Network Working Group
Internet-Draft
Intended Status: Standards Track
Expires: April 31 2012

M. Chandramouli
Cisco Systems, Inc.
B. Schoening
Independent Consultant
J. Quittek
T. Dietz
NEC Europe Ltd.
B. Claise
Cisco Systems, Inc.
October 31, 2011

Power and Energy Monitoring MIB
draft-ietf-eman-energy-monitoring-mib-01

Status of this Memo

Copyright Notice

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].

Table of Contents

1. Introduction

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

Energy management is applicable to devices in communication networks. Target devices for this specification include (but are not limited to): routers, switches, Power over Ethernet (PoE) endpoints, protocol gateways for building management

systems, intelligent meters, home energy gateways, hosts and servers, sensor proxies, etc. Target devices and the use cases for Energy Management are discussed in Energy Management Applicability Statement [EMAN-AS].

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

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

2. The Internet-Standard Management Framework

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

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

3. Use Cases

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

use cases for Energy Management have been identified in the "Energy Management (EMAN) Applicability Statement" [EMAN-AS]. An illustrative example scenario is presented in Section 8.

4. Terminology

The definitions of basic terms such as Energy Object, Energy Object Parent, Energy Object Child, Energy Object Meter Domain, Power State can be found in the terminology draft draft-parello-eman-definitions.

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.

EDITOR NOTE: Use the latest definition from draft-parello-eman-definitions

Power State

A Power State is defined as a specific power setting for an Energy Object (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 NOTE: Use the latest definition from draft-parello-eman-definitions

5. Architecture Concepts Applied to the MIB Module

This section describes the concepts specified in the Energy Management Framework [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 energyObjectMib is focused on measurement of power and energy. The second MIB module powerQualityMIB is focused on Power Quality measurements.

The energyObjectMib MIB module consists of four tables. The first table eoPowerTable is indexed by eoPowerIndex. The second table eoPowerStateTable indexed by eoPowerIndex,and eoPowerStateIndex. . The eoEnergyParametersTable and eoEnergyTable are indexed by eoPowerIndex.

```
 eoPowerTable(1)
  |
  +---eoPowerEntry(1) [eoPowerIndex]
  |   |
  |   +-- --- Integer32         eoPowerIndex(1)
  |   +---r-n Integer32         eoPower(2)
  |   +-- r-n Integer32         eoPowerNamePlate(3)
  |   +-- r-n UnitMultiplier    eoPowerUnitMultiplier(4)
  |   +-- r-n Integer32         eoPowerAccuracy(5)
  |   +-- r-n INTEGER           eoMeasurementCaliber(6)
  |   +-- r-n INTEGER           eoPowerCurrentType(7)
  |   +-- r-n INTEGER           eoPowerOrigin(8)
  |   +-- rwn Integer32         eoPowerAdminState(9)
  |   +-- r-n Integer32         eoPowerOperState(10)
  |   +-- r-n OwnerString       eoPowerStateEnterReason(11)
  |   |
  |   |
  +---eoPowerStateTable(2)
  |      +--eoPowerStateEntry(1)
  |      |      [eoPowerIndex,
  |      |       eoPowerStateIndex]
  |      |
  |      +-- --- IANAPowerStateSet  eoPowerStateIndex(1)
  |      +-- r-n Intenger32         eoPowerStateMaxPower (2)
  |      +-- r-n UnitMultiplier
  |                  eoPowerStatePowerUnitMultiplier (3)
  |      +-- r-n TimeTicks          eoPowerStateTotalTime(4)
  |      +-- r-n Counter64          eoPowerStateEnterCount(5)
  |

  +eoEnergyParametersTable(1)
  +---eoEnergyParametersEntry(1) [eoPowerIndex]
  |
  |   +-- r-n TimeInterval
  |               eoEnergyParametersIntervalLength (1)
  |   +-- r-n Integer32
  |               eoEnergyParametersIntervalNumber (2)
```

```
     |   +-- r-n Integer32
     |               eoEnergyParametersIntervalMode (3)
     |   +-- r-n TimeInterval
     |               eoEnergyParametersIntervalWindow (4)
     |   +-- r-n Integer32
     |               eoEnergyParametersSampleRate (5)
     |   +-- r-n RowStatus  eoEnergyParametersStatus (6)
     |
     +eoEnergyTable(1)
     +---eoEnergyEntry(1) [eoPowerIndex]
     |
     |   +-- r-n TimeInterval  eoEnergyIntervalStartTime (1)
     |   +-- r-n Integer32     eoEnergyIntervalEnergyConsumed (2)
     |   +-- r-n Integer32     eoEnergyIntervalEnergyProduced (3)
     |   +-- r-n Integer32     eoEnergyIntervalEnergyNet (4)
     |   +-- r-n UnitMultiplier
     |                eoEnergyIntervalEnergyUnitMultiplier (5)
     |   +-- r-n Integer32     eoEnergyIntervalEnergyAccuracy(6)
     |   +-- r-n Integer32     eoEnergyIntervalMaxConsumed (7)
     |   +-- r-n Integer32     eoEnergyIntervalMaxProduced (8)
     |   +-- r-n TimeTicks
     |                   eoEnergyIntervalDiscontinuityTime(9)
     |   +-- r-n RowStatus     eoEnergyParametersStatus (10)
```

The powerQualityMIB consists of four tables. eoACPwrQualityTable is indexed by eoPowerIndex. eoACPwrQualityPhaseTable is indexed by eoPowerIndex and eoPhaseIndex. eoACPwrQualityWyePhaseTable and eoACPwrQualityDelPhaseTable are indexed by eoPowerIndex and eoPhaseIndex.

```
   eoPowerTable(1)
     |
     +---eoACPwrQualityEntry (1) [eoPowerIndex]
     |   |
     |   |
     |   +----- INTEGER      eoACPwrQualityConfiguration (1)
     |   +-- r-n Interger32  eoACPwrQualityAvgVoltage (2)
     |   +-- r-n Integer32   eoACPwrQualityAvgCurrent (3)
     |   +-- r-n Integer32   eoACPwrQualityFrequency  (4)
     |   +-- r-n UnitMultiplier
     |             eoACPwrQualityPowerUnitMultiplier (5)
     |   +-- r-n Integer32   eoACPwrQualityPowerAccuracy (6)
     |   +-- r-n Interger32  eoACPwrQualityTotalActivePower (7)
     |   +-- r-n Integer32
     |            eoACPwrQualityTotalReactivePower (8)
     |   +-- r-n Integer32   eoACPwrQualityTotalApparentPower (9)
     |   +-- r-n Integer32   eoACPwrQualityTotalPowerFactor(10)
```

```
     |   +-- r-n Integer32   eoACPwrQualityThdAmpheres (11)
     |
     +eoACPwrQualityPhaseTable (1)
     +---EoACPwrQualityPhaseEntry(1)[eoPowerIndex,
     |     |                          eoPhaseIndex]
     |     |
     |     +-- r-n Integer32  eoPhaseIndex  (1)
     |     +-- r-n Integer32
     |     |          eoACPwrQualityPhaseAvgCurrent (2)
     |     +-- r-n Integer32
     |     |          eoACPwrQualityPhaseActivePower (3)
     |     +-- r-n Integer32
     |     |          eoACPwrQualityPhaseReactivePower (4)
     |     +-- r-n Integer32
     |     |          eoACPwrQualityPhaseApparentPower (5)
     |     +-- r-n Integer32
     |     |          eoACPwrQualityPhasePowerFactor (6)
     |     +-- r-n Integer32
     |     |          eoACPwrQualityPhaseImpedance (7)
     |     |
     +eoACPwrQualityDelPhaseTable (1)
     +-- eoACPwrQualityDelPhaseEntry(1)
     |     |                            [eoPowerIndex,
     |     |                             eoPhaseIndex]
     |     +-- r-n Integer32
     |     |    eoACPwrQualityDelPhaseToNextPhaseVoltage (1)
     |     +-- r-n Integer32
     |     |    eoACPwrQualityDelThdPhaseToNextPhaseVoltage (2)
     |     +-- r-n Integer32  eoACPwrQualityDelThdCurrent (3)
     |     |
     +eoACPwrQualityWyePhaseTable (1)
     +-- eoACPwrQualityWyePhaseEntry (1)
     |     |                              [eoPowerIndex,
     |     |                               eoPhaseIndex]
     |     +-- r-n Integer32
     |     |    eoACPwrQualityWyePhaseToNeutralVoltage (1)
     |     +-- r-n Integer32
     |     |     eoACPwrQualityWyePhaseCurrent (2)
     |     +-- r-n Integer32
     |     |    eoACPwrQualityWyeThdPhaseToNeutralVoltage (3)
     |     .
```

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

```
   +--------------------------+
   |    Energy Object ID      |
   |                          |
   |  Energy-aware-MIB  (*)   |
   |                          | +---------------------------+
   |                          | |                           |
   | eoPowerIndex             | |_ EnergyObject Attributes  |
   |                          | |                           |
   +--------------------------+ | eoPowerNamePlate          |
             |                | | eoPowerMeasurementCaliber |
             |                | | eoPowerOrigin             |
             |                | | eoPowerCurrentType        |
             |                | +---------------------------+
             |                |       |
             |                |       |
             v                |       v
   +-----------------------------------------+
   |  EnergyObjec Measurement                |
   |                                         |
   | eoPower                                 |
   | eoPowerUnitMultiplier                   |
   | eoPowerAccuracy                         |
   +-----------------------------------------+
             ^                 |      ^
             |                 |      |
   +-------------------------+ |      |
   |    EnergyObject State   | |  +------------------------+
   |                         | |  | EnergyObject   State   |
   | eoPowerAdminState       | |  |    Statistics          |
   | eoPowerOperState        | |  |                        |
   | eoPowerStateEnterReason | |  | eoPowerStateMaxPower   |
   +-------------------------+ |  | eoPowerStateTotalTime  |
                               |  | eoPowerStateEnterCount |
                               |  +------------------------+
                               |
                               |
                               |
                               |
```

Figure 1:UML diagram for powerMonitor MIB

(*)   Link with the ENERGY-AWARE-MIB

```
                          |
                          |
                          |
                          V
  +-----------------------------------------+
  |    Energy Table                         |
  |                                         |
  |  eoEnergyIntervalStartTime              |
  |  eoEnergyIntervalEnergyConsumed         |
  |  eoEnergyIntervalEnergyProduced         |
  |  eoEnergyIntervalEnergyNet              |
  |  eoEnergyIntervalEnergyUnitMultiplier   |
  |  eoEnergyIntervalEnergyAccuracy         |
  |  eoEnergyIntervalMaxConsumed            |
  |  eoEnergyIntervalMaxProduced            |
  |  eoEnergyIntervalDiscontinuityTime      |
  +-----------------------------------------+



   +---------------------------+
   |    EnergyObject ID        |
   |                           |
   |  Energy-aware-MIB  (*)    |
   |                           |
   | eoPowerIndex              |
   |                           |
   +---------------------------+
                  |
                  v
      +--------------------------------------+
      |  Power Quality                       |
      |                                      |
      | eoACPwrQualityConfiguration          |
      | eoACPwrQualityAvgVoltage             |
      | eoACPwrQualityAvgCurrent
      | eoACPwrQualityFrequency              |
      | eoACPwrQualityPowerUnitMultiplier    |
      | eoACPwrQualityPowerAccuracy          |
      | eoACPwrQualityTotalActivePower       |
      | eoACPwrQualityTotalReactivePower     |
```

```
              | eoACPwrQualityTotalApparentPower    |
              | eoACPwrQualityTotalPowerFactor      |
              | eoACPwrQualityThdAmpheres           |
              +-------------------------------------+ ^
                               ^                   ^  |
                               |                   |  -------
                               |                   ----     |
                               |                       |    |
                               |                       |    |
             +-------------------------------------+   |    |
             |  Power Phase Quality                |   |    |
             |                                     |   |    |
             | eoPhaseIndex                        |   |    |
             | eoACPwrQualityPhaseAvgCurrent       |   |    |
             | eoACPwrQualityAvgCurrent            |   |    |
             | eoACPwrQualityFrequency             |   |    |
             | eoACPwrQualityPowerUnitMultiplier   |   |    |
             | eoACPwrQualityPowerAccuracy         |   |    |
             | eoACPwrQualityPhaseActivePower      |   |    |
             | eoACPwrQualityPhaseReactivePower    |   |    |
             | eoACPwrQualityPhaselApparentPower   |   |    |
             | eoACPwrQualityPhaseImpedance        |   |    |
             +-------------------------------------+   |    |
                                                       |    |
                                                       |    |
           +---------------------------------------------+  |
           |  Power Quality DEL Configuration            |  |
           |                                             |  |
           | eoACPwrQualityDelPhaseToNextPhaseVoltage    |  |
           | eoACPwrQualityDelThdPhaseToNextPhaseVoltage |  |
           | eoACPwrQualityDelThdCurrent                 |  |
           +---------------------------------------------+  |
                                                            |
                                                            |
               +---------------------------------------------+
               |  Power Quality WYE Configuration            |
               |                                             |
               | eoACPwrQualityWyePhaseToNeutralVoltage      |
               | eoACPwrQualityWyePhaseCurrent               |
               | eoACPwrQualityWyeThdPhaseToNeutralVoltage   |
               +---------------------------------------------+
```

Figure 2: UML diagram for the powerQualityMIB

5.1. Energy Object Information

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

The Energy Object identity information is specified in the MIB ENERGY-AWARE-MIB module [EMAN-AWARE-MIB] primary table, i.e. the eoTable. In this table, every Energy Object SHOULD have a printable name eoName, and MUST HAVE a unique Energy Object index eoIndex. The ENERGY-AWARE-MIB module returns the relationship (parent/child) between Energy Objects .

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 States" section in [EMAN-FRAMEWORK] for background information.

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

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

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

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

5.2.1. Power State Set

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

There are currently three Power State Sets advocated:

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

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

5.2.2. IEEE1621 Power State Set

The IEEE1621 Power State Set [IEEE1621] consists of 3 rudimentary states : on, off or sleep.
  on(0)   - The device is fully On and all features of the device are in working mode.
  off(1)   - The device is mechanically switched off and does not consume energy.
  sleep(2) - The device is in a power saving mode, and some features may not be available immediately.

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

5.2.3. DMTF Power State Set

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

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

5.2.4. EMAN Power State Set

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

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

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

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

```
   IEEE1621 Power(off):

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

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

5.3. Energy Object Usage Information

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

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

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

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

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

5.4. Optional Power Usage 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 eoACPwrQualityTable table, that defines power quality measurements for supported eoPowerIndex entities, as a sparse extension of the eoPowerTable (with eoPowerIndex as primary index). This eoACPwrQualityTable 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 eoACPwrQualityPhaseTable additional table is populated with power quality measurements per phase (so double indexed by the eoPowerIndex and eoPhaseIndex). This table, which describes attributes common to both WYE and DEL configurations, contains the average current, active/reactive/apparent power, power factor, and impedance.

In case of 3-phase power with a DEL configuration, the eoACPwrQualityDelPhaseTable 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 eoACPwrQualityWyePhaseTable 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 an Energy Object, and not when the power measurement is assumed or predicted as specified in the description clause of the object eoPowerMeasurementCaliber.

Two tables are introduced to characterize energy measurement of an Energy Object: eoEnergyTable and eoEnergyParametersTable. Both energy and demand information can be represented via the eoEnergyTable. Energy information will be an accumulation with no interval. Demand information can be represented as an average accumulation per interval of time.

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

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

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

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

- The vertical axis represents the time interval of sampling and the value of eoEnergyIntervalEnergyUsed 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 eoEnergyParametersIntervalMode

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

eoEnergyIntervalStartTime plus eoEnergyParametersIntervalLength.
S2=S1+L; S3=S2+L, ...

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

Figure 5 : Sliding eoEnergyParametersIntervalMode

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

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

Figure 4 : Total eoEnergyParametersIntervalMode

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

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

The eoEnergyTable consists of energy measurements in eoEnergyIntervalEnergyUsed , the units of the measured energy eoEnergyIntervalEnergyUnitMultiplier, and the maximum observed energy within a window - eoEnergyIntervalMax.

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

The following example illustrates the eoEnergyTable and eoEnergyParametersTable:

First, in order to estimate energy, a time interval to sample energy should be specified, i.e. eoEnergyParametersIntervalLength can be set to "900 seconds" or 15 minutes and the number of consecutive intervals over which the maximum energy is calculated (eoEnergyParametersIntervalNumber) as "10". The sampling rate internal to the Energy Object for measurement of power usage (eoEnergyParametersSampleRate) can be "1000 milliseconds", as set by the Energy Object as a reasonable value. Then, the eoEnergyParametersStatus is set to active (value 1) to indicate that the Energy Object should start monitoring the usage per the eoEnergyTable.

The indices for the eoEnergyTable are eoPowerIndex, which identifies the Energy Object, and eoEnergyIntervalStartTime, which denotes the start time of the energy measurement interval based on sysUpTime [RFC3418]. The value of eoEnergyIntervalEnergyUsed is the measured energy consumption over the time interval specified (eoEnergyParametersIntervalLength) based on the Energy Object internal sampling rate (eoEnergyParametersSampleRate). While choosing the values for the eoEnergyParametersIntervalLength and

eoEnergyParametersSampleRate, it is recommended to take into consideration either the network element resources adequate to process and store the sample values, and the mechanism used to calculate the eoEnergyIntervalEnergyUsed. The units are derived from eoEnergyIntervalPowerUnitMultiplier. For example, eoEnergyIntervalPowerUsed can be "100" with eoEnergyIntervalPowerUnits equal to 0, the measured energy consumption of the Energy Object is 100 watt-hours. The eoEnergyIntervalMax is the maximum energy observed and that can be "150 watt-hours".

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

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

5.6. Fault Management

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

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 Energy Objects and the relationships between those (notion of Parent/Child).

In the ENERGY-AWARE-MIB module tables, the Energy Objects are indexed by the eoIndex.

If an implementation of the ENERGY-AWARE-MIB module is available in the local SNMP context, for the same Energy Object , the eoIndex value (EMAN-AWARE-MIB) MUST be assigned to the eoPowerIndex. The eoPowerIndex characterizes the Energy Object in the energyObjectMib and powerQualityMIB MIB modules (this document).

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

If the Energy Object is an Aggregator or a Proxy, the MIB module would be populated with the Energy Object Parent and Children information, which have their own Energy Object index value (eoPowerIndex). 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 eoPowerIndex to index the Energy Object.

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 Energy Objects. Indeed, the index for the Energy Objects in the MIB modules specified in this document is the eoPowerIndex, 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 described in Section 6.1. the NMS must then poll the eoPowerStateTable (specified in the energyObjectMib module in this document), indexed by the Energy Object (eoPowerIndex that

inherited the entPhysicalIndex value), by the Power State (eoPowerStateIndex). Then the NMS has discovered every Power State within each Power State Set supported by the Energy Object.

Note that, without the ENERGY-AWARE-MIB module, the Energy Object 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 Energy Object acts as a 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 equieoent indexed by the ENTITY MIB, this MIB proposes a customized power scale for power measurement and different power state states of networking equipment, and functionality to configure the power state states.

When this MIB module is used to monitor the power usage of devices like routers and switches, the ENTITY MIB and ENTITY-

SENSOR MIB SHOULD be implemented. In such cases, the Energy Objects are modeled by the entPhysicalIndex through the entPhysicalEntity MIB object specified in the eoTable in the ENERGY-AWARE-MIB MIB module [EMAN-AWARE-MIB].

However, the ENTITY-SENSOR MIB [RFC3433] does not have the ANSI C12.x accuracy classes required for electricity (i.e., 1%, 2%, 0.5% accuracy classes). Indeed, entPhySensorPrecision [RFC3433] represents "The number of decimal places of precision in fixed-point sensor values returned by the associated entPhySensorValue object". The ANSI and IEC Standards are used for power measurement and these standards require that we use an accuracy class, not the scientific-number precision model specified in RFC3433. The eoPowerAccuracy MIB object models this accuracy. Note that eoPowerUnitMultipler 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 Energy Objects that need to be monitored. A typical example is a converged building gateway, monitoring several other devices in the building, doing the proxy between SNMP and a protocol like BACNET. Another example is the home energy controller. In such cases, the eoPhysicalEntity value contains the zero value, thanks to PhysicalIndexOrZero textual convention.

The eoPowerIndex MIB object has been kept as the unique index of the Energy Object. The eoPower is similar to entPhySensorValue [RFC3433] and the eoPowerUnitMultipler is similar to entPhySensorScale.

7.2. Link with the ENTITY-STATE MIB

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

(entStateStandby: unknown, hotStandby, coldStandby, providingService).

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

7.3. Link with the POWER-OVER-ETHERNET MIB

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

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

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

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

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

7.4. Link with the UPS MIB

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

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

- upsIdent: Identifies the UPS entity (name, model, etc.).

- upsBattery group: Indicates the battery state (upsbatteryStatus, upsEstimatedMinutesRemaining, etc.)

- upsInput group: Characterizes the input load to the UPS (number of input lines, voltage, current, etc.).

- upsOutput: Characterizes the output from the UPS (number of output lines, voltage, current, etc.)

- upsAlarms: Indicates the various alarm events.

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

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

7.5. Link with the LLDP and LLDP-MED MIBs

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

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

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

The power priority specified in the LLDP-MED MIB [LLDP-MED-MIB] actually comes from the Power-over-Ethernet MIB [RFC3621]. If the Power-over-Ethernet MIB [RFC3621] is supported, the exact value from the pethPsePortPowerPriority [RFC3621] is copied over in the lldpXMedRemXPoEPDPowerPriority [LLDP-MED-MIB]; otherwise the value in lldpXMedRemXPoEPDPowerPriority is "unknown". From the Power and Energy Monitoring MIB, it is possible to identify the pethPsePortPowerPriority [RFC3621], thanks to the eoethPortIndex and eoethPortGrpIndex.

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

8. Implementation Scenario

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

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

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

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

The switch has implementations of Entity MIB [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, eoPowerIndex "1", eoPhysicalEntity "2", and eoUUID "UUID 1000". The power usage of the switch is "440 Watts". The switch does not have an Energy Object Parent.

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

The attributes of the PC are given below. The PC does not implementation of Entity MIB, and thus does not have eoPhysicalEntity. The eoPowerIndex (eoIndex) of the PC is "57", the eoUUID is "UUID 1000:57 ". The PC has an Energy Object Parent, i.e. the switch port whose eoUUID is "UUID 1000:3". The power usage of the PC is "120 Watts" and is communicated to the switch port.

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

```
   |---------------------------------------------------------------|
   |                           Switch                              |
   |===============================================================|
   |  Switch  | Switch   | Switch        | Switch     | Switch     |
   | eoIndex | eoPhyIdx  | eoUUID         |eoParentId  | eoPower   |
   | ============================================================  |
   |     1    |    2     | UUID 1000     |    null    |   440      |
   | ============================================================  |
   |                                                               |
   |                          SWITCH PORT                          |
   | ============================================================  |
   | | Switch  | Switch   | Switch        | Switch     | Switch    |
   | | Port    | Port     | Port          | Port       | Port    | |
   | | eoIndex| eoPhyIdx | eoUUID        | eoParentId | eoPower | |
   | ============================================================  |
   | |    3    |    12    | UUID 1000:3  | UUID 1000  |    12   | |
   | ============================================================  |
   |                                    ^                          |
   |                                    |                          |
   |------------------------------------|--------------------------|
                                        |
                                        |
                  POE IP PHONE          |
                                        |
                                        |
   ==============================================================
   | IP phone | IP phone |IP phone      | IP phone   |IP phone|
   | eoIndex  | eoPhyIdx |eoUUID        |eoParentID  |eoPower |
   ============================================================
   |  31       |     0   |UUID 1000:31 | UUID 1000:3 |  12   |
   =============================================================
                                         |
                                         |
   PC connected to switch via IP phone  |
                                         |
   ==============================================================
   | PC     | PC      |PC            |PC           | PC           |
   |eoIndex| eoPhyIdx |eoUUID        |eoParentID  | eoPower      |
   =============================================================
   | 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 energyObjectMibObject. The eoPowerTable table of energyObjectMibObject describes the power measurement attributes of an Energy Object entity. The notion of identity of the device in terms of uniquely identification of the Energy Object and its relationship to other entities in the network are addressed in [EMAN-AWARE-MIB].

The power measurement of an Energy Object contains information describing its power usage (eoPower) and its current power state (eoPowerOperState). In addition to power usage, additional information describing the units of measurement (eoPowerAccuracy, eoPowerUnitMultiplier), how power usage measurement was obtained (eoPowerMeasurementCaliber), the source of power (eoPowerOrigin) and the type of power (eoPowerCurrentTtype) are described.

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

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

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

10. MIB Definitions

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

ENERGY-OBJECT-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY,
    OBJECT-TYPE,
```

```
        NOTIFICATION-TYPE,
        mib-2,
        Integer32, 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;

    energyObjectMib MODULE-IDENTITY
        LAST-UPDATED    "201110310000Z"     -- 31 October 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

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

              Editors:
                 Mouli Chandramouli
                 Cisco Systems, Inc.
                 Sarjapur Outer Ring Road
                 Bangalore,
                 IN
                 Phone: +91 80 4426 3947
                 Email: moulchan@cisco.com

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

                 Juergen Quittek
                 NEC Europe Ltd.
                 NEC Laboratories Europe
                 Network Research Division
                 Kurfuersten-Anlage 36
```

```
                Heidelberg  69115
                DE
                Phone: +49 6221 4342-115
                Email: quittek@neclab.eu

                Thomas Dietz
                NEC Europe Ltd.
                NEC Laboratories Europe
                Network Research Division
                Kurfuersten-Anlage 36
                69115 Heidelberg
                DE
                Phone: +49 6221 4342-128
                Email: Thomas.Dietz@nw.neclab.eu

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

       DESCRIPTION
          "This MIB is used to monitor power and energy in
          devices."
       REVISION
           "201110310000Z"     -- 31 October 2011

       DESCRIPTION
          "Initial version, published as RFC XXXX."

      ::= { mib-2 xxx }


   energyObjectMibNotifs OBJECT IDENTIFIER
       ::= { energyObjectMib 0 }

   energyObjectMibObjects OBJECT IDENTIFIER
       ::= { energyObjectMib 1 }

   energyObjectMibConform  OBJECT IDENTIFIER
       ::= { energyObjectMib 2 }


   -- Textual Conventions
```

```
   IANAPowerStateSet ::= TEXTUAL-CONVENTION
       STATUS  current
       DESCRIPTION

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

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

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

       SYNTAX      INTEGER {
                      other(0),        -- indicates other set
                      unknown(255),    -- unknown power state

                      ieee1621(256), -- indicates IEEE1621 set
                      ieee1621On(257),
                      ieee1621Off(258),
                      ieee1621Sleep(259),

                      dmtf(512),   -- indicates DMTF set
                      dmtfOn(513),
                      dmtfSleepLight(514),
                      dmtfSleepDeep(515),
                      dmtfOffHard(516),
                      dmtfOffSoft(517),
                      dmtfHibernate(518),
                      dmtfPowerOffSoft(519),
                      dmtfPowerOffHard(520),
                      dmtfMasterBusReset(521),
                      dmtfDiagnosticInterrapt(522),
                      dmtfOffSoftGraceful(523),
```

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

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

   UnitMultiplier ::= TEXTUAL-CONVENTION
       STATUS          current
       DESCRIPTION
          "The Unit Multiplier is an integer value that represents
          the IEEE 61850 Annex A units multiplier associated with
          the integer units used to measure the power or energy.

          For example, when used with eoPowerUnitMultiplier, -3
          represents 10^-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


   eoPowerTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoPowerEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table lists Energy Objects."
       ::= { energyObjectMibObjects 1 }


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

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

   eoPowerIndex OBJECT-TYPE
       SYNTAX          Integer32 (0..2147483647)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
         "A unique value, for each  Energy Object.
```

```
          If an implementation of the ENERGY-AWARE-MIB module is
          available in the local SNMP context, then the same index,
          eoIndex, as the one in the ENERGY-AWARE-MIB MUST be
          assigned for the identical Energy Object. In this case,
          entities without an assigned value for eoIndex cannot be
          indexed by the eoPowerStateTable.

          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 eoPowerStateTable.

          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 eoPowerIndex 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."

        ::= { eoPowerEntry 1 }



    eoPower OBJECT-TYPE
        SYNTAX          Integer32
        UNITS           "Watts"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
           "This object indicates the power measured for the Energy
           Object. For alternating current, this value is obtained
           as an average over fixed number of AC cycles.  .  This
           value is specified in SI units of watts with the
           magnitude of watts (milliwatts, kilowatts, etc.)
           indicated separately in eoPowerUnitMultiplier. The
           accuracy of the measurement is specfied in
           eoPowerAccuracy. The direction of power flow is indicated
           by the sign on eoPower. If the Energy Object is consuming
```

```
          power, the eoPower value will be positive. If the Energy
          Object is producing power, the eoPower value will be
          negative.

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

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


   eoPowerNameplate OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Watts"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object indicates the rated maximum consumption for
          the fully populated Energy Object.  The nameplate power
          requirements are the maximum power numbers and, in almost
          all cases, are well above the expected operational
          consumption.  The eoPowerNameplate is widely used for
          power provisioning.  This value is specified in either
          units of watts or voltage and current.  The units are
          therefore SI watts or equivalent Volt-Amperes with the
          magnitude (milliwatts, kilowatts, etc.) indicated
          separately in eoPowerUnitMultiplier."
       ::= { eoPowerEntry 3 }

   eoPowerUnitMultiplier OBJECT-TYPE
       SYNTAX          UnitMultiplier
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "The magnitude of watts for the usage value in eoPower
          and eoPowerNameplate."
       ::= { eoPowerEntry 4 }

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

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

           ANSI and IEC define the following accuracy classes for
           power measurement:
                IEC 62053-22  60044-1 class 0.1, 0.2, 0.5, 1  3.
                ANSI C12.20 class 0.2, 0.5"
        ::= { eoPowerEntry 5 }


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

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

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

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

           - estimated(4): Indicates that the usage was not
           determined by physical measurement. The value is a
           derivation based upon the device type, state, and/or
```

```
          current utilization using some algorithm or heuristic. It
          is presumed that the entity's state and current
          configuration were used to compute the value.

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

    ::= { eoPowerEntry 6 }

   eoPowerCurrentType OBJECT-TYPE
         SYNTAX      INTEGER  {
                          ac(1),
                          dc(2),
                          unknown(3)
                      }
          MAX-ACCESS  read-only
          STATUS      current
       DESCRIPTION
          "This object indicates whether the eoUsage for the
          Energy Object reports alternative current AC(1), direct
          current DC(2), or that the current type is unknown(3)."
    ::= { eoPowerEntry 7 }

   eoPowerOrigin  OBJECT-TYPE
       SYNTAX          INTEGER  {
                           self (1),
                           remote (2)
                       }
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object indicates the source of power measurement
          and can be useful when modeling the power usage of
          attached devices. The power measurement can be performed
          by the entity itself or the power measurement of the
          entity can be reported by another trusted entity using a
          protocol extension.  A value of self(1) indicates the
          measurement is performed by the entity, whereas remote(2)
          indicates that the measurement was performed by another
          entity."
       ::= { eoPowerEntry 8 }

   eoPowerAdminState OBJECT-TYPE
       SYNTAX          IANAPowerStateSet
```

```
       MAX-ACCESS      read-write
       STATUS          current
       DESCRIPTION

           "This object specifies the desired Power State and the
           Power State Set for the Energy Object. Note that
           other(0) is not a Power State Set and unknown(255) is
           not a Power State as such, but simply an indication that
           the Power State of the Energy Object is unknown.
           Possible values of eoPowerAdminState within the Power
           State Set are registered at IANA.
           A current list of assignments can be found at
           <http://www.iana.org/assignments/eman>
           RFC-EDITOR: please check the location after IANA"
       ::= { eoPowerEntry 9  }

   eoPowerOperState OBJECT-TYPE
       SYNTAX          IANAPowerStateSet
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION

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

           Possible values of eoPowerAdminState within the Power
           State Set are registered at IANA.
           A current list of assignments can be found at
           <http://www.iana.org/assignments/eman>
           RFC-EDITOR: please check the location after IANA"

       ::= { eoPowerEntry 10   }

   eoPowerStateEnterReason OBJECT-TYPE
        SYNTAX     OwnerString
        MAX-ACCESS read-create
        STATUS     current
        DESCRIPTION
           "This string object describes the reason for the
           eoPowerAdminState
           transition Alternatively, this string may contain with
           the entity that configured this Energy Object to this
           Power State."
```

```
        DEFVAL { "" }
        ::= { eoPowerEntry 11  }

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

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

   eoPowerStateEntry OBJECT-TYPE
       SYNTAX          EoPowerStateEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "A eoPowerStateEntry extends a corresponding
          eoPowerEntry.  This entry displays max usage values at
          every single possible Power State supported by the Energy
          Object.
          For example, given the values of a Energy Object
          corresponding to a maximum usage of 11W at the
          state 1 (mechoff), 6 (ready), 8 (mediumMinus), 12 (High):

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

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

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

   EoPowerStateEntry ::= SEQUENCE {
           eoPowerStateIndex                IANAPowerStateSet,
           eoPowerStateMaxPower             Integer32,
           eoPowerStatePowerUnitMultiplier  UnitMultiplier,
           eoPowerStateTotalTime            TimeTicks,
           eoPowerStateEnterCount           Counter64
   }

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


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

          For Power States not enumerated, the value of
          eoPowerStateMaxPower might be interpolated by using the
          next highest supported Power State."
       ::= { eoPowerStateEntry 3 }
```

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

   eoPowerStateTotalTime OBJECT-TYPE
       SYNTAX      TimeTicks
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
         "This object indicates the total time in hundreds
         of seconds that the Energy Object has been in this power
         state since the last reset, as specified in the
         sysUpTime."
       ::= { eoPowerStateEntry 5 }

   eoPowerStateEnterCount OBJECT-TYPE
       SYNTAX      Counter64
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION
          "This object indicates how often the Energy
           Object has
           entered this power state, since the last reset of the
           device as specified in the sysUpTime."
       ::= { eoPowerStateEntry 6  }


   eoEnergyParametersTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoEnergyParametersEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
      "This table is used to configure the parameters for Energy
      measurement collection in the table  eoEnergyTable."
       ::= { energyObjectMibObjects 4 }

   eoEnergyParametersEntry OBJECT-TYPE
       SYNTAX          EoEnergyParametersEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
```

```
          "An entry controls an energy measurement in
          eoEnergyTable."
       INDEX  { eoPowerIndex }
       ::= { eoEnergyParametersTable 1 }

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

   eoEnergyParametersIntervalLength 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 eoEnergyIntervalEnergyUsed
          measurement in the eoEnergyTable table. The computation
          is based on the Energy Object's internal sampling rate of
          power consumed or produced by the Energy Object. The
          sampling rate is the rate at which the Energy Object can
          read the power usage and may differ based on device
          capabilities. The average energy consumption is then
          computed over the length of the interval."
       DEFVAL { 900 }
       ::= { eoEnergyParametersEntry 1 }

   eoEnergyParametersIntervalNumber OBJECT-TYPE
       SYNTAX          Integer32
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
          "The number of intervals maintained in the eoEnergyTable.
          Each interval is characterized by a specific
          eoEnergyIntervalStartTime, used as an index to the table
          eoEnergyTable . 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 eoEnergyIntervalMax, in which case
          the measurement the measurement over the next oldest
          interval is replaced."
        DEFVAL { 10 }
```

```
     ::= { eoEnergyParametersEntry 2 }

   eoEnergyParametersIntervalMode OBJECT-TYPE
     SYNTAX          INTEGER  {
                         period(1),
                         sliding(2),
                         total(3)
                     }
     MAX-ACCESS      read-create
     STATUS          current
     DESCRIPTION
       "A control object to define the mode of interval calculation
       for the computation of the average
       eoEnergyIntervalEnergyUsed measurement in the eoEnergyTable
       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 eoEnergyParametersIntervalWindow.

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

   eoEnergyParametersIntervalWindow 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
        eoEnergyIntervalEnergyUsed measurement in the eoEnergyTable
        table  This is valid only when the
        eoEnergyParametersIntervalMode is sliding(2). The
        eoEnergyParametersIntervalWindow value should be a multiple
        of eoEnergyParametersSampleRate."
          ::= { eoEnergyParametersEntry 4 }

   eoEnergyParametersSampleRate OBJECT-TYPE
       SYNTAX          Integer32
```

```
       UNITS           "Milliseconds"
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
          "The sampling rate, in milliseconds, at which the  Energy
          Object should poll power usage in order to compute the
          average eoEnergyIntervalEnergyUsed measurement in the
          table eoEnergyTable.  The  Energy Object should initially
          set this sampling rate to a reasonable value, i.e., a
          compromise between intervals that will provide good
          accuracy by not being too long, but not so short that
          they affect the  Energy Object performance by requesting
          continuous polling. If the sampling rate is unknown, the
          value 0 is reported. The sampling rate should be selected
          so that eoEnergyParametersIntervalWindow is a multiple of
          eoEnergyParametersSampleRate."
        DEFVAL { 1000 }
       ::= { eoEnergyParametersEntry 5 }

   eoEnergyParametersStatus OBJECT-TYPE
       SYNTAX          RowStatus
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
         "The status of this row. The eoEnergyParametersStatus is
         used to start or stop energy usage logging. An entry
         status may not be active(1) unless all objects in the
         entry have an appropriate value.  If this object is not
         equal to active(1), all associated usage-data logged into
         the eoEnergyTable will be deleted. The data can be
         destroyed by setting up the eoEnergyParametersStatus to
         destroy(2)."
       ::= {eoEnergyParametersEntry 6 }

   eoEnergyTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoEnergyIntervalEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table lists Energy Object energy measurements.
          Entries in this table are only created if the
          corresponding value of object eoPowerMeasurementCaliber
          is active(2), i.e., if the power is actually metered."
       ::= { energyObjectMibObjects 5 }

   eoEnergyIntervalEntry OBJECT-TYPE
```

```
        SYNTAX          EoEnergyIntervalEntry
        MAX-ACCESS      not-accessible
        STATUS          current
        DESCRIPTION
            "An entry describing energy measurements."
        INDEX  { eoPowerIndex, eoEnergyParametersIntervalMode,
    eoEnergyIntervalStartTime }
        ::= { eoEnergyTable 1 }

    EoEnergyIntervalEntry ::= SEQUENCE {
         eoEnergyIntervalStartTime            TimeTicks,
         eoEnergyIntervalEnergyConsumed       Integer32,
         eoEnergyIntervalEnergyProduced       Integer32,
         eoEnergyIntervalEnergyNet            Integer32,
         eoEnergyIntervalEnergyUnitMultiplier UnitMultiplier,
         eoEnergyIntervalEnergyAccuracy       Integer32,
         eoEnergyIntervalMaxConsumed          Integer32,
         eoEnergyIntervalMaxProduced          Integer32,
         eoEnergyIntervalDiscontinuityTime    TimeTicks
    }

    eoEnergyIntervalStartTime 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."
        ::= { eoEnergyIntervalEntry 1 }



    eoEnergyIntervalEnergyConsumed OBJECT-TYPE
        SYNTAX          Integer32
        UNITS           "Watt-hours"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
    "This object indicates the energy consumed in units of watt-
    hours for the Energy Object over the defined interval.
    This value is specified in the common billing units of watt-
    hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.)
```

```
   indicated separately in eoEnergyIntervalEnergyUnitMultiplier."
       ::= { eoEnergyIntervalEntry 2 }


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


   eoEnergyIntervalEnergyNet OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Watt-hours"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
   "This object indicates the resultant of the energy consumed and
   energy produced for an energy object in units of watt-hours for
   the Energy Object over the defined interval. This value is
   specified in the common billing units of watt-hours
   with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.)
   indicated separately in eoEnergyIntervalEnergyUnitMultiplier."
       ::= { eoEnergyIntervalEntry 4 }

   eoEnergyIntervalEnergyUnitMultiplier OBJECT-TYPE
       SYNTAX          UnitMultiplier
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
          "This object is the magnitude of watt-hours for the
          energy field in eoEnergyIntervalEnergyUsed."
       ::= { eoEnergyIntervalEntry 5  }


   eoEnergyIntervalEnergyAccuracy OBJECT-TYPE
       SYNTAX          Integer32 (0..10000)
```

```
        UNITS           "hundredths of percent"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
    "This object indicates a percentage value, in 100ths of a
    percent, representing the presumed accuracy of Energy usage
    reporting. eoEnergyIntervalEnergyAccuracy is applicable to all
    Energy measurements in the eoEnergyTable.

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

        ::= { eoEnergyIntervalEntry 6 }

    eoEnergyIntervalMaxConsumed OBJECT-TYPE
        SYNTAX          Integer32
        UNITS           "Watt-hours"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
           "This object is the maximum energy ever observed in
           eoEnergyIntervalEnergyConsumed 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
           eoEnergyIntervalEnergyUnits."
        ::= { eoEnergyIntervalEntry 7  }


    eoEnergyIntervalMaxProduced OBJECT-TYPE
        SYNTAX          Integer32
        UNITS           "Watt-hours"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
           "This object is the maximum energy ever observed in
           eoEnergyIntervalEnergyProduced since the monitoring
           started. This value is specified in the units of watt-
           hours with the magnitude of watt-hours (kW-Hr,   MW-Hr,
           etc.) indicated separately in
           eoEnergyIntervalEnergyUnits."
        ::= { eoEnergyIntervalEntry 8 }


     eoEnergyIntervalDiscontinuityTime 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."
        ::= { eoEnergyIntervalEntry 9 }

    -- Notifications

    eoPowerStateChange NOTIFICATION-TYPE
        OBJECTS       {eoPowerAdminState, eoPowerOperState,
    eoPowerStateEnterReason}
        STATUS        current
        DESCRIPTION
            "The SNMP entity generates the eoPowerStateChange when
            the value(s) of eoPowerAdminState or eoPowerOperState,
           in the context of the Power State Set, have changed for
           the Energy Object represented by the eoPowerIndex."
       ::= { energyObjectMibNotifs 1 }

    -- Conformance

    energyObjectMibCompliances  OBJECT IDENTIFIER
        ::= { energyObjectMib 3 }

    energyObjectMibGroups  OBJECT IDENTIFIER
        ::= { energyObjectMib 4 }

    energyObjectMibFullCompliance MODULE-COMPLIANCE
        STATUS          current
        DESCRIPTION
            "When this MIB is implemented with support for
            read-create, then such an implementation can
            claim full compliance. Such devices can then
            be both monitored and configured with this MIB."
        MODULE          -- this module
        MANDATORY-GROUPS {
                    energyObjectMibTableGroup,
                    energyObjectMibStateTableGroup,
                    energyObjectMibEnergyTableGroup,
                    energyObjectMibEnergyParametersTableGroup,
                    energyObjectMibNotifGroup
                        }
        ::= { energyObjectMibCompliances 1 }
```

```
   energyObjectMibReadOnlyCompliance MODULE-COMPLIANCE
       STATUS          current
       DESCRIPTION
           "When this MIB is implemented without support for
           read-create (i.e. in read-only mode), then such an
           implementation can claim read-only compliance.  Such a
           device can then be monitored but cannot be
           configured with this MIB. "
       MODULE          -- this module
       MANDATORY-GROUPS {
                           energyObjectMibTableGroup,
                           energyObjectMibStateTableGroup,
                           energyObjectMibNotifGroup
                       }

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

   -- Units of Conformance

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

   energyObjectMibStateTableGroup OBJECT-GROUP
          OBJECTS      {
                            eoPowerStateMaxPower,
                            eoPowerStatePowerUnitMultiplier,
                            eoPowerStateTotalTime,
                            eoPowerStateEnterCount
```

```
                       }
               STATUS          current
               DESCRIPTION
                   "This group contains the collection of all the
                   objects related to the Power State."
               ::= { energyObjectMibGroups 2 }




   energyObjectMibEnergyParametersTableGroup OBJECT-GROUP
       OBJECTS         {
                           eoEnergyParametersIntervalLength,
                           eoEnergyParametersIntervalNumber,
                           eoEnergyParametersIntervalMode,
                           eoEnergyParametersIntervalWindow,
                           eoEnergyParametersSampleRate,
                           eoEnergyParametersStatus
                       }
       STATUS          current
       DESCRIPTION
           "This group contains the collection of all the objects
           related to the configuration of the Energy Table."
       ::= { energyObjectMibGroups 3 }

   energyObjectMibEnergyTableGroup OBJECT-GROUP
       OBJECTS         {
                           -- Note that object
                           -- eoEnergyIntervalStartTime is not
                           -- included since it is not-accessible

                           eoEnergyIntervalEnergyConsumed,
                           eoEnergyIntervalEnergyProduced,
                           eoEnergyIntervalEnergyNet,
                           eoEnergyIntervalEnergyUnitMultiplier,
                           eoEnergyIntervalEnergyAccuracy,
                           eoEnergyIntervalMaxConsumed,
                           eoEnergyIntervalMaxProduced,
                           eoEnergyIntervalDiscontinuityTime
                       }
       STATUS          current
       DESCRIPTION
           "This group contains the collection of all the objects
           related to the Energy Table."
       ::= { energyObjectMibGroups 4 }

   energyObjectMibNotifGroup NOTIFICATION-GROUP
```

```
      NOTIFICATIONS    {
                           eoPowerStateChange
                       }
       STATUS          current
       DESCRIPTION
           "This group contains the notifications for the power and
           energy monitoring MIB Module."
       ::= { energyObjectMibGroups 5 }

   END


   -- ************************************************************
   --
   -- This MIB module is used to monitor power quality of networked
   -- devices with measurements.
   --
   -- This MIB module is an extension of energyObjectMib 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, eoPowerIndex
           FROM ENERGY-OBJECT-MIB
       OwnerString
           FROM RMON-MIB;

   powerQualityMIB MODULE-IDENTITY

       LAST-UPDATED    "201110310000Z"     -- 31 October 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

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

Editors:

Mouli Chandramouli
Cisco Systems, Inc.
Sarjapur Outer Ring Road
Bangalore,
IN
Phone: +91 80 4426 3947
Email: moulchan@cisco.com

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

Juergen Quittek
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
Heidelberg 69115
DE
Phone: +49 6221 4342-115
Email: quittek@neclab.eu

Thomas Dietz
NEC Europe Ltd.
NEC Laboratories Europe
Network Research Division
Kurfuersten-Anlage 36
69115 Heidelberg
DE
Phone: +49 6221 4342-128
Email: Thomas.Dietz@nw.neclab.eu

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

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

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

             "201110310000Z"    -- 31 October 2011



       DESCRIPTION
            "Initial version, published as RFC YYY."

        ::= { mib-2 yyy }


   powerQualityMIBConform  OBJECT IDENTIFIER
       ::= { powerQualityMIB 0 }


   powerQualityMIBObjects OBJECT IDENTIFIER
       ::= { powerQualityMIB 1 }

   -- Objects


   eoACPwrQualityTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoACPwrQualityEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This table defines power quality measurements for
           supported eoPowerIndex entities. It is a sparse
           extension of the eoPowerTable."
       ::= { powerQualityMIBObjects 1 }

   eoACPwrQualityEntry OBJECT-TYPE
       SYNTAX          EoACPwrQualityEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This is a sparse extension of the eoPowerTable 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 { eoPowerIndex }
        ::= { eoACPwrQualityTable 1 }

    EoACPwrQualityEntry ::= SEQUENCE {
        eoACPwrQualityConfiguration       INTEGER,
        eoACPwrQualityAvgVoltage          Integer32,
        eoACPwrQualityAvgCurrent          Integer32,
        eoACPwrQualityFrequency           Integer32,
        eoACPwrQualityPowerUnitMultiplier UnitMultiplier,
        eoACPwrQualityPowerAccuracy       Integer32,
        eoACPwrQualityTotalActivePower    Integer32,
        eoACPwrQualityTotalReactivePower  Integer32,
        eoACPwrQualityTotalApparentPower  Integer32,
        eoACPwrQualityTotalPowerFactor    Integer32,
        eoACPwrQualityThdAmpheres         Integer32,
        eoACPwrQualityThdVoltage          Integer32
    }

    eoACPwrQualityConfiguration 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."
        ::= { eoACPwrQualityEntry 1 }

    eoACPwrQualityAvgVoltage OBJECT-TYPE
        SYNTAX          Integer32
        UNITS           "0.1 Volt AC"
        MAX-ACCESS      read-only
```

```
        STATUS          current
        DESCRIPTION
            "A measured value for average of the voltage measured
            over an integral number of AC cycles   For a 3-phase
            system, this is the average voltage (V1+V2+V3)/3.  IEC
            61850-7-4 measured value attribute 'Vol'"
        ::= { eoACPwrQualityEntry 2 }

    eoACPwrQualityAvgCurrent 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'"
        ::= { eoACPwrQualityEntry 3 }

    eoACPwrQualityFrequency 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'."
        ::= { eoACPwrQualityEntry 4 }

    eoACPwrQualityPowerUnitMultiplier OBJECT-TYPE
        SYNTAX          UnitMultiplier
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
            "The magnitude of watts for the usage value in
            eoACPwrQualityTotalActivePower,
            eoACPwrQualityTotalReactivePower
            and eoACPwrQualityTotalApparentPower measurements.  For
            3-phase power systems, this will also include
            eoACPwrQualityPhaseActivePower,
            eoACPwrQualityPhaseReactivePower and
            eoACPwrQualityPhaseApparentPower"
        ::= { eoACPwrQualityEntry 5 }

    eoACPwrQualityPowerAccuracy 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"
        ::= { eoACPwrQualityEntry 6 }

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

    eoACPwrQualityTotalReactivePower 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'."
        ::= { eoACPwrQualityEntry 8 }

    eoACPwrQualityTotalApparentPower 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'."
        ::= { eoACPwrQualityEntry 9 }
```

```
   eoACPwrQualityTotalPowerFactor 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'."
       ::= { eoACPwrQualityEntry 10 }

   eoACPwrQualityThdAmpheres 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'."
       ::= { eoACPwrQualityEntry 11 }

   eoACPwrQualityThdVoltage 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'."
       ::= { eoACPwrQualityEntry 12 }

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

```
   eoACPwrQualityPhaseEntry OBJECT-TYPE
       SYNTAX          EoACPwrQualityPhaseEntry
       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
           eoPowerIndex 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
           eoACPwrQualityTable.

           These attributes correspond to IEC 61850-7.4 MMXU phase
           measurements."
       INDEX { eoPowerIndex, eoPhaseIndex }
       ::= { eoACPwrQualityPhaseTable 1 }

   EoACPwrQualityPhaseEntry ::= SEQUENCE {
           eoPhaseIndex                       Integer32,
           eoACPwrQualityPhaseAvgCurrent      Integer32,
           eoACPwrQualityPhaseActivePower     Integer32,
           eoACPwrQualityPhaseReactivePower   Integer32,
           eoACPwrQualityPhaseApparentPower   Integer32,
           eoACPwrQualityPhasePowerFactor     Integer32,
           eoACPwrQualityPhaseImpedance       Integer32
   }

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

   eoACPwrQualityPhaseAvgCurrent 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'"
        ::= { eoACPwrQualityPhaseEntry 2 }

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

   eoACPwrQualityPhaseReactivePower 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'"
        ::= { eoACPwrQualityPhaseEntry 4 }

   eoACPwrQualityPhaseApparentPower 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'."
        ::= { eoACPwrQualityPhaseEntry 5 }

   eoACPwrQualityPhasePowerFactor 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."
      ::= { eoACPwrQualityPhaseEntry 6 }

   eoACPwrQualityPhaseImpedance 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'."
       ::= { eoACPwrQualityPhaseEntry 7 }

   eoACPwrQualityDelPhaseTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoACPwrQualityDelPhaseEntry
       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 eoACPwrQualityPhaseTable."
       ::= { powerQualityMIBObjects 3 }

   eoACPwrQualityDelPhaseEntry OBJECT-TYPE
       SYNTAX          EoACPwrQualityDelPhaseEntry
       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 eoPhaseIndex is
          compared against the following phase at +120 degrees.
          Thus, the possible values are:

                        eoPhaseIndex        Next Phase Angle
                              0                  120
                            120                  240
                            240                    0
          "
       INDEX { eoPowerIndex, eoPhaseIndex}
       ::= { eoACPwrQualityDelPhaseTable 1}
```

```
   EoACPwrQualityDelPhaseEntry ::= SEQUENCE {
       eoACPwrQualityDelPhaseToNextPhaseVoltage      Integer32,
       eoACPwrQualityDelThdPhaseToNextPhaseVoltage   Integer32,
       eoACPwrQualityDelThdCurrent                   Integer32
   }

   eoACPwrQualityDelPhaseToNextPhaseVoltage 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'."
       ::= { eoACPwrQualityDelPhaseEntry 2 }

   eoACPwrQualityDelThdPhaseToNextPhaseVoltage 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'."
       ::= { eoACPwrQualityDelPhaseEntry 3 }

   eoACPwrQualityDelThdCurrent 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'."
       ::= { eoACPwrQualityDelPhaseEntry 4 }

   eoACPwrQualityWyePhaseTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoACPwrQualityWyePhaseEntry
       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 eoACPwrQualityPhaseTable."
       ::= { powerQualityMIBObjects 4 }
```

```
   eoACPwrQualityWyePhaseEntry OBJECT-TYPE
       SYNTAX          EoACPwrQualityWyePhaseEntry
       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 eoPowerIndex
          entry.  Voltage measurements are relative to neutral.

          This is a sparse extension of the
          eoACPwrQualityPhaseTable.

          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 { eoPowerIndex, eoPhaseIndex }
       ::= { eoACPwrQualityWyePhaseTable 1}

   EoACPwrQualityWyePhaseEntry ::= SEQUENCE {
           eoACPwrQualityWyePhaseToNeutralVoltage       Integer32,
           eoACPwrQualityWyePhaseCurrent                Integer32,
           eoACPwrQualityWyeThdPhaseToNeutralVoltage    Integer32
   }

   eoACPwrQualityWyePhaseToNeutralVoltage 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'."
       ::= { eoACPwrQualityWyePhaseEntry 1 }

   eoACPwrQualityWyePhaseCurrent 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'."
       ::= { eoACPwrQualityWyePhaseEntry 2 }
```

```
   eoACPwrQualityWyeThdPhaseToNeutralVoltage 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'."
       ::= { eoACPwrQualityWyePhaseEntry 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 eoPowerIndex is NOT
                           -- included since it is not-accessible
                           eoACPwrQualityConfiguration,
                           eoACPwrQualityAvgVoltage,
                           eoACPwrQualityAvgCurrent,
                           eoACPwrQualityFrequency,
                           eoACPwrQualityPowerUnitMultiplier,
                           eoACPwrQualityPowerAccuracy,
                           eoACPwrQualityTotalActivePower,
                           eoACPwrQualityTotalReactivePower,
                           eoACPwrQualityTotalApparentPower,
                           eoACPwrQualityTotalPowerFactor,
                           eoACPwrQualityThdAmpheres,
                           eoACPwrQualityThdVoltage
                       }    STATUS          current
       DESCRIPTION
          "This group contains the collection of all the power
          quality objects related to the Energy Object."
       ::= { powerQualityMIBGroups  1 }


   powerACPwrQualityPhaseMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                           -- Note that object eoPowerIndex is NOT
                           -- included since it is not-accessible
                           eoACPwrQualityPhaseAvgCurrent,
                           eoACPwrQualityPhaseActivePower,
                           eoACPwrQualityPhaseReactivePower,
                           eoACPwrQualityPhaseApparentPower,
                           eoACPwrQualityPhasePowerFactor,
                           eoACPwrQualityPhaseImpedance
                       }
       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 eoPowerIndex and
                       -- eoPhaseIndex are NOT included
                       -- since they are not-accessible
                       eoACPwrQualityDelPhaseToNextPhaseVoltage ,
                       eoACPwrQualityDelThdPhaseToNextPhaseVoltage,
                       eoACPwrQualityDelThdCurrent
                       }
       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 eoPowerIndex and
                          -- eoPhaseIndex are NOT included
                          -- since they are not-accessible
                          eoACPwrQualityWyePhaseToNeutralVoltage,
                          eoACPwrQualityWyePhaseCurrent,
                          eoACPwrQualityWyeThdPhaseToNeutralVoltage
                       }
       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 eoPowerOperState (via theeoPowerAdminState) MAY disrupt the power settings of the differentEnergy Objects, and therefore the state of functionality of the respective Energy Objects.
- Unauthorized changes to the eoEnergyParametersTable MAY disrupt energy measurement in the eoEnergyTable table.

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

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

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

12. IANA Considerations

12.1. IANA Considerations for the MIB Modules

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

Descriptor	OBJECT IDENTIFIER value
energyObjectMib	{ mib-2 xxx }
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. IANA maintains a Textual Convention IANAPowerStateSet with the initial set of Power State Sets and the Power States within those Power State Sets. The current version of Textual convention can be accessed http://www.iana.org/assignments/IANAPowerStateSet

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

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

12.2.1. IANA Registration of the IEEE1621 Power State Set

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

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

12.2.2. IANA Registration of the DMTF Power State Set

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

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

12.2.3. IANA Registration of the EMAN Power State Set

This document specifies a set of values for the EMAN Power State Set. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) has created a new registry for EMAN Power State Set identifiers and filled it with the initial list in the Textual Convention IANAPowerStateSet.
New assignments (or potentially deprecation) for EMAN Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description.

12. 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.

We would like to thank Juergen Schoenwalder for proposing the design of the Textual Convention for IANAPowerStateSet and Ira McDonald for his feedback.

14. Open Issues

OPEN ISSUE 1 : Double-check all the IEC references in the draft.

IEC 61850-7-4 has been widely referenced in many EMAN drafts. The other IEC references suggested in the email list are IEC 61000-4-30 and IEC 62053-21 and IEC 62301. It is important to resolve the correct IEC references soon.

OPEN ISSUE 2 : Description clause of eoPowerIndex. 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 eoPowerIndex, 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 3: Time Series of measurements required ? Mechanism pull or push ? What shall the table consist of ? Power, Voltage, Current, Energy and Demand.

OPEN ISSUE 4: Demand computation method

"Energy not obtained by periodically polling a power measurement with a eoEnergyParametersSampleRate ; Energy (E) is measured to the product's certified IEC 62053-21 accuracy class"

Need to verify with IEC62053-21.

OPEN ISSUE 5: Consideration of IEEE-ISTO PWG in the IANA list of Power State Set ? Printer Power series could be added once the IANA procedure is in place.

OPEN ISSUE 6: check if all the requirements from [EMAN-REQ] are covered.

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

[RFC1628] S. Bradner, "UPS Management Information Base", RFC 1628, May 1994

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

[RFC3418] Presun, R., Case, J., McCloghrie, K., Rose, M, and S. Waldbusser, "Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)", RFC3418, December 2002.

[RFC3433] Bierman, A., Romascanu, D., and K. Norseth, "Entity Sensor Management Information Base", RFC 3433, December 2002.

[RFC4268] Chisholm, S. and D. Perkins, "Entity State MIB", RFC 4268,November 2005.

[RFC5226] Narten, T. Alverstrand, H., A. and K. McCloghrie, "Guidelines for Writing an IANA Considerations Section in RFCs ", BCP 26, RFC 5226, May 2008.

[EMAN-REQ] Quittek, J., Winter, R., Dietz, T., Claise, B., and M. Chandramouli, " Requirements for Energy Management ", draft-ietf-eman-requirements-03 (work in progress),July 2011. .

[EMAN-FRAMEWORK] Claise, B., Parello, J., Schoening, B., and J. Quittek, "Energy Management Framework", draft-ietf-eman-framework-02 , July 2011.

[EMAN-MONITORING-MIB] M. Chandramouli, Schoening, B., Dietz, T., Quittek, J. and B. Claise "Energy and Power Monitoring MIB ", draft-claise-energy-monitoring-mib-09, July 2011.

[EMAN-AS] Tychon, E., Laherty, M., and B. Schoening, "Energy Management (EMAN) Applicability Statement", draft-tychon-eman-applicability-statement-02, work in progress, June 2011.

[ACPI] "Advanced Configuration and Power Interface Specification",http://www.acpi.info/DOWNLOADS/ACPIspec30b.pdf

[DMTF] "Power State Management Profile DMTF DSP1027 Version 2.0" December 2009 http://www.dmtf.org/sites/default/files/standards/documents/DSP1027_2.0.0.pdf

[IEEE1621] "Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments", IEEE 1621, December 2004.

[IEC.61850-7-4] International Electrotechnical Commission, "Communication networks and systems for power utility automation Part 7-4: Basic communication structure Compatible logical node classes and data object classes", 2010.

[IEC.62053-21] International Electrotechnical Commission, "Electricity metering equipment (a.c.) Particular requirements Part 22: Static meters for active energy (classes 1 and 2)", 2003.

[IEC.62053-22]International Electrotechnical Commission, "Electricity metering equipment (a.c.) Particular requirements Part 22: Static meters for active energy (classes 0,2 S and 0,5 S)", 2003.

Authors' Addresses

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

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

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

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

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

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

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

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

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