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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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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 use cases for Energy Management have been identified in the "Energy Management (EMAN) Applicability Statement" [EMAN-AS].

Some of these scenarios are presented later in Section 8. " Implementation Scenarios".

4. Terminology

The definitions of basic terms like Power Monitor, Power Monitor Parent, Power Monitor Child, Power Monitor Meter Domain, Power State can be found in the Power Management Architecture [EMAN-FRAMEWORK].

EDITOR’S NOTE: it is foreseen that some more term will follow such a Proxy, Aggregator, Energy Management, etc...

Power State Set

A Power State Set is defined as a sequence of incremental energy saving modes of a device. The elements of this set can be viewed as an interface for the underlying device-implemented power settings of a device. Examples of Power State Sets include DTMF [DMTF], IEEE1621 [IEEE1621], ACPI [ACPI] and EMAN.

Power State

A Power State is defined as a specific power setting for a Power Monitor (e.g., shut, hibernate, sleep, high). Within the context of a Power State Set, the Power State of a device is one of the power saving modes in that Power State Set.

EDITOR’S NOTE: the definitions of Power State Series and Power State should be copied over in [EMAN-FRAMEWORK], and referenced here.

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].

The Energy Monitoring MIB has 2 independent MIB modules. The first MIB module powerMonitorMIB is focused on measurement of power and energy. The second MIB module powerQualityMIB is focused on Power Quality measurement.

The powerMonitorMIB MIB module consists of four tables. The first table pmPowerTable is indexed by pmPowerIndex and pmPowerStateSetIndex. The second table pmPowerStateTable indexed by pmPowerIndex, pmPowerStateSetIndex and pmPowerStateIndex. pmEnergyParametersTable and pmEnergyTable are indexed by pmPowerIndex.

```
 pmPowerTable(1)
  |
  +---pmPowerEntry(1) [pmPowerIndex, pmPowerStateSet]
  |   |
  |   +-- --- Integer32         pmPowerIndex(1)
  |   +-- --- PowerStateSet  pmPowerStateSet(2)
  |   +-- r-n Integer32         pmPower(3)
  |   +-- r-n Integer32         pmPowerNamePlate(4)
  |   +-- r-n UnitMultiplier    pmPowerUnitMultiplier(5)
  |   +-- r-n Integer32         pmPowerAccuracy(6)
  |   +-- r-n INTEGER           pmMeasurementCaliber(7)
  |   +-- r-n INTEGER           pmPowerCurrentType(8)
  |   +-- r-n INTEGER           pmPowerOrigin(9)
  |   +-- rwn Integer32         pmPowerAdminState(10)
  |   +-- r-n Integer32         pmPowerOperState(11)
  |   +-- r-n OwnerString       pmPowerStateEnterReason(12)
  |   |
  |   |
  +---pmPowerStateTable(2)
  |      +--pmPowerStateEntry(1)
  |      |      [pmPowerIndex,
  |      |       pmPowerStateSet,
  |      |       pmpowerStateIndex]
  |      +-- --- Integer32       pmPowerStateIndex(1)
  |      +-- r-n Interger32      pmPowerStateMaxPower (2)
  |      +-- r-n UnitMultiplier
  |                  pmPowerStatePowerUnitMultiplier (3)
  |      +-- r-n TimeTicks       pmPowerStateTotalTime(4)
  |      +-- r-n Counter64       pmPowerStateEnterCount(5)
  |

  +pmEnergyParametersTable(1)
  +---pmEnergyParametersEntry(1) [pmPowerIndex]
  |
  |   +-- r-n TimeInterval
  |               pmEnergyParametersIntervalLength (1)
  |   +-- r-n Integer32
  |               pmEnergyParametersIntervalNumber (2)
  |   +-- r-n Integer32
  |               pmEnergyParametersIntervalMode (3)
```

```
     |   +-- r-n TimeInterval
     |               pmEnergyParametersIntervalWindow (4)
     |   +-- r-n Integer32
     |               pmEnergyParametersSampleRate (5)
     |   +-- r-n RowStatus  pmEnergyParametersStatus (6)
     |
     +pmEnergyTable(1)
     +---pmEnergyEntry(1) [pmPowerIndex]
     |
     |   +-- r-n TimeInterval  pmEnergyIntervalStartTime (1)
     |   +-- r-n Integer32  pmEnergyIntervalEnergyUsed (2)
     |   +-- r-n UnitMultiplier
     |                pmEnergyIntervalEnergyUnitMultiplier (3)
     |   +-- r-n Integer32  pmEnergyIntervalMax (4)
     |   +-- r-n TimeTicks
     |                pmEnergyIntervalDiscontinuityTime(5)
     |   +-- r-n RowStatus  pmEnergyParametersStatus (6)
```

The powerQualityMIB consists of four tables. PmACPwrQualityTable is indexed by pmPowerIndex. PmACPwrQualityPhaseTable is indexed by pmPowerIndex and pmPhaseIndex. pmACPwrQualityWyePhaseTable and pmACPwrQualityDelPhaseTable are indexed by pmPowerIndex and pmPhaseIndex.

```
   pmPowerTable(1)
     |
     +---PmACPwrQualityEntry (1) [pmPowerIndex]
     |   |
     |   |
     |   +----- INTEGER  pmACPwrQualityConfiguration (1)
     |   +-- r-n Interger32  pmACPwrQualityAvgVoltage (2)
     |   +-- r-n Integer32   pmACPwrQualityAvgCurrent (3)
     |   +-- r-n Integer32   pmACPwrQualityFrequency  (4)
     |   +-- r-n UnitMultiplier
     |             pmACPwrQualityPowerUnitMultiplier (5)
     |   +-- r-n Integer32  pmACPwrQualityPowerAccuracy (6)
     |   +-- r-n Interger32 pmACPwrQualityTotalActivePower (7)
     |   +-- r-n Integer32
     |            pmACPwrQualityTotalReactivePower (8)
     |   +-- r-n Integer32 pmACPwrQualityTotalApparentPower (9)
     |   +-- r-n Integer32 pmACPwrQualityTotalPowerFactor(10)
     |   +-- r-n Integer32 pmACPwrQualityThdAmpheres (11)
     |
     +pmACPwrQualityPhaseTable (1)
     +---PmACPwrQualityPhaseEntry(1)[pmPowerIndex,
     |     |                            pmPhaseIndex]
     |     |
```

```
     |      +-- r-n Integer32  pmPhaseIndex  (1)
     |      +-- r-n Integer32
     |      |          pmACPwrQualityPhaseAvgCurrent (2)
     |      +-- r-n Integer32
     |      |          pmACPwrQualityPhaseActivePower (3)
     |      +-- r-n Integer32
     |      |          pmACPwrQualityPhaseReactivePower (4)
     |      +-- r-n Integer32
     |      |          pmACPwrQualityPhaseApparentPower (5)
     |      +-- r-n Integer32
     |      |          pmACPwrQualityPhasePowerFactor (6)
     |      +-- r-n Integer32
     |      |          pmACPwrQualityPhaseImpedance (7)
     |      |
     +pmACPwrQualityDelPhaseTable (1)
     +-- pmACPwrQualityDelPhaseEntry(1)
     |      |                            [pmPowerIndex,
     |      |                             pmPhaseIndex]
     |      +-- r-n Integer32
     |      |    pmACPwrQualityDelPhaseToNextPhaseVoltage (1)
     |      +-- r-n Integer32
     |      |   pmACPwrQualityDelThdPhaseToNextPhaseVoltage (2)
     |      +-- r-n Integer32  pmACPwrQualityDelThdCurrent (3)
     |      |
     +pmACPwrQualityWyePhaseTable (1)
     +-- pmACPwrQualityWyePhaseEntry (1)
     |      |                              [pmPowerIndex,
     |      |                               pmPhaseIndex]
     |      +-- r-n Integer32
     |      |      pmACPwrQualityWyePhaseToNeutralVoltage (1)
     |      +-- r-n Integer32
     |      |     pmACPwrQualityWyePhaseCurrent (2)
     |      +-- r-n Integer32
     |      |     pmACPwrQualityWyeThdPhaseToNeutralVoltage (3)
     |      .
```

A UML representation of the MIB objects in the two MIB modules are powerMonitorMIB and powerQualityMIB are presented.

```
   +--------------------------+
   |    PowerMonitor ID       |
   |                          |
   |  Energy-aware-MIB  (*)   |
   |                          | +---------------------------+
   |                          | |                           |
   | pmPowerIndex             | |  PowerMonitor Attributes  |
   | pmPowerStateSetIndex     | |                           |
   +--------------------------+ | pmPowerNamePlate          |
             |                | | pmPowerMeasurementCaliber |
             |                | | pmPowerOrigin             |
             |                | | pmPowerCurrentType        |
             |                | +---------------------------+
             |                |       |
             |                |       |
             v                |       v
   +-----------------------------------------+
   |  PowerMonitor Measurement               |
   |                                         |
   | pmPower                                 |
   | pmPowerUnitMultiplier                   |
   | pmPowerAccuracy                         |
   +-----------------------------------------+
             ^                 |      ^
             |                 |      |
   +------------------------+ |      |
   |    PowerMonitor State   | |  +----------------------+
   |                        | |  | PowerMonitor State     |
   | pmPowerAdminState      | |  |    Statistics          |
   | pmPowerOperState       | |  |                        |
   | pmPowerStateEnterReason | |  | pmPowerStateMaxPower   |
   +------------------------+ |  | pmPowerStateTotalTime  |
                               |  | pmPowerStateEnterCount |
                               |  +----------------------+
                               |
                               |
                               |
                               |
```

Figure 1:UML diagram for powerMonitor MIB

(*)   Link with the ENERGY-AWARE-MIB

```
                              |
                              |
                              |
                              V
          +------------------------------------+
          |    Energy Table                    |
          |                                    |
          |  pmEnergyIntervalStartTime         |
          |  pmEnergyIntervalEnergyUsed        |
          |  pmEnergyIntervalMax               |
          |  pmEnergyIntervalDiscontinuityTime |
          +------------------------------------+



           +--------------------------+
           |    PowerMonitor ID       |
           |                          |
           |  Energy-aware-MIB  (*)   |
           |                          |
           | pmPowerIndex             |
           | pmPowerStateSetIndex     |
           +--------------------------+
                          |
                          v
              +-------------------------------------+
              |  Power Quality                      |
              |                                     |
              | pmACPwrQualityConfiguration         |
              | pmACPwrQualityAvgVoltage            |
              | pmACPwrQualityAvgCurrent
              | pmACPwrQualityFrequency             |
              | pmACPwrQualityPowerUnitMultiplier   |
              | pmACPwrQualityPowerAccuracy         |
              | pmACPwrQualityTotalActivePower      |
              | pmACPwrQualityTotalReactivePower    |
              | pmACPwrQualityTotalApparentPower    |
              | pmACPwrQualityTotalPowerFactor      |
              | pmACPwrQualityThdAmpheres           |
              +-------------------------------------+ ^
                               ^                   ^  |
                               |                   |  -------
                               |                   ----     |
                               |                       |    |
                               |                       |    |
             +-------------------------------------+   |    |
             |  Power Phase Quality                |   |    |
```

```
             |                                     |   |    |
             | pmPhaseIndex                        |   |    |
             | pmACPwrQualityPhaseAvgCurrent       |   |    |
             | pmACPwrQualityAvgCurrent            |   |    |
             | pmACPwrQualityFrequency             |   |    |
             | pmACPwrQualityPowerUnitMultiplier   |   |    |
             | pmACPwrQualityPowerAccuracy         |   |    |
             | pmACPwrQualityPhaseActivePower      |   |    |
             | pmACPwrQualityPhaseReactivePower    |   |    |
             | pmACPwrQualityPhaselApparentPower   |   |    |
             | pmACPwrQualityPhaseImpedance        |   |    |
             +-------------------------------------+   |    |
                                                       |    |
                                                       |    |
           +---------------------------------------------+  |
           |  Power Quality DEL Configuration            |  |
           |                                             |  |
           | pmACPwrQualityDelPhaseToNextPhaseVoltage    |  |
           | pmACPwrQualityDelThdPhaseToNextPhaseVoltage |  |
           | pmACPwrQualityDelThdCurrent                 |  |
           +---------------------------------------------+  |
                                                            |
                                                            |
               +---------------------------------------------+
               |  Power Quality WYE Configuration            |
               |                                             |
               | pmACPwrQualityWyePhaseToNeutralVoltage      |
               | pmACPwrQualityWyePhaseCurrent               |
               | pmACPwrQualityWyeThdPhaseToNeutralVoltage   |
               +---------------------------------------------+
```

Figure 2: UML diagram for the powerQualityMIB

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 identity information is specified in the MIB ENERGY-AWARE-MIB module [EMAN-AWARE-MIB] primary table, i.e. the pmTable.In this table, every Power Monitor SHOULD have a printable name pmName, and MUST HAVE a unique Power Monitor index pmIndex. The ENERGY-AWARE-MIB module returns the relationship (parent/child) between Power Monitors.

EDITOR'S NOTE: this last sentence will have to be updated with terms such as Aggregator, Proxy, etc... when the [EMAN-FRAMEWORK] will stabilize.

5.2. Power State

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

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

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

The MIB objects pmPowerOperState, pmPowerAdminState , and pmPowerStateEnterReason are contained in the pmPowerTable MIB table.

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

5.2.1. Power State Set

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

There are currently three Power State Sets advocated:

```
Reserved(0)
IEEE1621(1) - [IEEE1621]
DMTF(2)     - [DMTF]
EMAN(3)     - [EMAN-MONITORING-MIB]
```

The respective specific states related to each Power State Set are specified in the following sections.

5.2.2. IEEE1621 Power State Set

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

on(0) - The device is fully On and all features of the device are in working mode.

off(1) - The device is mechanically switched off and does not consume energy.

sleep(2) - The device is in a power saving mode, and some features may not be available immediately.

5.2.3. DMTF Power State Set

DMTF [DMTF] standards organization has defined a power profile standard based on the CIM (Common Information Model) model that consists of 15 power states ON (2), SleepLight (3), SleepDeep (4), Off-Hard (5), Off-Soft (6), Hibernate(7), PowerCycle Off-Soft (8), PowerCycle Off-Hard (9), MasterBus reset (10), Diagnostic Interrupt (11), Off-Soft-Graceful (12), Off-Hard Graceful (13), MasterBus reset Graceful (14), Power-Cycle Off-Soft Graceful (15), PowerCycle-Hard Graceful (16). DMTF standard is targeted for hosts and computers. Details of the semantics of each Power State within the DMTF Power State Set can be obtained from the DMTF Power State Management Profile specification [DMTF].

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

DMTF Power State	ACPI Power State
Reserved(0)	
Reserved(1)	
ON (2)	G0-S0
Sleep-Light (3)	G1-S1 G1-S2
Sleep-Deep (4)	G1-S3
Power Cycle (Off-Soft) (5)	G2-S5
Off-hard (6)	G3
Hibernate (Off-Soft) (7)	G1-S4
Off-Soft (8)	G2-S5
Power Cycle (Off-Hard) (9)	G3
Master Bus Reset (10)	G2-S5
Diagnostic Interrupt (11)	G2-S5
Off-Soft Graceful (12)	G2-S5
Off-Hard Graceful (13)	G3
MasterBus Reset Graceful (14)	G2-S5
Power Cycle off-soft Graceful (15)	G2-S5
Power Cycle off-hard Graceful (16)	G3

Figure 3: DMTF and ACPI Powe State Set Mapping

5.2.4. EMAN Power State Set

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

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

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

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

IEEE1621 Power(off):

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

IEEE1621 Power(sleep)

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

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

standby(5) : No entity features are available, except for out-of-band management, for example wake-up mechanisms. This mode is analogous to cold-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.

IEEE1621 Power(on):

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

low(8) : Indicates some features may not be available and the entity has taken

measures or selected options to provide
less than mediumMinus(9) usage.

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

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

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

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

5.3. Power Monitor Usage Information

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). Power measurement magnitude should conform to the IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22] definition of unit multiplier for the SI (System International) units of measure. Measured values are represented in SI units obtained by BaseValue * 10 raised to the power of the scale.

For example, if current power usage of 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, pmEnergyIntervalEnergyUnitMultiplier, 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 pmPowerTable (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 and demand Measurement" section in [EMAN-FRAMEWORK] for the definition and terminology information.

It is relevant to measure energy 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 energy measurement of a Power Monitor: pmEnergyTable and pmEnergyParametersTable. Both energy and demand information can be represented via the pmEnergyTable. Energy information will be an accumulation with no interval. Demand information can be represented as an average accumulation per interval of time.

The pmEnergyParametersTable consists of the parameters defining the duration of measurement intervals in seconds, (pmEnergyParametersIntervalLength), the number of successive intervals to be stored in the pmEnergyTable, (pmEnergyParametersIntervalNumber), the type of measurement technique (pmEnergyParametersIntervalMode), and a sample rate used to calculate the average (pmEnergyParametersSampleRate). Judicious choice of the sampling rate will ensure accurate measurement of energy while not imposing an excessive polling burden.

There are three pmEnergyParametersIntervalMode types used for energy measurement collection: period, sliding, and total. The choices of the the three different modes of collection are based on IEC standard 61850-7-4. Note that multiple 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 4 : 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 5 : Sliding pmEnergyParametersIntervalMode

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

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

Figure 4 : 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 used to start and stop energy usage logging. The status of this variable is "active" when all the objects in pmEnergyParametersTable are appropriate which in turn indicates if pmEnergyTable entries exist or not.

The pmEnergyTable consists of energy measurements inpmEnergyIntervalEnergyUsed , the units of the measured energy pmEnergyIntervalEnergyUnitMultiplier, and the maximum observed energy within a window - pmEnergyIntervalMax.

Measurements of the total energy consumed by a Power Monitor may suffer from interruptions in the continuous measurement of energy consumption. In order to indicate such interruptions, the object pmEnergyIntervalDiscontinuityTime is provided for indicating the time of the last interruption of total energy measurement. pmEnergyIntervalDiscontinuityTime shall indicate the sysUpTime [RFC3418] when the device was reset.

The following example illustrates the pmEnergyTable and pmEnergyParametersTable:

First, in order to estimate energy, a time interval to sample energy should be specified, i.e. pmEnergyParametersIntervalLength can be set to "900 seconds" or 15 minutes and the number of consecutive intervals over which the maximum energy 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 pmEnergyIntervalStartTime, which denotes the start time of the energy measurement interval based on sysUpTime [RFC3418]. The value of pmEnergyIntervalEnergyUsed 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 pmEnergyIntervalPowerUnitMultiplier. For example, pmEnergyIntervalPowerUsed can be "100" with pmEnergyIntervalPowerUnits equal to 0, the measured energy consumption of the Power Monitor is 100 watt-hours. The pmEnergyIntervalMax is the maximum energyobserved and that 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 energymeasurements, including the maximum.

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

5.6. Fault Management

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

6. Discovery

6.1. ENERGY-AWARE-MIB Module Implemented

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

If an implementation of the ENERGY-AWARE-MIB module is available in the local SNMP context, for the same Power Monitor, the pmIndex value (EMAN-AWARE-MIB) MUST be assigned to the pmPowerIndex for The pmPowerIndex characterizes the Power Monitor in the powerMonitorMIB and powerQualityMIB MIB modules (this document).

From there, the NMS must poll the pmPowerStateTable (specified in the powerMonitorMIB module in this document), which enumerates, amongst other things, the maximum power usage. As the entries in pmPowerStateTable table are indexed by the Power Monitor (pmPowerIndex), by the Power State Set (pmPowerStateSetIndex), and by the Power State (pmPowerStateIndex), the maximum power usage is discovered per Power Monitor, per Power State Set, and per Power Usage. In other words, polling the pmPowerStateTable allows the discovery of each Power State within every Power State Set supported by the Power Monitor.

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

Finally, the NMS can monitor the Power Quality thanks to the powerQualityMIB MIB module, which reuses the pmPowerIndex to index the Power Monitor.

6.2. ENERGY-AWARE-MIB Module Not Implemented, ENTITY-MIB Implemented

When the ENERGY-AWARE-MIB module [EMAN-AWARE-MIB] is not implemented, the NMS must poll the ENTITY-MIB [RFC4133] in order to discover some more information about the Power Monitors. Indeed, the index for the Power Monitors in the MIB modules specified in this document is the pmPowerIndex, which specifies: "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."

As the Section 6.1. , the NMS must then poll the pmPowerStateTable (specified in the powerMonitorMIB module in this document), indexed by the Power Monitor (pmPowerIndex that inherited the entPhysicalIndex value), by the Power State Set (pmPowerStateSetIndex), and by the Power State (pmPowerStateIndex). Then the NMS has discovered every Power State within each Power State Set supported by the Power Monitor.

Note that, without the ENERGY-AWARE-MIB module, the Power Monitor acts as an standalone device, i.e. the notion of parent/child can’t be specified.

6.3. ENERGY-AWARE-MIB Module and ENTITY-MIB Not Implemented

If neither the ENERGY-AWARE-MIB module [EMAN-AWARE-MIB] nor of the ENTITY MIB module [RFC4133] are available in the local SNMP context, then this MIB module may choose identity values from a further MIB module providing entity identities.

Note that, without the ENERGY-AWARE-MIB module, the Power Monitor acts as an standalone device, i.e. the notion of parent/child can’t be specified.

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 in the ENERGY-AWARE-MIB MIB module [EMAN-AWARE-MIB].

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

Power measurements specifying the qualifier 'UNITS' for each measured value in watts are used in the LLDP-EXT-MED-MIB, POE [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, Amperes and Watts. The units of power measurement are RMS volts and RMS Amperes. They are not based on the EntitySensorDataScale and EntitySensorDataPrecision of Entity-Sensor MIB.

Both the Power and Energy Monitoring MIB and the UPS MIB may be implemented on the same UPS SNMP agent, without conflict. In this case, the UPS device itself is the 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. Implementation Scenarios

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

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

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

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

The switch has implementations of Entity MIB [RFC4133] and energy-aware MIB [EMAN-AWARE-MIB] while the PC does not have implementation of the Entity MIB, but has an implementation of energy-aware MIB. The switch has the following attributes, 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 1000:3". The power metered at the POE switch port is "12 watts". In this example, the POE switch port has the switch as the Power Monitor Parent, with its pmParentID of "1000".

The attributes of the PC are given below. The PC does not implementation of Entity MIB, and thus does not have pmPhysicalEntity. The pmPowerIndex (pmPIndex) of the PC is "57", the pmPowerMonitorId is "UUID 1000:57 ". The PC has a Power Monitor Parent, i.e. the switch port whose pmPowerMonitorId is "UUID 1000:3". The power usage of the PC is "120 Watts" and is communicated to the switch port.

This example illustrates the important distinction between the 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 1000:3  | UUID 1000  |    12   | |
| ============================================================= |
|                                    ^                          |
|                                    |                          |
|------------------------------------|--------------------------|
                                     |
                                     |
                 POE IP PHONE        |
                                     |
                                     |
==============================================================
| IP phone | IP phone |IP phone        |IP phone   |IP phone|
| pmPIndex  | pmPhyIdx |pmPowerMonitorId|pmParentID |pmPower|
============================================================
|  31       |     0  | UUID 1000:31  | UUID 1000:3 |  12   |
=============================================================
                                      |
                                      |
PC connected to switch via IP phone   |
                                      |
==============================================================
| PC     | PC      |PC               |PC         | PC          |
|pmPIndex| pmPhyIdx|pmPowerMonitorId|pmParentID| pmPower     |
```

```
============================================================
| 57      |    0   |  UUID  1000:57 | UUID 1000:3 | 120     |
=============================================================
```

Figure 1: Example scenario

9. Structure of the MIB

The primary MIB object in this MIB module is the PowerMonitorMIBObject. The pmPowerTable table of PowerMonitorMibObject describes the power measurement attributes of a Power Monitor entity. The notion of identity of the device in terms of uniquely identification of the Power Monitor and its relationship to other entities in the network are addressed in [EMAN-AWARE-MIB].

The power measurement of Power Monitor contains information describing its power usage (pmPower) and its current power state (pmPowerOperState). In addition to power usage, additional information describing the units of measurement (pmPowerAccuracy, pmPowerUnitMultiplier), how power usage measurement was obtained (pmPowerMeasurementCaliber), the source of power (pmPowerOrigin) and the type of power (pmPowerCurrentTtype) are described.

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 measurement information over time.

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

10. 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    "201107080000Z"     -- 8 July 2011
       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

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                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
           "201107080000Z"     -- 8 July 2011
       DESCRIPTION
          "Initial version, published as RFC XXXX."

      ::= { mib-2 xxx }


   powerMonitorMIBNotifs OBJECT IDENTIFIER
       ::= { powerMonitorMIB 0 }

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

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


   -- Textual Conventions




   PowerStateSet ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
          "PowerStateSet is a TC that describes the Power State
          Set a Power Monitor supports. IANA has created a
          registry of Power State Sets supported by a Power
          Monitor entity and IANA shall administer the list of
          Power State Sets.

          One byte is used to represent the Power State Set.

                 field  octets  contents            range
                 -----  ------  --------            -----
                  1       1     Power State Set   1..255

          Note:
              the value of Power State Set in network byte order

          1 in the first byte indicates IEEE1621 Power State Set
          2 in the first byte indicates DMTF Power State Set
          3 in the first byte indicates EMAN Power State Set"

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

        SYNTAX      OCTET STRING (SIZE(1))



   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, pmPowerStateSetIndex}
       ::= { pmPowerTable  1 }

   PmPowerEntry ::= SEQUENCE {
           pmPowerIndex                       Integer32,
           pmPowerStateSetIndex               PowerStateSet,
           pmPower                            Integer32,
           pmPowerNameplate                   Integer32,
           pmPowerUnitMultiplier              UnitMultiplier,
           pmPowerAccuracy                    Integer32,
           pmPowerMeasurementCaliber          INTEGER,
           pmPowerCurrentType                 INTEGER,
           pmPowerOrigin                      INTEGER,
           pmPowerAdminState                  Integer32,
           pmPowerOperState                   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 }

   pmPowerStateSetIndex        OBJECT-TYPE
       SYNTAX                PowerStateSet
       MAX-ACCESS            not-accessible
       STATUS                current
       DESCRIPTION
           "This object indicates the Power State Set supported by
           the Power Monitor. The list of Power State Sets and
           their numbering are administered by IANA"
       ::= { pmPowerEntry  2 }

   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 3 }


   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 4 }

   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 5 }

   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 6 }


   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 7 }

   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 8 }

   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 9 }

   pmPowerAdminState OBJECT-TYPE
       SYNTAX          Integer32 (1..65535)
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION
           "This object specifies the desired Power State for the
           Power Monitor, in the context of the Power State Set
           specified by pmPowerStateSetIndex in this table.
           Possible values of pmPowerAdminState are registered at
           IANA, per Power States Set.  A current list of
           assignments can be found at
           <http://www.iana.org/assignments/eman>
           RFC-EDITOR: please check the location after IANA"

       ::= { pmPowerEntry 10  }

   pmPowerOperState OBJECT-TYPE
       SYNTAX          Integer32 (1..65535)
       MAX-ACCESS      read-only
```

```
       STATUS          current
       DESCRIPTION
           "This object specifies the current operational Power
           State for the Power Monitor, in the context of the Power
           State Set specified by pmPowerStateSetIndex in this
           table. Possible values of pmPowerOperState are
           registered at IANA, per Power States Set.  A current
           list of assignments can be found at
           <http://www.iana.org/assignments/eman>
           RFC-EDITOR: please check the list"
       ::= { pmPowerEntry 11  }

   pmPowerStateEnterReason OBJECT-TYPE
        SYNTAX     OwnerString
        MAX-ACCESS read-create
        STATUS     current
        DESCRIPTION
           "This string object describes the reason for the
           pmPowerAdminState
           transition Alternatively, this string may contain with
           the entity that configured this Power Monitor to this
           Power State."
        DEFVAL { "" }
        ::= { pmPowerEntry 12 }

   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
          pmPowerTable, containing rows describing each Power State
          for the corresponding Power Monitor. For every Power
          Monitor in the pmPowerTable, 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 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 (mechoff), 6 (ready), 8 (mediumMinus), 12 (High):

               State         MaxUsage Units
                1 (mechoff       0       W
                2 (softoff)      0       W
                3 (hibernate)    0       W
                4 (sleep)        0       W
                5 (standby)      0       W
                6 (ready)        8       W
                7 (lowMinus)     8       W
                8 (low)         11       W
                9 (medimMinus)  11       W
               10 (medium)      11       W
               11 (highMinus)   11       W
               12 (high)        11       W

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

                   INDEX   {
                             pmPowerIndex,
                             pmPowerStateSetIndex,
                             pmPowerStateIndex

                           }
       ::= { pmPowerStateTable 1 }

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

   pmPowerStateIndex OBJECT-TYPE
       SYNTAX          Integer32 (1..65535)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This object specifies the Power State for the Power
           Monitor, in the context of the Power State Set specified
           by pmPowerStateSetIndex in this table.
```

```
            This object specifies the index of the Power State of
            the Power Monitor within a Power State Set. The
            semantics of the specific Power State can be obtained
            from the Power State Set definition."
        ::= { 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 3 }

   pmPowerStatePowerUnitMultiplier OBJECT-TYPE
        SYNTAX          UnitMultiplier
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
           "The magnitude of watts for the usage value in
           pmPowerStateMaxPower."
        ::= { pmPowerStateEntry 4 }

   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 5 }

   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 6  }


   pmEnergyParametersTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF PmEnergyParametersEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
      "This table is used to configure the parameters for Energy
      measurement collection in the 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 pmEnergyIntervalEnergyUsed
          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 interval."
       DEFVAL { 900 }
       ::= { pmEnergyParametersEntry 1 }

   pmEnergyParametersIntervalNumber OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
          "The number of intervals maintained in the pmEnergyTable.
          Each interval is characterized by a specific
          pmEnergyIntervalStartTime, used as an index to the table
          pmEnergyTable . Whenever the maximum number of entries is
          reached, the measurement over the new interval replaces
          the oldest measurement , except if the oldest measurement
          were to be the maximum pmEnergyIntervalMax, in which case
          the measurement the measurement over 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
       pmEnergyIntervalEnergyUsed 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
        pmEnergyIntervalEnergyUsed 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 pmEnergyIntervalEnergyUsed 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 energy 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 energy 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 [RFC3418] 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       {pmPowerAdminState, pmPowerOperState,
   pmPowerStateEnterReason}
       STATUS        current
       DESCRIPTION
           "The SNMP entity generates the PmPowerStateChange when
           the value(s) of pmPowerAdminState or pmPowerOperState,
          in the context of the Power State Set, have 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,
                   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,
                           powerMonitorMIBNotifGroup
                       }

       OBJECT          pmPowerOperState
       MIN-ACCESS      read-only
       DESCRIPTION
           "Write access is not required."
       ::= { powerMonitorMIBCompliances 2 }

   -- Units of Conformance

   powerMonitorMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                           pmPower,
                           pmPowerNameplate,
                           pmPowerUnitMultiplier,
                           pmPowerAccuracy,
                           pmPowerMeasurementCaliber,
                           pmPowerCurrentType,
                           pmPowerOrigin,
                           pmPowerAdminState,
                           pmPowerOperState,
                           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 }



   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 Energy Table."
       ::= { powerMonitorMIBGroups 3 }

   powerMonitorMIBEnergyTableGroup OBJECT-GROUP
       OBJECTS         {
                           -- Note that object
                           -- pmEnergyIntervalStartTime 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 Energy Table."
       ::= { powerMonitorMIBGroups 4 }

   powerMonitorMIBNotifGroup NOTIFICATION-GROUP
      NOTIFICATIONS    {
                           pmPowerStateChange
                       }
       STATUS          current
```

```
       DESCRIPTION
           "This group contains the notifications for the power and
           energy monitoring MIB Module."
       ::= { powerMonitorMIBGroups 5 }

   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    "201107080000Z"     -- 8 July 2011
       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
```

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

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DESCRIPTION

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

           "201107080000Z"    -- 8 July 2011

     DESCRIPTION
          "Initial version, published as RFC YYY."

      ::= { mib-2 yyy }


   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 pmPowerTable 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
```

11. Security Considerations

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

12. IANA Considerations

12.1. IANA Considerations for the MIB Modules

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

Descriptor	OBJECT IDENTIFIER value
PowerMonitorMIB	{ mib-2 xxx }
powerQualityMIB	{ mib-2 yyy }

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

12.2. IANA Registration of new Power State Set

This document specifies an initial set of Power State Sets. The list of these Power State Sets with their numeric identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) has created a new registry for Power State Sets numeric identifiers and filled it with the initial list as in Section 5.2.1. New Assignments to Power State Sets shall be administered by IANA and the guidelines and procedures are listed in this Section.

New assignments in Power State Sets require a Standards Action [RFC5226], i.e., they are to be made via Standards Track RFCs approved by the IESG. The new Power State Set based on the following guidelines; firstly check if there are devices or entities that have implementations of the proposed Power State Set or secondly, if the new Power State Set has been adopted or approved by the respective energy management standards organizations. A pure vendor specific implementation of Power State Set shall not be adopted; since it would lead to proliferation of Power State Sets.

12.2.1. IANA Registration of the IEEE1621 Power State Set

This document specifies a set of values for the IEEE1621 Power State Set [IEEE1621]. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) created a new registry for IEEE1621 Power State Set identifiers and filled it with the initial list in Section 5.2.2.

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

12.2.2. IANA Registration of the DMTF Power State Set

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

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

12.2.3. IANA Registration of the EMAN Power State Set

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

New assignments (or potentially deprecation) for EMAN Power State Set New assignments in Power State Set require a Standards Action , i.e., they are to be made via Standards Track RFCs approved by the IESG.

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.

14. Open Issues

OPEN ISSUE : double-check all the IEC references in the draft.

OPEN ISSUE: Description clause of pmPowerIndex Do we need this text Juergen Quittek to comment:

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

OPEN ISSUE : Juergen Schoenwalder review comments email May 25, 2011

PowerStateSeries ::= TEXTUAL-CONVENTION
Why is this an OCTET STRING (SIZE(1)) and not simply an enumerated INTEGER? And if this is to be maintained by IANA, why not create a IANA-POWER-SERIES-TC MIB module so that one can simply fetch the latest version from IANA?

New assignments in Power State Series require a Standards Action [RFC5226], i.e., they are to be made via Standards Track RFCs approved by the IESG.

This raises the bar pretty high. If some future organization defines popular power states, do you think someone is going to go through the trouble of producing a standards-track specification for this?

I also do not see why all objects in the pmPowerEntry are necessarily indexed by power series - some appear to me to be rather a property of the monitor and not the power state series the monitor happens to support.

Since I started looking at the IANA considerations, I believe this text needs to be removed:

OPEN ISSUE : Michael Schroff email comments Feb 24, 2011

TimeStamps for Power measurements

AC Power, Voltage, currrent measurement terminology

3-phase WYE or Delta or hybrid of WYE and Delta

NamePlate power consumption clarification

Circuit breakers in scope of EMAN

Response sent to mailing list requesting for more information and Clarification June 29, 2011.

15. References

15.2. Normative References

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

[RFC2578] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Structure of Management Information Version 2 (SMIv2)", STD 58, RFC 2578, April 1999.

[RFC2579] McCloghrie, K., Ed., Perkins, D., Ed., and J. Schoenwaelder, Ed., "Textual Conventions for SMIv2", STD 58, RFC 2579, April 1999.

[RFC2580] McCloghrie, K., Perkins, D., and J. Schoenwaelder, "Conformance Statements for SMIv2", STD 58, RFC 2580, April 1999.

[RFC3621] Berger, A., and D. Romascanu, "Power Ethernet MIB", RFC3621, December 2003.

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

[LLDP-MED-MIB] ANSI/TIA-1057, "The LLDP Management Information Base extension module for TIA-TR41.4 media endpoint discovery information", July 2005.

[EMAN-AWARE-MIB] J. Parello, and B. Claise, "draft-ietf-eman-energy-aware-mib-02 ", work in progress, July 2011.

15.3. Informative References

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Definition of Managed Objects for Battery Monitoring
draft-ietf-eman-battery-mib-02

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.

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 provides means for monitoring batteries in or attached to managed devices. The Battery MIB module defined in Section 5 meets the requirements for monitoring the status of batteries specified in [I-D.ietf-eman-requirements].

The Battery MIB module serves for monitoring the battery status. It does not implement a Power Monitor as defined in the framework for energy management [I-D.ietf-eman-framework]. Amongst other things, the Battery MIB allows to monitor:

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

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

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 but no additional hardware instrumentation for battery monitoring.

Since there are a lot of devices in use that contain more than one battery, means for battery monitoring defined in this document support addressing multiple batteries within a single device. Also, batteries today often come in packages that can include identification and might contain additional hardware and firmware. The former allows to trace a battery and allows continuous monitoring even if the battery is e.g. installed in another device. The firmware version is useful information as the battery behavior might be different for different firmware versions.

Not explicitly in scope of definitions in this document are very small backup batteries, such as for example, batteries used on PC motherboard to run the clock circuit and retain configuration memory while the system is turned off. Other means may be required for reporting on these batteries. However, the MIB module defined in Section 3 can be used for this purpose.

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

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

2. The Internet-Standard Management Framework

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

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

3. 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 the batteries to be reported on by individual values for managed object entPhysicalIndex, then it is REQUIRED that these values are used as index values for the batteryTable.

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

The batteryTable contains three groups of objects. The first group (OIDs ending with 2-10) provides information on static properties of the battery. The second group of objects (OIDs ending with 11-18) provides information on the current battery state, if it is charging or discharging, how much it is charged, its remaining capacity, the number of experienced charging cycles, etc.

```
batteryTable(1)
+--batteryEntry(1) [batteryIndex]
   +-- --- Integer32       batteryIndex(1)
   +-- r-n SnmpAdminString batteryIdentifier(2)
   +-- r-n SnmpAdminString batteryFirmwareVersion(3)
   +-- r-n Enumeration     batteryType(4)
   +-- r-n Unsigned32      batteryTechnology(5)
   +-- r-n Unsigned32      batteryNominalVoltage(6)
   +-- r-n Unsigned32      batteryNumberOfCells(7)
   +-- r-n Unsigned32      batteryNominalCapacity(8)
   +-- r-n Unsigned32      batteryMaxChargingCurrent(9)
   +-- r-n Unsigned32      batteryTrickleChargingCurrent(10)
   +-- r-n Unsigned32      batteryActualCapacity(11)
   +-- r-n Unsigned32      batteryChargingCycleCount(12)
   +-- r-n DateAndTime     batteryLastChargingCycleTime(13)
   +-- r-n Enumeration     batteryChargingState(14)
   +-- r-n Unsigned32      batteryCurrentCharge(15)
   +-- r-n Unsigned32      batteryCurrentVoltage(16)
   +-- r-n Integer32       batteryCurrentCurrent(17)
   +-- r-n Integer32       batteryTemperature(18)
   +-- rwn Unsigned32      batteryLowAlarmCharge(19)
   +-- rwn Unsigned32      batteryLowAlarmVoltage(20)
   +-- rwn Unsigned32      batteryReplacementAlarmCapacity(21)
   +-- rwn Unsigned32      batteryReplacementAlarmCycles(22)
   +-- r-n Integer32       batteryHighAlarmTemperature(23)
```

The third group of objects in this table (OIDs ending with 19-23) 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 three notifications. One indicating a low battery charging state, one indicating an aged battery that may need to be replaced and one indicating the battery temperature to have risen above a predefined value.

4. Battery Technologies and Properties

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

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

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

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

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

5. Definitions

```
BATTERY-MIB DEFINITIONS ::= BEGIN

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

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

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

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

           Redistribution and use in source and binary forms, with or
           without modification, is permitted pursuant to, and subject
           to the license terms contained in, the Simplified BSD
           License set forth in Section 4.c of the IETF Trust's Legal
           Provisions Relating to IETF Documents
           (http://trustee.ietf.org/license-info).

           This version of this MIB module is part of RFC yyyy; see
           the RFC itself for full legal notices."
   -- replace yyyy with actual RFC number & remove this notice

   --  Revision history

       REVISION "201106261200Z"         -- 26 June 2010
       DESCRIPTION
           "Initial version, published as RFC yyyy."
   -- replace yyyy with actual RFC number & remove this notice

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

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

```
--******************************************************************

batteryNotifications OBJECT IDENTIFIER ::= { batteryMIB 0 }
batteryObjects       OBJECT IDENTIFIER ::= { batteryMIB 1 }
batteryConformance   OBJECT IDENTIFIER ::= { batteryMIB 2 }

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

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

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

BatteryEntry ::=
    SEQUENCE {
       batteryIndex                    Integer32,
       batteryIdentifier               SnmpAdminString,
       batteryFirmwareVersion          SnmpAdminString,
       batteryType                     INTEGER,
       batteryTechnology               Unsigned32,
       batteryNominalVoltage           Unsigned32,
       batteryNumberOfCells            Unsigned32,
       batteryNominalCapacity          Unsigned32,
       batteryMaxChargingCurrent       Unsigned32,
       batteryTrickleChargingCurrent   Unsigned32,
       batteryActualCapacity           Unsigned32,
       batteryChargingCycleCount       Unsigned32,
       batteryLastChargingCycleTime    DateAndTime,
       batteryChargingState            INTEGER,
       batteryCurrentCharge            Unsigned32,
```

```
          batteryCurrentVoltage           Unsigned32,
          batteryCurrentCurrent           Integer32,
          batteryTemperature              Integer32,
          batteryLowAlarmCharge           Unsigned32,
          batteryLowAlarmVoltage          Unsigned32,
          batteryReplacementAlarmCapacity Unsigned32,
          batteryReplacementAlarmCycles   Unsigned32,
          batteryHighAlarmTemperature     Integer32
      }

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

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

   batteryIdentifier OBJECT-TYPE
       SYNTAX      SnmpAdminString
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "This object contains an identifier for the battery.

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

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

           The value of this object must be an empty string if there
```

```
          is no battery identifier or if the battery idenitfier is
          unknown."
      ::= { batteryEntry 2 }

   batteryFirmwareVersion OBJECT-TYPE
       SYNTAX      SnmpAdminString
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "This object indicates the version number of the firmware
           that is included in a battery module.

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

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

           The value of this object must be an empty string if there
           is no firware or if the version number of the firware is
           unknown."
       ::= { batteryEntry 3 }

   batteryType OBJECT-TYPE
       SYNTAX      INTEGER {
                       unknown(1),
                       other(2),
                       primary(3),
                       rechargeable(4),
                       capacitor(5)
                   }
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "This object indicates the type of battery.
           It distinguishes between primary (not re-chargeable)
           batteries, secondary (rechargeable) batteries and capacitors
           which are not really batteries but often used in the same
           way as a battery.

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

   batteryTechnology OBJECT-TYPE
       SYNTAX      Unsigned32
```

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

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

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

   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 6 }

   batteryNumberOfCells OBJECT-TYPE
       SYNTAX      Unsigned32
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "This object indicates the number of cells contained in the
           battery.

           A value of 0 indicates that the number of cells is unknown."
       ::= { batteryEntry 7 }

   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 8 }

  batteryMaxChargingCurrent OBJECT-TYPE
      SYNTAX      Unsigned32
      UNITS       "milliampere"
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
          "This object provides the maximal current to be used for
          charging the battery in units of milliampere (mA).

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

          A value of 0 indicates that the maximal charging current is
          unknown."
      ::= { batteryEntry 9 }

  batteryTrickleChargingCurrent OBJECT-TYPE
      SYNTAX      Unsigned32
      UNITS       "milliampere"
      MAX-ACCESS  read-only
      STATUS      current
      DESCRIPTION
          "This object provides the recommended current to be used for
          trickle charging the battery in units of milliampere (mA).

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

          A value of 0 indicates that the recommended trickle charging
          current is unknown."
      ::= { batteryEntry 10 }

  batteryActualCapacity OBJECT-TYPE
      SYNTAX      Unsigned32
      UNITS       "milliampere hours"
      MAX-ACCESS  read-only
```

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

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

            A value of 'ffffffff'H indicates that the actual capacity
            cannot be determined."
        ::= { batteryEntry 11 }

    batteryChargingCycleCount OBJECT-TYPE
        SYNTAX      Unsigned32
        MAX-ACCESS  read-only
        STATUS      current
        DESCRIPTION
            "This object indicates the number of completed charging
            cycles that that the battery underwent. In line with the
            Smart Battery Data Specification Revision 1.1, a charging
            cycle is defined as the process of discharging the battery
            by a total amount equal to the battery nominal capacity as
            given by object batteryNominalCapacity. A charging cycle
            may include several steps of charging and discharging the
            battery until the discharging amount given by
            batteryNominalCapacity has been reached. As soon as a
            charging cycle has been completed the next one starts
            immediately independent of the battery's current charge at
            the end of the cycle.

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

            A value of 'ffffffff'H indicates that the number of charging
            cycles cannot be determined."
        ::= { batteryEntry 12 }

    batteryLastChargingCycleTime OBJECT-TYPE
        SYNTAX      DateAndTime
        MAX-ACCESS  read-only
        STATUS      current
        DESCRIPTION
            "The date and time of the last charging cycle.  The value
            '0000000000000000'H is returned if the battery has not been
            charged yet or if the last charging time cannot be
            determined.
```

```
           For batteries of type primary(1) the value of this object is
           always '0000000000000000'H."
       ::= { batteryEntry 13 }

   batteryChargingState OBJECT-TYPE
       SYNTAX      INTEGER {
                       unknown(1),
                       charging(2),
                       maintainingCharge(3),
                       noCharging(4),
                       discharging(5)
                   }
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "This object indicates the current charging state of the
           battery.

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

           Value charging(2) indicates that the battery is being
           charged in a way that the charge of the battery increases.

           Value maintainingCharge(3) indicates that the battery is
           being charged with a low current that compensates
           self-discharging. This includes trickle charging, float
           charging and other methods for maintaining the current
           charge of a battery.

           Value noCharging(4) indicates that the battery is not
           charged or discharged by electric current between the
           battery and electric circuits external to the battery.
           Note that the battery may still be subject to
           self-discharging.

           Value discharging(5) indicates that the battery is being
           discharged and that the charge of the battery decreases."
       ::= { batteryEntry 14 }

   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 15 }

   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 16 }

   batteryCurrentCurrent OBJECT-TYPE
       SYNTAX      Integer32
       UNITS       "milliampere"
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "This object provides the current charging or discharging
           current of the battery in units of milliampere (mA).
           Charging current is represented by positive values,
           discharging current is represented by negative values.

           A value of '7fffffff'H indicates that the current current
           cannot be determined."
       ::= { batteryEntry 17 }

   batteryTemperature OBJECT-TYPE
       SYNTAX      Integer32
       UNITS       "degrees Celsius"
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
           "The ambient temperature at or near the battery.

           A value of '7fffffff'H indicates that the temperature
           cannot be determined."
       ::= { batteryEntry 18 }
```

```
   batteryLowAlarmCharge OBJECT-TYPE
       SYNTAX      Unsigned32
       UNITS       "milliampere hours"
       MAX-ACCESS  read-write
       STATUS      current
       DESCRIPTION
           "This object provides the lower threshold value for object
           batteryCurrentCharge.  If the value of object
           batteryCurrentCharge falls below this threshold,
           a low battery alarm will be raised.  The alarm procedure may
           include generating a batteryLowNotification.

           A value of 0 indicates that no alarm will be raised for any
           value of object batteryCurrentCharge."
       ::= { batteryEntry 19 }

   batteryLowAlarmVoltage OBJECT-TYPE
       SYNTAX      Unsigned32
       UNITS       "millivolt"
       MAX-ACCESS  read-write
       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 no alarm will be raised for any
           value of object batteryCurrentVoltage."
       ::= { batteryEntry 20 }

   batteryReplacementAlarmCapacity OBJECT-TYPE
       SYNTAX      Unsigned32
       UNITS       "milliampere hours"
       MAX-ACCESS  read-write
       STATUS      current
       DESCRIPTION
           "This object provides the lower threshold value for object
           batteryActualCapacity.  If the value of object
           batteryActualCapacity falls below this threshold,
           a battery aging alarm will be raised.  The alarm procedure
           may include generating a batteryAgingNotification.

           A value of 0 indicates that no alarm will be raised for any
           value of object batteryActualCapacity."
       ::= { batteryEntry 21 }
```

```
   batteryReplacementAlarmCycles OBJECT-TYPE
       SYNTAX      Unsigned32
       UNITS       "milliampere hours"
       MAX-ACCESS  read-write
       STATUS      current
       DESCRIPTION
           "This object provides the upper threshold value for object
           batteryChargingCycleCount.  If the value of object
           batteryChargingCycleCount rises above this threshold,
           a battery aging alarm will be raised.  The alarm procedure
           may include generating a batteryAgingtNotification.

           A value of 0 indicates that no alarm will be raised for any
           value of object batteryChargingCycleCount."
       ::= { batteryEntry 22 }

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

           A value of '7fffffff'H indicates that no alarm will be
           raised for any value of object batteryCurrentCharge."
       ::= { batteryEntry 23 }


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

   batteryLowNotification NOTIFICATION-TYPE
       OBJECTS     {
           batteryCurrentCharge,
           batteryCurrentVoltage
       }
       STATUS      current
       DESCRIPTION
           "This notification can be generated when the current charge
           (batteryCurrentCharge) or the current voltage
           (batteryCurrentVoltage) of the battery falls below a
           threshold defined by object batteryLowAlarmCharge or
```

```
          object batteryLowAlarmVoltage, respectively."
      ::= { batteryNotifications 1 }

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

  batteryHighTemperatNotification NOTIFICATION-TYPE
      OBJECTS     {
          batteryTemperature
      }
      STATUS      current
      DESCRIPTION
          "This notification can be generated when the actual
          temperature (batteryTemperature) rises above a threshold
          defined by object batteryHighAlarmTemperature."
      ::= { batteryNotifications 3 }


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

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

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

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

          A compliant implementation MUST implement the objects
```

```
            defined in the mandatory groups batteryDescriptionGroup
            and batteryStatusGroup."
        MODULE  -- this module
        MANDATORY-GROUPS {
            batteryDescriptionGroup,
            batteryStatusGroup
        }
        GROUP   batteryAlarmThresholdsGroup
        DESCRIPTION
           "A compliant implementation does not have to implement
            the batteryAlarmThresholdsGroup."
        GROUP   batteryNotificationsGroup
        DESCRIPTION
           "A compliant implementation does not have to implement
            the batteryNotificationsGroup."
        ::= { batteryCompliances 1 }

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

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

    batteryStatusGroup OBJECT-GROUP
        OBJECTS {
           batteryActualCapacity,
           batteryChargingCycleCount,
           batteryLastChargingCycleTime,
           batteryChargingState,
           batteryCurrentCharge,
           batteryCurrentVoltage,
           batteryCurrentCurrent,
```

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

   batteryAlarmThresholdsGroup OBJECT-GROUP
       OBJECTS {
          batteryLowAlarmCharge,
          batteryLowAlarmVoltage,
          batteryReplacementAlarmCapacity,
          batteryReplacementAlarmCycles,
          batteryHighAlarmTemperature
       }
       STATUS      current
       DESCRIPTION
          "A compliant implementation does not have to implement the
          object contained in this group."
       ::= { batteryGroups 3 }

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

6. Security Considerations

This sections needs to be updated after changing four managed objects from read-only to read-write.

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

Some of the readable objects in this MIB module (i.e., objects with a

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

- o This list is still to be done.

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

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

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

7. IANA Considerations

7.1. SMI Object Identifier Registration

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

Descriptor	OBJECT IDENTIFIER value
batteryMIB	{ mib-2 xxx }

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

7.2. Battery Technology Registration

Object batteryTechnology defined in Section 5 reports battery technologies. 18 values for battery technologies have initially been defined. They are listed in a table in Section 4.

For ensuring extensibility of this list, IANA has created a registry for battery technologies at http://www.iana.org/assignments/eman and filled it with the initial list given in Section 4.

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

[NOTE for IANA: Please create a new registry under http://www.iana.org/assignments/eman for battery types. Please fill the registry with values from the table in Section 4]

8. Open Issues

8.1. Writable Notification thresholds

Do we want to have the thresholds for sending notifications (batteryLowAlarmPercentage, batteryLowAlarmVoltage, batteryReplacementAlarmCapacity, batteryReplacementAlarmCycles) to be read-write or read-only?

8.2. Re-arming batteryLowNotification

What needs to happen after sending a batteryLowNotification before another batteryLowNotification can be sent for the same battery?

8.3. Alignment with the Smart Battery Data Specification

How closely do we need to align with the Smart Battery Data Specification [SBS]?

9. Acknowledgements

We would like to thank Steven Chew for his input.

10. References

10.1. Normative References

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10.2. Informative References

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July 8, 2011

Energy-aware Networks and Devices MIB
draft-ietf-eman-energy-aware-mib-02

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].

Table of Contents

OPEN ISSUES:

1. The terminology must be consistent for all EMAN drafts, and this one included.

2. Apparently, a Child can have different parents in the monitoring, control, and power distribution. And a Child can have multiple parents in each of the topologies. In other words, the different relationships as defined in the EMAN framework must be inserted in this draft, and the pmParentProxyAbilities re-worked.

3. Length and format of pmUUID. The pmUUID should be a unique id that identifies 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.

4. Some editor’s notes.

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 focus of this MIB module 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 is based on the Energy Management Framework [EMAN-FMWK], and meets the requirements specified in the Energy Management requirements [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, along with the power and energy consumption of network devices. 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. Requirements and Use Cases

Requirements for power and energy monitoring for networking devices are specified in [EMAN-REQ]. The requirements in [EMAN-REQ] include communications network devices, such as switches, routers, and various connected endpoints. Beyond the networking devices, 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.

The use cases are specified in the EMAN applicability statement document [EMAN-AS].

EDITOR’S NOTE: say a few words about the use cases when we will have a stable version of the EMAN applicability statement document.

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

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: all terms will be copied over in the final version of the draft. The reason is that [EMAN-FMWK] is an informational document, while this document is standard track.

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 (*)  |
   |  pmPowerCategory         |    |  pmMgmtDNSName (*)      |
   +--------------------------+    +-------------------------+
             |                             |
             |                             |
             |                             |
             v                             v
     +-----------------------------------------+
     |  Power Monitor Information              |
     |_--------------------------------------- |
  |->| pmIndex                                 |
  |  | pmUUID                                  |
  |  | pmName                                  |
  |  | pmDomainName                            |
  |  +-----------------------------------------+
  |
  |
  |
  |  +-------------------------------+
  |--|   Links to other Identifiers  |
     | ----------------------------- |
     |  pmPhysicalEntity (**)        |
     |  pmEthPortIndex (***)         |
     |  pmEthPortGrpIndex (***)      |
     |  pmLldpPortNumber (****)      |
     |  pmAlternateKey               |
     +-------------------------------+

     (*)    May also be implemented by the Parent
     (**)   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, linked to the Power Monitor Information objects, and in particular the pmIndex index:

1) The Power Monitor Information. See Section 5.1 Power Monitor Information"
2) The links to other MIB modules. See Section 5.1.2. "Links to other Identifiers"
3) The Power Monitor Child specific information. See Section 5.2 Power Monitor Parent and Child"
4) The Context Information. See Section 5.3 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].

5.1.1. Power Monitor Identifier

Every Power Monitor MUST HAVE a unique Power Monitor index pmIndex, which identifies the primary Power Monitor information in the ENERGY-AWARE-MIB module pmTable table. 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 complemented by the Power Monitor Universally Unique Identifier [RFC4122] in the pmUUID MIB object.

5.1.2. Links to other Identifiers

While the pmIndex is the primary index for all MIB objects in the ENERGY-AWARE-MIB module, the Energy Management Systems (EMS) and Network Management Systems (NMS) must be able to make the link with the identifier(s) in other supported MIB modules.

The Power Monitor pmPhysicalEntity MUST contain the entPhysicalIndex from the ENTITY MIB [RFC4133], if the ENTITY-MIB is supported by the Power Monitor SNMP agent.

The Power Monitor pmethPortIndex and pmethPortGrpIndex MUST contain the values of pethPsePortIndex and pethPsePortGroupIndex from the Power over Ethernet MIB [RFC3621], if the Power over Ethernet MIB is supported by the Power Monitor SNMP agent.

The Power Monitor pmLldpPortNumber MUST contain the lldpLocPortNum from the LLDP MIB [LLDP-MIB], if the LLDP-MED MIB is supported on the Power Monitor SNMP agent.

The intent behind the links to the other MIB module identifier(s) is certainly not to limit the scope of the ENERGY-AWARE-MIB to cases where the ENTITY-MIB, the Power over Ethernet, and the LLDP MIB modules are supported by the SNMP agent. Indeed, some use cases would not implement any of these three MIB modules on the Power Monitor. However, in situation where any of these three MIB modules is implemented, the EMS/NMS must be able to correlate the instances in the different MIB modules.

The pmAlternateKey alternate key object specifies a manufacturer defined string that can be used to identify the Power Monitor. Since EMS/NMS may need to correlate objects across management systems, this alternate key is provided to facilitate such a link. This optional value is intended as a foreign key or alternate identifier for a manufacturer or 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.

5.1.3. Power Monitor Name

Every Power Monitor SHOULD have a printable name pmName. If the 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 value specified in the ENTITY-MIB. If the entPhysicalName is not present, the process to assign the pmName can be implementation specific. Example: DNS Name, MAC address in canonical form, ifName, etc. Possible conventions for pmName are: a text string uniquely identifying the Power Monitor, textual DNS name, MAC-address of the device, interface ifName, etc...

As an example, in the case of IP phones that don’t support the ENTITY-MIB, the pmName can be the device DNS name, while in the case of router/switch line cards (which support the ENTITY-MIB), the pmName should contain the entPhysicalName.

5.1.4. 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 members of the same Power Monitor Meter Domain, specified by the pmDomainName MIB Object. The pmDomainName, which is an element of the pmTable, is a read-write MIB object. Note that the Power Monitor MUST belong to a single Power Monitor Meter Domain or in other words, a Power Monitor can not belong to more than one 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 parameters from the Power Monitor Parent or the Power Monitor Meter Domain MAY be configured directly in a Power Monitor Child.

5.1.5. Power Monitor Identity Persistence

In some situations, the Power Monitor identity information should be persistent even after a device reload. For example, in a static setup where a switch monitors a series of connected PoE phones, there is a clear benefit for the 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 module.

5.2 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 Power Monitor Child MUST set the pmParentId content to its Power Monitor Parent pmUUID. 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 Wake-on-LAN)), or any combination of capabilities. These capabilities 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 may not be via SNMP (as defined in EMAN-FMWK), a Power Monitor Child can have additional MIB objects that can be used for easier identification by the NMS. The optional objects pmMgmtMacAddress, omMgmtAddressType pmMgmtDNSName can be used to help identify the relationship between the child and other NMS objects. These objects can be used as an alternate key to help link the Power Monitor with other keyed information that may be stored within the NMS(s) or EMS(s).

The pmParentId, pmParentProxyAbilities, pmMgmtMacAddress, pmMgmtAddress, pmMgmtAddressType, and pmMgmtDNSName MIB objects SHOULD be implemented for Power Monitor Children, and MAY be implemented for Power Monitor Parents.

The pmParentId, and pmParentProxyAbilities MUST be implemented by Power Monitor Children. The pmMgmtMacAddress, pmMgmtAddress, pmMgmtAddressType, and pmMgmtDNSName MIB objects SHOULD be implemented for Power Monitor Children, and MAY be implemented for Power Monitor Parents.

5.3 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 energyAwareMIB Object. The pmTable table of energyAwareMIB Object describes an entity in the network that is a Power Monitor according the [EMAN-FMWK].

```
+--  rwn TruthValue      pmTablePersistence(1)
+- pmTable(2)
   |
   +- pmEntry(1) [pmIndex]
   |  |
   |  +-- --- Integer32                     pmIndex(1)
   |  +-- r-n PowerMonitorUUID              pmUUID(2)
   |  +-- r-n PhysicalIndexOrZero           pmPhysicalEntity(3)
   |  +-- r-n PethPsePortIndexOrZero        pmEthPortIndex(4)
   |  +-- r-n PethPsePortGroupIndexOrZero  pmEthPortGrpIndex(5)
   |  +-- r-n LldpPortNumberOrZero          pmLldpPortNumber(6)
   |  +-- rwn SnmpAdminString               pmName(7)
   |  +-- rwn SnmpAdminString               pmDomainName(8)
   |  +-- rwn SnmpAdminString               pmRoleDescription(9)
   |  +-- rwn MacAddress                    pmMgmtMacAddress(10)
   |  +-- r-n pmMgmtAddressType             pmMgmtAddressType(11)
   |  +-- r-n InetAddress                   pmMgmtAddress(12)
   |  +-- r-n SnmpAdminString               pmMgmtDNSName(13)
   |  +-- rwn SnmpAdminString               pmAlternateKey(14)
   |  +-- rwn PowerMonitorKeywordList       pmKeywords(15)
   |  +-- rwn Integer32                     pmImportance(16)
   |  +-- r-n INTEGER                       pmPowerCategory(17)
   |  +-- r-n PowerMonitorId                pmParentId(18)
   |  +-- r-n BITS                     pmParentProxyAbilities(19)
```

7. MIB Definitions

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

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

       DESCRIPTION
          "This MIB is used for describing the identity and the
          context information of power monitors in network "
       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

   PowerMonitorUUID                ::= 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,
           pmUUID                      PowerMonitorUUID,
           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                   PowerMonitorUUID,
           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."
        ::= { pmEntry 1 }

   pmUUID OBJECT-TYPE
       SYNTAX          PowerMonitorUUID
       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. If the 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. If entPhysicalName is
          not present, the process to assign the pmName can be
          implementation specific. Example: DNS Name, MAC address
          in canonical form, ifName, etc.
          "
       ::= { 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 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 typically only applies to Power
          Monitor Children. This object can be used as an alternate
          key to help link the Power Monitor with other keyed
          information that may be stored within the NMS(s) or
          EMS(s). The pmMgmtMacAddress MIB object SHOULD be
          implemented for Power Monitor Children, and MAY be
          implemented for Power Monitor Parents."
       ::= { 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 MUST be
         implemented when pmMgmtAddress is populated.  The
         pmMgmtAddressType MIB object SHOULD be implemented for
         Power Monitor Children, and MAY be implemented for Power
         Monitor Parents."
       ::= { 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 can be used as an
         alternate key to help link the Power Monitor with other
         keyed information that may be stored within the NMS(s) or
         EMS(s).   The pmMgmtAddress MIB object SHOULD be
         implemented for Power Monitor Children, and MAY be
         implemented for Power Monitor Parents."
       ::= { 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 can be used as an alternate key to help link
          the Power Monitor with other keyed information that may
          be stored within the NMS(s) or EMS(s).  The pmMgmtDNSName
          MIB objects SHOULD be implemented for Power Monitor
          Children, and MAY be implemented for Power Monitor
          Parents."

       ::= { 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 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."
       ::= { 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),
                           producer(1),
                           consumer-producer(2),
                           meter(3)
                       }
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object describes the Power Monitor category, which
          indicates the expected behavior or physical property of
          the Power Monitor, based on its design. A Power Monitor
          can be a consumer(0), producer(1) or consumer-producer
          (2) or meter (3).

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

          In some cases, a meter is required to measure the power
          consumption. In such a case, this meter Power Monitor
          category is meter(3). "
       ::= { pmEntry 17 }

   pmParentId OBJECT-TYPE
       SYNTAX       PowerMonitorUUID
       MAX-ACCESS   read-only
       STATUS       current
       DESCRIPTION
          "If the current Power Monitor has a Power Monitor Parent,
          then the parent is uniquely identified by setting
          pmParentId of the child equal to the pmUUID of the
          parent. 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,
                           pmUUID,
                           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

10.1. Normative References

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10.2. Informative References

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[EMAN-AS] Tychon, E., Laherty, M., and B. Schoening, "Energy Management (EMAN) Applicability Statement", draft-tychon-eman-applicability-statement-01.txt, work in progress, March 2011.

11. Acknowledgments

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July 8, 2011

Energy Management Framework
draft-ietf-eman-framework-02

Status of this Memo

This Internet-Draft will expire on October, 2011.

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Abstract

This document defines a framework for providing Energy Management for devices within or connected to communication networks. The framework defines a domain of Energy Management devices that is a logical unit of Energy Management. Within a domain each device is identified, classified and given context. Devices can be monitored and/or controlled with respect to power, power state, energy, demand, electrical quality, and battery. Additionally the framework models relationships and capabilities between devices in a domain.

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TO DO/OPEN ISSUE

- IPFIX or not? Initially IPFIX was mentioned in [EMAN-REQ], then we see now: "A solution for this is that the concerned entity or another entity closely interacting with the concerned entity collect time series of power values and make them available via push or pull mechanisms to receivers of the information.". So, the questions are: Is IPFIX a requirement? What other mechanism do we have to PUSH time series of power values (no, SNMP notifications are not suitable)? So should we or not include IPFIX in this document?

- Power Monitor has been renamed to Energy Managed Object. Get consensus on the terminology. Another example is Power Quality
- A couple of EDITOR'S NOTES in the draft

1. Introduction

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

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

The identified device can then be monitored for Energy Management by obtaining measurements for power, energy, demand and electrical quality. If a device contains a battery(s) the characteristics and performance of the battery(s) can also be managed. A device's state can be monitored or controlled by providing an interface expressed as one or more Power State Sets. The most basic example of energy management is a single device reporting information about itself. However, in many cases, energy is not measured by the device itself, but by a meter located upstream in the power distribution tree. An example is a power distribution unit (PDU) that measures energy consumption of attached devices and may report this to an Energy Management System. Therefore, devices are recognized as having relationships to other devices in the network from the point of view of Energy Management. These relationships include Aggregation, Metering, Power Source(s), Proxy, and Dependency.

1.1. Energy Management Document Overview

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

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

The [EMAN-AWARE-MIB] provides objects for addressing identification, classification, context information, and relationships form the point of view of Energy Management.

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

Definition of Managed Objects for Battery Monitoring [EMAN-BATTERY-MIB] defines managed objects that provide information on the status of batteries in managed devices.

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. Requirements & Use Cases

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

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

For example, target devices for this specification can include (but are not limited to):

- Simple electrical appliances / fixtures
- Hosts, such as a PC or a datacenter server
- Routers
- Switches
- Switches with line card components
- Power over Ethernet (PoE) endpoints,
- Power Distribution Units (PDU)
- Protocol gateways devices for Building Management Systems (BMS)
- Electrical Meters

- Sensor controllers with subtended sensors

There may also exist varying protocols deployed among these parallel networks.

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

3. Terminology

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

This section contains definitions of terms used throughout this specification. Defined terms have their first letter capitalized. Entities, relationships and or capabilities are defined with respect to well known software patterns as described in [GAMMA] and [EIPATT]

Energy Management System (EnMS)

An EnMS is a set of systems or procedures upon which organizations can develop and implement an energy policy, set targets, action plans and take into account legal requirements related to energy use. An EnMS allows organizations to improve energy performance and demonstrate conformity to requirements, standards and/or legal requirements. This definition is in line with the definition of "Energy management systems - Requirements with guidance for use" [ISO50001].

With respect to communication networks these same goals will apply to the communications networks and attached devices within an organization.

Energy Management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization. In that light, Energy Management is a system congruent to any of FCAPS area of management in the ISO/OSI Network Management Model [TMN] Energy Management for communication networks and attached devices is a subset or part of an organization's greater EnMS.

Energy Management Systems

An Energy Management System (EMS) is congruent to a Network Management System (NMS) and is a combination of hardware and software used to administer a network with the primarily purpose being Energy Management.

Energy Monitoring

Energy Monitoring is a part of Energy Management that deals with collecting or reading measurements from devices to aid in Energy Management. This could include Energy, Power, Demand, Quality, Context and/or Battery information.

Energy

Energy

Energy is the capacity of a system to produce external activity or perform work and can be electricity, fuels, steam, heat, compressed air, and other like media. Energy is typically expressed in watt hours or joules.

Power

Power is a rate of energy conversion. As the unit of time approaches zero a power measurement is called an instantaneous power reading. Typically when implementing Power monitoring in hardware, a measuring device may have to compute an average value per some unit of time to express a reading to approximate an instantaneous power measurement.

Demand

Demand is an average of Power measurements over an interval(s) of time and typically expressed in kilowatt hours. This measurement is significant because some utilities or energy providers bill by Demand measurements as well as for maximum

Demand per billing periods. Power values may spike during short-terms by devices, but Demand measurements recognize that maximum Demand does not equal maximum Power during an interval.

Power Quality

EDITOR'S NOTE: This may be rephrased as Electrical Characteristics.

Power Quality is defined as a set of values to describe the electrical characteristics of Power as provided by an electrical source as seen by the Energy Managed Object. For example: AC phase, apparent and reactive power, etc.

Energy Control

Energy Control is a part of Energy Management that deals with modifying or setting the state of an Energy Managed Object in order to optimize or ensure its efficiency.

Energy Managed Object

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

Energy Aware Object

An Energy Managed Object may not have the capability to provide information necessary for Energy Management itself. If an Energy Managed Object can provide Energy Management Context, Energy Monitor and optionally Energy Control values for itself then the Energy Managed Object is said to be an Energy Aware Object

For example: as the most simplistic example, a set of light bulbs where all values are provided by an EMS through estimation and or catalogue information are not Energy Aware. In contrast a set of network switches that can report the same information based upon hardware sensing is said to be Energy Aware.

Energy Managed Object Identification

Energy Managed Object Identification is a set of attributes that enable an Energy Managed Object to be: uniquely identified among all Energy Management Domains; linked to other systems; classified as to type model and or manufacturer.
RFC EDITOR’S: the uniqueness must be clarified in [EMAN-REQ]

Energy Managed Object Context

Energy Managed Object Context is a set of attributes that allow an Energy Management system to classify the use of the Energy Managed Object within an organization. The classification contains use and/or ranking of the Energy Managed Object as compared to other Energy Managed Objects in the Energy Management Domain.

Energy Management Domain

An Energy Management Domain is a name or name space that logically groups Energy Managed Objects into a zone of Energy Management. Typically, this zone will have as members all Energy Managed Objects that are powered from the same electrical panel(s) for which there is a meter or sub meter.
For example: All Energy Managed Objects drawing power from the same distribution panel with the same AC voltage within a building, or all Energy Managed Objects in a building for which there is one main meter, would comprise an Energy Management Domain.

From the standpoint of Energy Management, it is useful to report Energy as the sum of the Energy of all the Energy Managed Objects within an Energy Management Domain and then correlate that value with metered values.

Energy Managed Object Relationships

Energy Managed Objects may have functional relationships to each other within an Energy Management Domain. The functional relationships include Aggregation, Metering, Power Source(s), Proxy, and Dependency. One device will provide a capability or functional value in the relationship and another will be the receiver of the capability. These capabilities include Aggregation, Metering, Power Source, Proxy and Dependency.

Aggregation Relationship

An Energy Managed Object may aggregate the Energy Management information of one or more Energy Managed Objects and is referred to as an Aggregation Relationship. An Energy Managed Object may be aggregated by another Energy Managed Object(s). Aggregate values are obtained by reading values from multiple Energy Managed Objects and producing a single value of more significant meaning such as average, count, maximum, median, minimum, mode and most commonly sum.

Metering Relationship

An Energy Managed Object may measure the Energy of another Energy Managed Object(s) and is referred to as a Metering Relationship. An Energy Managed Object may be metered by another Energy Managed Object(s). Example: a PoE port on a switch measure the Power it provides to the connected Energy Managed Object.

Power Source Relationship

An Energy Managed Object may be the source of or distributor of power to another Energy Managed Object(s) and is referred to as a Power Source Relationship. An Energy Managed Object may be powered by another Energy Managed Object(s). Example: a PDU provides power for a connected host.

Proxy Relationship

An Energy Managed Object that provides Energy Management capabilities on behalf of another Energy Managed Object so that is appears to be Energy Aware is referred to a Proxy Relationship. An Energy Managed Object may be proxied by another Energy Managed Object(s). Example: a protocol gateways device for Building Management Systems (BMS) with subtended devices.

Dependency Relationship

An Energy Managed Object may be a component of or rely completely upon another Energy Managed Object to operate and is referred to as a Dependency Relationship. An Energy Managed Object may be dependent on another Energy Managed Object(s). Example: A Switch chassis with multiple line cards

Energy Managed Object Parent

An Energy Managed Object Parent is an Energy Managed Object that provides one or more of the Energy Managed Object Relationships capabilities.

Energy Managed Object Child

An Energy Managed Object Child is an Energy Managed Object that has at least one Energy Managed Object Relationship capability provided by another Energy Managed Object.

Power State

A Power State is a way to classify a Power setting on an Energy Managed Object (e.g., on, off, or sleep). A Power State can be viewed as a method for Energy Control

Manufacturer Power State

A Manufacturer Power State is a device-specific way to classify a Power setting implemented on an Energy Managed Object.

Power State Set

A collection of Power States that comprise one named or logical grouping of control is a Power State Set. For example, the states {on, off, and sleep} as defined in [IEEE1621], or the 16 power states as defined by the [DMTF] can be considered two different Power State Sets.

Nameplate Power

The Nameplate Power is the maximal (nominal) Power that a device can support. This is typically determined via load testing and is specified by the manufacturer as the maximum value required to operate the device. This is sometimes referred to as the worst-case Power. The actual or average Power may be lower. The Nameplate Power is typically used for provisioning and capacity planning.

4. Energy Management Reference Model

The scope of this framework is to enable network and network-attached devices to be administered for Energy Management. The framework recognizes that in complex deployments Energy Managed

Objects may communicate over varying protocols. For example the communications network may use IP Protocols (SNMP) but attached Energy Managed Object Parent may communicate to Energy Managed Object Children over serial communication protocols like BACNET, MODBUS etc. The likelihood of getting these different topologies to convert to a single protocol is not very high considering the rate of upgrades of facilities and energy related devices. Therefore the framework must address the simple case of a uniform IP network and a more complex mixed topology/deployment.

As displayed in the Figure 1, the most basic energy reference model is composed of an Energy Management System (EMS) that obtains Energy Management information from Energy Managed Objects. The Energy Managed Object returns information for Energy Management directly to the EMS.

The protocol of choice for Energy Management is SNMP, as three MIBs are specified for Energy Management: the energy-aware MIB [EMAN-AWARE-MIB], the energy monitoring MIB [EMAN-MON-MIB], and the battery MIB [EMAN-BATTERY-MIB]. However, the EMAN requirement document [EMAN-REQ] also require the push of time series of power values. Therefore, IPFIX [RFC5101] is also mentioned in the following figures.

```
                    +---------------+
                    |      EMS      |                -   -
                    +-----+---+-----+                ^   ^
                          |   |                      |   |
                          |   |                      |S  |I
                +---------+   +----------+           |N  |P
                |                        |           |M  |F
                |                        |           |P  |I
       +-----------------+      +--------+--------+  |   |X
       | EMO           1 |  ... | EMO           N |  v   |
       +-----------------+      +-----------------+  -   -
```

Figure 1: Simple Energy Management

As displayed in the Figure 2, a more complex energy reference model includes Energy Managed Object Parents and Children. The Energy Managed Object Parent returns information for themselves as well as information according to the Energy Managed Object Relationships.

```
                      +---------------+
                      |      EMS      |               -   -
                      +-----+--+------+               ^   ^
                            |  |                      |   |
                            |  |                      |S  |I
               +------------+  +--------+             |N  |P
               |                        |             |M  |F
               |                        |             |P  |I
       +------------------+     +-------+----------+  |   |X
       | EMO              |     | EMO              |  v   |
       | Parent 1         | ... | Parent N         |  -   -
       +------------------+     +------------------+
                      |||                  .
     One or           |||                  .
     Multiple         |||                  .
     Enery Managed    |||                  .
     Object           |||                  .
     Relationship(s): |||
     - Aggregation    |||      +-----------------------+
     - Metering       |||------| EMO Child 1           |
     - Power Source   ||       +-----------------------+
     - Proxy          ||
     - Dependency     ||       +-----------------------+
                      ||-------| EMO Child 2           |
                      |        +-----------------------+
                      |
                      |
                      |--------          ...
                      |
                      |
                      |        +-----------------------+
                      |--------| EMO Child M           |
                               +-----------------------+
```

Figure 2: Complex Energy Management Model

While both the simple and complex Energy Management models contain an EMS, this framework doesn’t impose any requirements regarding a topology with a centralize EMS or one with a distributed Energy Management via the Energy Managed Objects within the deployment.

Given the pattern in figure 2, the complex relationships between Energy Managed Objects can be modeled (refer also to section 5.3):

- A PoE device modeled as an Energy Managed Object Parent with the Power Source, Metering, and Proxy Relationships for this powered device
- A PDU modeled as an Energy Managed Object Parent with the Power Source and Metering for the plugged in host
- A PC with line cards modeled as an Energy Managed Object Parent with Dependency Relationships for the line cards
- Building management gateway, used as proxy for non IP protocols, is modeled as an Energy Managed Object Parent with the Proxy Relationship, and potentially the Aggregation Relationship
- Etc.

The communication between the Energy Managed Object Parent and Energy Managed Object Children is out of the scope of this framework.

5. Framework High Level Concepts and Scope

Energy Management can be organized into areas of concern that include:

- Energy Managed Object Identification and Context - for modeling and planning
- Energy Monitoring - for energy measurements
- Energy Control - for optimization
- Energy Procurement - for optimization of resources

The framework addresses Energy Management but excludes Energy Procurement and the environmental impact of energy use. As such the framework does not include:

- Manufacturing costs of an Energy Managed Object in currency or environmental units
- Embedded carbon or environmental equivalences of an Energy Managed Object
- Cost in currency or environmental impact to dismantle or recycle an Energy Managed Object
- Relationship or capabilities of an Energy Managed Object to an electrical or smart grid

- Supply chain analysis of energy sources or Energy Managed Object deployment
- Conversion of the usage or production of energy to units expressed from the source of that energy (such as the greenhouse gas emissions associated with 1000kW from a diesel source).

The next sections describe Energy Management organized into the following areas:

- Energy Managed Object and Energy Management Domain
- Energy Managed Object Identification and Context
- Energy Managed Object Relationships
- Energy Monitoring
- Energy Control
- Deployment Topologies

5.1. Energy Managed Object and Energy Management Domain

An Energy Management 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, a meter refers to the meter provided by the utility used for billing and measuring power to an entire building or unit within a building. A sub-meter refers to a customer or user installed meter that is not used by the utility to bill but instead used to get readings from sub portions of a building.

An Energy Management Domain should map 1-1 with a metered or sub-metered portion of the site. The Energy Management Domain should be configured on an Energy Managed Object. An Energy Managed Object Child may inherit the domain value from an Energy Managed Object Parent or the Energy Management Domain may be configured directly in an Energy Managed Object Child.

5.2. Energy Managed Object Identification and Context

5.2.1 Identification

Energy Managed Objects MUST contain a value that uniquely identifies the Energy Managed Object among all the Energy Management Domains within an EnMS. It is recommended that a universal identifier (UUID) be used to uniquely identify the Energy Managed Object.

Every Energy Managed Object should have a unique printable name. Possible naming conventions are: textual DNS name, MAC-address of the device, interface ifName, or a text string uniquely identifying the Energy Managed Object. As an example, in the case of IP phones, the Energy Managed Object name can be the device DNS name.

5.2.2 Context in General

In order to aid in reporting and in differentiation between Energy Managed Objects, each Energy Managed Object optionally contains information establishing its business, site, or organizational context within a deployment.

5.2.3 Context: Importance

An Energy Managed Object 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 Energy Management Systems and administrators can establish their own ranking, the following is a broad recommendation:

. 90 to 100 Emergency response

. 80 to 90 Executive or business-critical

. 70 to 79 General or Average

. 60 to 69 Staff or support

. 40 to 59 Public or guest

. 1 to 39 Decorative or hospitality

5.2.4 Context: Keywords

An Energy Managed Object 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 Energy Management 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 Energy Managed Objects. 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 Energy Managed Object 1, keywords: gangA

Outlet 2 Energy Managed Object 2, keywords: gangA

Outlet 3 Energy Managed Object 3, keywords: gangA, gangB

Outlet 4 Energy Managed Object 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.

5.2.5 Context: Role

An Energy Managed Object can provide a "role description" string that indicates the purpose the Energy Managed Object serves in the EnMS. 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.

5.3. Energy Managed Object Relationships

An Energy Managed Object MAY be an Energy Managed Object Parent or Energy Managed Object Child of another Energy Managed Object.

Energy Managed Objects establish a parent and child relationship when one Energy Managed Object provides capabilities for another Energy Managed Object.

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 Energy Managed Object Parent is the switch, and the Energy Managed Object Child is the device attached to the switch.

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.

5.3.1 Energy Managed Object Children Discovery

There are multiple ways that the Energy Managed Object Parent can discover its Energy Managed Object Children, if they are not present on the same physical network:

- In case of PoE, the Energy Managed Object Parent automatically discovers an Energy Managed Object Child when the Child requests power.
- The Energy Managed Object Parent and Children may run the Link Layer Discovery Protocol [LLDP], or any other discovery protocol, such as Cisco Discovery Protocol (CDP). The Energy Managed Object Parent might even support the LLDP-MED MIB [LLDP-MED-MIB], which returns extra information on the Energy Managed Object Children.
- The Energy Managed Object 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.
- Energy Managed Object Parent/Energy Managed Object Child relationships may be set by manual or automatic network configuration functions.

Note that the communication specifications between the Energy Managed Object Parent and Children is out of the scope of this document.

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

5.4. Energy Monitoring

For the purposes of this framework energy will be limited to electrical energy in watt hours. Other forms of Energy Managed Objects that use or produce non-electrical energy may be part of an Energy Management Domain but MUST provide information converted to and expressed in watt hours.

Each Energy Managed Object will have information that describes Power and Energy information along with how that measurement was obtained or derived.

Optionally, an Energy Managed Object can further describe the power information with power quality information reflecting the electrical characteristics of the measurement.

Optionally, an Energy Managed Object can provide Demand information over time

Power 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 Energy Managed Object should describe how it intends to measure Power as one of consumer, producer or meter of usage. Given the intent readings can be summarized or analyzed by an 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.

Power measurement magnitude should conform to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure. Measured values are represented in SI units obtained by BaseValue * 10 raised to the power of the scale. For example, if current power usage of an Energy Managed Object 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 an Energy Managed Object usage measurement was obtained:

. Whether the measurements were made at the device itself or from a remote source.

. Description of the method that was used to measure the power and whether this method can distinguish actual or estimated values.

An 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.

Optional Power Quality

Given a Power measurement it may in certain circumstances be desirable to know the electrical characteristics associated with that measurement. The information model must adhere to the IEC 61850 7-2 standard for describing AC measurements. In some Energy Management Domains, the power quality may not be needed, available, or relevant to the EMS.

Optional Demand

It is well known in commercial electrical utility rates that Demand is used as a measurement for billing. Also the highest peak demand measured over a time horizon, such as 1 month or 1 year, is often the basis for charges. A single window of time of high usage can penalize the consumer with higher energy consumption charges. However, it is relevant to measure the Demand only when there are actual power measurements from an Energy Managed Object, and not when the power measurement is assumed or predicted.

Optional Battery

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

. 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.

5.5. Energy Control

Energy Managed Objects can be controlled by setting it to a Power State. Sets of Power States can be seen as an interface by which an Energy Managed Object can be controlled. Each Energy Managed Object should indicate the Power State Sets that is implements. Well known Power State Sets should be registered with IANA

When and individual Power State is configured from a specific Power State Set, an Energy Managed Object may be busy at the request time. The Energy Managed Object 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

There are several standards and implementations of Power State Set. An Energy Managed Object can support one or multiple Power State Set implementations concurrently.

This framework list three initial possible Power State Series that can be supported by an Energy Managed Object:

IEEE1621 - [IEEE1621]

DMTF - [DMTF]

EMAN - Specified here

5.5.1 IEEE1621 Power State Series

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

on(0) - The device is fully On and all features of the device are in working mode.

off(1) - The device is mechanically switched off and does not consume energy.

sleep(2) - The device is in a power saving mode, and some features may not be available immediately.

5.5.2 DMTF Power State Series

DMTF [DMTF] standards organization has defined a power profile standard based on the CIM (Common Information Model) model that consists of 15 power states ON (2), SleepLight (3), SleepDeep (4), Off-Hard (5), Off-Soft (6), Hibernate(7), PowerCycle Off-Soft (8), PowerCycle Off-Hard (9), MasterBus reset (10), Diagnostic Interrupt (11), Off-Soft-Graceful (12), Off-Hard Graceful (13), MasterBus reset Graceful (14), Power-Cycle Off-Soft Graceful (15), PowerCycle-Hard Graceful (16). DMTF standard is targeted for hosts and computers. Details of the semantics of each Power State within the DMTF Power State Series can be obtained from the DMTF Power State Management Profile specification [DMTF].

DMTF power profile extends ACPI power states. The following table provides a mapping between DMTF and ACPI Power State Series and EMAN Power State Sets (described in the next section):

State	DMTF Power State	ACPI State	EMAN Power State Name
Non-operational states:			
1	Off-Hard	G3, S5	MechOff
2	Off-Soft	G2, S5	SoftOff
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

5.5.3 EMAN Power State Series

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

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

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

IEEE1621 Power(off):

mechoff(1) : An off state where no Energy Managed Object features are available. The Energy Managed Object is unavailable. No energy is being consumed and the power connector can be removed. This corresponds to ACPI state G3.

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

IEEE1621 Power(sleep)

hibernate(3): No Energy Managed Object features are available. The Energy Managed Object may be awakened without requiring a complete boot, but the time for availability is longer than sleep(4). An example for state hibernate(3) is a save to-disk state where DRAM context is not maintained.

Typically, energy consumption is zero or close to zero. This corresponds to state G1, S4 in ACPI.

sleep(4) : No Energy Managed Object 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 Energy Managed Object 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 Energy Managed Object features are available, except for out-of-band management, for example wake-up mechanisms. This mode is analogous to hot-standby. The Energy Managed Object can be quickly transitioned into an operational state. For example, processors are not executing, but processor context is maintained. This corresponds to state G1, S1 in ACPI.

IEEE1621 Power(on):

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

low(8) : Indicates some features may not be available and the Energy Managed Object has taken measures or selected options to provideless than mediumMinus(9) usage.

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

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

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

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

Energy Managed Objects may have Manufacturer Power States Sets and can map these to the EMAN Power State Sets. The follow shows examples when Manufacturer Power State Sets have fewer or more states than the EMAN Power State Set

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 Energy Managed Object States, the Power State will remain 0 throughout, 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 Energy Managed Object Power States is achievable, both series of states must exist in the MIB module in the Energy Managed Object 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 / MechOff	0 / none
2 / SoftOff	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 Energy Managed Object 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 Energy Managed Objects to a Power State would be conservative in terms of disabled functionality on the Energy Managed Object.

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 / MechOff                  0 / off
          2 / SoftOff                  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 framework allows the configuration of the Power State, while configuring the Manufacturer Power State from the MIB directly is not possible.

6. Structure of the Information Model: UML Representation

EDITOR'S NOTE: right place here or in the appendix?

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

EMO RELATIONSHIPS AND CONTEXT

```
                                +----------------------------+
                                | _Child Specific Info __    |
                                |----------------------------|
   +---------------------------+ |  parentId : UUID           |
   |    Context Information    | |  parentProxyAbilities      |
   |---------------------------| |            : bitmap        |
   |  roleDescription : string | | _mgmtMacAddress : octets   |
   |  keywords[0..n] : string  | |  mgmtAddress : inetaddress |
   |  importance : int         | |  mgmtAddressType : enum    |
   |  category :  enum         | |  mgmtDNSName : inetaddress |
   +---------------------------+ +----------------------------+
             |                             |
             |                             |
             |                             |
             v                             v
     +------------------------------------------+
     |  Energy Managed Object Information       |
     |------------------------------------------|
     | index : int                              |
     | powerMonitorId | UUID                    |
     | name : string                            |
     | meterDomainName | string                 |
     | alternateKey | string                    |
     +------------------------------------------+
             ^
             |
             |
             |
   +-------------------------+
   |    Links Object         |
   |-------------------------|
   |  physicalEntity : int   |
   |  ethPortIndex : int     |
   |  ethPortGrpIndex : int  |
   |  lldpPortNumber : int   |
   +-------------------------+
```

EMO AND MEASUREMENTS

```
   +------------------------------------------------+
   |              Energy Managed Object             |
   |------------------------------------------------|
```

```
   |  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             |
                            +------------------------------+
```

```
                      EMO & STATES

      +----------------------------------------------+
      |         Energy Managed Object                |
      |----------------------------------------------|
```

```
      | 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. Configuration

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

- Energy Managed Object name: A unique printable name for the Energy Managed Object.
- Energy Managed Object Role: An administratively assigned name to indicate the purpose an Energy Managed Object serves in the network.
- Energy Managed Object Importance: A ranking of how important the Energy Managed Object is, on a scale of 1 to 100, compared with other Energy Managed Objects in the same Energy Management Domain.
- Energy Managed Object Keywords: A list of keywords that can be used to group Energy Managed Objects for reporting or searching.
- Energy Management Domain: Specifies the name of an Energy Management Domain for the Energy Managed Object.

- Energy Managed Object State: Specifies the current Power State (0..12) for the Energy Managed Object.
- Demand parameters: For example, which interval length to report the Deman over, the number of intervals to keep, etc.
- Assigning an Energy Managed Object Parent to an Energy Managed Object Child
- Assigning an Energy Managed Object Child to an Energy Managed Object Parent.

When an Energy Managed Object requires a mapping with the Manufacturer Power State, the Energy Managed Object configuration is done via the Power State settings, and not directly via the Manufacturer Power States, which are read-only. Taking into account Figure 7, 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 framework will not set the Manufacturer Power State to one percent granularity without communicating over or configuring the proprietary protocol for this Energy Managed Object.

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

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

8. Fault Management

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

9. Relationship with Other Standards Development Organizations

9.1. Information Modeling

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

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

Specific examples include:

- The scaling factor, which represents Energy Managed Object usage magnitude, conforms to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure.

- The electrical characterisitc is based on the ANSI and IEC Standards, which require that we use an accuracy class for power measurement. ANSI and IEC define the following accuracy classes for power measurement:

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

  - ANSI C12.20 class 0.2, 0.5

- The electrical characteristics and quality adheres closely to the IEC 61850 7-2 standard for describing AC measurements.

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

10. 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.

10.1. Security Considerations for SNMP

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

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

- Unauthorized changes to the Power Domain or business context of an Energy Managed Object may result in misreporting or interruption of power.
- Unauthorized changes to a power state may disrupt the power settings of the different Energy Managed Objects, and therefore the state of functionality of the respective Energy Managed Objects.
- Unauthorized changes to the demand history may disrupt proper accounting of energy usage.

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

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

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

11. IANA Considerations

EDITOR'S NOTE: Add power states

12. Acknowledgments

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Requirements for Energy Management
draft-ietf-eman-requirements-04

Abstract

This document defines requirements for standards specifications for energy management. Defined requirements concern monitoring functions as well as control functions. Covered functions include identification of powered entities, monitoring of their power state, power inlets, power outlets, actual power, consumed energy, and contained batteries. Further included is control of powered entities' power supply and power state. This document does not specify the features that must be implemented by compliant implementations but rather features that must be supported by standards for energy management.

Table of Contents

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 systems and frameworks.

This document defines requirements for standards specifications for energy management. Defined requirements concern monitoring functions as well as control functions. Covered functions include identification of powered entities, monitoring of their power state, power inlets, power outlets, actual power, consumed energy, and contained batteries. Further included is control of powered entities' power supply and power state. Note that this document does not specify the features that must be implemented by compliant implementations but rather features that must be supported by standards for energy management.

The main subject of energy management are powered entities that consume electric energy. Powered entities include devices that have an IP address and can be addressed directly, such as hosts, routers, and middleboxes, as well as devices indirectly connected to an IP network, for which a proxy with an IP address provides a management interface, for example, devices in a building management infrastructure using BACNET or MODBUS protocols.

The requirements specified in this document explicitly concern the standards specification process and not the implementation of specified standards. All requirements in this document must be reflected by standards specifications to be developed. But which of the features specified by these standards will be mandatory, recommended, or optional for compliant implementations is to be defined by the concrete standards track document(s) and not in this document.

This document first discusses general objectives of energy management in Section 3. Requirements for an energy management standard are specified in Sections 4 to 8.

1.1. Conventional requirements for energy management

The specification of requirements for an energy management standard starts with Section 4 addressing the identification of powered entities and the granularity of reporting of energy-related information. A standard must support unique identification of powered entities. Furthermore, it must support more than just reporting per powered device. Support is required for also reporting energy-related information on individual components of a device or subtended devices. This is why this draft uses the more general term "powered entity" rather than "powered device". A powered entity may be a device or a component of a device.

Section 5 specifies requirements related to monitoring of powered entities. This includes general (type, context) information and specific information on power states, power inlets, power outlets, power, energy, and batteries. Control power state and power supply of powered entities is covered by requirements specified in Section 6.

1.2. Specific requirements for energy management

At first glance the rather conventional requirements summarized above seem to be all that would be needed for energy management. But it turns out that there are some significant differences between energy management and most of the well known conventional network management functions. The most significant difference from many other management functions is the need for some devices to report on other entities. There are three major reasons for this.

- o For monitoring and controlling a particular powered entity in general it is not sufficient to communicate with the powered entity only, but in many cases also communication with other powered entities along the power distribution path may be necessary, for example, with power switches and power meters. Indeed, there are situations where a power or energy meter is not located in the powered entity, but in a different physical location. For example, a Power Distribution Unit (PDU), which supplies power for a server connected to a PDU socket, would meter the power supplied, while the server may not have the capability to measure its power consumption. A second example is a Power over Ethernet port, which provides power to the attached device, and which can meter how much power/energy it delivers to the attached device.
- o Energy management often extends its scope beyond powered entities with IP network interfaces, for example toward non-IP building networks, that are accessed via an IP gateway. Requirements in this document do not fully cover all these networks, but they cover means for opening IP network management towards them.
- o For monitoring of particular powered entities, it is sometimes not a scalable approach to communicate directly with all the powered entities directly from a central energy management system as the number of powered entities keeps increasing.

This specific issue of energy management and a set of further ones are covered by requirements specified in Sections 7 and 8.

2. Terminology

2.1. Energy

the definition of the term energy is to be agreed on in the EMAN WG.

The term 'energy consumption' is commonly used for both, for referring to the amount of consumed energy and also for referring to the rate of consuming energy. In the first case it addresses consumed energy measured by joule, watthour, or another energy unit, in the second one it addresses power, typically an average power measured by watt.

However, in this document the term "consumed energy" always refers to an energy quantity (measured in joule, watthour, etc.) and not to a power quantity (measured in watt, etc.).

2.2. Power

the definition of the term power is to be agreed on in the EMAN WG.

2.3. Powered entity

A powered entity is a consumer of energy that is subject to energy management. In general, all managed physical entities in a communication network consume electric energy and thus are subject to energy management including particularly energy monitoring and energy control.

A powered entity can be a managed device or a component of a managed device, which is monitored or controlled individually.

2.4. Power state

Power state of a powered entitiy is defined as a specific settings of a powered entitiy that influences its power. Examples of power states of a powered entitiy are on, off, and sleep.

2.5. Power monitor

Energy management requires retrieving energy-related information on powered entities. In many cases this information is not available at the powered entities themselves, but at other powered entities. For example measurement of power and energy consumption can be conducted by power meters at other locations along the power distribution tree for the powered entity.

A power monitor is a module that reports energy-related information on powered entities. A power monitor may be integrated into a powered entity or located remotely of the powered entity. Instances of power monitors may report information on, for example, power supply, power, and power state of a powered entity. There may be multiple power monitors reporting information on the same powered entity.

2.6. Power inlet

Powered entities receive power at their power inlets. Powered entities may have multiple inlets, for example, servers with redundant power supply. Examples for power inlets are AC power cords of a powered entity or an Ethernet port at which the powered entity receives DC Power over Ethernet (PoE).

2.7. Power outlet

Powered entities may have means to supply others with electrical power. Power is delivered to other powered entities through power outlets. Power sourcing entities often have more than one power outlet. Examples for power outlets are AC power sockets at a Power Distribution Unit (PDU) and Ethernet ports at a Power over Ethernet (PoE) Power Sourcing Equipment (PSE), that can supply powered entities with DC power using the Ethernet cable.

2.8. Energy management

the definition of the term power is to be agreed on in the EMAN WG.

2.9. Energy management standard

This document specifies requirements for an energy management standard. This term refers to a collections of documents specifying standards for energy-related monitoring and control. The energy management standard specifies means for building energy management systems.

Requirements specified in this document concern the means that an energy management standard must provide. It does not imply that all required means must be implemented in all energy standard scenarios. Which means and features must be implemented by compliant implementations is to be specified by the energy management standard itself, not by this requirements document.

Note that for meeting individual requirements specified in this document, new standards are not necessarily required. It is recommended to rather use existing standards than specify new ones.

3. General Objectives of Energy Management

The basic objective of energy management is operating communication networks and other equipment with minimal amount of energy, while maintaining a certain level of service. A set of use cases for energy management can be found in [I-D.tychon-eman-applicability-statement].

3.1. Power states

One approach to achieve this goal is by setting all powered entities to an operational state that results in lower energy consumption, but still meets the 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 powered entity 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 sleep state (not functional, but immediately available)
- o off state (may imply requiring significant time for becoming operational)

In actual implementations the number of power states and their properties vary a lot. Very simple powered entities may just have only the extreme states, full power and off state. Some implementations might use IEEE1621 model of three states on, off, and sleep. However, more granular power states can be implemented with many levels of off, sleep, and reduced power states.

3.2. Trade-offs

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, service, 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 powered entities to lower power states when higher performance is not needed.

3.3. Local and network-wide energy management

Many energy saving functions can be executed locally by a powered entitiy. The basic principle is that a powered entitiy monitors its usage and dynamically adapts its energy consumption according to the required performance. It may switch to a sleep state when it is not in use at all. Potential interactions with an energy management system for such an entity include the observation of the entity’s power state and the configuration of power saving policies, for example, by setting thresholds for power state changes.

Energy savings can also be achieved with policies implemented by a network management system that controls power states of managed entities. In order to make policy decisions properly, information about the energy consumption of powered entities in different power states is required. Often this information is acquired best through monitoring.

Both methods, network-wide and local energy management, have advantages and disadvantages. Most buildings use both of them. In some cases for example, significant energy savings can be achieved by simply setting all powered entities in a network to sleep, when the network is not needed. However, in general it is dangerous to set all powered entities of a group to the same state, because there is a risk that such actions ignore specifics of individual powered entities or violate local service level agreements.

3.4. Energy monitoring

It should be noted that only monitoring energy consumption and power states is obviously not a means to reduce the energy consumption of a powered entitiy. In fact, it is likely to increase the power consumption of a powered entitiy slightly because monitoring energy may require instrumentation that consumes energy when in use. And also reporting of measured quantities over the network consumes energy. 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.

Monitoring operational power states and energy consumption can also be required for other energy management purposes including but not limited to:

- investigating power saving potential
- evaluating the effectiveness of energy saving policies and measures
- deriving, implementing, and testing power management strategies
- accounting for the total power consumption of a powered entity, a network, or a service
- predicting a powered entitiy’s reliability based on power usage
- choosing time of next maintenance cycle for a powered entitiy

3.5. Overview of energy management requirements

From the considerations described above the following basic management functions appear to be required for energy management:

- o monitoring power states
- o monitoring power (energy consumption rate)
- o monitoring (accumulated) energy consumption
- o setting power states
- o setting and enforcing power saving policies

It should be noted that active power control is complementary (but essential) to other energy savings measures such as low power electronics, energy saving protocols (for example, IEEE 802.3az), energy-efficient device design (for example, sleep and low-power modes for individual components of a device), and energy-efficient network architectures. Measurement of energy consumption may also provide useful input for developing these technologies.

4. Identification of Powered Entities

As already stated Section 1.1, powered entities on which energy-related information is provided are identified in a sufficiently unique way. This holds in particular for powered entities that are components of managed devices and in case that one powered entity reports information on another one, see Section 7. For powered entities that control other powered entities it is important to identify the powered entities they control, see Section 8.

Also stated already in Section 1.1 is the requirement of providing means for reporting energy-related information on components of a managed device. An entity in this document may be an entire managed device or just a component of it. Examples of components of interest are a hard drive, a battery, or a line card. For controlling entities it may be required to be able to address individual components in order to save energy. For example, server blades can be switched off when the overall load is low or line cards at switches may be powered down at night times.

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.

Detailed Requirements:

4.1. Identifying powered entities

The energy management standard must provide means for uniquely and persistently identifying powered entities that are monitored or controlled by an energy management system. Uniqueness must be given in a domain that is large enough to avoid collisions of identities at potential receivers of monitored information.

4.2. Identifying components of powered devices

The energy management standard must provide means for identifying not just entire devices as powered entities, but also individual components of powered devices.

4.3. Persistency of Identifiers

The energy management standard must provide means for indicating whether identifiers of powered entities are persistent across a re-start of the powered entitiy that provides the identifiers.

5. Information on Powered Entities

This section describes energy-related information on powered entities for which an energy management standard must provide means for retrieving and reporting.

Note that the fact that an energy management standard provides required means does not imply that all of them must be implemented by every compliant implementation. The concrete specification of standards based on these requirements may label individual features as mandatory, recommended, or optional.

Required information on powered entities can be structured into six groups. Section 5.1 specifies requirements for general information on powered entities, such as type of powered entity or context information. Section 5.2 covers requirements related to entities' power states. Requirements for information on power inlets and power outlets of powered entities are specified in Section 5.3. Monitoring of power and energy is covered by Sections 5.4 and 5.5, respectively. Finally, Section 5.6 specified requirements for monitoring batteries.

5.1. General information on powered entities

For energy management it may be required to understand the role and context of a powered entitiy. When monitoring, it may be helpful to group energy consumption per kind of entity. When controlling and setting power states it may be helpful to understand the kind and role of a powered entitiy in a network, for example, in order to avoid switching off vital network components.

Detailed Requirements:

5.1.1. Type of powered entity

The energy management standard must provide means to retrieve and report the type of powered entities according to a standrdized classification scheme.

5.1.2. Context information on powered entities

The energy management standard must provide means for retrieving and reporting context information on powered entities, for example tags associated with a powered entity that indicate the powered entitiy's role, or importance.

5.1.3. Grouping of powered entities

The energy management standard must provide means for grouping powered entities, for example, into energy monitoring domains, energy control domains, power supply domains, groups of powered entities of the same type, etc.

5.2. Power state

Many powered entities have a limited number of discrete power states, such as, for example, full power, low power, sleep, and off.

Obviously, there is a need to report the actual power state of a powered entitiy. Beyond that, there is also a requirement for standardizing means for retrieving the list of all supported power states of a powered entitiy.

Different standards bodies have already defined their own sets of power states for powered entities. Further organizations are in the process of adding more of these sets. In order to support multiple management systems possibly using different power state sets, while simultaneously interfacing with a particular powered entity, the energy management standard must provide means for supporting multiple power state sets used simultaneously at a powered entity.

Power states have parameters that describe its properties It is required to have standardized means for reporting some key properties, such as mean power and maximum power of a powered entitiy in a certain state.

There also is a need to report statistics on power states including the time spent an the energy consumed in a power state.

For some network management tasks, it may be desirable to receive notifications from powered entities, for example, when the components or the entire entity change their power state.

Detailed Requirements:

5.2.1. Actual power state

The energy management standard must provide means for reporting the actual power state of a powered entitiy.

5.2.2. List of supported power states

The energy management standard must provide means for retrieving the list of all potential power states of a powered entitiy.

5.2.3. Multiple power state sets

The energy management standard must provide means for supporting multiple power state sets simultaneously at a powered entity.

5.2.4. List of supported power state sets

The energy management standard must provide means for retrieving the list of all power state sets supported by a powered entitiy.

5.2.5. List of supported power states

Referring to the "list of supported power state sets" requirement, the energy management standard must provide means for retrieving the list of all potential power states of a powered entitiy that belong to a given power state set.

5.2.6. Maximum and average power per power state

The energy management standard must provide means for retrieving the maximum power and the average power as a typically static property for each supported power state.

5.2.7. Power state statistics

The energy management standard must provide means for monitoring statistics per power state including at least the total time spent in a power state, the number of times a state was entered and the last time a state was entered. More power state statistics are addressed by requirement 5.5.3.

5.2.8. Power state changes

The energy management standard must provide means for generating a notification when the actual power state of a powered entity changes.

5.3. Power inlet and power outlet

Powered entities have power inlets at which they are supplied with electric power. Most powered entities just have a single power inlet, while some have multiple ones. Often different power inlets are connected to separate power distribution trees. For energy monitoring, it is important information which power inlets a powered entitiy has, if power is available at an inlet and which of them are actually in use.

Some powered entities have power outlets for supplying other powered entities with electric power. A powered entitiy may have multiple power outlets. Examples are Power Distribution Units (PDUs) and Power over Ethernet (PoE) Power Sourcing Equipment (PSE).

For identifying and potentially controlling the source of power received at an inlet, it may be required to identify the power outlet of another powered entity at which the received power is provided. Analogously, for each outlet it is of interest to identify the power inlets that receive the power provided at a certain outlet.

Static properties of each power inlet and each power outlet are required information for energy management. Static properties include the kind of electric current (Alternating Current (AC) or Direct Current (DC)), the nominal voltage, the nominal AC frequency, and the number of AC phases.

Detailed Requirements:

5.3.1. List of power inlets and power outlets

The energy management standard must provide means for monitoring the list of power inlets and power outlets at a powered entitiy.

5.3.2. Corresponding power outlet

The energy management standard must provide means for identifying the power outlet that provides the power received at a power inlet.

5.3.3. Corresponding power inlets

The energy management standard must provide means for identifying the list of power inlets that receive the power provided at a power outlet.

5.3.4. Availability of power

The energy management standard must provide means for monitoring the availability of power at each power inlet and each power outlet. This information indicates whether at a power providing outlet power supply is switched on or off.

5.3.5. Use of power

The energy management standard must provide means for monitoring for each power inlet and each power outlet if it is in actual use. For the inlet this means that the powered entitiy actually receives power at the inlet. For the outlet this means that actually power is provided to one or more powered entities at the outlet.

5.3.6. Type of current

The energy management standard must provide means for reporting the type of current (Alternating Current (AC) or Direct Current (DC)) for each power inlet and each power outlet of a powered entity.

5.3.7. Nominal voltage

The energy management standard must provide means for reporting the nominal voltage for each power inlet and each power outlet of a powered entity.

5.3.8. Nominal AC frequency

The energy management standard must provide means for reporting the nominal AC frequency for each power inlet and each power outlet of a powered entity.

5.3.9. number of AC phases

The energy management standard must provide means for reporting the number of AC phases for each power inlet and each power outlet of a powered entity.

5.4. Power

Power is a quantity measured as instantaneous power or as average power over a time interval. In contrast to power state values, this quantity may change continuously.

Obtaining highly accurate values for power and energy may be costly. Often dedicated metering hardware is needed for this purpose. Powered entities without the ability to measure their power and energy consumption with high accuracy may just report estimated values, for example based on load monitoring or even just the entity type.

Depending on how power and energy consumption values are obtained the confidence in the reported value and its accuracy may vary. Powered entities reporting such values should qualify the confidence in the reported values and quantify the accuracy of measurements. For reporting accuracy, the accuracy classes specified in IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22] should be considered.

In addition to the plain real power value, also further properties of the supplied power are subject to monitoring. In case of AC power supply, there are more power values beyond the real power to be reported including the apparent power, the reactive power, and the phase angle of the current or the power factor. For both AC and DC power the power quality is also subject of monitoring. Power quality parameters include the actual voltage, the actual frequency, the Total Harmonic Distortion (THD) of voltage and current, the impedance of an AC phase or of the DC supply. Power quality monitoring should be in line with existing standards, such as [IEC.61850-7-4].

For some network management tasks, it is required to obtain time series of power values (or energy consumption values). In general these could be obtained in many different ways. It should be avoided that such time series can only be obtained by regular polling by the energy management system. Means should be provided to either push such values from the place they are available to the management system or to have them stored at the powered entitiy for a sufficiently long period of time such that a management system can retrieve a stored time series of values.

Detailed Requirements:

5.4.1. Real power

The energy management standard must provide means for reporting the real power for each power inlet and each power outlet of a powered entity.

5.4.2. Power measurement interval

The energy management standard must provide means for reporting the corresponding time or time interval for which a power value is reported. The power value can be measured at the corresponding time or averaged over the corresponding time interval.

5.4.3. Confidence in power values

The energy management standard must provide means for reporting the confidence in reported power values by indicating the way these values have been obtained. for example, by power measurement, by estimation based on performance values, or hard coding average power values for a powered entity.

5.4.4. Accuracy of power and energy values

The energy management standard must provide means for reporting the accuracy of reported power values.

5.4.5. Complex power

The energy management standard must provide means for reporting the complex power for each power inlet and each power outlet of a powered entity. Besides the real power, at least two out of the following three quantities need to be reported: apparent power, reactive power, phase angle. The phase angle can be substituted by the power factor. In case of AC power supply, means must be provided for reporting the complex power per phase.

5.4.6. Actual voltage and current

The energy management standard must provide means for reporting the actual voltage and actual current for each power inlet and each power outlet of a powered entity. In case of AC power supply, means must be provided for reporting the actual voltage and actual current per phase.

5.4.7. Actual AC frequency

The energy management standard must provide means for reporting the actual AC frequency for each power inlet and each power outlet of a powered entity.

5.4.8. Total harmonic distortion

The energy management standard must provide means for reporting the Total Harmonic Distortion (THD) of voltage and current for each power inlet and each power outlet of a powered entity. In case of AC power supply, means must be provided for reporting the THD per phase.

5.4.9. Power supply impedance

The energy management standard must provide means for reporting the impedance of power supply for each power inlet and each power outlet of a powered entity. In case of AC power supply, means must be provided for reporting the impedance per phase.

5.4.10. Time series of power values

The energy management standard must provide means for collecting time series of real power values for each power inlet and for each power outlet of a powered entitiy without requiring to regularly poll the powered entitiy from an energy management station. A solution for this is that the concerned powered entity or another powered entity closely interacting with the concerned powered entity collect time series of power values and make them available via push or pull mechanisms to receivers of the information.

5.5. Energy

Monitoring of electrical energy consumed (or converted) at a powered entitiy can be done in various ways. One is collecting time series of power values for the powered entitiy and calculating the consumed energy from these values. An alternative is the powered entity itself or another powered entity taking care of energy measurement and reporting energy consumption values for certain time intervals. Time intervals of interest are the time from the last restart of the powered entitiy to the reporting time, the time from another past event to the reporting time, or the last given amount of time before the reporting time.

In order to monitor energy consumption in different power states, it is useful if powered entities record their energy consumption per power state and report these quantities.

For some network management tasks, it is required to obtain time series of energy values. In general these could be obtained in many different ways. It should be avoided that such time series can only be obtained by regular polling by the energy management system. Means should be provided to either push such values from the place they are available to the management system or to have them stored at the powered entitiy for a sufficiently long period of time such that a management system can retrieve a stored time series of values.

Detailed Requirements:

5.5.1. Energy

The energy management standard must provide means for reporting the consumed energy received at a power input or provided at a power outlet of a powered entitiy. Reports must be made for a clearly specified time interval.

5.5.2. Time intervals

The energy management standard must provide means for reporting the consumed energy of a powered entitiy for certain time intervals.

- o Reports must be supported for the time interval starting at the last restart of the powered entitiy and ending at a certain point in time, such as the time when a report was delivered.
- o Reports must be supported for a sequence of consecutive non-overlapping time intervals of fixed size (periodic reports).
- o Reports must be supported for a sequence of consecutive overlapping time intervals of fixed size (periodic reports).
- o Reports must be supported for an interval of given length ending at a certain point in time, such as the time when a report was delivered (sliding window)

5.5.3. Energy per power state

The energy management standard must provide means for reporting the consumed energy individually for each power state. This extends the requirement 5.2.7 on power state statistics.

5.5.4. Time series of energy values

The energy management standard must provide means for collecting time series of energy values for each power inlet and for each power outlet of a powered entitiy without requiring to regularly poll the powered entitiy from an energy management station. A solution for this is that the concerned powered entity or another powered entity closely interacting with the concerned powered entity collect time series of energy values and make them available via push or pull mechanisms to receivers of the information.

5.6. Battery State

Today more and more powered entities 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 an powered entity, particularly the charging status is typically controlled by automatic functions that act locally on the powered entitiy and manually by users of the powered entity. In addition to this, there is a need to monitor the battery status of these entities by network management systems.

The management requirements discussed above in Sections 5.1 to 5.5 concern energy-related information on powered entities. Powered entities may be powered devices or components of powered devices. Devices containing batteries can be modeled in two ways. The entire device can be modeled as a single powered entity on which energy-related information is reported or the battery can be modeled as an individual powered entity for which energy-related information is monitored individually according to requirements in Sections 5.1 to 5.5.

In both cases further information on batteries is of interest for energy management, such as the current charge of the battery, the number of completed charging cycles, the charging state of the battery, and further static and dynamic battery properties. Also desirable is to receive notifications if the charge of a battery becomes very low or if a battery needs to be replaced.

Detailed Requirements:

5.6.1. Battery charge

The energy management standard must provide means for reporting the current charge of a battery.

5.6.2. Battery charging state

The energy management standard must provide means for reporting the charging state (charged, discharged, etc.) of a battery.

5.6.3. Battery charging cycles

The energy management standard must provide means for reporting the number of completed charging cycles of a battery.

5.6.4. Actual battery capacity

The energy management standard must provide means for reporting the actual capacity of a battery.

5.6.5. Static battery properties

The energy management standard must provide means for reporting static properties of a battery, including the nominal capacity, the number of cells, the nominal voltage, and the battery technology.

5.6.6. Low battery charge notification

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

5.6.7. Battery replacement notification

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

5.6.8. Multiple batteries

The energy management standard must provide means for meeting requirements 5.6.1 to 5.6.7 for each individual battery contained in a single powered entity.

6. Control of Powered Entities

Many powered entities control their power state locally by self-managed dynamic adaptation to the environment. But other powered entities without that capability need interfaces for a energy management system to control their power states in order to save energy. Even for self-managed powered entities such interface may be required for overruling local policy decisions by global ones from an energy management system.

Power supply is typically not self-managed by powered entities. And controlling power supply is typically not conducted as interaction between energy management system and the powered entity itself. It is rather an interaction between the management system and an entity providing power at its power outlets. Still, requirements for power state control apply accordingly to power supply control.

Note that shutting down the power supply abruptly may have severe consequences for the powered entity.

Detailed Requirements:

6.1. Controlling power states

The energy management standard must provide means for setting power states of powered entities.

6.2. Controlling power supply

The energy management standard must provide means for switching power supply off or turning power supply on at power outlets providing power to one or more powered entity.

7. Reporting on Other Powered Entities

As already discussed in the introduction of Section 5, not all energy-related information may be available at the concerned powered entity. Such information may be provided by other powered entities, such as a Power Distribution Unit (PDU), external power meter, or a Power over Ethernet (PoE) Power Sourcing Equipment (PSE). Some of these entities (PDU, PSE) can also control the power provided to the other powered entities, while some can just report on the remote powered entities (external power meter). This section covers reporting of information (monitoring) only. See Section 8 for requirements on controlling other powered entities.

There are cases where a power supply unit switches power for several powered entities by turning power on or off at a single power outlet or where a power meter measures the accumulated power of several powered entities at a single power line. Consequently, it should be possible to report that a monitored value does not relate to just a single powered entity, but is an accumulated value for a set of powered entities. All of these powered entities belonging to that set need to be identified.

If a powered entity has information about where energy-related information on itself can be retrieved, then it would be very useful if it has a way to communicate this information to an energy management system. This applies even if the information only provides accumulated quantities for several powered entities.

Detailed Requirements:

7.1. Reports on other powered entities

The energy management standard must provide means for a powered entitiy to report energy-related information on another powered entity.

7.2. Identity of other powered entities on which is reported

The energy management standard must provide means for reporting the identity of another powered entity on which energy-related information is reported.

7.3. Reporting quantities accumulated over multiple powered entities

For powered entities reporting single values that are accumulated over multiple powered entities, the energy management standard must provide means for reporting the list of all powered entities from which contributions are included in the accumulated value.

7.4. List of all powered entities on which is reported

The energy management standard must provide means for a powered entitiy to report the list of all other powered entities on which it can report energy-related information.

7.5. Content of reports on other powered entities

The energy management standard must provide means for a powered entitiy to indicate for each other powered entity on which it can provide energy-related information which energy-related information can be provided for this powered entity.

7.6. Indicating source of remote information

The energy management standard must provide means for a powered entity to indicate another powered entity at which energy-related information on itself can be retrieved.

7.7. Indicating source of remote information

For a powered entity that has another powered entity at which energy-related information on itself can be retrieved, the energy management standard must provide means for indicating the information that is available at other powered entities per other powered entity.

8. Controlling Other Powered Entities

This section specifies requirements for controlling power states and power supply of powered entities by communicating not with these powered entities themselves, but with other powered entities that have means for controlling power state or power supply of others.

8.1. Controlling power states of other powered entities

Some powered entities may have control of power states of other powered entities. For example a gateway to a building network may have means to control the power state of powered entities in the building that do not have an IP interface. For this and similar cases means are needed to make this control accessible to the energy management system.

In addition to this, it is required that a powered entitiy that has its state controlled by other powered entities has means to report the list of these other powered entities.

Detailed Requirements:

8.1.1. Control of power states of other powered entities

The energy management standard must provide means for an energy management system to send power state control commands to a powered entity that concern the power states of other powered entities than the one the command was send to.

8.1.2. Identity of other power state controlled entities

The energy management standard must provide means for reporting the identity of another powered entity for which the reporting powered entity has means to control the power state.

8.1.3. List of all power state controlled entities

The energy management standard must provide means for a powered entitiy to report the list of all powered entities for which it can control the power state.

8.1.4. List of all power state controllers

The energy management standard must provide means for a powered entitiy that receives commands controlling its power state from other powered entities to report the list of all those entities.

8.2. Controlling power supply of other powered entities

Some powered entities may have control of the power supply of other powered entities, for example, because the other powered entity is supplied via a power outlet of the powered entitiy. For this and similar cases means are needed to make this control accessible to the energy management system.

In addition to this, it is very required that a powered entitiy that has its supply controlled by other powered entities has means to report the list of these other powered entities.

Detailed Requirements:

8.2.1. Control of power supply of other powered entities

The energy management standard must provide means for an energy management system to send power supply control commands to a powered entity that concern the power supply of other powered entities than the one the command was send to.

8.2.2. Identity of other power supply controlled powered entities

The energy management standard must provide means for reporting the identity of another powered entity for which the reporting powered entity has means to control the power supply.

8.2.3. List of all power supply controlled powered entities

The energy management standard must provide means for a powered entitiy to report the list of all other powered entities for which it can control the power supply.

8.2.4. List of all power supply controllers

The energy management standard must provide means for a powered entitiy that has other powered entities controlling its power supply to report the list of all those powered entities.

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 powered entities shall be discovered during discovery and detect/discard powered entities without a trusted relationship to be included among the powered entities 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 powered entities, then it is important to authenticate and/or authorize such powered entities. In addition, in the case of control of other powered entities, it would be highly desirable to have some form of an authentication mechanism to ensure that only the designated powered entities shall control the powered entities within its control domain. It should be possible to prevent a powered entity which does not have the appropriate authorization and authority to control or configure powered entities in its control domain/purview. Secondly, it should be possible to prevent malicious powered entities from exercising control over entities.

10. IANA Considerations

This document has no actions for IANA.

11. Acknowledgements

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12. Open issues

12.1. Revise security considerations

A discussion of the sensitivity of the content of the monitoring data is missing.

12.2. High/Low power notifications

For some network management tasks it may be desirable to receive notifications from entities when the power of an powered entity exceeds or falls below certain thresholds. Do we want to make this a requirement?

Proposal: added "for example" so that we don't restrict the framework to only this notification

12.3. Power and energy time series?

We have requirements for reporting of time series of power and energy values. Do we need both or just one of them? If just one, then which one?

12.4. Inlet/outlet combinations

How to model the case that an inlet or outlet changes during operation from one kind to the other. An example is a battery that receives power at a socket at one time. Then the socket is an inlet. At another time the battery provides power at the same socket. Then it's an outlet. The same holds for entities with integrated power generators.

One solution would be to introduce a new kind of hybrid in/outlets. Another one would be to model the same socket as inlet as well as as outlet. It would appear twice in the list of all inlets and outlets. Then received power/energy would be reported under the inlet entry and provided power/energy would be reported under the outlet entry.

These would be two solutions. What would be the concrete requirement behind them?

12.5. Aggregation functions

Aggregation functions are not covered (yet). Are there requirements on aggregation? Which are they?

12.6. Add a definition of 'demand'

12.7. IEC references

References to mentioned IEC standards are missing. Also these references should be double checked.

12.8. Standard references for BACNET or MODBUS

Section 1 mentions BACNET or MODBUS as examples for building network protocols. We need references to the standards specifications for these protocols.

12.9. IEEE 1621 and 802.3az references

A reference to the IEEE 1621 standard is missing in section 3.1 and a reference to IEEE 802.3az is missing in section 3.4. The references should be double checked if they are well applicable in the respective section.

12.10. DC power quality covered by IEC standard?

Is there an IEC standard on DC power quality?

12.11. Introduce 'disconnected from power' as power state

We need to introduce the concept of a device being "disconnected" from power. This is a subset of the Off state. Shall we do it here or rather in the framework draft?

12.12. Need for basic state 'reduced power'?

Are "full power" and "reduced power" really different basic types of power states? Both may be forms of the on state. Identifying "full" separately is arbitrary. (For something like a computer, "idle" is the most common state so would be the one to call out separately rather than "full".)

12.13. Local and network-wide energy management

All but first sentence of the third paragraph in section 3.3 seem to be true not needed here. Proposal: remove them.

12.14. Do we need entity types?

Or shall we remove Section 5.1.1?

12.15. Power availability mode 'minimum' or 'ready'?

Do we need an additional mode for power availability called "minimum" or "ready" for power availability in xref target="availability"/>? This would reflect a PoE state at which the PSE is ready to serve the PD.

12.16. Is there a need for metering power supply inpedance?

12.17. Confidence in power values

Shall we rename "confidence in power values" to "method for determining power values"?

12.18. Terminology for reporting on other entitites

In Section 7 we need some additional terms here to streamline the text (and ultimately our thinking). Nominations include:

- o "powered entity" (which may be "self-reporting")
- o "reporting entity" (can be "self" or "other")
- o "other entity" (a reporting entity reporting not on itself; likely a different term would be better for this)
- o "controlled entity", "controlling entity" (section 8.1)
- o "switched entity", "switching entity" (section 8.2)

Also, there are two cases for an "other entity". One is where the powered entity cannot report the value in question itself (either because it can't report anything, or doesn't know the value in question, e.g. when metering is external).

The second is where the powered entity can report, but the other entity is doing the reporting for some convenience. We need to be aware of both even if the framework does not need to make the distinction.

There may be multiple other reporting entities, not just a single one.

Do components of devices ever report, or do only devices do the reporting? This seems like an important point.

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Appendix A. Existing Standards

This section analyzes existing standards for energy consumption and power state monitoring. It shows that there are already several standards that cover only some part of the requirements listed above, but even all together they do not cover all of the requirements for energy management.

A.1. Existing IETF Standards

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

A.1.1. ENTITY MIB

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

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

Yet another example, is smart-PDUs, which can report the energy 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.

A.1.2. ENTITY STATE MIB

RFC 4268 [RFC4268] defines the ENTITY STATE MIB module. Implementations of this module provide information on entities including the standby status (hotStandby, coldStandby, providingService), the operational status (disabled, enabled, testing), the alarm status (underRepair, critical, major, minor, warning), and the usage status (idle, active, busy). This information is already useful as input for policy decisions and for other network management tasks. However, the number of states would cover only a small subset of the requirements for power state monitoring and it does not provide means for energy consumption monitoring. For associating the information conveyed by the ENTITY STATE MIB to specific components of a device, the ENTITY STATE MIB module makes use of the means provided by the ENTITY MIB module [RFC4133]. Particularly, it uses the entPhysicalIndex for identifying entities.

The standby status provided by the ENTITY STATE MIB module is related to power states required for energy management, but the number of states is too restricted for meeting all energy management requirements. For energy management several more power states are required, such as different sleep and operational states as defined by the Advanced Configuration and Power Interface (ACPI) [ACPI.R30b] or the DMTF Power State Management Profile [DMTF.DSP1027].

A.1.3. ENTITY SENSOR MIB

RFC 3433 [RFC3433] defines the ENTITY SENSOR MIB module. Implementations of this module offer a generic way to provide data collected by a sensor. A sensor could be an energy consumption meter delivering measured values in Watt. This could be used for reporting current power of an entity and its components. Furthermore, the ENTITY SENSOR MIB can be used to retrieve the accuracy of the used power meter.

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

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

A.1.4. UPS MIB

RFC 1628 [RFC1628] defines the UPS MIB module. Implementations of this module provide information on the current real power of entities attached to an uninterruptible power supply (UPS) device. This application would require identifying which entity is attached to which port of the UPS device.

UPS MIB provides information on the state of the UPS network. The MIB module contains several variables that are used to identify the UPS entity (name, model,..), the battery state, to characterize the input load to the UPS, to characterize the output from the UPS, to indicate the various alarm events. The measurements of power in UPS MIB are in Volts, Amperes and Watts. The units of power measurement are RMS volts, RMS Amperes and are not based on Entity-Sensor MIB [RFC3433].

A.1.5. POWER ETHERNET MIB

Similar to the UPS MIB, implementations of the POWER ETHERNET MIB module defined in RFC3621 [RFC3621] provide information on the current energy consumption of the entities that receive Power over Ethernet (PoE). This information can be retrieved at the power sourcing equipment. Analogous to the UPS MIB, it is required to identify which entities are attached to which port of the power sourcing equipment.

The POWER ETHERNET MIB does not report power and energy 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.

A.1.6. LLDP MED MIB

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

A.2. Existing standards of other bodies

A.2.1. DMTF

The DMTF has defined a power state management profile [DMTF.DSP1027] that is targeted at computer systems. It is based on the DMTF's Common Information Model (CIM) and rather an entity 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 an entity (e.g. to shutdown the entity) which is an aspect of but not sufficient for active energy management.

A.2.2. OVDA

ODVA is an association consisting of members from industrial automation companies. ODVA supports standardization of network technologies based on the Common Industrial Protocol (CIP). Within ODVA, there is a special interest group focused on energy and standardization and inter-operability of energy aware entities.

A.2.3. IEEE-ISTO Printer WG

The charter of the IEEE-ISTO Printer Working Group is for open standards that define printer related protocols, that printer manufacturers and related software vendors shall benefit from the interoperability provided by conformance to these standards. One particular aspect the Printer WG is focused on is power monitoring and management of network printers and imaging systems PWG Power Management Model for Imaging Systems [IEEE-ISTO]. Clearly, these devices are within the scope of energy management since these devices consume power and are attached to the network. In addition, there is ample scope of power management since printers and imaging systems are not used that often. IEEE-ISTO Printer working group has defined MIB modules for monitoring the power consumption and power state series that can be useful for power management of printers. The energy management framework should also take into account the standards defined in the Printer working group. In terms of other standards, IETF Printer MIB RFC3805 [RFC3805] has been standardized, however, this MIB module does not address power management of printers.

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Communication of Energy Price Information
draft-jennings-energy-pricing-01

Abstract

This specification defines media types for representing the future price of energy in JSON. It also defines a way for a client device, such as a car, refrigerator, air conditioner, water heater, or display to discover a web server that can provide the future price for local electrical energy. This will allow the client device to make intelligent decisions about when to use energy, and enable price distribution when the building is off-grid. It enables obtaining price from a local or non-local price server.

This draft is an early skeleton of a draft to start discussion around this idea.

1. Overview

Many uses of energy can be shifted in time, or changed in quantity, based on price. Consider charging an electric car. For users that plug in cars at 9pm, they may not care when it actually charges, as long as it is ready at 8am when they need to go to work. This is a classic real time problem and can be optimized as long as the charger for the car has relevant information about how long it will take to charge and the cost of electricity between the current time and the time when the task needs to be complete.

Other devices such as refrigerators, air conditioners, and washers can similarly shift load. For their primary temperature regulation function, they can lower their setpoint (for cooling devices) when costs are low, and increase it when costs are high. The amount of deviation from the base target is keyed to the value of the price, operational considerations (e.g. not letting food freeze or spoil), or other non-price information available (e.g. occupancy). Devices such as displays (TV or computer) or lights can dim in some proportion to the electricity price, to balance cost and functionality. Devices with user-oriented time-outs (e.g. when an occupancy sensor’s lack of seeing anyone in a space leads to a light going off) can adjust the length of such time-outs in proportion to price. Periodic functions (e.g. a refrigerator defrost cycle) can be shifted to the lowest cost time in the relevant time horizon. In general, the end-use device itself usually has the most knowledge about how best to act, and the the best access to internal actuators to accomplish the change.

Development around "Demand Response (DR)" has been advancing since around 2000. Most work in that area involves sending signals from the grid (DR-service provider) to a large building (commercial/ industrial) or large device within it, to request load shedding or load shifting. There are then financial arrangements to pay the building owner for the service. More recently, the DR community and regulators have turned to enabling dynamic pricing so that the price customers actually pay at the meter more closely corresponds to the actual costs that the utility faces. Prices can be sent from the grid to an end use device, or from the grid to a gateway device (could be the meter) that then sends the prices to end use devices.

This specification defines a simple JSON[RFC4627]media type to provide the cost of energy at future points of time. It is an array of objects in which each object contains the time a new price will come into effect and the price at that time. JSON also defines a well known URL on a web server so that an HTTP client can retrieve this data. Finally as a way to automatically discover the web server, this specification defines a DHCP option to provide the host name of the web server.

At this time, only electricity is contemplated, but other resources do plausibly have time-varying prices, such as centrally provided steam or hot/cold water. Any resource (e.g. water) could use this mechanism to have a local price to distribute. Resources with a local supply constraint will then have a local price to ensure a balance with demand.

The base usage case for this specification is a time-varying electricity price with the current price and a set of future prices (confirmed or estimates), usually for a 24 hour period. This price comes from the electric utility. The price can be fetched directly from the utility. However, many alternate cases are also expected and supported. The building may have one entity (likely a piece of network equipment since it is always on already) that gets prices from the grid and all others get it from this building-local 'price server'. Both transactions use this mechanism.

The operator of the building may choose to present a higher price to devices in the building to take into account carbon emissions or other pollution from generating electricity. The building may also have local generation and/or storage, whose state and operation may indicate changes in price. For example, a building with an excess of solar power on-site may sell marginal electricity back to the grid at a low price. This would suggest lowering the price until supply and demand in the building were approximately in balance.

Some buildings operate off-grid, either all the time or intermittently. A building is a structure that uses resources and provides services. Common examples are homes, office, retail, and institutional buildings. Other building types include vehicles such as cars, ships, and airplanes. All these building types have electricity systems that would benefit from a price mechanism.

There are other protocols designed to get prices from the grid to a building, particularly to a building control system. One example of these is OpenADR. This mechanism complements rather than replaces these other mechanisms.

Electricity pricing has other aspects that complicate pricing. For example, in many places electricity use over a monthly billing period is sold in blocks, with the price increasing or decreasing with larger blocks depending on what the utility is trying to accomplish with the price. For example, the first five hundred kWh could be $0.10/kWh, the second 500 kWh $0.15, and so on. Thus, the monthly marginal price (what is paid if the consumption goes up or down modestly) is the last block used. This could be substantially different from an average price. There are many options for how utilities could combine blocks with dynamic prices. This specification is not attempting to provide a set of prices that are legally binding. Rather, it is intended to provide a simple and reasonably reliable set of prices that devices can use (when the alternative may be in fact no information at all).

Consider a typical residence with broadband Internet and a residential gateway that gets its IP address via DHCP from the service provider. The service provider would provide the domain of the local power provider via DHCP. The residential gateway would get this and provide it in DHCP requests sent to the residential gateway. The residential gateway would also be able to override this, so if the consumer had arranged power from an alternative power provider, the name of that provider could be configured in the device.

A device on the residential network, such as a dishwasher, could find the energy provider name via DHCP. The dishwasher would then make an HTTP GET request to the well known URI defined in this specification. In other words, it would do an HTTP GET to the /.well_known/ electricity-price.json and would receive back an energyprice+json media type. For example


```
{
"currency" : "USD",
"prices":[
    { "time": "2011-04-12T23:20:00.00Z", "price": "0.028" },
    { "time": "2011-04-12T23:21:00.00Z", "price": "0.025" },
    { "time": "2011-04-12T23:22:00.00Z", "price": "0.021" }
]}
```


The above example shows a case where at 21:00 UTC, the price falls from 2.8 cents per KWh to 2.5 cents per kWh. Using kWh is fixed.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",

"SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

3. Semantics

Each media type carries a single JSON object that represents a set of prices and times. This object contains optional attributes described below and a mandatory array of one or more measurements.

validTill: Time at which this data series will become invalid. UTC time in RFC 3339 format.
currency: Optional. Specify currency in ISO 4217 [REF] currency code.
prices: Array of price objects. Mandatory and there must be at least one object in the array. Objects MUST be ordered in this array by time.

Each price time object contains several attributes, some of which are optional and some of which are mandatory.

time: Time this price becomes effective. UTC time in RFC 3339 format.
price: Price per kWh. The cost of energy changes to this price at the time in this object and remains at this price until the time of the next object in the prices array.

Open Issue: What is the best representation for time?

Open Issue: Is it OK that currency is optional?

Open Issue: How many entries can the array have? It would be nice to have some maximum size.

The price in the last entry in the series is ignored. That is, the purpose of the last entry is to close the time of the last period. While 24 hours will be a typical time horizon, it could be shorter or longer.

Question: Can the request have a start time (zero for the present), so that if there is a limit on array size, one can get the rest?

Open Issue: should we be able to represent both buy and sell prices?

4. Well Known URL

A client that implements this specification uses the path "//.well-known/electricity-price.json" for the resource name unless the client has been configured with an alternative path.

5. DHCP

Open Issues: Is DHCP the best approach to discovery or would something else be better?

6. IANA Considerations

Note to RFC Editor: Please replace all occurrences of "RFC-AAAA" with the RFC number of this specification.

6.1. Well-Known URI Registration

IANA will make the following "Well Known URI" registration as described in RFC 5785:

URI suffix:	electricity-price.json
Change controller:	IETF <iesg@ietf.org>
Specification document(s):	[RFC-AAAA]
Related information:	None

6.2. DHCP Options

TBD

6.3. Media Type Registration

The following registrations are done following the procedure specified in [RFC4288] and [RFC3023].

Note to RFC Editor: Please replace all occurrences of "RFC-AAAA" with the RFC number of this specification.

6.3.1. energyprice+json Media Type Registration

TBD

7. Mapping to OpenADR

Lawrence Berkeley National Laboratory led the development of OpenADR initially (OpenADR v1.0), and it is now being formalized as an open standard through OASIS and national Smart Grid activity (OpenADR v2.0). At present, there are two relevant OASIS technical committees (TCs) that are relevant to the dynamic pricing (includes real-time prices) discussion: the Energy Interoperation TC (EI) and the Energy Market Information Exchange TC (EMIX). Each committee has a draft standard of the same name as the technical committee.

The OpenADR v2.0 standard will become a subset of what EI produces. EMIX is charged with defining a standard abstract form of price signaling. The details of how to represent a price product is defined in EMIX[EMIX] (then EI[EI] would reference and build implementation models, for e.g., XML schemas).

Both committees cover much more than just price (and price forecast) information. The discussion below focuses only on features relevant to this IETF specification. The OpenADR model uses XML as the data description language. OpenADR v1.0 and v2.0 can specify prices in different terms - absolute, multiple, or in relative terms to a base price (either additive or multiplicative).

Pricing can be a very complicated topic, but for the discussion here, we limit it to what this specification does- a schedule of time periods and a price for each period.

To represent time, EI and EMIX use WS-Calendar (also an OASIS standard), which provides for complex scheduling; simple price sequences use only a small part of this. Sequences are represented as a start time and a sequence of interval durations. As WS-Calendar builds on iCalendar (see RFC 5545) it uses the same date/time format as this draft.

A related issue is how to specify the current time to assure that the price source and user of the price have consistent time (or know how to adjust the schedule for a difference in time). This discussion does not consider this topic. So long as prices do not vary significantly from one time period to the next, and the time differences are not large, this issue is not of great concern.

EMIX can encode prices in several ways, including relative prices. For absolute prices, the price is simply a numeric value in cents/kWh for the U.S. Other additional attributes relevant to price representations are under consideration (e.g., currency). The following is a sample excerpt of an OpenADR v1.0 price schedule:

```
<p:drEventData>
  <p:notificationTime>2009-06-02T17:15:00.0</p:notificationTime>
  <p:startTime>2009-06-03T00:00:00.0</p:startTime>
  <p:endTime>2009-06-03T23:59:00.0</p:endTime>
  <p:eventInfoInstances>
     <p:eventInfoTypeID>PRICE_ABSOLUTE</p:eventInfoTypeID>
     <p:eventInfoName>Price</p:eventInfoName>
     <p:eventInfoValues>
        <p:value>0.0</p:value>
        <p:timeOffset>0</p:timeOffset>
     </p:eventInfoValues>
     <p:eventInfoValues>
        <p:value>0.0</p:value>
        <p:timeOffset>3600</p:timeOffset>
     </p:eventInfoValues>
     ...
     <p:eventInfoValues>
        <p:value>0.0</p:value>
        <p:timeOffset>82800</p:timeOffset>
     </p:eventInfoValues>
  </p:eventInfoInstances>
</p:drEventData>
```

TBD - define a simple mapping to and from OpenADR.

8. Security Considerations

TBD

Further discussion of security proprieties for media types can be found in Section 6.3.

9. Privacy Considerations

TBD

10. Acknowledgement

We would like to thank Girish Ghatikar at LBNL for information and text about OpenADR. Thanks for helpful comments from many people including Scott Brim, <get your name here>.

11. References

11.1. Normative References

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[RFC3023] Murata, M., St. Laurent, S., and D. Kohn, "XML Media Types", RFC 3023, January 2001.

[RFC4288] Freed, N. and J. Klensin, "Media Type Specifications and Registration Procedures", BCP 13, RFC 4288, December 2005.

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

11.2. Informative References

[EMIX] OASIS, "Energy Market Information Exchange (EMIX) Version 1.0, Committee Specification Draft 02 / Public Review Draft", April 2011, <http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emix>.

[EI] OASIS, "Energy Interoperation Version 1.0, Committee Specification Draft 01", November 2010, <http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=energyinterop>.

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Energy Management Framework
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Status of this Memo

Copyright Notice

Abstract

This document contains definitions and terms used in the Energy Management Working Group. Each term contains a definition(s), example, and reference to a normative, informative or well know source. Terms originating in this draft must be either composed of or derived from other terms in the draft with a source. The defined terms will then be used in other drafts as defined here.

Table of Contents

TODO:

- Compile all references

- Add examples where needed

- Review all drafts and collect any dangling terms and include here

1. Introduction

Within Energy Management there are terms that may seem obvious to a casual reader but in fact require a rigorous and sourced definition. To avoid any confusion in terms among the working group drafts, one glossary / lexicon of terms should exist that all drafts can refer to. This will allow avoid a review of terms multiplied across drafts.
This draft will contain a glossary of definitions of terms that can be agreed upon by the working group outside of the context of the drafts and then included in or sourced to this draft. Each term will contain a definition(s), an example and a normative or informative reference. All terms should be rooted with a well-known reference.
If a definition is take verbatim from a reference then the source is listed in square brackets. If a definition is derived from a well-known reference then the source is listed as "derived from" with the reference listed in square brackets. If a defined term is newly defined here the reference will indicated the composing terms from this document.

2. Terminology

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

3. Definitions

Energy Management System (EnMS)

An EnMS is a set of systems or procedures upon which organizations can develop and implement an energy policy, set targets, action plans and take into account legal requirements related to energy use. An EnMS allows organizations to improve energy performance and demonstrate conformity to requirements, standards and/or legal requirements.
Example:
A set of workflow procedures setup by an organization to track and archive utility billing records to ensure an auditable history of targets.
Reference:
[ISO50001]

Energy Management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization. In that light, Energy Management is a system congruent to any of FCAPS area of management in the ISO/OSI Network Management Model [TMN] Energy Management for communication networks and attached devices is a subset or part of an organization’s greater EnMS.
Example:
A set of computer systems that will poll electrical meters and store the readings
Reference:
Derived from [ITU-T-M-3400]

Energy Management Systems

An Energy Management System (EMS) is congruent to a Network Management System (NMS) and is a combination of hardware and software used to administer a network with the primarily purpose being Energy Management.
Example:
Reference:
Derived from [1037C]

Energy Monitoring

Energy Monitoring is a part of Energy Management that deals with collecting or reading measurements from devices to aid in Energy Management. This could include Energy, Power, Demand, Quality, Context and/or Battery information.
Example:
Reference:

Energy

Energy is the capacity of a system to produce external activity or perform work and can be electricity, fuels, steam, heat,

compressed air, and other like media. Energy is typically expressed in watt hours or joules.
Example:
Reference:
[ISO50001]

Power

Power is a rate of energy conversion. As the unit of time approaches zero a power measurement is called an instantaneous power reading. Typically when implementing Power monitoring in hardware, a measuring device may have to compute an average value per some unit of time to express a reading to approximate an instantaneous power measurement.
Example:
Reference:
Derived from [ISO50001]

Demand

Demand is an average of Power measurements over an interval(s) of time and typically expressed in kilowatt hours. This measurement is significant because some utilities or energy providers bill by Demand measurements as well as for maximum Demand per billing periods. Power values may spike during short-terms by devices, but Demand measurements recognize that maximum Demand does not equal maximum Power during an interval.
Example:
Reference:

Power Quality

Power Quality is defined as a set of values to describe the electrical characteristics of Power as provided by an electrical source as seen by the Energy Managed Object. For example: AC phase, apparent and reactive power, etc.
Example:
Reference:

Energy Control

Energy Control is a part of Energy Management that deals with modifying or setting the state of an Energy Managed Object in order to optimize or ensure its efficiency.

Example:
Reference:

Energy Managed Object

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

Example:
Reference:

Energy Aware Object

An Energy Managed Object may not have the capability to provide information necessary for Energy Management itself. If an Energy Managed Object can provide Energy Management Context, Energy Monitor and optionally Energy Control values for itself then the Energy Managed Object is said to be an Energy Aware Object

Example:
For example: as the most simplistic example, a set of light bulbs where all values are provided by an EMS through estimation and or catalogue information are not Energy Aware. In contrast a set of network switches that can report the same information based upon hardware sensing is said to be Energy Aware.

Reference:

Energy Managed Object Identification

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

Energy Managed Object Context

Energy Managed Object Context is a set of attributes that allow an Energy Management system to classify the use of the Energy Managed Object within an organization. The classification contains use and/or ranking of the Energy Managed Object as compared to other Energy Managed Objects in the Energy Management Domain.
Example:
Reference:

Energy Management Domain

An Energy Management Domain is a name or name space that logically groups Energy Managed Objects into a zone of Energy Management. Typically, this zone will have as members all Energy Managed Objects that are powered from the same electrical panel(s) for which there is a meter or sub meter.

Example: All Energy Managed Objects drawing power from the same distribution panel with the same AC voltage within a building, or all Energy Managed Objects in a building for which there is one main meter, would comprise an Energy Management Domain.

Reference:

Energy Managed Object Relationships

Energy Managed Objects may have functional relationships to each other within an Energy Management Domain. The functional relationships include Aggregation, Metering, Power Source(s), Proxy, and Dependency. One device will provide a capability or functional value in the relationship and another will be the receiver of the capability. These capabilities include Aggregation, Metering, Power Source, Proxy and Dependency.

Example:
Reference:

Aggregation Relationship

An Energy Managed Object may aggregate the Energy Management information of one or more Energy Managed Objects and is

referred to as an Aggregation Relationship. An Energy Managed Object may be aggregated by another Energy Managed Object(s). Aggregate values are obtained by reading values from multiple Energy Managed Objects and producing a single value of more significant meaning such as average, count, maximum, median, minimum, mode and most commonly sum.
Example:
Reference: [SQL]

Metering Relationship

An Energy Managed Object may measure the Energy of another Energy Managed Object(s) and is referred to as a Metering Relationship. An Energy Managed Object may be metered by another Energy Managed Object(s). Example: a PoE port on a switch measure the Power it provides to the connected Energy Managed Object.

Example:
Reference:

Power Source Relationship

An Energy Managed Object may be the source of or distributor of power to another Energy Managed Object(s) and is referred to as a Power Source Relationship. An Energy Managed Object may be powered by another Energy Managed Object(s).

Example: a PDU provides power for a connected host.

Reference:

Proxy Relationship

An Energy Managed Object that provides Energy Management capabilities on behalf of another Energy Managed Object so that is appears to be Energy Aware is referred to a Proxy Relationship. An Energy Managed Object may be proxied by another Energy Managed Object(s). Example: a protocol gateways device for Building Management Systems (BMS) with subtended devices.

Example:
Reference:

Dependency Relationship

An Energy Managed Object may be a component of or rely completely upon another Energy Managed Object to operate and is referred to as a Dependency Relationship. An Energy Managed Object may be dependent on another Energy Managed Object(s).
Example: A Switch chassis with multiple line cards
Reference:

Energy Managed Object Parent

An Energy Managed Object Parent is an Energy Managed Object that provides one or more of the Energy Managed Object Relationships capabilities.
Energy Managed Object Child
An Energy Managed Object Child is an Energy Managed Object that has at least one Energy Managed Object Relationship capability provided by another Energy Managed Object.

Example:
Reference:

Power State

A Power State is a way to classify a Power setting on an Energy Managed Object (e.g., on, off, or sleep). A Power State can be viewed as a method for Energy Control

Example:
Reference:

Manufacturer Power State

A Manufacturer Power State is a device-specific way to classify a Power setting implemented on an Energy Managed Object.
Power State Set
A collection of Power States that comprise one named or logical grouping of control is a Power State Set. For example, the states {on, off, and sleep} as defined in [IEEE1621], or the 16 power states as defined by the [DMTF] can be considered two different Power State Sets.

Example:
Reference:

Nameplate Power

The Nameplate Power is the maximal (nominal) Power that a device can support. This is typically determined via load testing and is specified by the manufacturer as the maximum value required to operate the device. This is sometimes referred to as the worst-case Power. The actual or average Power may be lower. The Nameplate Power is typically used for provisioning and capacity planning.

Example:
Reference:

4. Security Considerations

None

5. IANA Considerations

None

6. Acknowledgments

The author would like to thank the authors of the current working group drafts for the discussions and definition clarifications

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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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Intended status: Informational B. Schoening
Expires: December 24,2011 Noveda Technologies, Inc.
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Cisco Systems Inc.
June 24, 2011

Energy Management (EMAN) Applicability Statement
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Status of this Memo

Copyright Notice

Abstract

The objective of Energy Management (EMAN) is to provide an energy management framework for networked devices. In this document the applicability of the EMAN framework for a variety of network scenarios is described. This document lists a number of use-cases that can implement the EMAN framework and the associated MIB modules. Furthermore, we describe the relationship of the EMAN framework to other energy monitoring standards and architectures.

Table of Contents

1. Introduction

The focus of Energy Management (EMAN) framework is on energy monitoring and management of energy aware devices. The scope of devices considered for energy management are network entities and devices connected to the network. As a fundamental objective, Energy Management framework enables devices to be energy aware; i.e. to report their power usage (directly or indirectly) and secondly to optimize their energy usage. EMAN framework enables heterogeneous devices to report their energy consumption, and if permissible, enable configuration of policies for power savings. 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.

The EMAN framework describes how energy information can be retrieved, controlled and monitored from IP-enabled energy aware devices using Simple Network Management Protocol (SNMP). In essence, the Energy Management framework defines Management Information Base (MIBs) for SNMP.

In this document, typical applications of the EMAN framework are described; as well as opportunities and limitations of the framework. Furthermore, other standards that are similar to EMAN but address different domains are described. In addition, this document serves as an introductory reference for an overall understanding of Energy efficiency of networks and this document contains the references to other Energy standards.

1.1. Energy Management Overview

Firstly, a brief introduction to the definitions of Energy and Power are presented.

Energy is defined as the capacity to perform a particular work. The particular form of energy of interest is electrical energy consumption by energy aware devices. Electrical energy is typically expressed in kilowatt-hour units (noted kWh). One kilowatt-hour is defined as the electrical energy used by a 1 Kilowatt appliance for one hour. Power is defined as the rate of electrical energy consumed by the device. In other words, power = energy / time. Power is often measured in Watts. Billing is based on electrical energy (measured in Watt-hours) supplied by the utility.

Towards the goal of attaining energy efficiency in networks, a first step is to enable devices to report the energy usage over time. Energy Management framework addresses this problem. An information model on how to model the device: its identity, the device context, the power measurement and measurement attributes are captured in an information model.

SNMP based MIB module is proposed based on the information model. Any network device that has implementation of the MIB module, can report its energy consumption. In that context, from an energy-monitoring point of view, it is important to distinguish the device types; i.e.; devices that can report its energy usage and the other type of devices who collect and aggregate energy usage of a group of subtended devices.

The scope of devices considered for Energy Management is listed in the Use case section with detailed examples.

1.2. Energy Measurement

More and more devices today are able to measure and report their own energy consumption. Smart power strips and some of the 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 a 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, across various equipment, in a unified and consistent manner is one pillar of the EMAN framework.

Given that a device can consume energy and possibly provide energy to other devices, it is possible to consider three types of meters for energy measurement; i.e., meter for energy consumed, meter for energy supplied to other devices, and a net (resultant) meter which is the sum of consumed and provided.

1.3. Energy Management

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 the phones, because some phones may 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.

Beyond monitoring, the EMAN framework shall be generalized to consider the mechanisms for control of devices for power savings.

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. EMAN framework Application

In this section, the typical application of EMAN framework is described. A network operator can install management software for collecting energy information for devices in the network. The scope of the devices considered for energy management is listed in Section 2.

A Network Management System (NMS) is the entity that requests information from compatible devices using SNMP. It may be a system which also implements other network management functions, e.g. security management, identity management and so on), or one that only deals with energy in which case it is called EMS (Energy

Management System). It may be limited to monitoring energy use, or it may also implement control functions.

Energy Management can be implemented by extending existing SNMP support to the EMAN specific MIBs to deal with energy reporting.

By using SNMP, we have an industry proven and well-known technique to discover, secure, measure and control SNMP enabled end devices. EMAN framework provides an information and data model to unify access to a large range of devices.

1.5. EMAN WG Documents Overview

The EMAN working group at IETF and its charter is focused on a series of Internet standard drafts in the area of Energy management of networks. The following drafts are currently under discussion in the working group.

Requirements draft [EMAN-REQ] This draft presents the requirements of Energy Monitoring and the scope of the devices considered.

Applicability Statement draft [EMAN-AS] This draft presents the use cases and scenarios for energy monitoring. In addition, other relevant energy standards and architectures are listed.

Framework draft [EMAN-FRAMEWORK] This draft defines the terminology and explains the different concepts associated with energy monitoring. These concepts are used in the MIB modules.

Energy-Aware MIB draft [EMAN-AWARE-MIB] This draft proposes a MIB module that characterizes the identity of the device and the devices context.

Monitoring MIB draft [EMAN-MONITORING-MIB] This draft contains a MIB module for monitoring the power and energy consumption of the device. In addition, the MIB module contains an optional module for the power quality metrics.

Battery MIB draft [EMAN-BATTERY-MIB] This draft contains a MIB module for monitoring the energy consumption of a battery device.

2. Scenarios and Target devices

In this section a selection of scenarios for energy management is presented. For each scenario, a list of target devices is given in the section heading, for which the energy management framework is required and thus can be applied.

2.1. Network devices-Routers, switches

This scenario covers network devices and its components. Power management of network devices is considered as a fundamental requirement (basic first step) of Energy Management of networks. The objective of this example scenario is to illustrate monitoring of network devices and the granularity of monitoring.

From an energy management perspective, it is important to monitor the power state and energy consumption of devices at a granularity level that is finer than just the device level. For these network devices, the chassis draws power from an outlet and feeds all its internal sub-components. It is highly desirable to have monitoring available for individual components, such as line cards, processors, hard drives but also peripherals like USB devices or display monitor.

As an illustrative example of network device scenario, consider a switch with the following list of grouping of sub-entities of the switch for which monitoring the energy monitoring could be useful.

- physical view: chassis (or stack), line cards, service modules of the switch
- component view: CPU, ASICs, fans, power supply, ports (single port and port groups), storage and memory
- logical view: system, data-plane, control-plane, etc.

2.2. Devices attached to a network, PoE powered devices

This scenario covers devices using Power over Ethernet (PoE). Such a connection provides both network connectivity as well as power over a single connection. Down the PoE ports can be IP Phones, Wireless Access Points, IP Camera devices.

The switch uses its own power supply to power itself us, as well as all the downstream PoE ports. Monitoring the power consumption of the switch and the power consumption of the PoE endpoints is a simple use case of this scenario.

A PoE Power Sourcing Equipment (PSE), a PoE switch, provides power to a Powered Device (PD), 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. Power probes and Smart Meters-PDUs

This use case describes the scenario of devices that can not measure their own power consumption. In this case, another piece of equipment can be used and measure the device power consumption. Examples are smart meter and smart PDUs.

Some devices are not equipped with sufficient instrumentation to measure their own actual power and accumulated energy consumption. External probes can be connected to the power supply to measure these properties for a single device or for a set of devices.

Power Distribution Unit (PDUs) attached to racks in a data center and other smart power strips are evolving in parallel with smart meters. Each socket of the PDU distributes power to a device in the rack. The smart meters at the PDUs report the power consumption of the device connected to the socket at PDU. Power consumption can be measured at socket level and the switch provides the network connectivity and can be the aggregator of power consumption for all entities. These PDUs have remote management functionality which can also be used to control power supply of each socket of the PDU. Homes, buildings, have smart meters that monitor and report accumulated power consumption of an entire home, a set of offices.

2.4. Mid-level managers

This use case describes the scenario of devices that receive power supply from one source. The reporting of power measurement and possibly control can be performed by some other entity.

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 powered by the switch, but have their own power supply as, for example, laptops..

In a daisy-chain scenario, a switch port can have both a PoE connection powering the IP Phone, and a PC connected to the IP Phone for network connectivity. The PC draw power from the wall outlet, the phone draws power from the switch.

However, it would be possible to monitor the power consumption of even those non-PoE devices. The devices report their power consumption to the switch and the switch is the aggregator for the power consumption of those non-PoE devices.

Thus, the switch is the mid-level manager, offering reporting and aggregation of power consumption even for devices it does not supply power, devices connected to it and supplies power, and itself.

Yet another similar use case is when laptop computers connected to the wireless access points. The wireless access points are connected to the PoE ports of the switch. The switch, acting as a mid-level manager, can aggregate the power consumption of those non-PoE devices.

2.5. Gateways to building networks

This use case describes the scenario of energy management of buildings. In these networks, there is a gateway interfacing to building network protocols.

Building Management Systems (BMS) are often in place for many years and most of them are not based on IP. For the purpose of uniform management interface through EMAN, it is possible to have a gateway interfacing between the EMAN framework and building management network protocols.

Due to the potential energy savings, energy management of buildings has received significant attention. There are gateway network elements to manage the multiple components of a building energy management network such as Heating Ventilating Air Conditioning (HVAC), lighting, electrical, fire and emergency systems, elevators etc. The gateway device communicates building network protocols with those devices and collects their energy usage and reports the measurement to the network management systems.

This is an example of a proxy with possibly different protocols for the network domain and building infrastructure domain. 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.

2.6. Home energy gateways

This use case describes the scenario of energy management of a home. The home gateway scenario is an example of a proxy with interfaces to electrical appliances and devices and the electrical grid.

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/response and energy pricing from the grid.

2.7. Data center devices

This use case describes the scenario of energy management of a Data Center.

Energy efficiency of data centers has become a fundamental challenge of data center operation. The motivation is due to the fact that datacenters are big energy consumers. The equipment generates heat, and heat needs to be evacuated though a HVAC (Heating, Ventilating, and Air Conditioning) system.

Energy management can be implemented on different aggregation levels, such as network level, Power Distribution Unit (PDU) level, and server level.

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.

Power consumption of all network elements and the servers in the Data center should be measured. The switch can be the aggregator for the power consumption of the data center.

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.

The battery scenario useful for providing backup power for a finite duration for a single device can be generalized to energy storage devices that can provide backup power for many devices contained in data centers. Energy monitoring of such energy storage devices is vital from a data center network operations point of view.

A server with an internal battery is shown. When the connection to the PDU is disconnected, the Server runs on the internal battery. It is important to monitor the power consumption of the battery.

2.8. Ganged outlets on a PDU Multiple power sources

This use case describes the scenario of multiple power sources of a devices and logical groupings

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

  - o Gang A -> Outlets 1, 2 and 3
  - o 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.

3. Use case patterns

The list of use cases presented can be abstracted in to one of the following broad patterns.

3.1. Internal or External Metering

- . Entities that consume power can perform internal power metering on its own

- . Entities that consume power but have an external power meter

3.2. Power supply and Metering and/or Control

- . Entities that supply power for other devices however does not perform power metering for devices

- . Entities that supply power for other devices and also perform power metering function

- Entities supply power for other devices and also perform power metering and control for other devices

3.3. Metering and/or Control

- Entities that do not supply power but perform only metering function for other designated devices
- Entities which do not supply power but perform both metering and control for other designated devices

3.4. Multiple Power Sources

- Entities that have multiple power sources and metering and control is performed by one source
- Entities that have multiple power sources and metering and is performed by one source and control another source

4. Relationship of EMAN to other Energy Standards

EMAN as a framework is tied with other standards and efforts in the energy arena. Existing standards are leveraged as much as possible, as well as providing control to adjacent technologies such as Smart Grid.

Most of them are listed below with a brief description of their objectives and the current state.

4.1. IEC

The International Electro technical 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.

Concepts from IEC Standards have been reused in the EMAN WG drafts. In particular, AC Power Quality measurements have been reused from IEC 61850-7-4. The concept of Accuracy Classes for measurement of power and energy has been reused IEC 62053-21 and IEC 62053-22.

4.2. 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 62053-22.

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 EMAN standard should be compatible with existing ANSI C12 and IEC standards.

4.3. DMTF

The DMTF [DMTF] has standardized management solutions for managing servers and desktops, including 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 EMAN standard should reuse the concepts of Power Profile from DMTF and has advocated that as one of the possible Power State Series.

4.3.1. 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.

4.3.2. DASH

DMTF DASH (DSP0232) (Desktop And Mobile Architecture for System Hardware) 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.

4.4. ODVA

ODVA is an association consisting of members from industrial automation companies. ODVA supports standardization of network technologies based on the Common Industrial Protocol (CIP). Within ODVA, there is a special interest group focused on energy and standardization and inter-operability of energy Aware devices.

While there are many similar concepts between the ODVA and EMAN framework, in particular, the concept of different energy meters based on the device properties has been reused.

4.5. Ecma SDC

The Ecma International committee on Smart Data Centre (TC38-TG2 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 monitoring and control. It only defines messages and properties, and does not reference any specific protocol. Its goal is to enable interoperability of such protocols as SNMP, BACNET, and HTTP by ensuring a common semantic model across them. Four power states are defined, Off, Sleep, Idle and Active. The standard does not include actual power measurements in kw or kwh.

The 14th draft of SDC process was published in March 2001 and the development of the standard is still underway. When used with EMAN, the SDC standard will provide a thin abstraction on top of the more detailed data model available in EMAN.

4.6. ISO

The ISO [ISO] is developing an energy management standard called ISO 50001, and complements ISO 9001 for quality management, and ISO 14001 for environment management. 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 does not 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 includes:

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

ISO 50001 has been developed by ISO project committee ISO/PC 242, Energy management.

4.7. EnergyStar

The US Environmental Protection Agency (EPA) and US Department of Energy (DOE) jointly sponsor the Energy Star program [ESTAR]. 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.

There is no immediate link between EMAN and EnergyStar, one being a protocol and the other a set of recommendations to develop energy efficient products.

4.8. 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).

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.

There is an obvious functional link between SmartGrid and EMAN in the form of demand/response, even if the EMAN framework does not take any specific step toward SmartGrid communication.

4.9. 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 [NAESB].
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."

4.10. ZigBee

The Zigbee Smart Energy 2.0 effort[ZIGBEE] 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.

The EMAN framework addresses the needs of IP-enabled networks through the usage of SNMP, while Zigbee looks for completely integrated and inexpensive mesh solution.

5. Limitations

EMAN Framework shall address the needs of energy monitoring in term of measurement and, to a lesser extent, on the control aspects of energy monitoring of networks.

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

Other legacy protocols may already exist (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, and distributors even if there is obvious link between them.

6. Security Considerations

EMAN shall use SNMP protocol for energy monitoring and thus has the functionality of SNMP’s security capabilities. More specifically, SNMPv3 [RFC3411] provides important security features such as confidentiality, integrity, and authentication.

7. IANA Considerations

This memo includes no request to IANA.

8. References

8.1. Normative References

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