCycleTime(9)
   +-- r-n Enumeration batteryState(10)
   +-- r-n Unsigned32  batteryCurrentCharge(11)
   +-- r-n Unsigned32  batteryCurrentChargePercentage(12)
   +-- r-n Unsigned32  batteryCurrentVoltage(13)
   +-- r-n Integer32   batteryCurrentCurrent(14)
   +-- r-n Unsigned32  batteryLowAlarmPercentage(15)
   +-- r-n Unsigned32  batteryLowAlarmVoltage(16)
   +-- r-n Unsigned32  batteryReplacementAlarmCapacity(17)
   +-- r-n Unsigned32  batteryReplacementAlarmCycles(18)
```

The third group of objects in this table (OIDs ending with 15-18) 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.

4. Definitions

```
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

batteryMIB MODULE-IDENTITY
    LAST-UPDATED "201102261200Z"         -- 26 February 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

           Editor:
             Juergen Quittek
             NEC Europe Ltd.
             NEC Laboratories Europe
             Kurfuersten-Anlage 36
             69115 Heidelberg
             Germany
             Tel: +49 6221 4342-115
             Email: quittek@neclab.eu"

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

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           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 "201102261200Z"         -- 26 February 2010
       DESCRIPTION
           "Initial version, published as RFC yyyy."
   -- replace yyyy with actual RFC number & remove this notice

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

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

   batteryNotifications OBJECT IDENTIFIER ::= { batteryMIB 0 }
   batteryObjects       OBJECT IDENTIFIER ::= { batteryMIB 1 }
```

```
   batteryConformance   OBJECT IDENTIFIER ::= { batteryMIB 2 }

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

   --------------------------------------------------------------------
   -- 1.1. Battery Table
   --------------------------------------------------------------------
   batteryTable  OBJECT-TYPE
       SYNTAX      SEQUENCE OF BatteryEntry
       MAX-ACCESS  not-accessible
       STATUS      current
       DESCRIPTION
           "This table provides information on batteries.
           It contains one conceptual row per battery."
       ::= { batteryObjects 1 }

   batteryEntry OBJECT-TYPE
       SYNTAX      BatteryEntry
       MAX-ACCESS  not-accessible
       STATUS      current
       DESCRIPTION
           "An entry providing information on a battery."
       INDEX  { batteryIndex }
       ::= { batteryTable 1 }

   BatteryEntry ::=
       SEQUENCE {
          batteryIndex                     Unsigned32,
          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
       }
```

```
   batteryIndex OBJECT-TYPE
       SYNTAX      Unsigned32
       MAX-ACCESS  not-accessible
       STATUS      current
       DESCRIPTION
           "This object identifies a battery for which status is
           reported. Index values MUST be locally unique.

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

   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 2 }

   batteryTechnology OBJECT-TYPE
       SYNTAX      INTEGER {
                       zincCarbon(1),
                       zincChloride(2),
                       oxyNickelHydroxide(3),
                       lithiumCopper(4),
                       lithiumIron(5),
                       lithiumManganese(6),
                       zincAir(7),
                       silverOxide(8),
                       alcaline(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 3 }

   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 4 }

   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 5 }

   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 6 }

   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 7 }

   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 8 }

   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 9 }

   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 onject 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 hte 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 10 }

   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 11 }

    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 12 }

    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 13 }
```

```
   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 batteryin units of milliampere (mA).  Charging
           current is indicated by positive values, discharging current
           is indicated by negative values.

           A value of '7fffffff'H indicates that the current current
           cannot be determined."
       ::= { batteryEntry 14 }

   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 15 }

   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 16 }

   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 17 }

   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 batteryAgingtNotification.

           A value of 0 indicates that the no alarm will be raised for
           any value of object batteryChargingCycleCount."
       ::= { batteryEntry 18 }


   --==================================================================
   -- 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
```

5. 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:

- 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.

6. 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
batteryMIB	{ mib-2 xxx }

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

7. Open Issues

7.1. Battery temperature

Is there a need to report the temperature of the battery? The UPS MIB does so with object upsBatteryTemperature.

7.2. Scale of the charge percentage

Should object batteryCurrentChargePercentage report the percentage of the current charge with respect to the nominal battery capacity or with respect to the remaining capacity?

7.3. Define Charging Cycle

The draft is not clear about what a charging cycle is. Is there any commonly accpted definition of it?

7.4. Define Battery States 'full' and 'emplty'

Is a battery 'full' if it is charged 99%? When is it empty? Is it full if it has reached remaining capacity or only if it has achieved nominal capacity?

7.5. batteryTable Indexing

Shall we link the index to the pmIndex in the POWER-AWARE-MIB?

8. References

8.1. Normative References

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[RFC4133] Bierman, A. and K. McCloghrie, "Entity MIB (Version 3)", RFC 4133, August 2005.

8.2. Informative References

[I-D.ietf-eman-requirements] Quittek, J., Winter, R., Dietz, T., Claise, B., and M. Chandramouli, "Requirements for Power Monitoring", draft-ietf-eman-requirements-00 (work in progress), December 2010.

[RFC1628] Case, J., "UPS Management Information Base", RFC 1628, May 1994.

[RFC3410] Case, J., Mundy, R., Partain, D., and B. Stewart, "Introduction and Applicability Statements for Internet-Standard Management Framework", RFC 3410, December 2002.

Authors' Addresses

Juergen Quittek
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-115
Email: quittek@neclab.eu

Rolf Winter
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-121
Email: Rolf.Winter@neclab.eu

Thomas Dietz
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-128
Email: Thomas.Dietz@neclab.eu

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Reference Model for Energy Management
draft-quittek-eman-reference-model-01

Abstract

This memo discusses suggest a reference model for energy consumption monitoring and control. It defines entities involved in energy management, their roles, and relationships among them. Considered entities include powered devices, power monitors, and power controllers, and energy management systems.

Status of this Memo

Copyright Notice

Table of Contents

1. Introduction

Managing energy consumption of devices with network connections is different from several well understood network management functions because of the special nature of energy supply and consumption.

The most basic example of energy management is a single device reporting information about its own energy status.

However, in many cases, energy consumption is not measured by the powered device itself, but by a power meter located upstream in the power distribution tree. An example is a power distribution unit (PDU) that measures energy consumption of attached devices and may report this to an energy management system. Unlike many other management functions, the powered device is not involved in this process.

This memo aims to clarify roles of entities involved in energy monitoring and control and the relationships among them.

There is already a reference model defined in section 4 of [I-D.claise-power-management-arch]. The intention of this memo is to refine this model based on recent discussions.

The reference model specification below describes several kinds of entities and interactions between them. According to the current scope of the EMAN WG, only reporting to the energy management system are potential subjects of standardization in this WG.

The reference model is described in two stages. Stage one is an energy monitoring model specified in Section 3. It covers only monitoring of power states and energy consumption. On stage two the monitoring model is extended to a full energy management reference model by adding control functions for power supply and power states. see Section 4.

2. Terminology

This section defines terms used for the description of the energy management reference model. Names for entities of the model are not defined here but in Section 3.2 and Section 4.1.

2.1. Energy Management

Energy management deals with assessing and influencing the consumption of energy in a network of powered devices. A typical objective of energy management is reducing the energy consumption in the network. This objective may be limited by other objectives of a general network management system, such as service level objectives.

2.2. Energy Monitoring

Energy monitoring is a part of energy management. It only covers monitoring and does not include influencing the consumption of energy.

2.3. Power, Energy, and Energy Consumption

Power is the rate of energy conversion. In energy management scenarios, electrical energy is delivered to a device that consumes it by converting the energy to other forms.

Power and consumed energy are essential quantities for network management. Power can be an instantaneous value of the current energy conversion rate or an average value of power over a time interval. Consumed energy is the total energy converted by a powered device during a time interval.

The term 'energy consumption' is commonly used for both, for referring to the amount of consumed energy and also for referring to the process of consuming energy. In this document we use this ambiguous term for addressing both power and consumed energy.

2.4. Identity

Identity is basic information about what a device is, in function, in its specific instance of manufacture, and its specific local human-readable name. Identity is not energy-specific, but essential for useful interpretation of energy information.

Some identify information never changes. The rest of it rarely or never changes. Thus, it needs to be queried much less frequently than the energy data.

3. Energy Monitoring Reference Model

This section specifies a reference model for energy monitoring. After introducing basic concepts of energy monitoring in Section 3.1 it defines entities of the model and their interactions in Section 3.2. Examples of devices and scenarios are illustrated in Section 3.5.

3.1. Introduction to Energy Monitoring

In this section we introduce basic concepts of energy monitoring starting with the most basic scenario and extending it stepwise to our full reference model.

The main subject of energy monitoring is a powered device. An energy monitoring system collects information about powered devices, their current power state (for example: on, sleep, off) and their actual power consumption.

3.1.1. Basic Energy Monitoring (local metering)

The most basic interaction in an energy monitoring system is a powered device directly reporting its own energy-related information, with no other devices involved, as shown below.

```
                       energy monitoring
                            system
                               ^
                               |
                            device
```

3.1.2. External Metering

Reporting its current power state is a relatively easy task for a powered device because usually information on the current power state is locally available at the device and a reporting function just needs some additional software to implement it.

Reporting the current power level of a device and its accumulated energy consumption is a harder task, particularly if there are strict requirements for accuracy. Today very few devices are instrumented with means for measuring their own energy consumption as that usually implies adding hardware for this purpose.

This can be addressed by external meters, that is, dedicated probes that can meter energy consumption on a power source (line). Some Power Distributions Units (PDUs) and Power over Ethernet (PoE) [IEEE-802.3af] switches integrate power source and power metering for individual devices.

For supporting scenarios with external meters we extend the basic model from above by an external power meter and a power source as shown below.

```
                         energy monitoring system
                           ^         ^         ^
                           |         |         |
                         power     power    powered
                         source    meter    device
                              ###############

              symbols ######### represent a power supply line
```

All three potentially report to the energy monitoring system. The power meter may report the current power and accumulated energy consumption and the power source may report if the power supply for the device is switched on or if it is off.

Implementation may be incomplete. For example, an energy management system may have access to only one or two of these three types of data.

3.1.3. Functions and Entities

This reference model operates at two levels/layers. One is simple basic functions that are implemented. The second is how they are arranged in devices. A device in this model may implement only a single function, or may implement many.

That is, having multiple entities does not require that all of them need to be instantiated by individual devices. For example, the power meter function may be co-located and integrated with the powered device, with the power source, or it may be implemented by a separate device.

3.1.4. Power Monitors

In the models above, the powered device and other components deliver reports directly to an energy monitoring system. However, there are energy monitoring scenarios where this is not possible or not desirable.

Extreme examples are energy consumers that do not have IP interfaces but can communicate by other means. For delivering their reports to an IP-based energy monitoring system, it may be required to use a gateway that can communicate with the energy monitoring system.

However, even if all involved devices (PDUs, power meters, and powered devices) can communicate via IP, it may be desirable to have mediation functions in place between powered devices and the energy monitoring system. An example, is an aggregating device that aggregates and reports information on several powered devices.

There are several further useful scenarios. To generalize the model (and to not exclude any kind of gateway, proxy, relay, mediator or other device) we define reporting entities called 'monitors'. The figure below shows three monitors, each of which reports to the energy monitoring system. This figure is the most generic representation of the energy monitoring reference model described by this document.

Energy Monitoring Reference Model

```
+-------------------------------------------------------------------+
|                     energy monitoring system                      |
+-------------------------------------------------------------------+
          ^                       ^                       ^
          |                       |                       |
+-------------------+   +-------------------+   +-------------------+
|    power source   |   |    power usage    |   |    power state    |
|      monitor      |   |      monitor      |   |      monitor      |
+-------------------+   +-------------------+   +-------------------+
          |                       |                       |
+-------------------+   +-------------------+   +-------------------+
|       power       |   |    power meter    |   |      powered      |
|       source      |   +-------------------+   |      device       |
+-------------------+###########################+-------------------+
```

symbols ######### represent a power supply line

A monitor function reports directly to the energy monitoring system using the EMON protocol (an Internet protocol). A monitor must have means to acquire the information it reports, but how this information is acquired is not relevant for our model. That is, only the interactions with a caret symbol in this and following diagrams is the subject of standardization. Those with only the vertical bar character are outside the scope of these documents; they may be IP or non-IP.

The reference model defines the communication between power monitors an the energy monitoring system. The communication lines between these entities are reference points of our model described in more detail in the following.

3.2. Energy Monitoring Entities

This section defines entities of the energy monitoring reference model and describes interactions between them. Examples scenarios are illustrated in Section 3.5.

3.2.1. Powered Device

A powered device is provided with energy (typically electrical) usuallly provided via power lines. Power state, power and consumed energy of powered devices are subject to monitoring and control functions of energy management.

3.2.2. Power Source

A power source provides a powered device with energy, typically via a power line. It may have means to switch on and off the power for the powered device. A power source does not necessarily generate power, but it may do so. It may be as simple as a power switch or a power plug, but it may also be a battery or a power generator. Regardless, the nature of the source does not affect energy monitoring.

Note that an internal battery within a device, such as the battery of a notebok PC or of a mobile phone are not considered to be a power source. When a device runs on battery only, there is n flow of energy into the device and consequently the power to be reported for this device is zero. On the other hand, when a device charges its battery, then the power supplied for charging needs to be accounted, even if the device is not operational.

3.2.3. Power Meter

A power meter measures power and/or consumed energy, and typically is electrically connected to power supply lines for powered devices. However, many devices can also provide a reliable estimate of their power consumption based on internal status information without having dedicated metering hardware. Regardless, all metering information is qualified by an indication of its accuracy.

The meter function also includes integrating power consumption over time to provide a "meter reading" with a time stamp to enable an energy monitoring system to track energy consumption over time.

3.2.4. Power Monitors

A power monitor has access to energy-related information concerning powered devices and is able to report this information to energy management systems.

A power monitor may also provide information on identity and properties of a powered device to the management system.

A power monitor may store energy-related information and process it, for example, for aggregating information or for extracting statistics that are provided to an energy management system.

There are three power monitor functions in the energy monitoring reference model: power state monitors, power source monitors, and power usage monitors.

3.2.4.1. Power State Monitor

A power state monitor has access to the power state of a powered device and is able to report this information to an energy monitoring system. For acquiring power state information it may interact with powered devices.

3.2.4.2. Power Source Monitor

A power state monitor has access to information on the power supply of powered devices and is able to report this information to an energy monitoring system. Typically, it will just report either 'on' or 'off'. In addition, it may report on power availability. For acquiring power source information it may interact with the power sources of powered devices.

3.2.4.3. Power Usage Monitor

A power usage monitor has access to information on energy consumption of powered devices and is able to report this information to energy management systems. For acquiring information on energy consumption it may interact with power meters.

3.2.5. Energy Monitoring System

An energy monitoring system receives information from power monitors, such as: power states, power source states, and energy consumption. An energy monitoring system may be centralized or distributed. In most of the example scenarios illustrated in Section 3.5 a centralized energy monitoring system is shown but in all cases can be replaced by a distributed monitoring system.

3.3. Standardization Scope

The reference model specifies interactions of an energy monitoring system with power monitors. They reference points of the model are potential subjects of standardization (in the EMAN working group). Interactions of power monitors with other entities are currently not considered to be subject of standardization.

It is argued in [I-D.quittek-power-monitoring-requirements] that for most of the relevant scenarios the best choice a management protocol for the reference points is SNMP [RFC3410]. The reference model defined in this document does not assume a specific protocol between energy monitoring system and power monitors. It is also applicable if other protocols, such as, for example, Syslog [RFC5675] or IPFIX [RFC5101] are used.

3.4. Entity Relationships

No restrictions on entity relationships have been identified for interacting entities of the energy monitoring reference model specified in this document. This means that all relationships between entities may be one-to-one, one-to-many, many-to-one, or many-to-many. For example,

- o a single power state monitor may report the power state of multiples powered entities,
- o a single powered entity may have its power states reported by< multiple power state monitors,
- o a single powered device may receive power from several power sources,
- o a single power monitor may report to multiple energy monitoring systems.

A few of scenarios with multiple instances of units are illustrated by the examples in the following Section 3.5.

3.5. Energy Monitoring Scenarios

This section describes common example scenarios for energy monitoring and how they are modeled with the entities and interactions described in the previous sections.

3.5.1. Simple Device with Power Meter

A very basic example is a powered device that has a built-in meter for measuring its own energy consumption and that reports its power state and power usage directly to the energy monitoring system.

```
   +-------------------------------------------------------------------+
   |                     energy monitoring system                      |
   +-------------------------------------------------------------------+
                                               ^
                                               |
                       +-----------------------------------------------+
                       |                       |                       |
                       |           +-----------+-----------+           |
                       |           |                       |           |
                       | +-------------------+   +-------------------+ |
                       | |    power usage    |   |    power state    | |
                       | |      monitor      |   |      monitor      | |
                       | +-------------------+   +-------------------+ |
                       |           |                       |           |
   +-----------------+ | +-------------------+   +-------------------+ |
   |      power      | | |    power meter    |   |      powered      | |
   |      source     | | +---------#---------+   |      device       | |
   +-----------------+#|#########################+-------------------+ |
                       |                                               |
                       | powered device with meter and power monitors  |
                       +-----------------------------------------------+
```

Scenario 1: Powered device metering and self-reporting

Here four entities are combined in a single device: the powered device, the power meter, and two power monitors.

3.5.2. External Power Meter

The second example shows a power meter that is attached to the power line of a powered device that does not have means for measuring its own energy consumption. The meter is integrated with a power usage monitor that reports metered data. The powered device may report its own power state by an integrated power state monitor.

```
   +-------------------------------------------------------------------+
   |                     energy monitoring system                      |
   +-------------------------------------------------------------------+
                                    ^
                                    |
                        +-----------------------+
                        |  external | meter     |
                        | +-------------------+ |
                        | |    power usage    | |
                        | |      monitor      | |
                        | +-------------------+ |
                        |           |           |
                        | +-------------------+ |
   +-----------------+  | |    power meter    | |  +-------------------+
   |      power      |  | +---------#---------+ |  |      powered      |
   |      source     |  +-----------#-----------+  |      device       |
   +-----------------+#############################+-------------------+
```

Scenario 2: An external meter

3.5.3. External Power Meter for Multiple Powered Devices

Power meters may be located at a power line that provides power for multiple powered devices. In scenario 3, a single power meter measures the accumulated power and energy consumption of multiple powered devices. In general, In this scenario it is usually not possible to derive power values for the individual powered devices from the accumulated measurement.

```
   +-------------------------------------------------------------------+
   |                     energy monitoring system                      |
   +-------------------------------------------------------------------+
                                    ^
                                    |
                        +-----------------------+
                        |  external | meter     |
                        | +-------------------+ |
                        | |    power usage    | |     +----------------+
                        | |      monitor      | |     |    powered     |
                        | +-------------------+ |     |    device      |
                        |           |           |  ###+----------------+
                        | +-------------------+ |  #
   +-----------------+  | |    power meter    | |  #  +----------------+
   |      power      |  | +---------#---------+ |  #  |    powered     |
   |      source     |  +-----------#-----------+  #  |    device      |
   +-----------------+################################+----------------+
                                                   #
                                                   #  +----------------+
                                                   #  |    powered     |
                                                   #  |    device      |
                                                   ###+----------------+
```

Scenario 3: An external meter for multiple powered devices

3.5.4. Powered Device with Dual Power Supply

Some powered devices have dual power supply. It may be that one supply comes from a power grid and the other one from a battery. High-reliability devices may have two power sources from different power distribution networks, as shown in scenarios 4 and 5.

```
   +-------------------------------------------------------------------+
   |                     energy monitoring system                      |
   +-------------------------------------------------------------------+
                                     ^
                                     |
                +-----------------------------------------+
                |                    |                    |
                | +-------------------------------------+ |
                | |         power usage monitor         | |
                | +-------------------------------------+ |
                |      |                           |      |
                | +---------+  +-----------+  +---------+ |
   +---------+  | |  power  |  |  powered  |  |  power  | |  +---------+
   |  power  |  | |  meter  |  |  device   |  |  meter  | |  |  power  |
   |  source |  | +----#----+  |           |  +----#----+ |  |  source |
   +---------+##|##############+-----------+##############|##+---------+
                |                                         |
                | powered device with dual power supply   |
                | and dual metering                       |
                +-----------------------------------------+
```

Scenario 4: powered device with dual power supply

In scenario 4 the device uses two meters, one for each power line and reports from both to the energy monitoring system. If the two power sources belong to different power distribution domains, it may be necessary to report power and energy separately for each supply.

3.5.5. Two energy monitoring systems

Scenario 5 is more complex. Both meters are individual external devices and there are even two separate energy monitoring systems involved, one for each power distribution tree.

```
   +--------------------------------+  +--------------------------------+
   |   energy monitoring system     |  |   energy monitoring system     |
   +--------------------------------+  +--------------------------------+
                     ^                               ^
                     |                               |
               +-----------+                   +-----------+
               |     |     |                   |     |     |
               | +-------+ |                   | +-------+ |
               | |power  | |                   | |power  | |
               | |usage  | |                   | |usage  | |
               | |monitor| |                   | |monitor| |
               | +-------+ |                   | +-------+ |
               |     |     |                   |     |     |
               | +-------+ |                   | +-------+ |
               | | power | |                   | | power | |
   +--------+  | | meter | |  +-------------+  | | meter | |  +--------+
   | power  |  | +---#---+ |  |   powered   |  | +---#---+ |  | power  |
   | source |  +-----#-----+  |   device    |  +-----#-----+  | source |
   +--------+#################+-------------+#################+--------+
```

Scenario 5: powered device with dual power supply
from different power distribution trees

3.5.6. Power over Ethernet Switch

This example shows a Power over Ethernet (PoE) [IEEE-802.3af] switch supplying a powered device. The switch contains a power source and a meter for each of its ports.

There typically are multiple instances of power sources and power meters in a PoE switch, but the drawing below shows only a single instance. The same applies to the powered devices that are represented by a single instance only.

Note that a typical PoE switch has also means to control power supply for powered devices (not shown here). Control of power supply is a subject of Section 4.

```
   +-------------------------------------------------------------------+
   |                     energy monitoring system                      |
   +-------------------------------------------------------------------+
                         ^
                         |
   +---------------------------------------------+
   |                     |                       |
   |          +----------+-----------+           |
   |          |                      |           |
   | +-----------------+   +-------------------+ |
   | |   power source  |   |    power usage    | |
   | |     monitor     |   |      monitor      | |
   | +-----------------+   +-------------------+ |
   |          |                      |           |
   | +-----------------+   +-------------------+ | +-------------------+
   | |      power      |   |    power meter    | | |      powered      |
   | |      source     |   +---------#---------+ | |      device       |
   | +-----------------+#########################|#+-------------------+
   |                                             |
   | Power over Ethernet switch                  |
   | or Power Distribution Unit                  |
   +---------------------------------------------+
     Scenarios 6 & 7: Power over Ethernet switch or Power Distribution
     Unit reporting on power source and power usage of powered devices
```

In this scenario the identification of the powered device can be done by the PoE switch by observing MAC and IP addresses of the powered devices. The switch can report them to the energy management system which then in turn can contact the devices directly to obtain further information.

3.5.7. Power Distribution Unit

The same figure as used for the PoE switch in the previous section is be used for scenario 7 modeling a power distribution unit (PDU). A PDU with meters for every socket can report power for each.

Identifying the powered devices can more difficult in this scenario than in the previous one with the PoE switch, because the PDU does not necessarily communicate with the powered devices. In this case the PDU or EMS needs to obtain this information by other means, for example by manual configuration.

3.5.8. Aggregator

Scenario 8 shows a power usage monitor acting as an aggregator. It collects power information from three powered devices and delivers all of the information to the energy monitoring system. The aggregator may deliver the full information or aggregated information, for example, just the sum of the power of all three powered devices.

```
+------------------------------------------------------------------+
|                      energy monitoring system                    |
+------------------------------------------------------------------+
                                  ^
                                  |
+------------------------------------------------------------------+
|                         power usage monitor                      |
+------------------------------------------------------------------+
     |                       |                       |
+--------------------+   +--------------------+   +--------------------+
|    |               |   |    |               |   |    |               |
|+-------+ +-------+|   |+-------+ +-------+|   |+-------+ +-------+|
|| power | |powered||   || power | |powered||   || power | |powered||
|| meter | |device ||   || meter | |device ||   || meter | |device ||
|+-------##+-------+|   |+-------##+-------+|   |+-------##+-------+|
+--------#----------+   +--------#----------+   +--------#----------+
         #                       #                       #
+------------------------------------------------------------------+
|                           power source                           |
+------------------------------------------------------------------+
```

Scenario 8: An aggregator collecting monitoring information from three powered devices

3.5.9. Energy Monitoring Gateway

Some energy monitoring scenarios include a gateway between the monitored units and the energy monitoring system. The powered device and the power meter may use means of communication other than IP.

The gateway is a relay and protocol converter that delivers energy information to a power monitor. A single device may implement logically independent gateways for multiple devices.

Scenario 9 can easily extended to a gateway that also contains a power source monitor.

```
   +-------------------------------------------------------------------+
   |                     energy monitoring system                      |
   +-------------------------------------------------------------------+
                                                 ^
                                                 |
                         +---------------------------------------------+
                         |                       |                     |
                         |           +-----------+-----------+         |
                         |           |                       |         |
                         | +-------------------+   +-----------------+ |
                         | |    power usage    |   |   power state   | |
                         | |      monitor      |   |     monitor     | |
                         | +-------------------+   +-----------------+ |
                         | gateway   |                       |         |
                         +---------------------------------------------+
                                     |                       |
   +-------------------+   +-------------------+   +-----------------+
   |       power       |   |    power meter    |   |     powered     |
   |       source      |   +---------#---------+   |     device      |
   +-------------------+###########################+-----------------+
```

Scenario 9: A gateway between monitored devices
and energy monitoring system

Here again, the problem of identifying the powered device has become very difficult, because neither can the power monitor provide an IP address of the powered device to the energy management system nor can the energy management system directly communicate with the powered device. Identification must be provided by other means. The Proxy can have a gateway function and relay identification between powered device and energy management system or the energy management system needs to acquire information on powered devices by other means, such as manual configuration.

3.5.10. Further Scenarios

More scenarios may be added to future versions of this document. Particularly, scenarios with multiple instances of an entity have not been elaborated a lot. Section 4.4 shows scenarios for energy control. They can also be considered as further monitoring scenarios if only their power monitors are considered and power controllers are ignored.

4. Energy Management Reference Model

This section extends the energy monitoring reference model specified in the previous Section 3 by adding power control functions. The resulting model is a complete energy management reference model.

As in Section 3 we first discuss entities and their relationships and then illustrate the model with example scenarios.

The extension from energy monitoring to energy management is straight forward. To achieve the required control functions the power source, power meter, and powered device have additional functions for control. For each power monitor a corresponding power controller is added as shown below.

Energy Management Reference Model

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
       ^          |           ^          |           ^          |
       |          v           |          v           |          v
   +--------+ +--------+   +--------+ +--------+   +--------+ +--------+
   | power  | | power  |   | power  | | power  |   | power  | | power  |
   | source | | source |   | usage  | | meter  |   | state  | | state  |
   | monitor| | ctrler |   | monitor| | ctrler |   | monitor| | ctrler |
   +--------+ +--------+   +--------+ +--------+   +--------+ +--------+
       |          |           |          |           |          |
   +-------------------+   +-------------------+   +-------------------+
   |       power       |   |    power meter    |   |      powered      |
   |       source      |   +-------------------+   |      device       |
   +-------------------+###########################+-------------------+

              symbols ######### represent a power line
```

4.1. Energy Management Entities

This section defines entities of the energy management reference model and describes interactions between them. Examples scenarios are illustrated in Section 4.4. For entities already specified in Section 3.2 of the energy monitoring reference model, only their additional properties are mentioned here. Power monitors are not discussed here again, because their specification in the energy management reference model do not change.

4.1.1. Powered Device

A powered device may be capable of changing its own power state from a request from the energy management system. Some devices may not be able to power up from an off state based on EMS request. Most devices that are asleep will be able to wake on EMES request.

4.1.2. Power Source

A power source may be capable of switching on and off power for powered devices.

4.1.3. Power Meter

A power meter may be switched on or off or have its metering parameters modified.

4.1.4. Power Controllers

A power controller receives commands from an energy management system to change the status or parameters of power sources, power meters, or powered devices.

There are three kinds of power controller entities: power state controllers, power source controllers, and power meter controllers.

4.1.4.1. Power State Controller

A power state controller can initiate a change in the power state of a powered device.

4.1.4.2. Power Source Controller

A power source controller can change the power supply of a powered device. Typically, it has means for switching power supply on and off. It may use these means without communicating with the affected powered device.

4.1.4.3. Power Meter Controller

A power meter controller has means for influencing the operation of a power meter. It may switch on and off the power meters and change parameters of their operation. For this purpose it may interact with power meters.

4.1.5. Energy Management System

An energy management system is an energy monitoring system extended by control functions. It interacts with power monitors and power controllers in order to achieve objectives of energy management.

It sends commands to power controllers. To power state controllers it sends requested power states for powered devices. To power source controllers it requests to switch on or off power for powered devices. To power meter controllers it sends commands concerning the operation of power meters.

4.2. Reference Points

Relevant for our reference model are interactions of the energy management system with power monitors and power controllers. They are reference points of our model and potential subjects of standardization in the EMAN working group. Interactions of power monitors and power controllers with other entities are currently not considered to be subject of standardization.

Monitoring protocols have already been discussed in Section 3.3. There are several choices of control protocols to be used for energy management. Among them are SNMP [RFC3410] and NETCONF [RFC4741].

4.3. Entity Relationships

The considerations on entity relationships for the energy monitoring reference model described in Section 3.4. apply as well to the energy management reference model: No restrictions on entity relationships have been identified.

4.4. Energy Management Scenarios

This section describes example scenarios for energy management and how they are modeled with the entities and interactions described above.

4.4.1. Simple Self-Managed Device

The first two examples are expected to become very common scenarios. Here, a powered device is managing its power state on its own based on input other than from the energy management system. The device may decide to change power state based on observation of its environment (no current load, high temperature, not sufficient light, scheduled time for service interruption, etc.) or it may receive external triggers, such as by a human-operated remote control.

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
                                                     ^
                                                     |
                                               +-----------------------+
                                               |     |                 |
                                               | +--------+ +--------+ |
                                               | | power  | | power  | |
                                               | | state  | | state  | |
                                               | | monitor| | ctrler | |
                                               | +--------+ +--------+ |
                                               |     |          |      |
   +-----------------+                         | +-------------------+ |
   |      power      |                         | |      powered      | |
   |      source     |                         | |      device       | |
   +-----------------+#|#########################+-------------------+ |
                                               |                       |
                                               | powered device with   |
                                               | power state control   |
                                               +-----------------------+
```

Scenario 10: A self-managed powered device

In any way, it’s power state control is independent of the energy management system. The only interaction with the system is reporting of power state to the energy management system in scenario 10, and in addition reporting of its current power and/or accumulated consumed energy in scenario 11.

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
                                               ^
                                               |
                       +-----------------------------------------------+
                       |                       |                       |
                       |     +-----------------+-----+                 |
                       |     |                       |                 |
                       | +--------+ +--------+   +--------+ +--------+ |
                       | | power  | | power  |   | power  | | power  | |
                       | | usage  | | meter  |   | state  | | state  | |
                       | | monitor| | ctrler |   | monitor| | ctrler | |
                       | +--------+ +--------+   +--------+ +--------+ |
                       |     |          |            |          |      |
   +-----------------+ | +-------------------+   +-------------------+ |
   |      power      | | |    power meter    |   |      powered      | |
   |      source     | | +---------#---------+   |      device       | |
   +-----------------+#|#########################+-------------------+ |
                       |                                               |
                       | powered device with built-in meter            |
                       | and autonomous control                        |
                       +-----------------------------------------------+
```

Scenario 11: A self-managed powered device with built-in meter

In scenario 11 also the control of the power meter is handled by the device itself.

4.4.2. Simple Managed Device

In our model, the scenario does not change much if the powered devices are not self-managed but managed by the energy management system. Scenarios 12 and 13 show that just an interaction between the energy management system and the powered device is added that serves for sending commands concerning power states to the device.

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
                                                     ^          |
                                                     |          |
                                               +-----------------------+
                                               |     |          v      |
                                               | +--------+ +--------+ |
                                               | | power  | | power  | |
                                               | | state  | | state  | |
                                               | | monitor| | ctrler | |
                                               | +--------+ +--------+ |
                                               |     |          |      |
   +-----------------+                         | +-------------------+ |
   |      power      |                         | |      powered      | |
   |      source     |                         | |      device       | |
   +-----------------+#########################|#+-------------------+ |
                                               |                       |
                                               | powered device with   |
                                               | power state control   |
                                               +-----------------------+
```

Scenario 12: A managed powered device

Control of the power meter by the management system can easily added to scenario 13. It is not included here, because for built-in meters this seems not to be necessary in many common cases.

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
                                               ^                |
                                               |                |
                       +-----------------------------------------------+
                       |                       |                |      |
                       |     +-----------------+-----+          |      |
                       |     |                       |          v      |
                       | +--------+ +--------+   +--------+ +--------+ |
                       | | power  | | power  |   | power  | | power  | |
                       | | usage  | | meter  |   | state  | | state  | |
                       | | monitor| | ctrler |   | monitor| | ctrler | |
                       | +--------+ +--------+   +--------+ +--------+ |
                       |     |          |            |          |      |
   +-----------------+ | +-------------------+   +-------------------+ |
   |      power      | | |    power meter    |   |      powered      | |
   |      source     | | +---------#---------+   |      device       | |
   +-----------------+#|#########################+-------------------+ |
                       |                                               |
                       | powered device with built-in meter            |
                       | and autonomous control                        |
                       +-----------------------------------------------+
```

Scenario 13: A managed powered device with built-in meter

4.4.3. Power over Ethernet Switch

Scenario 14 adds control functions to the PoE switch of scenario 6 in Section 3.5. Here the energy management system can explicitly request the power for a powered device to be switched on or off. It also can switch on and off metering and reporting of energy consumption per port of the switch

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
                   |     ^               |            ^
                   |     |               |            |
   +-------------------------------------------+ +---------------------+
   |               |     |               |     | |    |                |
   |    +----------------+----+          |     | |    |                |
   |    |          v          |          v     | |    |                |
   |+--------+ +--------+ +--------+ +--------+| |+--------+ +--------+|
   || power  | | power  | | power  | | power  || || power  | | power  ||
   || source | | source | | usage  | | meter  || || state  | | state  ||
   || monitor| | ctrler | | monitor| | ctrler || || monitor| | ctrler ||
   |+--------+ +--------+ +--------+ +--------+| |+--------+ +--------+|
   |    |          |          |          |     | |    |          |     |
   |+-------------------+ +-------------------+| |+-------------------+|
   ||       power       | |    power meter    || ||      powered      ||
   ||       source      | +---------#---------+| ||      device       ||
   |+-------------------+######################|#|+-------------------+|
   |                                           | |                     |
   | Power over Ethernet switch                | | powered device with |
   | or Power Distribution Unit                | | power state control |
   +-------------------------------------------+ +---------------------+
```

Scenario 14 & 15: Power over Ethernet switch
or Power Distribution Unit

Still, the powered device in this scenario is self-managed controlling its power state on its own and just reporting it to the energy management system.

4.4.4. Power Distribution Unit

Again, as in Section 3.5 the scenario for a power distribution unit looks exactly the same in our reference model as the scenario for a power distribution unit.

4.4.5. Energy Management Gateway

Starting from an energy monitoring gateway in Section 3.5 the extension towards an energy management gateway is again straight forward.

```
   +-------------------------------------------------------------------+
   |                     energy management system                      |
   +-------------------------------------------------------------------+
                                        |      ^                |
                                        |      |                |
                       +-----------------------------------------------+
                       |                |      |                |      |
                       |     +-----------------+-----+          |      |
                       |     | gateway  v            |          v      |
                       | +--------+ +--------+   +--------+ +--------+ |
                       | | power  | | power  |   | power  | | power  | |
                       | | usage  | | meter  |   | state  | | state  | |
                       | | monitor| | ctrler |   | monitor| | ctrler | |
                       | +--------+ +--------+   +--------+ +--------+ |
                       |     |          |            |          |      |
                       +-----------------------------------------------+
                             |          |            |          |
   +-----------------+   +-------------------+   +-------------------+
   |      power      |   |    power meter    |   |      powered      |
   |      source     |   +---------#---------+   |      device       |
   +-----------------+###########################+-------------------+
```

Scenario 16: A gateway between powered devices
and energy monitoring system

Here again, the problem of identifying the powered device has become very difficult, because neither can the power monitor provide an IP address of the powered device to the energy management system nor can the energy management system directly communicate with the powered device. Identification must be provided by other means. The Proxy can have a gateway function and relay identification between powered device and energy management system or the energy management system needs to acquire information on powered devices by other means, such as manual configuration.

4.4.6. Further Scenarios

More scenarios may be added to future versions of this document. Particularly, scenarios with multiple instances of an entity have not been elaborated, yet. Section 4.4 shows scenarios for energy control. They can also be considered as further monitoring scenarios if only their power monitors are considered and power controllers are ignored.

5. Security Considerations

This memo currently does not impose any security considerations.

6. IANA Considerations

This memo has no actions for IANA..

7. Acknowledgements

This memo was inspired by discussions with Benoit Claise, John Parello, Mouli Chandramouli, Rolf Winter, Thomas Dietz, Bill Mielke, and Chris Verges at IETF #79.

8. Open Isues

8.1. Short name for the protocol

We talk a lot in this document about reporting energy-related information to an energy management system. For this purpose the SNMP protocol will be used and required MIB modules are under development at the EMAN WG. It may simplify the text if we can refer to the process of reporting energy-related information with a placeholder, for example, 'EMON' for energy monitoring.

8.2. Identity Monitor

Shall we add a new building block called 'identity Monitor'?. This would tie in the work of the so-called POWER-AWARE-MIB.

8.3. Interactions with the EMS

Shall we discuss different kinds of interactions with the EMS? These would include

- o broadcasting to a subnet asking for all power monitors to report,
- o addressing a specific device and asking for all power monitor information it has,
- o asking a specific device about itself,
- o asking a specific device for specific information, which could include particular proxied devices, or pieces of EMON (state, meter, source, identity), aggregated data, or collected data.

Basically, these interactions are all cvered bythe IETF netwrk management framework. The question is whether to mention it explicitly in the reference model.

8.4. Third basic state for power source?

So far, a power source has the two basic states 'on' and 'off'. Should we describe a third basic state for a power source. This would be minimal (?trickle) power to enable communications but not activity. Would this model the way USB and PoE work? EMON would not specify the quantity of this power, but an EMS will know typical levels for relevant physical layer technologies.

8.5. Collector and Aggregator

It looks like we need to extend the model by a collctor function and an agregators function. A collector would collect energy-related information on other devices and report for multiple of them. An aggregator would use information from several devices and exceute operations n them, for example calculating a sum.

8.6. Gateways and Proxies

Is a gateway rather a scenario or a function? Scenarios 9 and 16 may need to be revised. In scenario 9 we talk about a 'proxy'. We need to explain what we mean with 'proxy'.

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Authors' Addresses

Juergen Quittek
NEC Europe Ltd.
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE

Phone: +49 6221 4342-115
Email: quittek@neclab.eu

Bruce Nordman
Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley 94720
US

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

Energy Management Working Group   E. Tychon
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                                                   Independent Consultant

March 15, 2011

Energy Management (EMAN) Applicability Statement
draft-tychon-eman-applicability-statement-01.txt

Status of this Memo

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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. We furthermore describe relations of the EMAN framework to other architectures and frameworks.

Table of Contents

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1. Introduction

The EMAN framework describes how energy information can be retrieved, controlled and monitored from IP-enabled consumers with traditional methods such as Simple Network Management Protocol (SNMP). In essence, the framework defines Management Information Base (MIBs) for SNMP.

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 similar to EMAN but addresses different domains or users.

EMAN will enable heterogeneous energy consumers to report their own consumption, and to a lesser extent, external system to control them. There are multiple scenarios where this is desirable, particularly today considering the increased importance of limiting consumption of finite energy resources and reducing operational expenses.

1.1. EMAN Documents Overview

The EMAN working group is actively working on a series of documents. (TODO: list existing documents)

1.2. Energy Measurement

More and more devices today are able to measure and report their own energy consumption. Smart power strips and some current generation Power-over-Ethernet switches are already able to meter consumption of the connected devices. However, when managed and reported through proprietary means, this information is not really useful at the enterprise level.

The primary goal of EMAN is to enable reporting and management within a standard framework that is applicable to the wide variety of today’s end devices, meters and proxies.

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.

1.3. 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 without considering the context. For instance you cannot turn off all phones, because some still need to be available in case of emergency. You can’t turn office cooling off totally during non-work hours, 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 soft-off modes [DQERM].

The EMAN framework will provide a control mechanism that is generalized for all devices, power states, and allows for fine-grained priority control, and emergency function.

Power control requires flexibility and support for different polices and mechanisms; including centralized management with a network management station, autonomous management by individual devices, and alignment with dynamic demand-response mechanisms.

1.4. Examples

1.4.1. Corporate Networks

Corporate networks connect computers, printers, phones, network equipment and other devices over local and wide area networks. These networks are typically centrally managed and operate 24x7.

Today, no standard MIB exists for monitoring and control of energy in enterprise network using SNMP.

1.4.2. 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 an emergency, such as a brownout risk day.

While building networks may be IP enabled, most use older network technologies including serial RS-485 and token ring technologies. Within these networks, gateways may connect the building system protocol to IP networks for management and control.

Air conditioning, lighting and so on can 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.

1.4.3. Home Energy Gateways

Home Energy Gateways (HEG) 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.

The HEG itself may use specific protocols, but using the EMAN framework, it will be able to report usage, pricing or other indicators to the user using SNMP. Using a simple application on its home network, the consumer is now empowered to see and decide how to use energy.

1.4.4. Datacenters

Datacenters too are big energy consumers. All that equipment generates heat, and heat needs to be evacuated though a HVAC (Heating, Ventilating, and Air Conditioning) system. Controlling the datacenter consumption means slowing down or turning off equipment and cooling.

The EMAN framework will enable a new level of control by providing a unified means of communication between heterogeneous devices over a network.

1.4.5. Intelligent Power Strips

Intelligent Power Strips are power distribution units with IP communication capability to remotely enable / disable a particular outlet, and often have the ability to measure power consumption for each outlet.

These devices are currently supporting either their own proprietary protocol or a proprietary SNMP MIB, but EMAN will provide a uniform framework designed for power control and monitoring for all vendors.

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 their objectives and the current state.

2.1. IEC

The International Electrotechnical Commission (IEC) has developed 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 electric utility automation. The abstract data model defined in 61850 is built upon and extends the Common Information Model (CIM). The complete 61850 CIM model includes over a hundred object classes and is widely used by utilities in the US and worldwide

This set of standards was originally conceived to automate control of a 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 original 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.

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

With its broad installed base and foundational data model for recent smart grid efforts, it’s highly advisable that the EMON model reuse as much as possible from the IEC standards.

2.2. ISO

The ISO is developing an energy management standard 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 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.

ISO 50001 is based on the common elements found in all of ISO's management system standards, assuring a high level of compatibility with ISO 9001 (quality management) and ISO 14001 (environmental management). ISO 50001 benefits will include

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

ISO 50001 is being developed by ISO project committee ISO/PC 242, Energy management and is expected to be published as an International Standard by 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), and 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 oriented toward the meter itself, and are therefore very specific and used by electricity distributors and producers.

The EMON standard should be compatible with existing ANSI C.12 standards.

2.4. EnergyStar

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

To earn Energy Star approval, appliances in the home or business must meet specific energy efficiency targets. 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 and comparative benchmarks.

http://www.energystar.gov/index.cfm?c=about.ab_history

2.5. DMTF

The DMTF has standardized management solutions for power-state configuration and management of elements in a heterogeneous environment. These specifications provide physical, logical and virtual system management requirements for power-state control.

Through various Working Group efforts these specifications continue to evolve and advance in features and functionalities. The full specifications can be found at the DMTF web site:

http://www.dmtf.org

2.5.1. Common Information Model Profiles

The DMTF uses CIM-based (Common Information Model) 'Profiles' to represent and manage power utilization and configuration of a managed element. The key profiles are 'Power Supply' (DSP 1015), 'Power State' (DSP 1027) and 'Power Utilization Management' (DSP 1085).

These profiles define monitoring and configuration of a Power Managed Element's static and dynamic power saving modes, power allocation limits and power states, among other features.

Power saving modes can be established as static or dynamic. Static modes are fixed policies that limit power to a utilization or wattage limit. Dynamic power saving modes rely upon internal feedback to control power consumption.

Power states are eight named operational and non operational levels. These are On, Sleep-Light, Sleep-Deep, Hibernate, Off-Soft, and Off-Hard. Power change capabilities provide immediate, timed interval, and graceful transitions between on, off, and reset power states. Table 3 of the Power State Profile defines the correspondence between the ACPI and DMTF power state models, although it is not necessary for a managed element to support ACPI. Optionally, a TransitingToPowerState property can represent power state transitions in progress.

2.5.2. Desktop And Mobile Architecture for System Hardware (DASH)

DMTF DASH (DSP0232) has addressed the challenges of managing heterogeneous desktop and mobile systems (including power) via in-band and out-of-band environments. Utilizing the DMTF's WS-Management web services and the CIM data model, DASH provides management and control of managed elements like power, CPU etc.

Both in service and out-of-service systems can be managed with the DASH specification in a fully secured remote environment. Full power lifecycle management is possible using out-of-band management.

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".

Smart Grid standards will provide distributed intelligence in the network and allow enhanced load shedding. For example, pricing signals will enable selective shutdown of non critical activities during peak-load pricing periods. These actions can be effected through both centralized and distributed management controls. Similarly, brown-outs, air quality alerts, and peak demand limits can be managed through the smart grid data models, based upon IEC 61850.

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 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 in term of measurement and, to a lesser extend, control over IP networks.

It is not the purpose of EMAN to create a new protocol stack for energy-aware endpoints, but rather to create a data model to measure and report energy and other metrics over SNMP.

Other legacy 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

EMAN uses the SNMP protocol and is subject to its own security. More specifically, SNMPv3 [RFC3411] provides important security features such as confidentiality, integrity, and authentication.

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

5. IANA Considerations

This memo includes no request to IANA.

6. References

6.1. Normative References

[RFC3411] An Architecture for Describing Simple Network Management Protocol (SNMP) Management Frameworks

6.2. Informative References

[DQERM] https://datatracker.ietf.org/doc/draft-quittek-eman-reference-model/

[NIST] http://www.nist.gov/smartgrid/

7. Acknowledgments

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Authors' Addresses

Emmanuel Tychon
Cisco Systems, Inc.
De Keleetlaan, 6A
B1831 Diegem
Belgium
Email: etychon@cisco.com

Matthew Laherty
Cisco Systems, Inc.
Email: mlaherty@cisco.com

Brad Schoening
44 Rivers Edge Drive
Little Silver, NJ 07739
USA
Email: brad@bradschoening.com

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Energy Monitoring and Management of Networked Entities using SNMP and Role-Specific Sparse Tables
draft-verges-eman-separate-modules-mib-00

Abstract

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

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols. In particular it defines objects for managing the power usage of a network entity.

The energy management schema is split into one core table to enumerate the entities being managed and numerous sparse table extensions that add role-specific functionality where appropriate.

Status of This Memo

Copyright Notice

Table of Contents

1. Introduction

This memo defines a portion 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 Energy Management Framework [EMAN-FMWK], which in turn, is based on Requirements for Power Monitoring [EMAN-REQ].

This module’s special focus is on monitoring energy-aware networks and devices. The module addresses enumeration of the entities being managed, reporting of energy data, control of the power state, mapping to physical and logical (business) contexts, and monitoring of self-reported health.

2. Energy Management Document Overview

The EMAN standards provides network administrators with energy management. This document is based on Energy Management Framework [EMAN-FMWK], which in turn, is based on Requirements for Power Monitoring [EMAN-REQ].

The EMAN-MIB contains five key subschemas which are given their own references for discussion purposes: EMAN-CORE-MIB, EMAN-DATA-MIB, EMAN-CONTROL-MIB, EMAN-CONTEXT-MIB, and EMAN-LLDP-MIB.

```
                         +---------------+
                         | EMAN-CORE-MIB |
                         +---------------+
                                 |
          +---------------+      |         +------------------+
          | EMAN-DATA-MIB |---------+---------| EMAN-CONTROL-MIB |
          +---------------+      |         +------------------+
                                 |
          +---------------+      |         +------------------+
          | EMAN-LLDP-MIB |---------+---------| EMAN-CONTEXT-MIB |
          +---------------+                +------------------+
```

Figure 1

The Core MIB [EMAN-CORE-MIB] described in Section 6 contains the core list of entities that are to be managed using the rest of this framework. It is separated from any role-specific functionality so that vendor-specific extensions and other future extensions may be developed independent from the core index.

The Energy Data MIB [EMAN-DATA-MIB] described in Section 7 contains the role-specific extensions needed to report power and energy usage for an entity. This MIB provides the detailed properties of the actual energy rate (power) and of accumulated energy, along with the power quality. EMAN-DATA-MIB is a sparse-table extension to EMAN-CORE-MIB.

The Energy Control MIB [EMAN-CONTROL-MIB] described in Section 8 contains the role-specific extensions needed to monitor and control power states for an entity. This MIB provides the current power state, power state transitions, and power state statistics.

The Energy Context MIB [EMAN-CONTEXT-MIB] described in Section 9 contains the role-specific extensions needed to establish physical and logical (business) context for an entity. This MIB provides a generic mechanism to create a classification category, map entities into the proper categories, and associate pricing data with each category.

The Energy LLDP MIB [EMAN-LLDP-MIB] described in Section 11 contains the role-specific extensions needed to link the entity with its associated Link Layer Discovery Protocol (LLDP) information.

3. Relationship to Other EMAN Proposals

At the time of this writing, two other MIB drafts are being considered by the EMAN working group: [PARELLO]/[CLAISE] and [QUITTEK]. The MIB proposed here combines aspects of both in a more generic structure, while still meeting all requirements of [EMAN-REQ]. (For the purposes of this explanation, [PARELLO] and [CLAISE] are referenced as a single group of tightly related drafts that must be considered together.)

In [PARELLO] and [CLAISE], the primary structure is centered around pmTable. Entities are defined by separate rows in the table structure, but the structure tightly couples the entity definition with context-related attributes of the entity’s use. For example:

- pmDomainName defines a single context for an entity. While the intention is that pmDomainName primarily describe a physical relationship that the entity may share with other entities (like being connected to the same branch circuit), it does not allow for other groupings due to the one-to-one relationship between pmDomainName and pmIndex. If such groupings were added at a later time using a sparse table extension, many attributes (like pmRoleDescription, pmKeywords, and pmImportance) would need to be duplicated in the sparse table, resulting in the same type of information living in separate OID subtrees.

- The LLDP information defined by pmLldpPortNumber, pmEthPortIndex, and pmEthPortGrpIndex are very specific to networking equipment such as routers and switches. Since such information is optional for other equipment (like servers and intelligent power distribution units), the LLDP properties should be split into a separate sparse table to make the coupling looser and increase MIB maintainability as it continues to be expanded in the future.

- o The control mechanism defined by pmPowerLevelTable forces a single interface for power control, on an arbitrary 0-12 scale. While the authors have maintained on the mailing list that the pmPowerLevelMappingTable can be used to map other mechanisms such as ACPI or DMTF, such a structure forces the end user to map their own use onto the schema, rather than the schema supporting the operation desired by the end user.

- o The complex power data reporting structure defined by pmACPwrQualityTable, pmACPwrQualityPhaseTable, etc. attempts to link too much context awareness of the data into the schema itself, resulting in a bloated and cumbersome system. If an end user wanted to obtain data updates, several OID trees would need to be walked simultaneously in order to fully understand the data.

[QUITTEK] assumes that all entities that will ever be modeled must be physical in nature, so uses ENTITY-MIB as a core model. This results in an extremely simple MIB schema that cannot adequately meet the requirements of network switches that report power on behalf of PoE devices or intelligent power distribution units (iPDU’s). For example:

- o Given ENTITY-MIB’s natural structure to enumerate both physical and logical entities of a system, the attraction to re-use this structure is apparent. However, ENTITY-MIB distinguishes physical and logical entities by containing two MIB tables, one for each category. The result is that sparse table extensions (such as powerStateTable and energyConsumpTable) must choose whether to link to entPhysicalTable or entLogicalTable. For a server or other devices that are relatively simple in power distribution design, all components being modeled are generally physical, so entPhysicalTable makes sense. However, for intelligent power distribution units, a major limitation is reached. Some iPDU’s, for example, support "ganging" of outlets into a logical entity for management purposes. To represent such a collection in entPhysicalTable would misuse the core rationale behind entPhysicalTable. One solution that would use ENTITY-MIB to solve this problem would be to have two of everything in [QUITTEK], one for physical entities and one for logical entities. But this is not an ideal solution, as it both burdens the end user and the implementing vendor.

This draft attempts to correct those problems through the use of several specific changes:

1. Define both physical and logical entities that are power-related in a standalone table. If a power entity should be related to an entity defined by ENTITY-MIB, the value of the index can be placed into emanEntityPhysicalId or emanEntityLogicalId as appropriate; otherwise, the value should be zero for the unused column(s).

2. Similar to [QUITTEK], sparse tables that have a narrowly defined scope extend off this core entity list. This allows for an end user to walk a single sparse table to obtain all data updates related to one group: data, control/state, LLDP information, etc.

3. Power entities are defined as one of two types: simple or complex. A simple entity can be fully described by a single data row or control/state row. A complex entity can be deconstructed into multiple simple entities. An example of a simple entity would be a single phase AC power meter, while a complex entity would be a three phase AC power meter. (A three phase meter can be thought of as being comprised by three or four individual single phase meters with phase relationship information added.) The result is a simplified MIB tree with a single "data" tree and a single "control" tree that can be accessed and understood with a single table walk.

4. Multiple control mechanisms are supported so that end users can think in whatever terms are familiar to them. For example, if an end user is more familiar with ACPI levels than DMTF Power State levels, they can use the emanAcpiControl object. If they work more with the DMTF, they can use the emanDmtfControl object. Or if they think more in terms of a percentage scale, they can use the emanPercentageControl object. It is up to the implementing vendor to figure out how to relate these different control mechanisms with each other in a way that makes sense to the agent’s core purpose. Exposing different interfaces only simplifies the process for the end user.

5. Context for an entity is not considered a core concept for defining what an entity is, but is instead a sparse table extension. Both physical contexts (like branch circuits) and logical contexts (like ownership by a common business unit) are enabled in the same context tree, allowing the user to access a single table that contains all of the context information, regardless of the context type.

The end result is a design which has low coupling and high cohesion, that will allow the IETF to continue to grow and expand it as the Smart Grid and other power-related technologies continue to mature and develop.

4. The Internet-Standard Management Framework

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

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

5. Conventions

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].

6. Structure of the EMAN-CORE-MIB Module

The primary structure in EMAN-CORE-MIB is the emanEntityTable. This structure comprises a list of entities that are to be managed under the EMAN schemas. The list is hierarchical in nature, where entities may have parent/child relationships.

6.1. Textual Conventions

6.1.1. EmanEntityRole

This textual convention specifies the type of entity being described. For example, the entity can either be a meter reporting on behalf of an another device or a consumer reporting its own use. Other entity types may be defined as future extensions.

6.1.2. EmanEntityCapabilities

This textual convention specifies the EMAN-specific capabilities that the entity is capable of supporting, as a SMIv2 BITS extension. Each role-specific extension is represented as one bit, and entities which support a role extension must advertise that capability by setting the corresponding bit.

6.1.3. Thousandths

This textual convention specifies a fixed point decimal value up to a 10^(-3) precision (0.001). Based on an Integer32 data type, this textual convention supports from -2,147,483.647 to +2,147,483.647.

6.1.4. UnitMultiplier

This textual convention 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, a UnitMultiplier of -3 corresponds with a unit scale of "milli", 10^-3.

When used in combination with a Thousandths TC value of 1234, for example, a UnitMultiplier of unit(0) would result in the value being equivalent to the original intent behind the Thousandths TC (1.234). Changing the UnitMultiplier to milli(-3) would result in the value being equivalent to 0.001234. Likewise, changing to kilo(3) would result in the value being 1,234.000.

6.2. The Notifications Subtree

EMAN-CORE-MIB implements no notifications at this time.

6.3. The Table Structures

The heart of the entire role-specific extension schema is the list of entities in emanEntityTable. An entity in this list may be simple (described in and of itself) or complex (described by several child entities.)

For example, consider a standard computer workstation with a single AC/DC power supply. The emanEntityTable to describe this scenario might contain the following:

Idx	Name	Type	Parent
1	PC Power Supply	consumer(1)	0

Table 1: Simple entities in emanEntityTable

Complex entities can be described using the same schema by describing a set of simple child entities. For example, consider an ingellient power distribution unit with one three-phase input cord and three single-phase banks of two outlets each:

Idx	Name	Type	Parent
1	Internal NIC	consumer(0)	0
2	Input Cord 1 - 3PH DELTA	meter(1)	0
3	Input Cord 1 - Line A	meter(1)	2
4	Input Cord 1 - Line B	meter(1)	2
5	Input Cord 1 - Line C	meter(1)	2
6	Bank 1 - Line AB	meter(1)	0
7	Bank 2 - Line BC	meter(1)	0
8	Bank 3 - Line CA	meter(1)	0
9	Outlet 1	meter(1)	0
10	Outlet 2	meter(1)	0
...	...	...	...

Table 2: Complex entities in emanEntityTable

In the above example, note how the complex entity of the three-phase input cord is subdivided into separate simple entities that are the individual lines in the input cord. This allows each entity (the input cord bundle and each of its lines) to be addressed separately, if desired, by role-specific extensions and enterprise-specific extensions.

In deciding whether an entity is simple or complex, an implementing vendor should consider the impact of using either type on the role-specific subschemas that the entity will implement. For example, a server can be modeled as either a simple entity (the server as a single, simple entity) or as a complex entity (the server as an aggregation of power supplies, internal batteries, processors, etc.) Both choices are equally valid, and the implementing agent should choose the one that makes the most sense for the end users that it serves.

Top-level entities should set their emanEntityParent to zero (0) if the entity has no parent. The emanEntityParent column refers to the emanEntityIndex of the parent entity.

If a row is added or deleted, the corresponding role-specific extensions should likewise update to reflect the new state.

7. Structure of the EMAN-DATA-MIB Module

EMAN-DATA-MIB builds on EMAN-CORE-MIB by providing power and energy data for entities that support it. Entities which implement EMAN-

DATA-MIB must set the instant(0) and/or historical(1) capabilities bits appropriately.

7.1. Textual Conventions

PhaseOffset specifies the phase angle offset of the entity’s voltage wave relative to zero (0) degrees. In a typical three-phase system, Line AN is 0 degrees, BN is 120 degrees, and CN is 240 degrees, for example. Negative values can indicate a positive or negative rotation.

DataAccuracy specifies the accuracy of the data as a percentage. This data type is based on the IEC classification of power meters (2.0%, 1.0%, 0.5%, etc.) A DataAccuracy value of 150 corresponds with an accuracy of 1.5%.

DataCaliber specifies the caliber of the data, whether it is unknown(0) or actual(1) or estimated(2) or presumed(3). If the data is measured, for example, the caliber is "actual."

7.2. The Notifications Subtree

EMAN-DATA-MIB implements no notifications at this time.

7.3. The Table Structures

The data represented in emanInstantDataTable represents the instantaneous data for an entity. To use this table, an implementing entity must set the instant(0) capability bit. All data in this table is "normalized" to single-phase AC or DC format to ensure consistency in the data returned and simplicity of third-party systems that will be using the data returned by the EMAN agent.

For example, consider modeling the instantaneous data for the three-phase input cord entity described earlier in Table 2:

Idx	(Name)	Voltage	Current	Active Power
2	Input Cord 1 - 3PH DELTA	208.830	33.481	6,991.848
3	Input Cord 1 - Line A	205.350	14.900	3,059.715
4	Input Cord 1 - Line B	212.031	7.455	1,580.691
5	Input Cord 1 - Line C	209.110	11.245	2,351.442

The complex input cord data entry reflects the proper three-phase power and the single-phase-equivalent voltage/current.

Table 3: Instantaneous data for complex entities

If an entity does not support one of the data types (ex. harmonic distortion), that column may optionally be ommitted for the entity’s row.

8. Structure of the EMAN-CONTROL-MIB Module

EMAN-CONTROL-MIB builds on EMAN-CORE-MIB by providing power state control for entities that support it. Since several different power state mechanisms are currently in use on various systems, EMAN-CONTROL-MIB offers a way for an entity to interface with all of the mechanisms, allowing both the implementing agent and end user the flexibility to choose the best mechanism for their purpose. Entities which implement EMAN-CONTROL-MIB must set the acpi(2), percent(3) and/or dmtf(7) capabilities bits appropriately.

8.1. Textual Conventions

AcpiState specifies the seven power usage states defined by the Advanced Configuration and Power Interface standard [ACPI].

Percentage specifies a gradiated scale from 0% (off) to 100% (full-power).

DmtfPowerState specifies the fifteen power usage states defined by the Distributed Management Task Force [DSP1027].

8.2. The Notifications Subtree

EMAN-CONTROL-MIB implements no notifications at this time.

8.3. The Table Structures

The control mechanisms in emanControlTable allow a end user to query and change the power state of the entity. To use emanAcpiControl, an implementing entity must set the acpi(2) capability bit. To use emanPercentageControl, an implementing entity must set the percentage(3) capability bit. To use emanDmtfControl, an implementing entity must set the dmtf(7) capability bit.

With one exception, the implementing entity will decide how to map the different control mechanisms to each other, based on what is appropriate for the entity. For example, consider a standard network workstation:

ACPI	Percentage
g0s0	100%
g1s1	75%
g1s2	66%
g1s3	30%
g1s4	1%
g2s5	5%
g3	0%

Table 4: Mapping of ACPI and Percentage Control Mechanisms for Workstation XYZ

The flexibility of supporting several different control mechanisms at the same time means that vendors who implement EMAN-CONTROL-MIB should carefully consider the mapping for the various mechanisms for their product. The exception is when an entity implements both acpi(2) and dmtf(7). The link between these states defined in [DSP1027] Table 3 must be observed to ensure entity compliance to the ACPI and DMTF standards.

9. Structure of the EMAN-CONTEXT-MIB Module

EMAN-CONTEXT-MIB builds on EMAN-CORE-MIB by providing context behind the power use of an entity. Entities which implement EMAN-CONTEXT-MIB must set the context(5) capability bit appropriately.

9.1. Textual Conventions

ContextType specifies what type of context is being defined -- physical(1) or logical(2). A physical context is one where the entities are related electrically, like a common branch circuit or transformer. A logical context is one where the entities are related in some other way, such as ownership or intended use.

9.2. The Notifications Subtree

EMAN-CONTEXT-MIB implements no notifications at this time.

9.3. The Table Structures

emanContextTable is a list of all contexts known by the agent. This allows contexts to be listed once and reused by several entities if such a mapping makes sense.

emanContextMappingTable creates a link between contexts and entities.

It uses a single entry, emanContextMappingRowStatus, to determine whether the mapping is active. Mappings can be added through 'createAndGo' or 'createAndWait' and can be removed through 'destroy'.

10. Structure of the EMAN-HEALTH-MIB Module

10.1. Textual Conventions

TBD

10.2. The Notifications Subtree

EMAN-HEALTH-MIB implements no notifications at this time.

10.3. The Table Structures

TBD

11. Structure of the EMAN-LLDP-MIB Module

11.1. Textual Conventions

The various textual conventions implemented by this MIB are fully described in the MIB itself.

11.2. The Notifications Subtree

EMAN-LLDP-MIB implements no notifications at this time.

11.3. The Table Structures

emanLldpTable provides LLDP-specific information for an entity.

12. Relationship to Other MIB Modules

[[anchor29: [TEMPLATE TODO]: The narrative part should include a section that specifies the relationship (if any) of the MIB modules contained in this internet drafts to other standards, particularly to standards containing other MIB modules. If the MIB modules defined by the specification import definitions from other MIB modules or are always implemented in conjunction with other MIB modules, then those facts should be noted in the narrataive section, as should any special interpretations of objects in other MIB modules. Note that citations may NOT be put into the MIB module portions of the internet draft, but documents used for Imported items are Normative references, so the citations should exist in the narrative section of the internet draft. The preferred way to fill in a REFERENCE clause in a MIB module is of the form: "Guidelines for Writing an IANA Considerations Section in RFCs", RFC2434, section 2.3.]]

12.1. Relationship to the [TEMPLATE TODO] MIB

[[anchor31: Example: The Interface MIB [RFC2863] requires that any MIB module which is an adjunct of the Interface MIB clarify specific areas within the Interface MIB. These areas were intentionally left vague in the Interface MIB to avoid over-constraining the MIB, thereby precluding management of certain media-types. Section 4 of [RFC2863] enumerates several areas which a media-specific MIB must clarify. The implementor is referred to [RFC2863] in order to understand the general intent of these areas.]]

12.2. MIB modules required for IMPORTS

[[anchor33: [TEMPLATE TODO]: Citations are not permitted within a MIB module, but any module mentioned in an IMPORTS clause or document mentioned in a REFERENCE clause is a Normative reference, and must be cited someplace within the narrative sections. If there are imported items in the MIB module, such as Textual Conventions, that are not already cited, they can be cited in text here. Since relationships to other MIB modules should be described in the narrative text, this section is typically used to cite modules from which Textual Conventions are imported. Example: "The following MIB module IMPORTS objects from SNMPv2-SMI [RFC2578], SNMPv2-TC [RFC2579], SNMPv2-CONF [RFC2580], and IF-MIB [RFC2863]."]]

13. Definitions

```
EMAN-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,
    Integer32, Unsigned32, mib-2
    FROM SNMPv2-SMI

    SnmpAdminString
    FROM SNMP-FRAMEWORK-MIB

    TEXTUAL-CONVENTION, RowStatus, TimeInterval,
    TruthValue
    FROM SNMPv2-TC

    MODULE-COMPLIANCE, OBJECT-GROUP, NOTIFICATION-GROUP
    FROM SNMPv2-CONF

    PhysicalIndexOrZero
```

```
    FROM ENTITY-MIB;

eman MODULE-IDENTITY
    LAST-UPDATED    "201102110000Z"
    ORGANIZATION    "Cyber Switching, Inc."
    CONTACT-INFO    "http://www.cyberswitching.com"
    DESCRIPTION     "The MIB for reporting and managing power usage of
                    networked entities through SNMP."
    REVISION        "201102110000Z"
    DESCRIPTION     "Initial draft release."
    ::= { mib-2 XXX }

EmanEntityRole ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the type of entity."
    SYNTAX          INTEGER {
                        meter(0),
                        consumer(1)
                    }

EmanEntityCapabilities ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the capabilities of the entity."
    SYNTAX          BITS {
                        instant(0),     -- instant data reporting
                        historical(1),  -- historical data reporting
                        acpi(2),        -- ACPI-based control
                        percent(3),     -- Percentage-based control
                        health(4),      -- health reporting
                        context(5),     -- context awareness
                        lldp(6),        -- LLDP awareness
                        dmtf(7)         -- DMTF Power State control
                    }

Thousandths ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "d-3"
    STATUS          current
    DESCRIPTION     "Specifies a value as 10^(-3) precision."
    SYNTAX          Integer32

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),     -- 10^0
                        kilo(3),      -- 10^3
                        mega(6),      -- 10^6
                        giga(9),      -- 10^9
                        tera(12),     -- 10^12
                        peta(15),     -- 10^15
                        exa(18),      -- 10^18
                        zetta(21),    -- 10^21
                        yotta(24)     -- 10^24
                    }

emanCore OBJECT IDENTIFIER
    ::= { eman 1 }

emanEntityTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanEntityEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A table of all power entities being managed."
    ::= { emanCore 1 }

emanEntityEntry OBJECT-TYPE
    SYNTAX          EmanEntityEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A power entity."
    INDEX           { emanEntityIndex }
    ::= { emanEntityTable 1 }

EmanEntityEntry ::=
    SEQUENCE {
        emanEntityIndex                 Unsigned32,
        emanEntityName                  SnmpAdminString,
        emanEntityAlias                 SnmpAdminString,
        emanEntityType                  EmanEntityRole,
```

```
        emanEntityCapabilities          EmanEntityCapabilities,
        emanEntityParent                Unsigned32,
        emanEntityPhysicalId            PhysicalIndexOrZero,
        emanEntityLogicalId             Integer32
    }

emanEntityIndex OBJECT-TYPE
    SYNTAX          Unsigned32
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The index of the entry in the table."
    ::= { emanEntityEntry 1 }

emanEntityName OBJECT-TYPE
    SYNTAX          SnmpAdminString
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The name of the entity."
    ::= { emanEntityEntry 2 }

emanEntityAlias OBJECT-TYPE
    SYNTAX          SnmpAdminString
    MAX-ACCESS      read-write
    STATUS          current
    DESCRIPTION     "The user-defined alias of the entity."
    ::= { emanEntityEntry 3 }

emanEntityType OBJECT-TYPE
    SYNTAX          EmanEntityRole
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The type of entity being modeled."
    ::= { emanEntityEntry 4 }

emanEntityCapabilities OBJECT-TYPE
    SYNTAX          EmanEntityCapabilities
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "A list of capabilities supported by this entity."
    ::= { emanEntityEntry 5 }

emanEntityParent OBJECT-TYPE
    SYNTAX          Unsigned32
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The index of the entity’s parent in the table."
   ::= { emanEntityEntry 6 }
```

```
emanEntityPhysicalId OBJECT-TYPE
    SYNTAX          PhysicalIndexOrZero
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The index of the entity's entry in
                    entPhysicalTable, or zero (0) if unused."
   ::= { emanEntityEntry 7 }

emanEntityLogicalId OBJECT-TYPE
    SYNTAX          Integer32
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The index of the entity's entry in
                    entLogicalTable, or zero (0) if unused."
   ::= { emanEntityEntry 8 }

--
-- EMAN Data Add-On
--

emanData OBJECT IDENTIFIER
    ::= { eman 2 }

PercentageDistortion ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "d-3"
    STATUS          current
    DESCRIPTION     "Specifies the distortion as a tenth of a percent
                    (0.1%)."
    SYNTAX          Unsigned32 (0..1000)

PhaseOffset ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "d"
    STATUS          current
    DESCRIPTION     "Specifies the phase offset."
    SYNTAX          Integer32 (-360..360)

DataAccuracy ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "d-4"
    STATUS          current
    DESCRIPTION     "Specifies the data accuracy as a hundredth of a
                    percent (ex. 0.0001 or 0.01%)."
    SYNTAX      Integer32 (-10000..10000)

DataCaliber ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the data caliber."
    SYNTAX          INTEGER {
                        unknown(0),
```

```
                        actual(1),
                        estimated(2),
                        presumed(3)
                    }

PowerType ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the type of power."
    SYNTAX          INTEGER {
                        unknown(0),
                        ac(1),
                        dc(2)
                    }

EmanDataType ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the data type to use for an alert
                    comparison."
    SYNTAX          INTEGER {
                        unknown(0),
                        undefined(1),
                        current(2),
                        voltage(3),
                        activepower(4),
                        reactivepower(5),
                        apparentpower(6),
                        frequency(7),
                        powerfactor(8)
                    }

ComparisonOperator ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies a comparison operator."
    SYNTAX          INTEGER {
                        unknown(0),
                        undefined(1),
                        equal(2),
                        notequal(3),
                        greater(4),
                        greaterorequal(5),
                        less(6),
                        lessorequal(7)
                    }

AlertSeverity ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies a severity level for an alert."
    SYNTAX          INTEGER {
```

```
                        emergency(0),
                        alert(1),
                        critical(2),
                        error(3),
                        warning(4),
                        notice(5),
                        informational(6),
                        debug(7)
                    }

emanInstantDataTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanInstantDataEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table of an entity's power data."
    ::= { emanData 1 }

emanInstantDataEntry OBJECT-TYPE
    SYNTAX          EmanInstantDataEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The real-time power data for an entity."
    INDEX           { emanEntityIndex }
    ::= { emanInstantDataTable 1 }

EmanInstantDataEntry ::=
    SEQUENCE {
        emanInstantAmperage             Thousandths,
        emanInstantVoltage              Thousandths,
        emanInstantPowerUnit            UnitMultiplier,
        emanInstantActivePower          Thousandths,
        emanInstantReactivePower        Thousandths,
        emanInstantApparentPower        Thousandths,
        emanInstantPowerFactor          Thousandths,
        emanInstantFrequency            Thousandths,
        emanInstantHarmonicDistortion   PercentageDistortion,
        emanInstantPhaseOffset          PhaseOffset
    }

emanInstantAmperage OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous RMS amperage."
    ::= { emanInstantDataEntry 1 }

emanInstantVoltage OBJECT-TYPE
    SYNTAX          Thousandths
```

```
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous RMS voltage."
    ::= { emanInstantDataEntry 2 }

emanInstantPowerUnit OBJECT-TYPE
    SYNTAX          UnitMultiplier
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The unit scale used for emanInstantActivePower,
                    emanInstantReactivePower, and
                    emanInstantApparentPower."
    ::= { emanInstantDataEntry 3 }

emanInstantActivePower OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous wattage."
    ::= { emanInstantDataEntry 4 }

emanInstantReactivePower OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous volt-amps (reactive)."
    ::= { emanInstantDataEntry 5 }

emanInstantApparentPower OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous volt-amps."
    ::= { emanInstantDataEntry 6 }

emanInstantPowerFactor OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous power factor."
    ::= { emanInstantDataEntry 7 }

emanInstantFrequency OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous frequency."
    ::= { emanInstantDataEntry 8 }
```

```
emanInstantHarmonicDistortion OBJECT-TYPE
    SYNTAX          PercentageDistortion
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous harmonic distortion."
    ::= { emanInstantDataEntry 9 }

emanInstantPhaseOffset OBJECT-TYPE
    SYNTAX          PhaseOffset
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The instantaneous phase offset."
    ::= { emanInstantDataEntry 10 }

emanDataPropertyTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanDataPropertyEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table of an entity's data attributes."
    ::= { emanData 2 }

emanDataPropertyEntry OBJECT-TYPE
    SYNTAX          EmanDataPropertyEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The power data attributes for an entity."
    INDEX           { emanEntityIndex }
    ::= { emanDataPropertyTable 1 }

EmanDataPropertyEntry ::=
    SEQUENCE {
        emanDataAccuracy                   DataAccuracy,
        emanDataCaliber                    DataCaliber,
        emanNameplatePowerUnit             UnitMultiplier,
        emanNameplateMaxPower              Thousandths,
        emanNameplateMaxCurrent            Thousandths,
        emanNameplateMaxVoltage            Thousandths,
        emanNameplateMinPower              Thousandths,
        emanNameplateMinCurrent            Thousandths,
        emanNameplateMinVoltage            Thousandths,
        emanPowerType                      PowerType
    }

emanDataAccuracy OBJECT-TYPE
    SYNTAX          DataAccuracy
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The accuracy of the power data reported."
```

```
    ::= { emanDataPropertyEntry 1 }

emanDataCaliber OBJECT-TYPE
    SYNTAX          DataCaliber
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The caliber of the power data reported."
    ::= { emanDataPropertyEntry 2 }

emanNameplatePowerUnit OBJECT-TYPE
    SYNTAX          UnitMultiplier
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The unit scale used for
                    emanNameplate[Max|Min]Power."
    ::= { emanDataPropertyEntry 3 }

emanNameplateMaxPower OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The maximum nameplate power rating."
    ::= { emanDataPropertyEntry 4 }

emanNameplateMaxCurrent OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The maximum nameplate current rating."
    ::= { emanDataPropertyEntry 5 }

emanNameplateMaxVoltage OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The maximum nameplate voltage rating."
    ::= { emanDataPropertyEntry 6 }

emanNameplateMinPower OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The minimum nameplate power rating."
    ::= { emanDataPropertyEntry 7 }

emanNameplateMinCurrent OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
```

```
    STATUS          current
    DESCRIPTION     "The minimum nameplate current rating."
    ::= { emanDataPropertyEntry 8 }

emanNameplateMinVoltage OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The minimum nameplate voltage rating."
    ::= { emanDataPropertyEntry 9 }

emanPowerType OBJECT-TYPE
    SYNTAX          PowerType
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The power type for the entity."
    ::= { emanDataPropertyEntry 10 }

emanDataAlertTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanDataAlertEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table of an entity's data alerts."
    ::= { emanData 3 }

emanDataAlertEntry OBJECT-TYPE
    SYNTAX          EmanDataAlertEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The power data alert for an entity."
    INDEX           { emanEntityIndex, emanDataAlertIndex }
    ::= { emanDataAlertTable 1 }

EmanDataAlertEntry ::=
    SEQUENCE {
        emanDataAlertIndex              Unsigned32,
        emanDataAlertName               SnmpAdminString,
        emanDataAlertEnabled            TruthValue,
        emanDataAlertCompareOn          EmanDataType,
        emanDataAlertComparison         ComparisonOperator,
        emanDataAlertValue              Thousandths,
        emanDataAlertUnit               UnitMultiplier,
        emanDataAlertDelay              TimeInterval,
        emanDataAlertSeverity           AlertSeverity,
        emanDataAlertRowStatus          RowStatus
    }

emanDataAlertIndex OBJECT-TYPE
```

```
    SYNTAX          Unsigned32
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The name of the alert condition."
    ::= { emanDataAlertEntry 1 }

emanDataAlertName OBJECT-TYPE
    SYNTAX          SnmpAdminString
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The name of the alert condition."
    ::= { emanDataAlertEntry 2 }

emanDataAlertEnabled OBJECT-TYPE
    SYNTAX          TruthValue
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The flag to indicate whether the alert is enabled."
    ::= { emanDataAlertEntry 3 }

emanDataAlertCompareOn OBJECT-TYPE
    SYNTAX          EmanDataType
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The data type to compare against for the alert."
    ::= { emanDataAlertEntry 4 }

emanDataAlertComparison OBJECT-TYPE
    SYNTAX          ComparisonOperator
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The comparison operation to perform for the alert."
    ::= { emanDataAlertEntry 5 }

emanDataAlertValue OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The value to compare against for the alert."
    ::= { emanDataAlertEntry 6 }

emanDataAlertUnit OBJECT-TYPE
    SYNTAX          UnitMultiplier
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The unit scale used for emanDataAlertValue."
    ::= { emanDataAlertEntry 7 }
```

```
emanDataAlertDelay OBJECT-TYPE
    SYNTAX          TimeInterval
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The time delay to wait after the alert condition is
                    triggered but before triggering the alert."
    ::= { emanDataAlertEntry 8 }

emanDataAlertSeverity OBJECT-TYPE
    SYNTAX          AlertSeverity
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The severity of the alert when triggered."
    ::= { emanDataAlertEntry 9 }

emanDataAlertRowStatus OBJECT-TYPE
    SYNTAX          RowStatus
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The mechanism to manage dynamic alert entries."
    ::= { emanDataAlertEntry 10 }

emanDataTrapVariables OBJECT IDENTIFIER
    ::= { emanData 4 }

emanDataAlertTriggeredValue OBJECT-TYPE
    SYNTAX          Thousandths
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The actual value when the alert condition
                    triggered."
    ::= { emanDataTrapVariables 1 }

emanDataTraps OBJECT IDENTIFIER
    ::= { emanData 5 }

emanDataTrapsReversible OBJECT IDENTIFIER
    ::= { emanDataTraps 0 }

emanDataAlertNotification NOTIFICATION-TYPE
    OBJECTS         {
                        emanDataAlertName,
                        emanDataAlertSeverity,
                        emanDataAlertValue,
                        emanDataAlertUnit,
                        emanDataAlertTriggeredValue
                    }
    STATUS          current
```

```
    DESCRIPTION     "Sent to notify a third-party about an alert
                    condition triggering."
    ::= { emanDataTrapsReversible 1 }

--
-- EMAN Control Add-On
--

emanControl OBJECT IDENTIFIER
    ::= { eman 5 }

AcpiState ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the states specified by the ACPI
                    standard."
    SYNTAX          INTEGER {
                        g0s0(0),
                        g1s1(1),
                        g1s2(2),
                        g1s3(3),
                        g1s4(4),
                        g2s5(5),
                        g3(6)
                    }

DmtfPowerState ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the states specified by the DMTF
                    DSP1027 standard.  The state powercyclehard(9)
                    is a transition state for offhard(6) followed by
                    on(2), so is a write-only operation to simplify the
                    SNMP client interaction with an agent."
    SYNTAX          INTEGER {
                        on(2),
                        sleeplight(3),
                        sleepdeep(4),
                        powercyclesoft(5),
                        offhard(6),
                        hibernate(7),
                        offsoft(8),
                        powercyclehard(9),
                        masterbusreset(10),
                        diaginterrupt(11),
                        offsoftgraceful(12),
                        offhardgraceful(13),
                        masterbusresetgraceful(14),
                        powercycleoffsoftgraceful(15),
                        powercycleoffhardgraceful(16)
```

```
                    }

Percentage ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "d"
    STATUS          current
    DESCRIPTION     "Specifies a percentage value."
    SYNTAX          Unsigned32 (0..100)

emanControlTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanControlEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table of all the entity's control
                    mechanisms."
    ::= { emanControl 1 }

emanControlEntry OBJECT-TYPE
    SYNTAX          EmanControlEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The control mechanisms for an entity."
    INDEX           { emanEntityIndex }
    ::= { emanControlTable 1 }

EmanControlEntry ::=
    SEQUENCE {
        emanAcpiControl                  AcpiState,
        emanPercentageControl            Percentage,
        emanDmtfControl                  DmtfPowerState
    }

emanAcpiControl OBJECT-TYPE
    SYNTAX          AcpiState
    MAX-ACCESS      read-write
    STATUS          current
    DESCRIPTION     "The current ACPI state of the entity."
    ::= { emanControlEntry 1 }

emanPercentageControl OBJECT-TYPE
    SYNTAX          Percentage
    MAX-ACCESS      read-write
    STATUS          current
    DESCRIPTION     "The current state of the entity as expressed by a
                    percentage of its full running capacity."
    ::= { emanControlEntry 2 }

emanDmtfControl OBJECT-TYPE
    SYNTAX          DmtfPowerState
```

```
    MAX-ACCESS      read-write
    STATUS          current
    DESCRIPTION     "The current DMTF power state of the entity."
    ::= { emanControlEntry 3 }

--
-- EMAN Context Add-On
--

emanContext OBJECT IDENTIFIER
    ::= { eman 4 }

ContextType ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION     "Specifies the type of context."
    SYNTAX          INTEGER {
                        physical(1),
                        logical(2)
                    }

emanContextTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanContextEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table of all the entity's usage contexts."
    ::= { emanContext 1 }

emanContextEntry OBJECT-TYPE
    SYNTAX          EmanContextEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A physical or logical context to describe the power
                    usage of an entity."
    INDEX           { emanContextIndex }
    ::= { emanContextTable 1 }

EmanContextEntry ::=
    SEQUENCE {
        emanContextIndex                Unsigned32,
        emanContextName                 SnmpAdminString,
        emanContextType                 ContextType
    }

emanContextIndex OBJECT-TYPE
    SYNTAX          Unsigned32
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The index for the context of the entity."
```

```
    ::= { emanContextEntry 1 }

emanContextName OBJECT-TYPE
    SYNTAX          SnmpAdminString
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The identifier for the context of the entity."
    ::= { emanContextEntry 2 }

emanContextType OBJECT-TYPE
    SYNTAX          ContextType
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "The type of the context."
    ::= { emanContextEntry 3 }

emanContextMappingTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanContextMappingEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table that maps an entity to a context."
    ::= { emanContext 3 }

emanContextMappingEntry OBJECT-TYPE
    SYNTAX          EmanContextMappingEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A simple mapping mechanism to link a context to an
                    entity."
    INDEX           { emanContextIndex, emanEntityIndex }
    ::= { emanContextMappingTable 1 }

EmanContextMappingEntry ::=
    SEQUENCE {
        emanContextMappingRowStatus     RowStatus
    }

emanContextMappingRowStatus OBJECT-TYPE
    SYNTAX          RowStatus
    MAX-ACCESS      read-create
    STATUS          current
    DESCRIPTION     "This object facilitates the addition and deletion
                    of a conceptual row mapping in the table."
    ::= { emanContextMappingEntry 1 }

--
-- EMAN LLDP Add-On
--
```

```
emanLldp OBJECT IDENTIFIER
    ::= { eman 6 }

LldpUuid ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "16a"
    STATUS          current
    DESCRIPTION     "Specifies a Universally Unique Identifier."
    REFERENCE       "IETF RFC 4122"
    SYNTAX          OCTET STRING (SIZE (16))

LldpPortIndexOrZero ::= 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)

LldpPortGroupIndexOrZero ::= 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)

emanLldpTable OBJECT-TYPE
    SYNTAX          SEQUENCE OF EmanLldpEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "A sparse table of all the entity’s LLDP
                    information."
    ::= { emanLldp 1 }

emanLldpEntry OBJECT-TYPE
    SYNTAX          EmanLldpEntry
    MAX-ACCESS      not-accessible
    STATUS          current
    DESCRIPTION     "The LLDP information for an entity."
    INDEX           { emanEntityIndex }
    ::= { emanLldpTable 1 }

EmanLldpEntry ::=
    SEQUENCE {
        emanLldpUuid                    LldpUuid,
        emanLldpPhysicalIndex           PhysicalIndexOrZero,
        emanLldpPortIndex               LldpPortIndexOrZero,
        emanLldpPortGroupIndex          LldpPortGroupIndexOrZero,
        emanLldpPort                    LldpPortNumberOrZero
    }

emanLldpUuid OBJECT-TYPE
    SYNTAX          LldpUuid
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The UUID of the entity."
    ::= { emanLldpEntry 1 }

emanLldpPhysicalIndex OBJECT-TYPE
    SYNTAX          PhysicalIndexOrZero
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The physical index of the entity in
                    ENTITY-MIB::entPhysicalTable."
```

```
    ::= { emanLldpEntry 2 }

emanLldpPortIndex OBJECT-TYPE
    SYNTAX          LldpPortIndexOrZero
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The port index of the entity."
    ::= { emanLldpEntry 3 }

emanLldpPortGroupIndex OBJECT-TYPE
    SYNTAX          LldpPortGroupIndexOrZero
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The port group index of the entity."
    ::= { emanLldpEntry 4 }

emanLldpPort OBJECT-TYPE
    SYNTAX          LldpPortNumberOrZero
    MAX-ACCESS      read-only
    STATUS          current
    DESCRIPTION     "The port number of the entity."
    ::= { emanLldpEntry 5 }

END
```

14. Security Considerations

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

- o emanControlTable - write access to the entries in this table allows an external user to change the power state of the entity. If not properly configured and secured, this could result in equipment being powered down accidentally or maliciously.

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 None at this time

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.

15. 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
eman	{ mib-2 XXX }

16. Contributors

A special thanks to John Parello, Brad Schoening, and Bruce Nordman for their help and feedback during the development of this draft.

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Appendix A. Acknowledgements

TBD

Author's Address

Chris Verges
Cyber Switching, Inc.
2050 Ringwood Avenue
San Jose, California 95131
USA

Phone: +1 408 436 9830
EMail: chrisv@cyberswitching.com