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Entity MIB (Version 4)
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Abstract

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, it describes managed objects used for managing multiple logical and physical entities managed by a single SNMP agent. This document specifies version of the Entity MIB, which obsoletes version 3 (RFC 4133).

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

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1. The SNMP Management Framework

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

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies a MIB module that is compliant to the SMIV2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

2. Overview

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

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

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

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

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

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

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

2.1. Terms

Some new terms are used throughout this document:

- Naming Scope

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

- Multi-Scoped Object

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

- Single-Scoped Object

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

- Logical Entity

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

- Physical Entity

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

- Containment Tree

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

2.2. Relationship to Community Strings

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

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

2.3. Relationship to SNMP Contexts

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

2.4. Relationship to Proxy Mechanisms

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

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

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

2.5. Relationship to a Chassis MIB

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

2.6. Relationship to the Interfaces MIB

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

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

2.7. Relationship to the Other MIBs

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

2.8. Relationship to Naming Scopes

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

For example, a community string used to access the management information for logical device 'bridge2' may allow access to all the non-bridge related objects in the 'default' naming scope, as well as a second instance of the Bridge MIB (RFC 1493 [RFC1493]).

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

2.9. Multiple Instances of the Entity MIB

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

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

When all of a physically-modular device is represented by a single agent, the entry (for which `entPhysicalContainedIn` has the value zero) would likely have 'chassis' as the value of its `entPhysicalClass`. Alternatively, for an agent on a module where the

agent represents only the physical entities on that module (not those on other modules), the entry (for which `entPhysicalContainedIn` has the value zero) would likely have 'module' as the value of its `entPhysicalClass`.

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

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

2.10. Re-Configuration of Entities

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

2.11. Textual Convention Change

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

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

2.12. MIB Structure

The Entity MIB contains five groups of MIB objects:

- `entityPhysical` group
Describes the physical entities managed by a single agent.
- `entityLogical` group
Describes the logical entities managed by a single agent.

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

2.12.1. entityPhysical Group

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

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

Each row is indexed by an arbitrary, small integer, and contains a description and type of the physical entity. It also optionally contains the index number of another entPhysicalEntry, indicating a containment relationship between the two.

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

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

- entPhysicalSerialNum
This string is provided to store a vendor-specific serial number string for physical components. This writable object is used when an agent cannot identify the serial numbers of all installed physical entities, and a network administrator wishes to configure the non-volatile serial number strings manually (via an NMS application).

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

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

This object contains one or more Uniform Resource Identifiers (URIs) and, therefore, the syntax of this object must conform to RFC 3986 [RFC3986] section 2. Uniform Resource Names (URNs), RFC 3406 [RFC3406], are resource identifiers with the specific requirements for enabling location independent identification of a resource, as well as longevity of reference. URNs are part of the larger URI family with the specific goal of providing persistent naming of resources. URI schemes and URN name spaces are registered by IANA (see <http://www.iana.org/assignments/uri-schemes> and <http://www.iana.org/assignments/urn-namespaces>).

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

URN:CLEI:D4CE18B7AA

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

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

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

2.12.2. entityLogical Group

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

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

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

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

2.12.3. entityMapping Group

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

- entLPMappingTable

This table contains mappings between entLogicalIndex values (logical entities) and entPhysicalIndex values (the physical components supporting that entity). A logical entity can map to more than one physical component, and more than one logical entity can map to (share) the same physical component. If an agent represents a single logical entity, or multiple logical entities within a single naming scope, then implementation of this table may be omitted by the agent.

- entAliasMappingTable

This table contains mappings between entLogicalIndex, entPhysicalIndex pairs, and 'alias' object identifier values. This allows resources managed with other MIBs (e.g., repeater ports, bridge ports, physical and logical interfaces) to be identified in the physical entity hierarchy. Note that each alias identifier is only relevant in a particular naming scope. If an agent represents a single logical entity, or multiple logical entities within a

single naming scope, then implementation of this table may be omitted by the agent.

- entPhysicalContainsTable
This table contains simple mappings between 'entPhysicalContainedIn' values for each container/'containee' relationship in the managed system. The indexing of this table allows an NMS to quickly discover the 'entPhysicalIndex' values for all children of a given physical entity.

2.12.4. entityGeneral Group

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

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

2.12.5. entityNotifications Group

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

2.13. Multiple Agents

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

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

2.14. Changes Since RFC 2037

2.14.1. Textual Conventions

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

2.14.2. New entPhysicalTable Objects

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

The entPhysicalSerialNum, entPhysicalMfgName, entPhysicalModelName, and entPhysicalIsFru objects have been added for better vendor identification for physical components. In the event the agent cannot identify this information, the entPhysicalSerialNum object can be set by a management station.

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

2.14.3. New entLogicalTable Objects

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

2.14.4. Bug Fixes

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

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

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

2.15. Changes Since RFC 2737

2.15.1. Textual Conventions

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

2.15.2. New Objects

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

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

2.15.3. Bug Fixes

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

2.16. Changes Since RFC 4133

2.16.1. MIB module addition Creation of a new MIB module IANA-ENTITY-MIB which makes the PhysicalIndex TC an IANA-maintained Textual Convention. Over time, there is the need to add new enumerated values for PhysicalClass. If the syntax of IANAPhysicalClass were defined in this MIB module then a new version of this MIB would have to be re-issued in order to define new values.

2.16.2. Modification to some of the MIB objects

Creation of a new MODULE-COMPLIANCE module entity4LowCompliance for devices with constrained resources like batteries, which might require a limited number of objects to be supported (entPhysicalIndex, entPhysicalName, entIANAPhysicalClass, entPhysicalUris) with the entPhysicalUris object read-only and restricted to a fixed size to allow only for RFC 4122 [RFC4122] compliant values.

3. MIB Definitions

3.1. ENTITY MIB

ENTITY-MIB DEFINITIONS ::= BEGIN

IMPORTS

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

Uri

FROM URI-TC-MIB
IANAPhysicalClass
FROM IANA-ENTITY-MIB;

entityMIB MODULE-IDENTITY

LAST-UPDATED "201207100000Z"

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DESCRIPTION

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

Copyright (C) The Internet Society (2012). This version of this MIB module is part of RFC xxxx; see

the RFC itself for full legal notices."

REVISION "201207100000Z"

DESCRIPTION

"Entity MIB (Version 4).

This revision obsoletes RFC 4133.

Additions:

-

Changes:

- according to comments made on draft-chandramouli-00

This version published as RFC xxxx."

REVISION "201206100000Z"

DESCRIPTION

"Initial Version of Entity MIB (Version 4).

This revision obsoletes RFC 4133.

Additions:

-

Changes:

-

This version published as RFC xxxx."

REVISION "200508100000Z"

DESCRIPTION

"Initial Version of Entity MIB (Version 3).

This revision obsoletes RFC 2737.

Additions:

- cpu(12) enumeration added to IANAPhysicalClass TC

- DISPLAY-HINT clause to PhysicalIndex TC

- PhysicalIndexOrZero TC

- entPhysicalMfgDate object

- entPhysicalUris object

Changes:

- entPhysicalContainedIn SYNTAX changed from

INTEGER to PhysicalIndexOrZero

This version published as RFC 4133."

REVISION "199912070000Z"

DESCRIPTION

"Initial Version of Entity MIB (Version 2).

This revision obsoletes RFC 2037.

This version published as RFC 2737."

REVISION "199610310000Z"

DESCRIPTION

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

entityMIBObjects OBJECT IDENTIFIER ::= { entityMIB 1 }

-- MIB contains four groups
entityPhysical OBJECT IDENTIFIER ::= { entityMIBObjects 1 }
entityLogical  OBJECT IDENTIFIER ::= { entityMIBObjects 2 }
entityMapping  OBJECT IDENTIFIER ::= { entityMIBObjects 3 }
entityGeneral  OBJECT IDENTIFIER ::= { entityMIBObjects 4 }


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

PhysicalIndexOrZero ::= TEXTUAL-CONVENTION
    DISPLAY-HINT    "d"
    STATUS          current
    DESCRIPTION
        "This textual convention is an extension of the
        PhysicalIndex convention, which defines a greater than zero
        value used to identify a physical entity. This extension
        permits the additional value of zero. The semantics of the
        value zero are object-specific and must, therefore, be
        defined as part of the description of any object that uses
        this syntax. Examples of the usage of this extension are
        situations where none or all physical entities need to be
        referenced."
    SYNTAX Integer32 (0..2147483647)

SnmpEngineIdOrNone ::= TEXTUAL-CONVENTION
    STATUS          current
    DESCRIPTION
        "A specially formatted SnmpEngineID string for use with the
        Entity MIB."
```

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

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

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

-- The Physical Entity Table

entPhysicalTable OBJECT-TYPE

SYNTAX SEQUENCE OF EntPhysicalEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table contains one row per physical entity. There is always at least one row for an 'overall' physical entity."

::= { entityPhysical 1 }

entPhysicalEntry OBJECT-TYPE

SYNTAX EntPhysicalEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"Information about a particular physical entity.

Each entry provides objects (entPhysicalDescr, entPhysicalVendorType, and entIANAPhysicalClass) to help an NMS identify and characterize the entry, and objects (entPhysicalContainedIn and entPhysicalParentRelPos) to help an NMS relate the particular entry to other entries in this table."

INDEX { entPhysicalIndex }

::= { entPhysicalTable 1 }

EntPhysicalEntry ::= SEQUENCE {

entPhysicalIndex	PhysicalIndex,
entPhysicalDescr	SnmpAdminString,
entPhysicalVendorType	AutonomousType,
entPhysicalContainedIn	PhysicalIndexOrZero,
entPhysicalClass	IANAPhysicalClass,
entPhysicalParentRelPos	Integer32,

```

    entPhysicalName          SnmpAdminString,
    entPhysicalHardwareRev   SnmpAdminString,
    entPhysicalFirmwareRev   SnmpAdminString,
    entPhysicalSoftwareRev   SnmpAdminString,
    entPhysicalSerialNum     SnmpAdminString,
    entPhysicalMfgName       SnmpAdminString,
    entPhysicalModelName     SnmpAdminString,
    entPhysicalAlias         SnmpAdminString,
    entPhysicalAssetID       SnmpAdminString,
    entPhysicalIsFRU         TruthValue,
    entPhysicalMfgDate       DateAndTime,
    entPhysicalUris          Uri
}

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

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

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

        An agent should set this object to an enterprise-specific

```

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

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

::= { entPhysicalEntry 3 }

entPhysicalContainedIn OBJECT-TYPE

SYNTAX PhysicalIndexOrZero

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

::= { entPhysicalEntry 4 }

entPhysicalClass OBJECT-TYPE

SYNTAX IANAPhysicalClass

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

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

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

entPhysicalParentRelPos OBJECT-TYPE

SYNTAX Integer32 (-1..2147483647)

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

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

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

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

Parent-relative ordering normally starts from '1' and continues to 'N', where 'N' represents the highest positioned child entity. However, if the physical entities (e.g., slots) are labeled from a starting position of zero,

then the first sibling should be associated with an entPhysicalParentRelPos value of '0'. Note that this ordering may be sparse or dense, depending on agent implementation.

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

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

::= { entPhysicalEntry 6 }

entPhysicalName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

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

::= { entPhysicalEntry 7 }

entPhysicalHardwareRev OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

(if present).

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

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

::= { entPhysicalEntry 8 }

entPhysicalFirmwareRev OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

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

::= { entPhysicalEntry 9 }

entPhysicalSoftwareRev OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

Note that if revision information is stored internally in a

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

If no specific software programs are associated with the

physical component, or if this information is unknown to the agent, then this object will contain a zero-length string."
 ::= { entPhysicalEntry 10 }

entPhysicalSerialNum OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..32))

MAX-ACCESS read-write

STATUS current

DESCRIPTION

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

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

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

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

If write access is implemented for an instance of entPhysicalSerialNum, and a value is written into the instance, the agent must retain the supplied value in the entPhysicalSerialNum instance (associated with the same physical entity) for as long as that entity remains instantiated. This includes instantiations across all re-initializations/reboots of the network management system, including those resulting in a change of the physical

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

entPhysicalMfgName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

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

::= { entPhysicalEntry 12 }

entPhysicalModelName OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

::= { entPhysicalEntry 13 }

entPhysicalAlias OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..32))

MAX-ACCESS read-write

STATUS current

DESCRIPTION

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

On the first instantiation of a physical entity, the value

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

If write access is implemented for an instance of entPhysicalAlias, and a value is written into the instance, the agent must retain the supplied value in the entPhysicalAlias instance (associated with the same physical entity) for as long as that entity remains instantiated. This includes instantiations across all re-initializations/reboots of the network management system, including those resulting in a change of the physical entity's entPhysicalIndex value."

```
::= { entPhysicalEntry 14 }
```

entPhysicalAssetID OBJECT-TYPE

SYNTAX SnmpAdminString (SIZE (0..32))

MAX-ACCESS read-write

STATUS current

DESCRIPTION

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

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

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

If write access is implemented for an instance of entPhysicalAssetID, and a value is written into the instance, the agent must retain the supplied value in the entPhysicalAssetID instance (associated with the same physical entity) for as long as that entity remains instantiated. This includes instantiations across all re-initializations/reboots of the network management system, including those resulting in a change of the physical entity's entPhysicalIndex value.

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

```
::= { entPhysicalEntry 15 }
```

entPhysicalIsFRU OBJECT-TYPE

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

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

```
::= { entPhysicalEntry 16 }
```

entPhysicalMfgDate OBJECT-TYPE

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

"This object contains the date of manufacturing of the managed entity. If the manufacturing date is unknown or not supported, the object is not instantiated. The special value '0000000000000000'H may also be returned in this case."

```
::= { entPhysicalEntry 17 }
```

entPhysicalUri OBJECT-TYPE

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

"This object contains additional identification information about the physical entity. The object contains URIs and, therefore, the syntax of this object must conform to RFC 3986, section 2.

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

If no additional identification information is known about the physical entity or supported, the object is not instantiated. A zero length octet string may also be

returned in this case."

REFERENCE

"RFC 3986, Uniform Resource Identifiers (URI): Generic Syntax, section 2, August 1998."

::= { entPhysicalEntry 18 }

-- The Logical Entity Table

entLogicalTable OBJECT-TYPE

SYNTAX SEQUENCE OF EntLogicalEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table contains one row per logical entity. For agents that implement more than one naming scope, at least one entry must exist. Agents which instantiate all MIB objects within a single naming scope are not required to implement this table."

::= { entityLogical 1 }

entLogicalEntry OBJECT-TYPE

SYNTAX EntLogicalEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"Information about a particular logical entity. Entities may be managed by this agent or other SNMP agents (possibly) in the same chassis."

INDEX { entLogicalIndex }

::= { entLogicalTable 1 }

EntLogicalEntry ::= SEQUENCE {

entLogicalIndex	Integer32,
entLogicalDescr	SnmpAdminString,
entLogicalType	AutonomousType,
entLogicalCommunity	OCTET STRING,
entLogicalTAddress	TAddress,
entLogicalTDomain	TDomain,
entLogicalContextEngineID	SnmpEngineIdOrNone,
entLogicalContextName	SnmpAdminString

}

entLogicalIndex OBJECT-TYPE

SYNTAX Integer32 (1..2147483647)

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

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

::= { entLogicalEntry 1 }

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

entLogicalType OBJECT-TYPE
SYNTAX AutonomousType
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"An indication of the type of logical entity. This will typically be the OBJECT IDENTIFIER name of the node in the SMI's naming hierarchy which represents the major MIB module, or the majority of the MIB modules, supported by the logical entity. For example:
a logical entity of a regular host/router -> mib-2
a logical entity of a 802.1d bridge -> dot1dBridge
a logical entity of a 802.3 repeater -> snmpDot3RptrMgmt
If an appropriate node in the SMI's naming hierarchy cannot be identified, the value 'mib-2' should be used."
 ::= { entLogicalEntry 3 }

entLogicalCommunity OBJECT-TYPE
SYNTAX OCTET STRING (SIZE (0..255))
MAX-ACCESS read-only
STATUS deprecated
DESCRIPTION
"An SNMPv1 or SNMPv2C community-string, which can be used to access detailed management information for this logical entity. The agent should allow read access with this community string (to an appropriate subset of all managed objects) and may also return a community string based on the privileges of the request used to read this object. Note that an agent may return a community string with read-only privileges, even if this object is accessed with a read-write community string. However, the agent must take

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

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

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

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

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

::= { entLogicalEntry 4 }

entLogicalTAddress OBJECT-TYPE

SYNTAX TAddress

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

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

```
 ::= { entLogicalEntry 5 }

entLogicalTDomain OBJECT-TYPE
    SYNTAX      TDomain
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Indicates the kind of transport service by which the
        logical entity receives network management traffic.
        Possible values for this object are presently found in the
        Transport Mappings for Simple Network Management Protocol'
        (STD 62, RFC 3417 [RFC3417])."
    ::= { entLogicalEntry 6 }

entLogicalContextEngineID OBJECT-TYPE
    SYNTAX      SnmpEngineIdOrNone
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "The authoritative contextEngineID that can be used to send
        an SNMP message concerning information held by this logical
        entity, to the address specified by the associated
        'entLogicalTAddress/entLogicalTDomain' pair.

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

        If no value has been configured by the agent, a zero-length
        string is returned, or the agent may choose not to
        instantiate this object at all."
    ::= { entLogicalEntry 7 }

entLogicalContextName OBJECT-TYPE
    SYNTAX      SnmpAdminString
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "The contextName that can be used to send an SNMP message
        concerning information held by this logical entity, to the
        address specified by the associated
        'entLogicalTAddress/entLogicalTDomain' pair.

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


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

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

::= { entLogicalEntry 8 }

entLPMappingTable OBJECT-TYPE

SYNTAX SEQUENCE OF EntLPMappingEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

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

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

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

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

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

::= { entityMapping 1 }

entLPMappingEntry OBJECT-TYPE

SYNTAX EntLPMappingEntry

MAX-ACCESS not-accessible

```
STATUS      current
DESCRIPTION
    "Information about a particular logical entity to physical
    equipment association. Note that the nature of the
    association is not specifically identified in this entry.
    It is expected that sufficient information exists in the
    MIBs used to manage a particular logical entity to infer how
    physical component information is utilized."
INDEX       { entLogicalIndex, entLPPhysicalIndex }
 ::= { entLPMappingTable 1 }

EntLPMappingEntry ::= SEQUENCE {
    entLPPhysicalIndex      PhysicalIndex
}

entLPPhysicalIndex OBJECT-TYPE
    SYNTAX      PhysicalIndex
    MAX-ACCESS   read-only
    STATUS      current
    DESCRIPTION
        "The value of this object identifies the index value of a
        particular entPhysicalEntry associated with the indicated
        entLogicalEntity."
    ::= { entLPMappingEntry 1 }

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

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

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

Note that only entPhysicalIndex values that represent physical ports (i.e., associated entPhysicalClass value is 'port(10)') are permitted to exist in this table."

```
INDEX { entPhysicalIndex, entAliasLogicalIndexOrZero }
::= { entAliasMappingTable 1 }
```

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

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

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

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

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

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

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

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

```

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

```

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

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

entAliasMappingIdentifier OBJECT-TYPE

SYNTAX RowPointer

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The value of this object identifies a particular conceptual row associated with the indicated entPhysicalIndex and entLogicalIndex pair.

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

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

entAliasMappingIdentifier:

```
entAliasMappingIdentifier.3.15 == rpPtrPortGroupIndex.5.2
```

```
entAliasMappingIdentifier.3.22 == ifIndex.17
```

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

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

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

-- physical mapping table

entPhysicalContainsTable OBJECT-TYPE

SYNTAX SEQUENCE OF EntPhysicalContainsEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

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

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

::= { entityMapping 3 }

entPhysicalContainsEntry OBJECT-TYPE

SYNTAX EntPhysicalContainsEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"A single container/'containee' relationship."

INDEX { entPhysicalIndex, entPhysicalChildIndex }

::= { entPhysicalContainsTable 1 }

EntPhysicalContainsEntry ::= SEQUENCE {
 entPhysicalChildIndex PhysicalIndex
}

entPhysicalChildIndex OBJECT-TYPE

SYNTAX PhysicalIndex

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The value of entPhysicalIndex for the contained physical entity."

::= { entPhysicalContainsEntry 1 }

-- last change time stamp for the whole MIB

entLastChangeTime OBJECT-TYPE

SYNTAX TimeStamp

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The value of sysUpTime at the time a conceptual row is created, modified, or deleted in any of these tables:

- entPhysicalTable
- entLogicalTable
- entLPMappingTable
- entAliasMappingTable

```

        - entPhysicalContainsTable
        "
 ::= { entityGeneral 1 }

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

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

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

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

        An NMS should periodically check the value of
        entLastChangeTime to detect any missed entConfigChange
        notification-events, e.g., due to throttling or transmission
        loss."
 ::= { entityMIBTrapPrefix 1 }

-- conformance information
entityConformance OBJECT IDENTIFIER ::= { entityMIB 3 }

entityCompliances OBJECT IDENTIFIER ::= { entityConformance 1 }
entityGroups      OBJECT IDENTIFIER ::= { entityConformance 2 }

-- compliance statements
entityCompliance MODULE-COMPLIANCE
    STATUS deprecated
```

```
DESCRIPTION
    "The compliance statement for SNMP entities that implement
    version 1 of the Entity MIB."
MODULE -- this module
    MANDATORY-GROUPS {
        entityPhysicalGroup,
        entityLogicalGroup,
        entityMappingGroup,
        entityGeneralGroup,
        entityNotificationsGroup
    }
 ::= { entityCompliances 1 }

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

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

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

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

NMS-assigned serial numbers.

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

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

OBJECT entPhysicalAlias

MIN-ACCESS read-only

DESCRIPTION

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

OBJECT entPhysicalAssetID

MIN-ACCESS not-accessible

DESCRIPTION

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

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

OBJECT entPhysicalClass

SYNTAX INTEGER {

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

}

DESCRIPTION

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

::= { entityCompliances 2 }


```
entity3Compliance MODULE-COMPLIANCE
  STATUS current
  DESCRIPTION
    "The compliance statement for SNMP entities that implement
    version 3 and 4 (full compliance) of the Entity MIB."
  MODULE -- this module
    MANDATORY-GROUPS {
      entityPhysicalGroup,
      entityPhysical2Group,
      entityGeneralGroup,
      entityNotificationsGroup
    }
  GROUP entityLogical2Group
  DESCRIPTION
    "Implementation of this group is not mandatory for agents
    that model all MIB object instances within a single naming
    scope."

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

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

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

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

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

  OBJECT entPhysicalAlias
```

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

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

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

```
entity4CRCompliance MODULE-COMPLIANCE
STATUS    current
DESCRIPTION
    "The compliance statement for SNMP entities that implement
    version 4 of the Entity MIB on devices with constrained
    resources."
MODULE -- this module
MANDATORY-GROUPS {
    entityPhysicalCRGroup
}

OBJECT entPhysicalUri
SYNTAX Uri    (SIZE (0 | 45))
MIN-ACCESS    read-only
DESCRIPTION
    "Write access is not required for agents that
    implement version 4 of the Entity MIB on devices with
    constrained resources.

    Size is constrained to 45 to allow only for RFC 4122
    compliant values and 0 for cases when the object is
    not instantiated."

::= { entityCompliances 4 }
```

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

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

    ::= { entityGroups 2 }

entityMappingGroup       OBJECT-GROUP
    OBJECTS {
        entLPPPhysicalIndex,
        entAliasMappingIdentifier,
        entPhysicalChildIndex
    }
    STATUS current
    DESCRIPTION
        "The collection of objects used to represent the
        associations between multiple logical entities, physical
        components, interfaces, and port identifiers, for which a
        single agent provides management information."
    ::= { entityGroups 3 }
```

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

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

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

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

entityLogical2Group      OBJECT-GROUP
  OBJECTS {
    entLogicalDescr,
    entLogicalType,
    entLogicalTAddress,
    entLogicalTDomain,
```

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

entityPhysicalCRGroup    OBJECT-GROUP
    OBJECTS {
        entPhysicalName,
        entPhysicalMfgDate,
        entPhysicalUris
    }
    STATUS current
    DESCRIPTION
        "The collection of objects used to represent physical
        system components for constrained resourced devices,
        for which a single agent provides
        management information."
    ::= { entityGroups 8 }
```

END

3.2. IANA-ENTITY-MIB

IANA-ENTITY-MIB DEFINITIONS ::= BEGIN

IMPORTS

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

ianaEntityMIB MODULE-IDENTITY

```
    LAST-UPDATED "201206100000Z" -- June 10, 2011
    ORGANIZATION "IANA"
    CONTACT-INFO "          Internet Assigned Numbers Authority

                        Postal: ICANN
                        4676 Admiralty Way, Suite 330
                        Marina del Rey, CA 90292
```

Tel: +1-310-823-9358
EMail: iana@iana.org"

DESCRIPTION

"This MIB module

Copyright (C) The IETF Trust (2012).
The initial version of this MIB module was published in
RFC yyyy; for full legal notices see the RFC itself.
Supplementary information may be available at:
<http://www.ietf.org/copyrights/ianamib.html>"

REVISION "201206100000Z" -- June 10, 2012

DESCRIPTION "Initial version of this MIB as published in
RFC yyyy."

::= { mib-2 xxx }

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

-- Textual Conventions

IANAPhysicalClass ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

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

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

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

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

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

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

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

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

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

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

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

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

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

The enumeration ?energyObject? is applicable if the physical entity is some sort of a energy object i.e. a piece of equipment that is part of or attached to a communications network that is monitored, controlled, or aids in the management of another device for Energy Management.

The enumeration ?battery? is applicable of the physical entity class is some sort of an energy battery device. "

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

END

4. Usage Examples

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

4.1. Router/Bridge

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

```
Physical entities -- entPhysicalTable:
1 Field-replaceable physical chassis:
  entPhysicalDescr.1 ==      'Acme Chassis Model 100'
  entPhysicalVendorType.1 == acmeProducts.chassisTypes.1
  entPhysicalContainedIn.1 == 0
  entPhysicalClass.1 ==      chassis(3)
  entPhysicalParentRelPos.1 == 0
  entPhysicalName.1 ==        '100-A'
  entPhysicalHardwareRev.1 == 'A(1.00.02)'
  entPhysicalSoftwareRev.1 == ''
  entPhysicalFirmwareRev.1 == ''
  entPhysicalSerialNum.1 ==   'C100076544'
  entPhysicalMfgName.1 ==      'Acme'
  entPhysicalModelName.1 ==    '100'
  entPhysicalAlias.1 ==        'cl-SJ17-3-006:rack1:rtr-U3'
  entPhysicalAssetID.1 ==      '0007372293'
  entPhysicalIsFRU.1 ==        true(1)
  entPhysicalMfgDate.1 ==      '2002-5-26,13:30:30.0,-4:0'
  entPhysicalUris.1 ==         'URN:CLEI:CNME120ARA'
2 slots within the chassis:
  entPhysicalDescr.2 ==      'Acme Chassis Slot Type AA'
  entPhysicalVendorType.2 == acmeProducts.slotTypes.1
  entPhysicalContainedIn.2 == 1
  entPhysicalClass.2 ==      container(5)
  entPhysicalParentRelPos.2 == 1
  entPhysicalName.2 ==        'S1'
  entPhysicalHardwareRev.2 == 'B(1.00.01)'
  entPhysicalSoftwareRev.2 == ''
  entPhysicalFirmwareRev.2 == ''
  entPhysicalSerialNum.2 ==   ''
  entPhysicalMfgName.2 ==      'Acme'
  entPhysicalModelName.2 ==    'AA'
  entPhysicalAlias.2 ==        ''
```

```

entPhysicalAssetID.2 ==      ''
entPhysicalIsFRU.2 ==       false(2)
entPhysicalMfgDate.2 ==     '2002-7-26,12:22:12.0,-4:0'
entPhysicalUris.2 ==        'URN:CLEI:CNME123ARA'

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

```

2 Field-replaceable modules:

Slot 1 contains a module with 3 ports:

```

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

entPhysicalDescr.5 ==       'Acme Ethernet-100 Port'
entPhysicalVendorType.5 ==  acmeProducts.portTypes.2
entPhysicalContainedIn.5 ==  4
entPhysicalClass.5 ==       port(10)
entPhysicalParentRelPos.5 == 1

```

```
entPhysicalName.5 ==          'P1'
entPhysicalHardwareRev.5 ==   'G(1.02)'
entPhysicalSoftwareRev.5 ==   ''
entPhysicalFirmwareRev.5 ==   '1.1'
entPhysicalSerialNum.5 ==     ''
entPhysicalMfgName.5 ==       'Acme'
entPhysicalModelName.5 ==     'FE-100'
entPhysicalAlias.5 ==         ''
entPhysicalAssetID.5 ==       ''
entPhysicalIsFRU.5 ==         false(2)
entPhysicalMfgDate.5 ==       '2003-7-18,14:20:22.0,-4:0'
entPhysicalUris.5 ==          'URN:CLEI:CNMES23ARA'

entPhysicalDescr.6 ==         'Acme Ethernet-100 Port'
entPhysicalVendorType.6 ==    acmeProducts.portTypes.2
entPhysicalContainedIn.6 ==    4
entPhysicalClass.6 ==         port(10)
entPhysicalParentRelPos.6 ==   2
entPhysicalName.6 ==          'P2'
entPhysicalHardwareRev.6 ==   'G(1.02)'
entPhysicalSoftwareRev.6 ==   ''
entPhysicalFirmwareRev.6 ==   '1.1'
entPhysicalSerialNum.6 ==     ''
entPhysicalMfgName.6 ==       'Acme'
entPhysicalModelName.6 ==     'FE-100'
entPhysicalAlias.6 ==         ''
entPhysicalAssetID.6 ==       ''
entPhysicalIsFRU.6 ==         false(2)
entPhysicalMfgDate.6 ==       '2003-7-19,10:15:15.0,-4:0'
entPhysicalUris.6 ==          'URN:CLEI:CNMES23ARA'

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

Slot 2 contains another 3-port module:

```

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

entPhysicalDescr.9 ==      'Acme Fddi-100 Port'
entPhysicalVendorType.9 == acmeProducts.portTypes.5
entPhysicalContainedIn.9 == 8
entPhysicalClass.9 ==      port(10)
entPhysicalParentRelPos.9 == 1
entPhysicalName.9 ==        'FDDI Primary'
entPhysicalHardwareRev.9 == 'CC(1.07)'
entPhysicalSoftwareRev.9 == '2.0.34'
entPhysicalFirmwareRev.9 == '1.1'
entPhysicalSerialNum.9 ==   ''
entPhysicalMfgName.9 ==     'Acme'
entPhysicalModelName.9 ==   'FDDI-100'
entPhysicalAlias.9 ==       ''
entPhysicalAssetID.9 ==     ''
entPhysicalIsFRU.9 ==       false(2)

entPhysicalDescr.10 ==     'Acme Ethernet-100 Port'
entPhysicalVendorType.10 == acmeProducts.portTypes.2
entPhysicalContainedIn.10 == 8
entPhysicalClass.10 ==     port(10)
entPhysicalParentRelPos.10 == 2
entPhysicalName.10 ==      'Ethernet A'
entPhysicalHardwareRev.10 == 'G(1.04)'
entPhysicalSoftwareRev.10 == ''
entPhysicalFirmwareRev.10 == '1.3'
entPhysicalSerialNum.10 ==  ''
entPhysicalMfgName.10 ==    'Acme'
entPhysicalModelName.10 ==  'FE-100'
entPhysicalAlias.10 ==     ''

```

```

entPhysicalAssetID.10 ==      ''
entPhysicalIsFRU.10 ==      false(2)
entPhysicalMfgDate.10 ==     '2002-7-26,13:30:15.0,-4:0'
entPhysicalUris.10 ==        'URN:CLEI:CNMES23ARA'

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

```

Logical entities -- entLogicalTable; no SNMPv3 support

2 OSPF instances:

```

entLogicalDescr.1 ==         'Acme OSPF v1.1'
entLogicalType.1 ==          ospf
entLogicalCommunity.1 ==     'public-ospf1'
entLogicalTAddress.1 ==      192.0.2.1:161
entLogicalTDomain.1 ==       snmpUDPDomain
entLogicalContextEngineID.1 == ''
entLogicalContextName.1 ==   ''

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

```

2 logical bridges:

```

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

```

```

entLogicalContextName.3 ==      ''

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

```

Logical to Physical Mappings:

```

1st OSPF instance: uses module 1-port 1
entLPPPhysicalIndex.1.5 ==      5

```

```

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

```

1st bridge group: uses module 1, all ports

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

```

entLPPPhysicalIndex.3.5 ==      5
entLPPPhysicalIndex.3.6 ==      6
entLPPPhysicalIndex.3.7 ==      7

```

2nd bridge group: uses module 2, all ports

```

entLPPPhysicalIndex.4.9 ==      9
entLPPPhysicalIndex.4.10 ==     10
entLPPPhysicalIndex.4.11 ==     11

```

Physical to Logical to MIB Alias Mappings -- entAliasMappingTable:

Example 1: ifIndex values are global to all logical entities

```

entAliasMappingIdentifier.5.0 == ifIndex.1
entAliasMappingIdentifier.6.0 == ifIndex.2
entAliasMappingIdentifier.7.0 == ifIndex.3
entAliasMappingIdentifier.9.0 == ifIndex.4
entAliasMappingIdentifier.10.0 == ifIndex.5
entAliasMappingIdentifier.11.0 == ifIndex.6

```

Example 2: ifIndex values are not shared by all logical entities;
(Bridge-1 uses ifIndex values 101 - 103 and Bridge-2 uses
ifIndex values 204-206.)

```

entAliasMappingIdentifier.5.0 == ifIndex.1
entAliasMappingIdentifier.5.3 == ifIndex.101
entAliasMappingIdentifier.6.0 == ifIndex.2

```

```

entAliasMappingIdentifier.6.3 == ifIndex.102
entAliasMappingIdentifier.7.0 == ifIndex.3
entAliasMappingIdentifier.7.3 == ifIndex.103
entAliasMappingIdentifier.9.0 == ifIndex.4
entAliasMappingIdentifier.9.4 == ifIndex.204
entAliasMappingIdentifier.10.0 == ifIndex.5
entAliasMappingIdentifier.10.4 == ifIndex.205
entAliasMappingIdentifier.11.0 == ifIndex.6
entAliasMappingIdentifier.11.4 == ifIndex.206

```

Physical Containment Tree -- entPhysicalContainsTable

chassis has two containers:

```

entPhysicalChildIndex.1.2 == 2
entPhysicalChildIndex.1.3 == 3

```

container 1 has a module:

```

entPhysicalChildIndex.2.4 == 4

```

container 2 has a module:

```

entPhysicalChildIndex.3.8 == 8

```

module 1 has 3 ports:

```

entPhysicalChildIndex.4.5 == 5
entPhysicalChildIndex.4.6 == 6
entPhysicalChildIndex.4.7 == 7

```

module 2 has 3 ports:

```

entPhysicalChildIndex.8.9 == 9
entPhysicalChildIndex.8.10 == 10
entPhysicalChildIndex.8.11 == 11

```

4.2. Repeaters

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

Note that this example assumes an older Repeater MIB implementation, (RFC 1516 [RFC1516]) rather than the new Repeater MIB (RFC 2108 [RFC2108]). The new version contains an object called 'rpPtrPortRpPtrId', which should be used to identify repeater port groupings, rather than using community strings or contexts.

Physical entities -- entPhysicalTable:

1 Field-replaceable physical chassis:

```

entPhysicalDescr.1 == 'Acme Chassis Model 110'
entPhysicalVendorType.1 == acmeProducts.chassisTypes.2
entPhysicalContainedIn.1 == 0

```

```
entPhysicalClass.1 ==      chassis(3)
entPhysicalParentRelPos.1 ==0
entPhysicalName.1 ==      '110-B'
entPhysicalHardwareRev.1 == 'A(1.02.00)'
entPhysicalSoftwareRev.1 == ''
entPhysicalFirmwareRev.1 == ''
entPhysicalSerialNum.1 ==  'C100079294'
entPhysicalMfgName.1 ==    'Acme'
entPhysicalModelName.1 ==  '110'
entPhysicalAlias.1 ==      'bldg09:floor1:rp1r18:0067eea0229f'
entPhysicalAssetID.1 ==    '0007386327'
entPhysicalIsFRU.1 ==      true(1)
```

2 Chassis Ethernet Backplanes:

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

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



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

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

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

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

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

entPhysicalDescr.8 ==      'Acme 10Base-T Port RB'
entPhysicalVendorType.8 == acmeProducts.portTypes.10
entPhysicalContainedIn.8 == 7
entPhysicalClass.8 ==      port(10)
entPhysicalParentRelPos.8 == 1
entPhysicalName.8 ==        'Ethernet-A'
entPhysicalHardwareRev.8 == 'A(1.04F)'
entPhysicalSoftwareRev.8 == ''
entPhysicalFirmwareRev.8 == '1.4'
entPhysicalSerialNum.8 ==   ''
entPhysicalMfgName.8 ==     'Acme'
entPhysicalModelName.8 ==   'RB'
entPhysicalAlias.8 ==       ''
entPhysicalAssetID.8 ==     ''
entPhysicalIsFRU.8 ==       false(2)

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

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

```
entPhysicalDescr.11 ==      'Acme 10Base-T Port RB'
entPhysicalVendorType.11 == acmeProducts.portTypes.10
entPhysicalContainedIn.11 == 7
entPhysicalClass.11 ==      port(10)
entPhysicalParentRelPos.11 == 4
entPhysicalName.11 ==       'Ethernet-D'
entPhysicalHardwareRev.11 == 'B(1.02.07)'
entPhysicalSoftwareRev.11 == ''
entPhysicalFirmwareRev.11 == '1.4'
entPhysicalSerialNum.11 ==  ''
entPhysicalMfgName.11 ==    'Acme'
entPhysicalModelName.11 ==  'RB'
entPhysicalAlias.11 ==      ''
entPhysicalAssetID.11 ==    ''
entPhysicalIsFRU.11 ==      false(2)
```

Slot 2 contains another ethernet module with 2 ports.

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

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

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

Logical entities -- entLogicalTable; with SNMPv3 support

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

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

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

```
entLogicalDescr.2 ==      'Acme repeater v3.1'
entLogicalType.2 ==       snmpDot3RptrMgt
entLogicalCommunity.2 ==  'public-repeater2'
entLogicalTAddress.2 ==   192.0.2.1:161
entLogicalTDomain.2 ==    snmpUDPDomain
```

```
entLogicalContextEngineID.2 == '80000777017c7d7e7f'H
entLogicalContextName.2 ==    'repeater2'
```

Logical to Physical Mappings -- entLPMappingTable:

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

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

```
repeater2 uses backplane 2, slot 1-ports 3 & 4, slot 2-port 2
entLPPhysicalIndex.2.3 ==      3
entLPPhysicalIndex.2.10 ==     10
entLPPhysicalIndex.2.11 ==     11
entLPPhysicalIndex.2.14 ==     14
```

Physical to Logical to MIB Alias Mappings -- entAliasMappingTable:

Repeater Port Identifier values are shared by both repeaters:

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

Physical Containment Tree -- entPhysicalContainsTable

chassis has two backplanes and three containers:

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

container 1 has a module:

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

container 2 has a module

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

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

```
module 1 has 4 ports:
    entPhysicalChildIndex.7.8 == 8
    entPhysicalChildIndex.7.9 == 9
    entPhysicalChildIndex.7.10 == 10
    entPhysicalChildIndex.7.11 == 11

module 2 has 2 ports:
    entPhysicalChildIndex.12.13 == 13
    entPhysicalChildIndex.12.14 == 14
```

5. Security Considerations

There are a number of management objects defined in this MIB that have 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.

There are a number of managed objects in this MIB that may contain sensitive information. These are:

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

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

```
entPhysicalAssetID
```

This object can allow asset identifiers for various system components to be exposed, in the event this MIB object is actually configured by an NMS application.

```
entLogicalDescr
entLogicalType
```

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

entLogicalCommunity

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

entLogicalTAddress entLogicalTDomain

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

entLogicalContextEngineID entLogicalContextName

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

It is thus important to control even GET access to these objects and possibly to even encrypt the values of these object when sending them over the network via SNMP. Not all versions of SNMP provide features for such a secure environment.

SNMPv1 by itself is not a secure environment. Even if the network itself is secure (for example by using IPSec), even then, there is no control as to who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in this MIB.

It is recommended that the implementers consider the security features as provided by the SNMPv3 framework. Specifically, the use of the User-based Security Model RFC 3414 [RFC3414] and the View-based Access Control Model RFC 3415 [RFC3415] is recommended.

It is then a customer/user responsibility to ensure that the SNMP entity giving access to an instance of this MIB, is properly configured to give access to the objects only to those principals (users) that have legitimate rights to indeed GET or SET (change/create/delete) them.

6. IANA Considerations

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

Descriptor	OBJECT IDENTIFIER value
-----	-----
entityMIB	{ mib-2 47 }

7. Acknowledgements

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

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

The authors also thank Juergen Schoenwaelder for his review and comments on this draft.

8. Open Issues

Open issue 1: entPhysicalUUID object with a compact UUID representation instead of using the URI format.

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Energy Management (EMAN) Applicability Statement
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Abstract

The objective of Energy Management (EMAN) is to provide an energy management framework for networked devices. This document presents the applicability of the EMAN framework for a variety of scenarios. This document lists use cases and target devices that can potentially implement the EMAN framework and associated SNMP MIB modules. These use cases are useful for identifying requirements for the framework. Further, we describe the relationship of the EMAN framework to relevant other energy monitoring standards and architectures.

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1. Introduction

The focus of the Energy Management (EMAN) framework is energy monitoring and management of energy objects [EMAN-DEF]. The scope of devices considered are network equipment and its components, and devices connected directly or indirectly to the network. The EMAN framework enables monitoring (heterogeneous devices to report their energy consumption) and, if permissible, control. There are multiple scenarios where this is desirable, particularly considering the increased importance of limiting consumption of finite energy resources and reducing operational expenses.

The EMAN framework [EMAN-FRAMEWORK] describes how energy information can be retrieved from IP-enabled devices using Simple Network Management Protocol (SNMP), specifically, Management Information Base (MIBs) for SNMP.

This document describes typical applications of the EMAN
framework, as well as its opportunities and limitations. Other

<Tychon, et al.>

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standards that are similar to EMAN but address different domains
are described. This document contains references to those other
standards and describes how they relate to the EMAN framework.

The rest of the document is organized as follows. Section 2
contains a list of use cases or network scenarios that EMAN
shall address. Section 3 contains an abstraction of the use case
scenarios to distinct patterns. Section 4 deals with the
standards related to EMAN and applicable to EMAN.

1.1. Energy Management Overview

EMAN addresses the electrical energy consumed by devices
connected to a network. A first step to increase the energy
efficiency in networks and buildings is to enable energy objects
to report their energy usage over time. The EMAN framework
addresses this problem with an information model for some
electrical equipment: energy object identification, energy
object context, power measurement and power characteristics.

The EMAN WG framework defines SNMP MIB modules based on the
information model. By implementing the SNMP MIB modules, any
energy object can report its energy consumption according to the
information model. In that context, it is important to
distinguish energy objects that can only report their own energy
usage from devices that can also collect and aggregate energy
usage of other energy objects.

Target devices and scenarios considered for Energy Management
are presented in Section 2 with detailed examples.

1.2. EMAN WG Document Overview

The EMAN working group charter called for producing a series of
Internet standard drafts in the area of energy management. The
following drafts were created by the working group.

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

Requirements [EMAN-REQ] this document presents the
requirements of energy management and the scope of the devices
considered.

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Framework [EMAN-FRAMEWORK] This document defines a framework
for providing Energy Management for devices within or
connected to communication networks.

Energy-Aware MIB [EMAN-AWARE-MIB] This document proposes a MIB
module that characterizes a device's identity, context and the
relationship to other entities.

Monitoring MIB [EMAN-MONITORING-MIB] This document defines a
MIB module for monitoring the power and energy consumption of
a device. The MIB module contains an optional module for
metrics associated with power characteristics.

Battery MIB [EMAN-BATTERY-MIB] This document contains a MIB
module for monitoring characteristics of an internal battery.

Energy Management Terminology [EMAN-DEF] This document lists
the definitions for the common terms used in the Energy
Management Working Group.

1.3. Energy Measurement

More and more devices are able to measure and report their own
energy consumption. Smart power strips and some Power over
Ethernet (PoE) switches can meter consumption of connected
devices. However, when managed and reported through proprietary
means, this information is minimally useful at the enterprise
level.

The primary goal of the EMAN MIBs is to enable reporting and
management within a standard framework that is applicable to a
wide variety of end devices, meters, and proxies. This enables a
management system to know who's consuming what, when, and how at
any time by leveraging existing networks, across various
equipment, in a unified and consistent manner.

Given that an energy object can consume energy and/or provide
energy to other devices, there are three types of energy
measurement: energy input to a device, energy supplied to other
devices, and net (resultant) energy consumed (the difference
between energy input and provided).

1.4. Energy Management

Beyond energy monitoring, the EMAN framework provides mechanisms
for energy control.

There are many cases where reducing energy consumption of devices is desirable, such as when the device utilization is low or when the electricity is expensive or in short supply.

In some cases, energy control requires considering the energy object context. For instance, in a building during non-business hours: usually not all phones would be turned off to keep some phones available in case of emergency; office cooling is usually not turned off totally, but the comfort level is reduced.

Energy object control requires flexibility and support for different policies and mechanisms: from centralized management with a network management station, to autonomous management by individual devices, and alignment with dynamic demand-response mechanisms.

The EMAN framework can be used as a tool for the demand/response scenario where in response to time-of-day fluctuation of energy costs or possible energy shortages, it is possible to respond and reduce the energy consumption for the network devices, effectively changing its power state.

1.5. EMAN Framework Application

A Network Management System (NMS) is the entity that requests information from compatible devices using SNMP protocol. An NMS implements many network management functions, e.g. security management, or identity management. An NMS that deals exclusively with energy is called EnMS Energy Management System. It may be limited to monitoring energy use, or it may also implement control functions. In a typical application of the EMAN framework, management software collects energy information for devices in the network.

Energy management can be implemented by extending existing SNMP support to the EMAN specific MIBs. SNMP provides an industry proven and well-known mechanism to discover, secure, measure, and control SNMP-enabled end devices. The EMAN framework provides an information and data model to unify access to a large range of devices.

The scope of the target devices and the network scenarios considered for energy management are listed in Section 2.

In this section a selection of scenarios for energy management are presented. The fundamental objective of the use cases is to list important network scenarios that the EMAN framework should solve. These use cases then drive the requirements for the EMAN framework.

Each scenario lists target devices for which the energy management framework can be applied, how the reported-on devices are powered, and how the reporting is accomplished. While there is some overlap between some of the use cases, the use cases serve as illustrative network scenarios EMAN framework supports.

2.1. Network Infrastructure Energy Objects

This scenario covers network devices and their components. Power management of energy objects is considered as a fundamental requirement of energy management of networks.

It can be important to monitor the energy consumption and possibly manage the power state of these devices at a granularity level finer than just the entire device. For these devices, the chassis draws power from one or more sources and feeds all its internal components. It is highly desirable to have monitoring available for individual components, such as line cards, processors, and hard drives as well as peripherals like USB devices.

As an illustrative example, consider a switch with the following grouping of sub-entities for which energy management could be useful.

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

The ENTITY-MIB provides the containment tree framework, for uniquely identifying the physical sub-components of network devices. A component can be an Energy Object and the ENTITY-MIB containment tree shall express if that Energy Object belongs to another Energy Object (e.g. line-card Energy Object contained in a chassis Energy Object. The table entPhysicalContainsTable which has the index of entPhysicalChildIndex and the MIB object entPhysicalContainedIn which points to the containing entity.

- . Target devices: network devices such as routers, switches and their components.
- . How powered: typically by a PDU on a rack or from a wall outlet. The components of a device are powered by the device chassis.
- . Reporting: direct power measurement can be performed at a device level. Components can report their power consumption directly or the chassis/device that can report on behalf of some components.

2.2. Devices Powered by and Connected to a Network Device

This scenario covers Power over Ethernet (PoE) devices. A PoE Power Sourcing Equipment (PSE) device [RFC3621] (e.g. a PoE switch) provides power to a Powered Device (PD) (e.g. a desktop phone). For each port, the PSE can control the power supply (switching it on and off) and meter actual power provided. PDs obtain network connectivity as well as power over a single connection so the PSE can determine which device is associated with each port.

PoE ports on a switch are commonly connected to devices such as IP phones, wireless access points, and IP cameras. The switch needs power for its internal use and to supply power to PoE ports. Monitoring the power consumption of the switch (supplying device) and the power consumption of the PoE end-points (consuming devices) is a simple use case of this scenario.

It is also possible to illustrate the relationships between entities. The PoE IP phone is powered by the switch. If there are many IP phones connected to the same switch and the power consumption of all the IP phones can be aggregated by the switch. In that case, the switch performs the aggregation function for other entities.

The essential properties of this use case are:

- . Target devices: power over Ethernet devices such as IP phones, wireless access points, and IP cameras.
- . How powered: PoE devices are connected to the switch port which supplies power to those devices.
- . Reporting: PoE device power consumption is measured and reported by the switch (PSE) which supplies power. In

addition, some devices can have support for the EMAN framework.

This use case can be subdivided into two sub cases:

- a) The end device supports the EMAN framework, in which case this device is an EMAN Energy Object by itself, with its own UUID, like in scenario "Devices Connected to a Network" below. The device is responsible for its own power reporting and control.
- b) The end device does not have EMAN capabilities, and the power measurement may not be able to be performed independently, and so is only performed by the supplying device. This scenario is similar to the "Mid-level Manager" below.

In the sub case (a) note that two power usage reporting for the same device are available: one performed by the PD itself and one performed by the PSE. Device specific implementations will dictate which one if the most accurate.

It is also possible to illustrate the relationships between entities. The PoE IP phone is powered by the switch. If there are many IP phones connected to the same switch and the power consumption of all the IP phones can be aggregated by the switch. In that case, the switch performs the aggregation function for other entities.

2.3. Devices Connected to a Network

The use case covers the metering relationship between an energy object and the parent energy object it is connected to, while receiving power from an external source such as a power brick.

An example is a PC which has a network connection to a switch, but draws power from a wall outlet. In this case, the PC can report power usage by itself, ideally through the EMAN framework.

The wall outlet the PC is plugged in can be metered for example by a Smart PDU, or unmetered.

- a) If metered, the PC has a powered-by relationship to the Smart PDU, and the Smart PDU will act as a "Mid-Level Manager"

b) If unmetered - or running on batteries - the PC will report its own energy usage as any other Energy Object to the switch, and the switch can possibly provide aggregation.

Note that a) and b) are not mutually exclusive.

In terms of relationships between entities, the PC has a powered by relationship to the PDU and if the power consumption of the PC is metered by the PDU then there is a metered by relation between the PC and the PDU.

The essential properties of this use case are:

- . Target devices: Energy objects that have a network connection, but receive power supply from another source.
- . How powered: Children (e.g.: PCs) receive power supply from the wall outlet (unmetered), or a PDU (metered). That can also be powered autonomously (batteries).
- . Reporting: Devices can measure and report the power consumption directly via the EMAN framework, or, communicate it to the network device (switch) and the switch can report the device's power consumption via the EMAN framework.

2.4. Power Meters

Some electrical devices are not equipped with instrumentation to measure their own power and accumulated energy consumption. External meters can be used to measure the power consumption of such electrical devices as well as collections of devices. This use case covers the proxy relationship of energy objects able to measure or report the power consumption of external electrical devices, not natively connected to the network. Examples of such metering devices are smart PDUs and smart meters.

Three types of external metering are relevant to EMAN: PDUs, standalone meters, and utility meters. External meters can measure consumption of a single device or a set of devices.

Power Distribution Unit (PDUs) have inbuilt meters for each socket and so can measure the power supplied to each device in an equipment rack. The PDUs have remote management functionality which can measure and possibly control the power supply of each outlet.

Standalone meters can be placed anywhere in a power distribution tree are allocated to specific devices.

Utility meters monitor and report accumulated power consumption of the entire building. There can be sub-meters to measure the power consumption of a portion of the building.

The essential properties of this use case are:

- . Target devices: PDUs and meters.
- . How powered: From traditional mains power but as passed through a PDU or meter.
- . Reporting: The PDUs reports power consumption of downstream devices, usually a single device per outlet.

The meters can have a metering relationship and possibly aggregation relationship between the meters and the devices for which power consumption is accumulated and reported by the meter.

2.5. Mid-level Managers

This use case covers aggregation of energy management data at "mid-level managers" that can provide energy management functions for themselves as well as associated devices.

A switch can provide energy management functions for all devices connected to its ports, whether or not these devices are powered by the switch or whether the switch provides immediate network connectivity to the devices; such a switch is a mid-level manager, offering aggregation of power consumption data for other devices. Devices report their EMAN data to the switch and the switch aggregates the data for further reporting.

The essential properties of this use case:

- . Target devices: Devices which can perform aggregation; commonly a switch or a proxy
- . How powered: Mid-level managers can be are commonly powered by a PDU or from a wall outlet and can be powered by any method.
- . Reporting: The middle-manager aggregates the energy data and reports that data to a NMS or higher mid-level manager.

2.6. Gateways to Building Systems

This use case describes energy management of buildings. Building Management Systems (BMS) have been in place for many years using

legacy protocols not based on IP. In these buildings, a gateway can provide a proxy relationship between IP and legacy building automation protocols. The gateway can provide an interface between the EMAN framework and relevant building management protocols.

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

The gateway performs protocol conversion and communicates via RS-232/RS-485 interfaces, Ethernet interfaces, and protocols specific to building management such as BACNET [ASHRAE], MODBUS [MODBUS-Protocol], or Zigbee [ZIGBEE].

The essential properties of this use case are:

- . Target devices: Building energy management devices - HVAC systems, lighting, electrical, fire and emergency systems.
- . How powered: Any method.
- . Reporting: The gateway collects energy consumption of non-IP systems and communicates the data via the EMAN framework.

2.7. Home Energy Gateways

This use case describes the scenario of energy management of a home. The home energy gateway is another example of a proxy that interfaces to the electrical appliances and other devices in a home. This gateway can monitor and manage electrical equipment (refrigerator, heating/cooling, washing machine etc.) using one of the many protocols that are being developed for the home area network products.

In its simplest form, metering can be performed at home. Beyond the metering, it is also possible to implement energy saving policies based on energy pricing from the utility grid. The EMAN information model can be applied to the protocols under consideration for energy management of a home.

The essential properties of this use case are:

- . Target devices: Home energy gateway and smart meters in a home.
- . How powered: Any method.
- . Reporting: Home energy gateway can collect power consumption of device in a home and possibly report the metering reading to the utility.

Beyond the canonical setting of a home drawing power from the utility, it is also possible to envision an energy neutral situation wherein the buildings/homes that can produce and consume energy with reduced or zero net importing energy from the utility grid. There are many energy production technologies such as solar panels, wind turbines, or micro generators. This use case illustrates the concept of covers self-contained energy generation and consumption and possibly the aggregation of the energy use of homes.

2.8. Data Center Devices

This use case describes energy management of a data center.

Energy efficiency of data centers has become a fundamental challenge of data center operation, as datacenters are big energy consumers and have expensive infrastructure. The equipment generates heat, and heat needs to be evacuated through a HVAC system.

A typical data center network consists of a hierarchy of electrical energy objects. At the bottom of the network hierarchy are servers mounted on a rack; these are connected to top-of-the-rack switches, which in turn are connected to aggregation switches, and then to core switches. Power consumption of all network elements, servers, and network storage devices in the data center should be measured. Energy management can be implemented on different aggregation levels, at the network level, Power Distribution Unit (PDU) level, and server level.

Beyond the network devices, storage devices and servers, data centers contain UPSs to provide back-up power for the network, storage devices in the event in the event of a power outage. A UPS can provide backup power for many devices in a data center for a finite period of time. Energy monitoring of such energy storage devices is vital from a data center network operations point of view. Presently, the UPS MIB can be useful in monitoring the battery capacity, the input load to the UPS and

Thus from a Data center energy management point of view, in addition, to monitoring the energy usage of network devices, it is also important to monitor the remaining capacity of the UPS.

In addition to monitoring the power consumption of a data center, additional power characteristic metrics should be monitored. Some of these are dynamic variations in the input power supply from the grid referred to as power characteristics is one metric. Secondly, how the devices utilize the power in terms of efficiency can be useful to monitor these metrics.

Lastly, the nameplate power consumption (the worst case possible power draw) of all devices will make it possible to know an aggregate of the potential worst-case power usage and compare it to the budgeted power in the data center.

The essential properties of this use case are:

- . Target devices: All IT devices in a data center, such as network equipment, servers, and storage devices, as well as power and cooling infrastructure.
- . How powered: Any method but commonly by one or more PDUs.
- . Reporting: Devices may report on their own behalf, or for other connected devices as described in other use cases.

2.9. Energy Storage Devices

There are two types of devices with energy storage: those whose primary function is to provide power to another device (e.g. a UPS), and those with a different primary function, but have an energy storage as a component as an alternate internal power source (e.g. a notebook). This use case covers both types of products.

The energy storage can be a conventional battery, or any other means to store electricity such as a hydrogen cell.

An internal battery can be a back-up or an alternative source of power to mains power. As batteries have a finite capacity and lifetime, means for reporting the actual charge, age, and state of a battery are required. An internal battery can be viewed as a component of a device and thus could have the containment

Battery systems are used in mobile telecom towers including for use in remote locations. It is important to monitor the remaining battery life and raise an alarm when the battery life is below a threshold.

The essential properties of this use case are:

- . Target devices: Devices that have an internal battery
- . How powered: From internal batteries or mains power
- . Reporting: The device reports on its internal battery

2.10. Industrial Automation Networks

Energy consumption statistics in the industrial sector are staggering. The industrial sector alone consumes about half of the world's total delivered energy, and a significant user of electricity. Thus, the need for optimization of energy usage in this sector is natural.

Industrial facilities consume energy in process loads, and in non-process loads.

The essential properties of this use case are:

- . Target devices: Devices used in industrial automation
- . How powered: Any method.
- . Reporting: Currently, CIP protocol is currently used for reporting energy for these devices

2.11. Printers

This use case describes the scenario of energy monitoring and management of printers.

Printers in this use case stand in for all imaging equipment, also including multi-function devices (MFDs), copiers, scanners, fax machines, and mailing machines.

Energy use of printers has been an industry concern for several decades, and they usually have sophisticated power management with a variety of low-power modes, particularly for managing energy-intensive thermo-mechanical components. Printers also have long made extensive use of SNMP for end-user system interaction and for management generally, and cross-vendor

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management systems manage fleets of printers in enterprises.
Power consumption during active modes can vary widely, with high
peak levels.

Printers can expose detailed power state information, distinct from operational state information, with some printers reporting transition states between stable long-term states. Many also support active setting of power states, and setting of policies such as delay times when no activity will cause automatic transition to a lower power mode. Other features include reporting on components, counters for state transitions, typical power levels by state, scheduling, and events/alarms.

Some large printers also have a "Digital Front End" which is a computer that performs functions on behalf of the physical imaging system. These typically have their own presence on the network and are sometimes separately powered.

There are some unique characteristics of printers from the point of view energy management. While the printer is not in use, there are timer based low power states, which consume very little power. On the other hand, while the printer is printing or copying the cylinder needs to be heated so that power consumption is quite high but only for a short period of time (duration of the print job). Given this work load, periodic polling of power levels alone would not suffice.

The essential properties of this use case are:

- . Target devices: All imaging equipment.
- . How powered: Typically AC from a wall outlet.
- . Reporting: Devices report for themselves by implementing [EMAN-MONITORING-MIB].

2.12. Off-Grid Devices

This use case concerns self-contained devices that use energy but are not connected to an infrastructure power delivery grid. These devices typically scavenge energy from environmental sources such as solar energy or wind power. The device generally contains a closely coupled combination of

- . power scavenging or generation component(s)
- . power storage component(s) (e.g., battery)
- . power consuming component(s)

With scavenged power, the energy input is often dependent on the random variations of the weather. These devices therefore require energy management both for internal control and remote reporting of their state. In order to optimize the performance of these devices and minimize the costs of the generation and storage components, it is desirable to vary the activity level, and, hopefully, the energy requirements of the consuming components in order to make best use of the available stored and instantaneously generated energy. With appropriate energy management, the overall device can be optimized to deliver an appropriate level of service without over provisioning the generation and storage components.

In many cases these devices are expected to operate autonomously, as continuous communications for the purposes of remote control is either impossible or would result in excessive power consumption. Non continuous polling requires the ability to store and access later the information collected while the communication was not possible.

The essential properties of this use case are:

Target Devices: Remote network devices (mobile network) that consume and produce energy

How Powered: Can be battery powered or using natural energy sources

Reporting: Devices report their power usage but only occasionally.

2.13. Demand/Response

Demand/Response from the utility or grid is a common theme that spans across some of the use cases. In some situations, in response to time-of-day fluctuation of energy costs or sudden energy shortages due power outages, it may be important to respond and reduce the energy consumption of the network. From EMAN use case perspective, the demand/response scenario can apply to a Data Center or a Building or a residential home. As a first step, it may be important to monitor the energy consumption in real-time of a Data center, building or home which is already discussed in the previous use cases. Then based on the potential energy shortfall, the Energy Management System (EMS) could formulate a suitable response, i.e., the EMS could shut down some selected devices that may be considered discretionary or uniformly reduce the power supplied to all devices. For multi-site data centers it may be possible to formulate policies such as follow-the-moon type of approach, by

2.14. Power Capping

Power capping is a technique to limit the total power consumption of a server. This technique can be useful for power limited data centers. Based on workload measurements, the server can choose the optimal power state of the server in terms of performance and power consumption. When the server operates at less than the power supply capacity, it runs at full speed. When the server power would be greater than the power supply capacity, it runs at a slower speed so that its power consumption matches the available power supply capacity. This gives vendors the option to use smaller, cost-effective power supplies that allow real world workloads to run at nominal themselves.

3. Use Case Patterns

The use cases presented above can be abstracted to the following broad patterns.

3.1. Metering

- energy objects which have capability for internal metering
- energy objects which are metered by an external device

3.2. Metering and Control

- energy objects that do not supply power, but can perform only power metering for other devices
- energy objects that do not supply power, but can perform both metering and control for other devices

3.3. Power Supply, Metering and Control

- energy objects that supply power for other devices but do not perform power metering for those devices
- energy objects that supply power for other devices and also perform power metering
- energy objects supply power for other devices and also perform power metering and control for other devices

3.4. Multiple Power Sources

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

4. Relationship of EMAN to other Standards

EMAN as a framework is tied to other standards and efforts that deal with energy. Existing standards are leveraged when possible. EMAN helps enable adjacent technologies such as Smart Grid.

The standards most relevant and applicable to EMAN are listed below with a brief description of their objectives, the current state and how that standard relates to EMAN.

4.1. Data Model and Reporting

4.1.1. IEC - CIM

The International Electro-technical Commission (IEC) has developed a broad set of standards for power management. Among these, the most applicable to EMAN is IEC 61850, a standard for the design of electric utility automation. The abstract data model defined in 61850 is built upon and extends the Common Information Model (CIM). The complete 61850 CIM model includes over a hundred object classes and is widely used by utilities worldwide.

This set of standards was originally conceived to automate control of a substation (facilities which transfer electricity from the transmission to the distribution system). While the original domain of 61850 is substation automation, the extensive data model has been widely used in other domains, including Energy Management Systems (EMS).

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

Concepts from IEC Standards have been reused in the EMAN WG drafts. In particular, AC Power Quality measurements have been reused from IEC 61850-7-4. The concept of Accuracy Classes for

4.1.2. DMTF

The Distributed Management Task Force (DMTF)[DMTF] has standardized management solutions for managing servers and PCs, including power-state configuration and management of elements in a heterogeneous environment. These specifications provide physical, logical and virtual system management requirements for power-state control.

The EMAN Framework references the DMTF Power Profile and Power State Set.

4.1.2.1. Common Information Model Profiles

The DMTF uses CIM-based (Common Information Model) 'Profiles' to represent and manage power utilization and configuration of managed elements (note that this is not the 61850 CIM). Key profiles for energy management are 'Power Supply' (DSP 1015), 'Power State' (DSP 1027) and 'Power Utilization Management' (DSP 1085). These profiles define monitoring and configuration of a Power Managed Element's static and dynamic power saving modes, power allocation limits and power states, among other features.

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

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

4.1.2.2. DASH

DMTF DASH [DASH] (Desktop And Mobile Architecture for System Hardware) addresses managing heterogeneous desktop and mobile systems (including power) via in-band and out-of-band communications. DASH provides management and control of managed

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

4.1.3. ODVA

The Open DeviceNet Vendors Association (ODVA) is an association for industrial automation companies and defines the Common Industrial Protocol (CIP). Within ODVA, there is a special interest group focused on energy.

The Open DeviceNet Vendors Association (ODVA) is developing an energy management framework for the industrial sector. There are synergies between the ODVA and EMAN approaches to energy management.

There are many similar concepts between the ODVA and EMAN frameworks towards monitoring and management of energy aware devices. In particular, one of the concepts being considered different energy meters based on if the device consumes electricity or produces electricity or a passive device.

ODVA defines a three-part approach towards energy management: awareness of energy usage, consuming energy more efficiently, and exchanging energy with the utility or others. Energy monitoring and management promote efficient consumption and enable automating actions that reduce energy consumption.

The foundation of the approach is the information and communication model for entities. An entity is a network-connected, energy-aware device that has the ability to either measure or derive its energy usage based on its native consumption or generation of energy, or report a nominal or static energy value.

4.1.4. Ecma SDC

The Ecma International committee on Smart Data Centre (TC38-TG2 SDC [Ecma-SDC]) is in the process of defining semantics for management of entities in a data center such as servers, storage, and network equipment. It covers energy as one of many functional resources or attributes of systems for monitoring and

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control. It only defines messages and properties, and does not reference any specific protocol. Its goal is to enable interoperability of such protocols as SNMP, BACNET, and HTTP by ensuring a common semantic model across them. Four power states are defined, Off, Sleep, Idle and Active. The standard does not include actual energy or power measurements in kW or kWh.

The 14th draft of SDC process was published in March 2011 and the development of the standard is still underway. When used with EMAN, the SDC standard will provide a thin abstraction on top of the more detailed data model available in EMAN.

4.1.5. IEEE-ISTO Printer Working Group (PWG)

The IEEE-ISTO Printer Working Group (PWG) defines SNMP MIB modules for printer management and has recently defined a "PWG Power Management Model for Imaging Systems v1.0" [PWG5106.4] and a companion SNMP binding in the "PWG Imaging System Power MIB v1.0" [PWG5106.5]. This PWG model and MIB are harmonized with the DMTF CIM Infrastructure [DSP0004] and DMTF CIM Power State Management Profile [DSP1027] for power states and alerts.

The PWG would like its MIBs to be harmonized as closely as possible with those from EMAN. The PWG covers many topics in greater detail than EMAN, as well as some that are specific to imaging equipment. The PWG also provides for vendor-specific extension states (i.e., beyond the standard DMTF CIM states.)

4.1.6. ASHRAE

In the U.S., there is an extensive effort to coordinate and develop standards related to the "Smart Grid". The Smart Grid Interoperability Panel, coordinated by the government's National Institute of Standards and Technology, identified the need for a building side information model (as a counterpart to utility models) and specified this in Priority Action Plan (PAP) 17. This was designated to be a joint effort by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and National Electrical Manufacturers Association (NEMA), both ANSI approved SDO's. The result is to be an information model, not a device level monitoring protocol.

The ASHRAE effort addresses data used only within a building as well as data that may be shared with the grid, particularly as it relates to coordinating future demand levels with the needs of the grid. The model is intended to be applied to any building type, both residential and commercial. It is expected

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that existing protocols will be adapted to comply with the new
information model, as would any new protocols.

There are four basic types of entities in the model: generators,
loads, meters, and energy managers.

The metering part of this model overlaps with the EMAN framework
to a large degree, though there are features unique to each.
The load part speaks to control capabilities well beyond what
EMAN covers. Details of generation and of the energy management
function are outside of EMAN scope.

A public review draft of the ASHRAE standard is expected soon,
and at that point detailed comparison of the two models can be
made. There are no apparent major conflicts between the two
approaches, but there are likely areas where some harmonization
is possible, and regardless, a description of the
correspondences would be helpful to create.

4.1.7. ZigBee

The Zigbee Smart Energy 2.0 effort[ZIGBEE] focuses on wireless
communication to appliances and lighting. Zigbee 1.x is not
based on IP, whereas Zigbee 2.0 is supposed to interoperate with
IP. It is intended to enable building energy management and
enable direct load control by utilities.

ZigBee protocols are intended for use in embedded applications
requiring low data rates and low power consumption. ZigBee
defines a general-purpose, inexpensive, self-organizing mesh
network that can be used for industrial control, embedded
sensing, medical data collection, smoke and intruder warning,
building automation, home automation, etc.

Zigbee is currently not an ANSI recognized SDO.

The EMAN framework addresses the needs of IP-enabled networks
through the usage of SNMP, while Zigbee looks for completely
integrated and inexpensive mesh solution.

4.2. Measurement

4.2.1. ANSI C12

The American National Standards Institute (ANSI) has defined a
collection of power meter standards under ANSI C12. The primary

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standards include communication protocols (C12.18, 21 and 22),
data and schema definitions (C12.19), and measurement accuracy
(C12.20). European equivalent standards are provided by IEC
62053-22. ANSI C12.20 defines accuracy classes for watt-hour
meters.

All of these standards are oriented toward the meter itself, and
are therefore very specific and used by electricity distributors
and producers.

The EMAN standard references ANSI C12 accuracy classes.

4.2.2. IEC

IEC 62301, "Household electrical appliances Measurement of
standby power", [IEC62301] specifies a power level measurement
procedure. While nominally for appliances and low-power modes,
many aspects of it apply to other device types and modes and it
is commonly referenced in test procedures for energy using
products.

While the standard is intended for laboratory measurements of
devices in controlled conditions, many aspects of it are
informative to those implementing measurement in products that
ultimately report via EMAN.

4.3. Other

4.3.1. ISO

The ISO [ISO] is developing an energy management standard, ISO
50001, to complement ISO 9001 for quality management, and ISO
14001 for environment management. The intent of the framework is
to facilitate the creation of energy management programs for
industrial, commercial and other entities. The standard defines
a process for energy management at an organization level. It
does not define the way in which devices report energy and
consume energy.

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

- o Integrating energy efficiency into management practices and
throughout the supply chain

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

ISO 50001 has been developed by ISO project committee ISO/PC 242, Energy management. EMAN is complementary to ISO 9001.

4.3.2. EnergyStar

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

To qualify as Energy Star, products must meet specific energy efficiency targets. The Energy Star program also provides planning tools and technical documentation to encourage more energy efficient building design. Energy Star is a program; it is not a protocol or standard.

For businesses and data centers, Energy Star offers technical support to help companies establish energy conservation practices. Energy Star provides best practices for measuring current energy performance, goal setting, and tracking improvement. The Energy Star tools offered include a rating system for building performance and comparative benchmarks.

There is no immediate link between EMAN and EnergyStar, one being a protocol and the other a set of recommendations to develop energy efficient products. However, Energy Star could include EMAN standards in specifications for future products, either as required or rewarded with some benefit.

4.3.3. SmartGrid

The Smart Grid standards efforts underway in the United States are overseen by the US National Institute of Standards and Technology [NIST]. NIST is responsible for coordinating a public-private partnership with key energy and consumer stakeholders in order to facilitate the development of smart grid standards. The NIST smart grid standards activities are monitored and facilitated by the SGIP (Smart Grid Interoperability Panel).

This group has working groups for specific topics including homes, commercial buildings, and industrial facilities as they relate to the grid. A stated goal of the group is to harmonize any new standard with the IEC CIM and IEC 61850.

When a working group detects a standard or technology gap, the team seeks approval from the SGIP for the creation of a Priority Action Plan (PAP), a private-public partnership to close the gap. There are currently 17 PAPs. PAP 17 is discussed in section 4.1.6.

PAP 10 addresses "Standard Energy Usage Information". Smart Grid standards will provide distributed intelligence in the network and allow enhanced load shedding. For example, pricing signals will enable selective shutdown of non critical activities during peak-load pricing periods. These actions can be effected through both centralized and distributed management controls.

There is an obvious functional link between SmartGrid and EMAN in the form of demand response, even if the EMAN framework does not take any specific step toward SmartGrid communication. As EMAN framework enables control, it can be used to realize power savings in the demand response through translation of a signal from an outside entity.

5. Limitations

EMAN Framework addresses the needs of energy monitoring in terms of measurement and, considers limited control capabilities of energy monitoring of networks.

EMAN does not create a new protocol stack, but rather defines a data and information model useful for measuring and reporting energy and other metrics over SNMP.

The EMAN framework does not address questions regarding SmartGrid, electricity producers, and distributors even if there is obvious link between them.

6. Security Considerations

EMAN shall use SNMP protocol for energy management and thus has the functionality of SNMP's security capabilities. SNMPv3 [RFC3411] provides important security features such as confidentiality, integrity, and authentication.

7. IANA Considerations

This memo includes no request to IANA.

8. Acknowledgements

Firstly, the authors would like thank Emmanuel Tychon for taking the lead for this draft and his contributions towards to this draft.

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9. Open Issues

OPEN ISSUE 1: Should review ASHRAE SPC 201P standard when it is released for public review

- . Need to review ASHRAE information model and the use cases and how it relates to EMAN

OPEN ISSUE 2: Should the Applicability Statement cover concepts that are only developed to implement the requirements in the framework, or only cover concepts that already are well-defined?

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Definition of Managed Objects for Battery Monitoring
draft-ietf-eman-battery-mib-05

Abstract

This memo defines a portion of the Management Information Base (MIB) for use with network management protocols in the Internet community. In particular, it defines managed objects that provide information on the status of batteries in managed devices.

Status of this Memo

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1. Introduction

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

In addition to this, there is a need to monitor battery status of these devices by network management systems. This document defines a portion of the Management Information Base (MIB) that provides means for monitoring batteries in or attached to managed devices. The Battery MIB module defined in Section 4 meets the requirements for monitoring the status of batteries specified in [I-D.ietf-eman-requirements].

The Battery MIB module serves for monitoring the battery status. According to the framework for energy management [I-D.ietf-eman-framework] it is an Energy Managed Object, and thus, MIB modules such as the Power and Energy Monitoring MIB [I-D.ietf-eman-energy-monitoring-mib] could in principle be implemented for batteries. The Battery MIB extends the more generic aspects of energy management by adding battery-specific information. Amongst other things, the Battery MIB allows to monitor:

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

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

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

Since there are a lot of devices in use that contain more than one battery, means for battery monitoring defined in this document

support addressing multiple batteries within a single device. Also, batteries today often come in packages that can include identification and might contain additional hardware and firmware. The former allows to trace a battery and allows continuous monitoring even if the battery is e.g. installed in another device. The firmware version is useful information as the battery behavior might be different for different firmware versions.

Not explicitly in scope of definitions in this document are very small backup batteries, such as for example, batteries used on PC motherboard to run the clock circuit and retain configuration memory while the system is turned off. Other means may be required for reporting on these batteries. However, the MIB module defined in Section 3.1 can be used for this purpose.

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

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

2. The Internet-Standard Management Framework

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

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies MIB modules that are compliant to the SMIV2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

3. Design of the Battery MIB Module

3.1. MIB Module Structure

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

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

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

The `batteryTable` contains three groups of objects. The first group (OIDs ending with 2-11) provides information on static properties of the battery. The second group of objects (OIDs ending with 12-19) provides information on the current battery state, if it is charging or discharging, how much it is charged, its remaining capacity, the number of experienced charging cycles, etc.


```

batteryTable(1)
+--batteryEntry(1) [batteryIndex]
    +--- --- Integer32      batteryIndex(1)
    +--- r-n SnmpAdminString batteryIdentifier(2)
    +--- r-n SnmpAdminString batteryFirmwareVersion(3)
    +--- r-n Enumeration    batteryType(4)
    +--- r-n Unsigned32     batteryTechnology(5)
    +--- r-n Unsigned32     batteryDesignVoltage(6)
    +--- r-n Unsigned32     batteryNumberOfCells(7)
    +--- r-n Unsigned32     batteryDesignCapacity(8)
    +--- r-n Unsigned32     batteryMaxChargingCurrent(9)
    +--- r-n Unsigned32     batteryTrickleChargingCurrent(10)
    +--- r-n Unsigned32     batteryActualCapacity(11)
    +--- r-n Unsigned32     batteryChargingCycleCount(12)
    +--- r-n DateAndTime    batteryLastChargingCycleTime(13)
    +--- r-n Enumeration    batteryChargingOperState(14)
    +--- rwn Enumeration    batteryChargingAdminState(15)
    +--- r-n Unsigned32     batteryActualCharge(16)
    +--- r-n Unsigned32     batteryActualVoltage(17)
    +--- r-n Integer32      batteryActualCurrent(18)
    +--- r-n Integer32      batteryTemperature(19)
    +--- rwn Unsigned32     batteryLowAlarmCharge(20)
    +--- rwn Unsigned32     batteryLowAlarmVoltage(21)
    +--- rwn Unsigned32     batteryReplacementAlarmCapacity(22)
    +--- rwn Unsigned32     batteryReplacementAlarmCycles(23)
    +--- rwn Integer32      batteryHighAlarmTemperature(24)
    +--- rwn Integer32      batteryLowAlarmTemperature(25)

```

The third group of objects in this table (OIDs ending with 20-25) indicates thresholds which can be used to raise an alarm if a property of the battery exceeds one of them. Raising an alarm may include sending a notification.

The Battery MIB defines four notifications. One indicating a low battery charging state, one indicating an aged battery that may need to be replaced and two dealing with battery temperature. The temperature-related notifications are either indicating the battery temperature to have risen above or fallen below a predefined value.

3.2. Battery Technologies

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

Since battery technologies are subject of intensive research and

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

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

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

3.3. Charging Cycles

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

After that the next charging cycle immediately starts.

4. Definitions

BATTERY-MIB DEFINITIONS ::= BEGIN

IMPORTS

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

batteryMIB MODULE-IDENTITY

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

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```

DESCRIPTION

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

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(<http://trustee.ietf.org/license-info>).

This version of this MIB module is part of RFC yyyy; see the RFC itself for full legal notices."

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

-- Revision history

REVISION "201106261200Z" -- 26 June 2010

DESCRIPTION

"Initial version, published as RFC yyyy."

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

::= { mib-2 zzz }

-- zzz to be assigned by IANA.

--*****

-- Top Level Structure of the MIB module

--*****

batteryNotifications OBJECT IDENTIFIER ::= { batteryMIB 0 }

batteryObjects OBJECT IDENTIFIER ::= { batteryMIB 1 }

batteryConformance OBJECT IDENTIFIER ::= { batteryMIB 2 }

-- 1. Object Definitions

-- 1.1. Battery Table

batteryTable OBJECT-TYPE

SYNTAX SEQUENCE OF BatteryEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table provides information on batteries.

It contains one conceptual row per battery."

::= { batteryObjects 1 }

batteryEntry OBJECT-TYPE

SYNTAX BatteryEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry providing information on a battery."

INDEX { batteryIndex }

::= { batteryTable 1 }

```
BatteryEntry ::=
  SEQUENCE {
    batteryIndex                Integer32,
    batteryIdentifier            SnmpAdminString,
    batteryFirmwareVersion      SnmpAdminString,
    batteryType                 INTEGER,
    batteryTechnology            Unsigned32,
    batteryDesignVoltage        Unsigned32,
    batteryNumberOfCells        Unsigned32,
    batteryDesignCapacity       Unsigned32,
    batteryMaxChargingCurrent    Unsigned32,
    batteryTrickleChargingCurrent Unsigned32,
    batteryActualCapacity       Unsigned32,
    batteryChargingCycleCount    Unsigned32,
    batteryLastChargingCycleTime DateAndTime,
    batteryChargingOperState     INTEGER,
    batteryChargingAdminState    INTEGER,
    batteryActualCharge          Unsigned32,
    batteryActualVoltage         Unsigned32,
    batteryActualCurrent         Integer32,
    batteryTemperature           Integer32,
    batteryLowAlarmCharge        Unsigned32,
    batteryLowAlarmVoltage       Unsigned32,
    batteryReplacementAlarmCapacity Unsigned32,
    batteryReplacementAlarmCycles Unsigned32,
    batteryHighAlarmTemperature  Integer32,
    batteryLowAlarmTemperature   Integer32
  }
```

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

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

```
batteryIdentifier OBJECT-TYPE
  SYNTAX      SnmpAdminString
  MAX-ACCESS  read-only
```

STATUS current
DESCRIPTION

"This object contains an identifier for the battery.

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

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

The value of this object must be an empty string if there is no battery identifier or if the battery identifier is unknown."

::= { batteryEntry 2 }

batteryFirmwareVersion OBJECT-TYPE

SYNTAX SnmpAdminString

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the version number of the firmware that is included in a battery module.

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

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

The value of this object must be an empty string if there is no firmware or if the version number of the firmware is unknown."

::= { batteryEntry 3 }

batteryType OBJECT-TYPE

SYNTAX INTEGER {
 unknown(1),
 other(2),
 primary(3),

```
        rechargeable(4),
        capacitor(5)
    }
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This object indicates the type of battery.
    It distinguishes between primary (not re-chargeable)
    batteries, secondary (rechargeable) batteries and capacitors
    which are not really batteries but often used in the same
    way as a battery.

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

batteryTechnology OBJECT-TYPE

```
SYNTAX Unsigned32
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This object indicates the technology used by the battery.
    Numbers identifying battery types are registered at IANA.
    A current list of assignments can be found at
    <http://www.iana.org/assignments/eman>.

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

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

batteryDesignVoltage OBJECT-TYPE

```
SYNTAX Unsigned32
UNITS "millivolt"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
    "This object provides the design (or nominal) voltage of the
    battery in units of millivolt (mV).

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

    A value of 0 indicates that the design voltage is unknown."
 ::= { batteryEntry 6 }
```

batteryNumberOfCells OBJECT-TYPE

SYNTAX Unsigned32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the number of cells contained in the battery.

A value of 0 indicates that the number of cells is unknown."

::= { batteryEntry 7 }

batteryDesignCapacity OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere hours"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the design (or nominal) capacity of the battery in units of milliampere hours (mAh).

Note that the design capacity is a constant value and typically different from the actual capacity of the battery. Usually, this is a value provided by the manufacturer of the battery.

A value of 0 indicates that the design capacity is unknown."

::= { batteryEntry 8 }

batteryMaxChargingCurrent OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the maximal current to be used for charging the battery in units of milliampere (mA).

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

A value of 0 indicates that the maximal charging current is unknown."

::= { batteryEntry 9 }

batteryTrickleChargingCurrent OBJECT-TYPE

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

"This object provides the recommended current to be used for trickle charging the battery in units of milliampere (mA).

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

A value of 0 indicates that the recommended trickle charging current is unknown."

::= { batteryEntry 10 }

batteryActualCapacity OBJECT-TYPE

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

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

Typically, the actual capacity of a battery decreases with time and with usage of the battery. It is usually lower than the design capacity

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

A value of 'ffffffff'H indicates that the actual capacity cannot be determined."

::= { batteryEntry 11 }

batteryChargingCycleCount OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates the number of completed charging cycles that the battery underwent. In line with the Smart Battery Data Specification Revision 1.1, a charging cycle is defined as the process of discharging the battery by a total amount equal to the battery design capacity as given by object batteryDesignCapacity. A charging cycle

may include several steps of charging and discharging the battery until the discharging amount given by `batteryDesignCapacity` has been reached. As soon as a charging cycle has been completed the next one starts immediately independent of the battery's current charge at the end of the cycle.

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

A value of `'ffffffff'H` indicates that the number of charging cycles cannot be determined."

::= { batteryEntry 12 }

`batteryLastChargingCycleTime` OBJECT-TYPE

SYNTAX DateAndTime

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The date and time of the last charging cycle. The value `'0000000000000000'H` is returned if the battery has not been charged yet or if the last charging time cannot be determined.

For batteries of type `primary(1)` the value of this object is always `'0000000000000000'H`."

::= { batteryEntry 13 }

`batteryChargingOperState` OBJECT-TYPE

SYNTAX INTEGER {
 unknown(1),
 charging(2),
 fastCharging(3),
 maintainingCharge(4),
 noCharging(5),
 discharging(6)
}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the current charging state of the battery.

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

Value `charging(2)` indicates that the battery is being

charged in a way that the charge of the battery increases.

Value fastCharging(3) indicated that the battery is being charged rapidly, i.e. faster than in the charging(2) state. If multiple fast charging states exist, all of these states are indicated by fastCharging(3).

Value maintainingCharge(4) indicates that the battery is being charged with a low current that compensates self-discharging. This includes trickle charging, float charging and other methods for maintaining the current charge of a battery.

Value noCharging(5) indicates that the battery is not being charged or discharged by electric current between the battery and electric circuits external to the battery. Note that the battery may still be subject to self-discharging.

Value discharging(6) indicates that the battery is being discharged and that the charge of the battery decreases."

::= { batteryEntry 14 }

batteryChargingAdminState OBJECT-TYPE

```
SYNTAX      INTEGER {
                charging(2),
                fastCharging(3),
                maintainingCharge(4),
                noCharging(5),
                discharging(6),
                notSet(7)
            }
```

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"The value of this object indicates the desired status of the charging state of the battery. The real state is indicated by object batteryChargingOperState. See the definition of object batteryChargingOperState for a description of the values.

When this object is initialized by an implementation of the BATTERY-MIB module, its value is set to notSet(7).

However, a SET request can only set this object to either charging(2), fastCharging(3), maintainingCharge(4), noCharging(5), or discharging(6). Attempts to set this object to notSet(7) will always fail with an

'inconsistentValue' error. In case multiple fast charging states exist, the battery logic can choose an appropriate fast charging state - preferably the fastest.

When the batteryChargingAdminState object is set, then the BATTERY-MIB implementation must try to set the battery to the indicated state. The result will be indicated by object batteryChargingOperState.

Due to operational conditions and limitations of the implementation of the BATTERY-MIB module, changing the battery status according to a set value of object batteryChargingAdminState may not be possible.

Setting the value of object batteryChargingAdminState may result in not changing the state of the battery to this value or even in setting the charging state to another value. For example, setting batteryChargingAdminState to value fastCharging(3) may have no effect when the battery logic is not allowing fast charging due to temperature constraints."

```
::= { batteryEntry 15 }
```

batteryActualCharge OBJECT-TYPE

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

"This object provides the actual charge of the battery in units of milliampere hours (mAh).

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

A value of 'ffffffff'H indicates that the actual charge cannot be determined."

```
::= { batteryEntry 16 }
```

batteryActualVoltage OBJECT-TYPE

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

"This object provides the actual voltage of the battery

in units of millivolt (mV).

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

::= { batteryEntry 17 }

batteryActualCurrent OBJECT-TYPE

SYNTAX Integer32

UNITS "milliampere"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object provides the actual charging or discharging current of the battery in units of milliampere (mA).

Charging current is represented by positive values, discharging current is represented by negative values.

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

::= { batteryEntry 18 }

batteryTemperature OBJECT-TYPE

SYNTAX Integer32

UNITS "deci-degrees Celsius"

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The ambient temperature at or near the battery.

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

::= { batteryEntry 19 }

batteryLowAlarmCharge OBJECT-TYPE

SYNTAX Unsigned32

UNITS "milliampere hours"

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object provides the lower threshold value for object batteryActualCharge. If the value of object batteryActualCharge falls below this threshold, a low battery alarm will be raised. The alarm procedure may include generating a batteryLowNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualCharge."

::= { batteryEntry 20 }

batteryLowAlarmVoltage OBJECT-TYPE

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

DESCRIPTION

"This object provides the lower threshold value for object batteryActualVoltage. If the value of object batteryActualVoltage falls below this threshold, a low battery alarm will be raised. The alarm procedure may include generating a batteryLowNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualVoltage."

::= { batteryEntry 21 }

batteryReplacementAlarmCapacity OBJECT-TYPE

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

DESCRIPTION

"This object provides the lower threshold value for object batteryActualCapacity. If the value of object batteryActualCapacity falls below this threshold, a battery aging alarm will be raised. The alarm procedure may include generating a batteryAgingNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryActualCapacity."

::= { batteryEntry 22 }

batteryReplacementAlarmCycles OBJECT-TYPE

SYNTAX Unsigned32
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object provides the upper threshold value for object batteryChargingCycleCount. If the value of object batteryChargingCycleCount rises above this threshold, a battery aging alarm will be raised. The alarm procedure may include generating a batteryAgingNotification.

A value of 0 indicates that no alarm will be raised for any value of object batteryChargingCycleCount."

::= { batteryEntry 23 }

batteryHighAlarmTemperature OBJECT-TYPE

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

    A value of '7fffffff'H indicates that no alarm will be
    raised for any value of object batteryTemperature."
 ::= { batteryEntry 24 }
```

batteryLowAlarmTemperature OBJECT-TYPE

```
SYNTAX      Integer32
UNITS       "deci-degrees Celsius"
MAX-ACCESS  read-write
STATUS      current
DESCRIPTION
    "This object provides the lower threshold value for object
    batteryTemperature.  If the value of object
    batteryTemperature rises above this threshold, a battery
    low temperature alarm will be raised.  The alarm procedure
    may include generating a batteryLowTemperatNotification.

    A value of '7fffffff'H indicates that no alarm will be
    raised for any value of object batteryTemperature."
 ::= { batteryEntry 25 }
```

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

batteryLowNotification NOTIFICATION-TYPE

```
OBJECTS     {
    batteryActualCharge,
    batteryActualVoltage
}
STATUS      current
DESCRIPTION
    "This notification can be generated when the current charge
    (batteryActualCharge) or the current voltage
    (batteryActualVoltage) of the battery falls below a
    threshold defined by object batteryLowAlarmCharge or object
    batteryLowAlarmVoltage, respectively. The notification can
```

only be sent again when the current voltage or the current charge become higher than the respective thresholds through charging before falling below the thresholds again (to avoid fluctuations through e.g. temperature). The notification can also be sent again when a charging process is interrupted and either the battery charge (batteryActualCharge) or battery voltage (batteryActualVoltage) is still below either the value of the object batteryLowAlarmCharge or the value of object batteryLowAlarmVoltage."

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

batteryAgingNotification NOTIFICATION-TYPE

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

batteryHighTemperatNotification NOTIFICATION-TYPE

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

batteryLowTemperatNotification NOTIFICATION-TYPE

```
OBJECTS      {
    batteryTemperature
}
STATUS       current
DESCRIPTION   "This notification can be generated when the actual
               temperature (batteryTemperature) falls below a threshold
               defined by object batteryLowAlarmTemperature."
::= { batteryNotifications 4 }
```



```
-----
-- 3. Conformance Information
-----

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

-----

-- 3.1. Compliance Statements
-----

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

        A compliant implementation MUST implement the objects
        defined in the mandatory groups batteryDescriptionGroup
        and batteryStatusGroup."
    MODULE -- this module
        MANDATORY-GROUPS {
            batteryDescriptionGroup,
            batteryStatusGroup
        }

    GROUP    batteryAlarmThresholdsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryAlarmThresholdsGroup."

    GROUP    batteryNotificationsGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryNotificationsGroup."

    GROUP    batteryAdminGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the batteryAdminGroup."

    OBJECT batteryLowAlarmCharge
    MIN-ACCESS read-only
    DESCRIPTION
        "The agent is not required to support set
        operations to this object."

    OBJECT batteryLowAlarmVoltage
```

MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

OBJECT batteryReplacementAlarmCapacity
MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

OBJECT batteryReplacementAlarmCycles
MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

OBJECT batteryHighTemperatNotification
MIN-ACCESS read-only
DESCRIPTION
"The agent is not required to support set
operations to this object."

::= { batteryCompliances 1 }

-- 3.2. MIB Grouping

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

batteryStatusGroup OBJECT-GROUP

```
OBJECTS {
    batteryActualCapacity,
    batteryChargingCycleCount,
    batteryLastChargingCycleTime,
    batteryChargingOperState,
    batteryActualCharge,
    batteryActualVoltage,
    batteryActualCurrent,
    batteryTemperature
}
STATUS      current
DESCRIPTION
    "A compliant implementation MUST implement the objects
    contained in this group."
::= { batteryGroups 2 }

batteryAdminGroup OBJECT-GROUP
OBJECTS {
    batteryChargingAdminState
}
STATUS      current
DESCRIPTION
    "A compliant implementation does not have to implement the
    object contained in this group."
::= { batteryGroups 3 }

batteryAlarmThresholdsGroup OBJECT-GROUP
OBJECTS {
    batteryLowAlarmCharge,
    batteryLowAlarmVoltage,
    batteryReplacementAlarmCapacity,
    batteryReplacementAlarmCycles,
    batteryHighAlarmTemperature,
    batteryLowAlarmTemperature
}
STATUS      current
DESCRIPTION
    "A compliant implementation does not have to implement the
    objects contained in this group."
::= { batteryGroups 4 }

batteryNotificationsGroup NOTIFICATION-GROUP
NOTIFICATIONS {
    batteryLowNotification,
    batteryAgingNotification,
    batteryHighTemperatNotification,
    batteryLowTemperatNotification
}
```

```
STATUS      current
DESCRIPTION
    "A compliant implementation does not have to implement the
    notifications contained in this group."
 ::= { batteryGroups 5 }
END
```

5. Security Considerations

There are a number of management objects defined in this MIB module with a MAX-ACCESS clause of read-write. Such objects may be considered sensitive or vulnerable in some network environments. The support for SET operations in a non-secure environment without proper protection can have a negative effect on network operations. These are the tables and objects and their sensitivity/vulnerability:

- o batteryChargingAdminState
Setting the battery charging state can be beneficial for an operator for various reasons such as charging batteries when the price of electricity is low. However, setting the charging state can e.g. be used by an attacker to discharge batteries of devices and thereby switching these devices off if they are powered solely by batteries. In particular, if the batteryLowAlarmCharge and batteryLowAlarmVoltage can also be set, this attack will go unnoticed (i.e. no notifications are sent).
- o batteryLowAlarmCharge and batteryLowAlarmVoltage
These objects set the threshold for an alarm to be raised when the battery charge or voltage falls below the corresponding one of them. An attacker setting one of these alarm values can switch off the alarm by setting it to the 'off' value 0 or modify the alarm behavior by setting it to any other value. The result may be loss of data if the battery runs empty without warning to a recipient expecting such a notification.
- o batteryReplacementAlarmCapacity and batteryReplacementAlarmCycles
These objects set the threshold for an alarm to be raised when the battery become older and less performant as required for stable operation. An attacker setting this alarm value can switch off the alarm by setting it to the 'off' value 0 or modify the alarm behavior by setting it to any other value. This may on one side lead to a costly too early replacement of a battery. But it may also cause that too old or too weak batteries are used. This may have the consequence that a battery cannot long enough provide power between two scheduled charging actions causing the powered device to shut down and potentially loose data.

- o batteryHighAlarmTemperature and batteryLowAlarmTemperature
These objects set thresholds for an alarm to be raised when the battery rises above/falls below them. An attacker setting one of these alarm values can switch off these alarms by setting them to the 'off' value '7fffffff'H or modify the alarm behavior by setting them to any other value. The result may e.g. be an unnecessary shutdown of a device if batteryHighAlarmTemperature is set to too low or damage to the device by too high temperatures if switched off or set to too high values or by damage to the battery when it e.g. is being charged. Batteries can also be damaged e.g. in an attempt to charge them at too low temperatures.

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

All potentially sensible or vulnerable objects of this MIB modules are in the batteryTable. In general, there are no serious operational vulnerabilities foreseen in case of an unauthorized read access to this table. However, privacy issues need to be considered. It may be a trade secret of the operator

- o how many batteries are installed in a managed node (batteryIndex)
- o how old these batteries are (batteryActualCapacity and batteryChargingCycleCount)
- o when the next replacement cycle for batteries can be expected (batteryReplacementAlarmCapacity and batteryReplacementAlarmCycles)
- o what battery type and make are used with which firmware version (batteryIdentifier, batteryFirmwareVersion, batteryType, and batteryTechnology)

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

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

Further, deployment of SNMP versions prior to SNMPv3 is NOT RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to

enable cryptographic security. It is then a customer/operator responsibility to ensure that the SNMP entity giving access to an instance of this MIB module is properly configured to give access to the objects only to those principals (users) that have legitimate rights to indeed GET or SET (change/create/delete) them.

6. IANA Considerations

6.1. SMI Object Identifier Registration

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

Descriptor	OBJECT IDENTIFIER value
-----	-----
batteryMIB	{ mib-2 xxx }

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

6.2. Battery Technology Registration

Object batteryTechnology defined in Section 4 reports battery technologies. 18 values for battery technologies have initially been defined. They are listed in a table in Section 3.2.

For ensuring extensibility of this list, IANA has created a registry for battery technologies at <http://www.iana.org/assignments/eman> and filled it with the initial list given in Section 3.2.

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

[NOTE for IANA: Please create a new registry under <http://www.iana.org/assignments/eman> for battery types. Please fill the registry with values from the table in Section 3.2]

7. Open Issues

7.1. Time estimations

Shall we add managed objects and notifications that are based on the estimated time that the battery will be able to provide power (time-to-empty) or will need until it is fully charged (time-to-full). In

general this is useful and desired information. However, this information is not reliable. It is based on the assumption that the actual current will be continuous drawn from the battery or used to charge the battery. Additionally, it is assumed that the battery chemistry works as expected. Both may not be the case.

The list of time estimations and related alarms on the table include: RemainingTimeAlarm, AtRateTimeToFull, AtRateTimeToEmpty, AtRateOK, RunTimeToEmpty, AverageTimeToEmpty, AverageTimeToFull.

From previous discussions it seems that the AtRate ones will be more difficult to implement and it is questionable whether the effort is worth the gain. The RunTimeToEmpty and AverageTimeToEmpty and AverageTimeToFull might be interesting but needs to be decided on the list. With the objects we have so far, this could also be implemented in the NMS.

7.2. Capacity reduction per time

Do we want to include a measure to show the capacity reduction over time. This can be seen as another measure of aging and battery quality.

7.3. Internal impedance

Is this a value we need?

7.4. Wireless charging

Are there any special requirements we need to cover that stem from wireless charging systems (e.g. charging states)?

7.5. Entity MIB augmentation

Should the batteryTable augment the entPhysicalTable from the Entity MIB?

8. Acknowledgements

We would like to thank Steven Chew and Bill Mielke for their valuable input.

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July 10, 2012

Energy Object Context MIB
draft-ietf-eman-energy-aware-mib-06

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<Parello, Claise>

Expires January 11, 2013

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Abstract

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

Conventions used in this document

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

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1. Introduction

The EMAN standards provide a specification for Energy Management. This document defines a subset of a Management Information Base (MIB) for use with network management protocols for Energy monitoring of network devices and devices attached to the network and possibly extending to devices in the industrial automation setting with a network interface.

The focus of the MIB module specified in this document is on the identification of Energy Objects and reporting the context and relationships of Energy Objects as defined in [EMAN-FMWK]. The module addresses Energy Object Identification, Energy Object Context, and Energy Object Relationships.

1.1. Energy Management Document Overview

This document specifies the ENERGY-OBJECT-CONTEXT-MIB module. This document is based on the Energy Management Framework [EMAN-FMWK] and meets the requirements on identification of Energy Objects and their context and relationships as specified in the Energy Management requirements [EMAN-REQ].

A second MIB module required by the [EMAN-FMWK], the Power and Energy Monitoring MIB [EMAN-MON-MIB], monitors the Energy Objects for Power States, for the Power and Energy consumption. Power State monitoring includes: retrieving Power States, Power State properties, current Power State, Power State transitions, and Power State statistics. In addition, this MIB module provides the Power Characteristics properties of the Power and Energy, along with optional characteristics.

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

2. The Internet-Standard Management Framework

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

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

3. Requirements and Use Cases

Firstly, to illustrate the importance of energy monitoring in networks and secondly to list some of the important areas to be addressed by the energy management Framework, several use cases and network scenarios are presented in the EMAN applicability statement document [EMAN-AS]. In addition, for each scenario, the target devices for energy management, and how those devices powered and metered are also presented. To address the network scenarios, requirements for power and energy monitoring for networking devices are specified in [EMAN-REQ]. Based on the requirements [EMAN-REQ], the [EMAN-FMWK] presents an solution approach.

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

4. Terminology

EDITOR'S NOTE:

The individual draft submission [EMAN-TERMINOLOGY] contains the terminology used in this draft. Please refer to WG draft [EMAN-FMWK] for the definitions of the terminology used in this draft.

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

The Energy Object Context MIB module defined in this document defines MIB objects for identification of Energy Objects, and reporting context and relationship of an Energy Object. The managed objects are contained in two tables eoTable and eoProxyTable.

The first table eoTable focuses on the link to the other MIB modules, context of the Energy Object. The second table eoRelationTable specifies the relationships between Energy Objects. This is a simplified representation of relationship between Energy Objects. The third table eoProxyTable describes the proxy capabilities of a Energy Object Parent for a specific local Energy Object Child.

```
+-- eoTable(2)
|
|+-- eoEntry(1) [entPhysicalIndex]
|   |
|   |--- r-n PethPsePortIndexOrZero          eoEthPortIndex(1)
|   |--- r-n PethPsePortGroupIndexOrZero     eoEthPortGrpIndex(2)
|   |--- r-n LldpPortNumberOrZero            eoLldpPortNumber(3)
|   |--- rwn MacAddress                      eoMgmtMacAddress(4)
|   |--- r-n eoMgmtAddressType                eoMgmtAddressType(5)
|   |--- r-n InetAddress                     eoMgmtAddress(6)
|   |--- r-n SnmpAdminString                 eoMgmtDNSName(7)
|   |--- rwn SnmpAdminString                 eoDomainName(8)
|   |--- rwn SnmpAdminString                 eoRoleDescription(9)
|   |--- rwn EnergyObjectKeywordList         eoKeywords(10)
|   |--- rwn Integer32                       eoImportance(11)
|   |--- r-n INTEGER                         eoPowerCategory(12)
|   |--- rwn SnmpAdminString                 eoAlternateKey(13)
|
|   +- eoRelationTable
|       |
|       |+- eoRelationEntry [entPhysicalIndex, eoRelationIndex]
|       |   |
|       |   |--- --n INTEGER                  eoRelationIndex(1)
|       |   |--- --n OctetString              eoRelationID(2)
|       |   |--- r-n BITS                     eoRelationship(3)
```

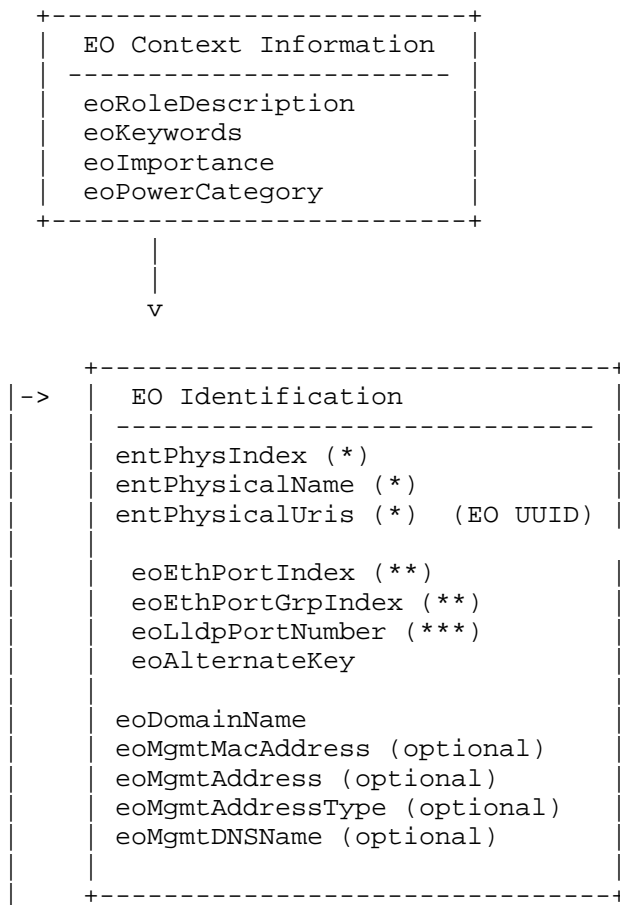


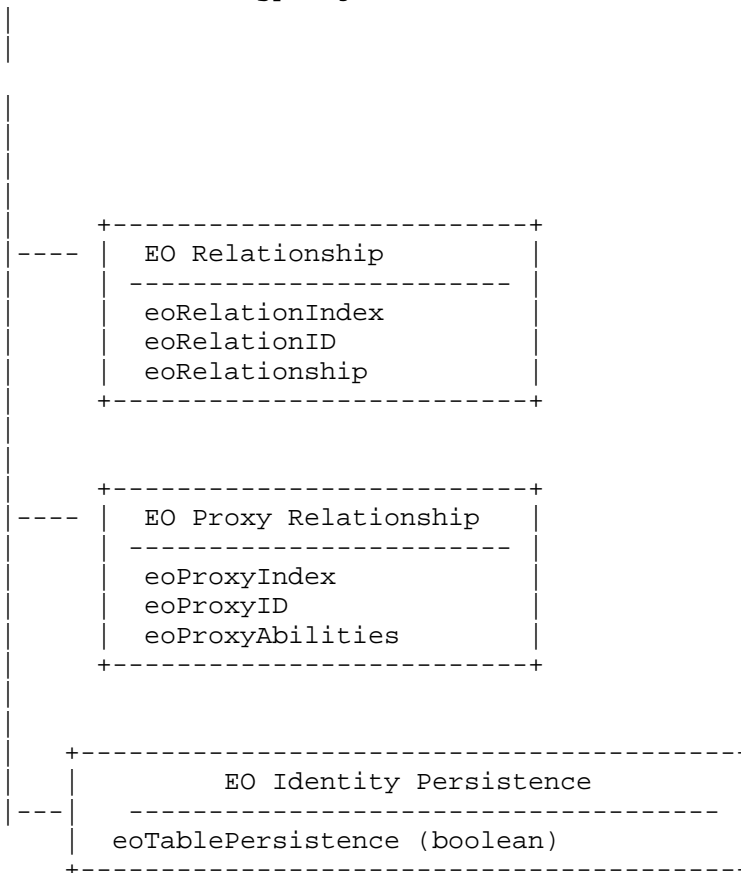
```

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|
|   +- eoProxyTable(3)
|
|       +- eoProxyEntry (1)[entPhysicalIndex , eoProxyIndex ]
|       |
|       |   +--- --n INTEGER                      eoProxyIndex(1)
|       |   +--- --n OctetString                  eoProxyID(2)
|       |   +--- r-n BITS                        eoProxyAbilities(3)
|

```

The following UML diagram illustrates the relationship of the MIB objects in the eoTable, eoRelationTable and eoProxyTable that describe the identity, context and relationship of an Energy Object.





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

Figure 1: MIB Objects Grouping

As displayed in figure 1, the MIB objects can be classified in different logical grouping of MIB objects.

- 1) The Energy Object Identification. See Section 5.1 "Energy Object Identification". Devices and their sub-components are characterized by the power-related attributes of a physical entity present in the ENTITY MIB [RFC4133].

- 2) The Context Information. See Section 5.2 "Energy Object Context"
- 3) The links to other MIB modules. See Section 5.3 "Links to other Identifiers"
- 4) The Energy Object Child Relationships specific information. See Section 5.4 "Child: Energy Objects Relationship."
- 5) The Energy Object Parent Relationships specific information. See Section 5.5 "Parent: Energy Objects Relationship."
- 6) The Energy Object Identity Persistence. See Section 5.6 "Energy Object Identity Persistence"

5.1 Energy Object Identification

Refer to the "Energy Object Information" section in [EMAN-FMWK] for background information about Energy Objects.

Every Energy Object MUST implement the unique index, `entPhysicalIndex`, from the ENTITY MIB [RFC4133], which is used as index for the primary Energy Object information in the ENERGY-OBJECT-CONTEXT-MIB module.

Every Energy Object MUST have a printable name assigned to it. Energy Objects MUST implement the `entPhysicalName` object specified in the ENTITY-MIB, which must contain the Energy Object name.

By the [RFC4133] definition, the `entPhysicalUris` contains a white space separated list of Uniform Resource Identifier (s)(URIs). For the ENERGY-OBJECT-CONTEXT-MIB compliance, every Energy Object instance MUST implement the `entPhysicalUris` from the ENTITY MIB [RFC4133]. The `entPhysicalUris` MUST contain the Energy Object UUID, in a form consistent with [RFC4122]. Note that the `entPhysicalUris`, from the ENTITY-MIB, is a read-write managed object, and that, as a consequence the UUID could be set by a management system.

As displayed in [RFC4122], the following is an example of the string representation of a UUID as a URN: `urn:uuid:f81d4fae-7dec-11d0-a765-00a0c91e6bf6`.

Other ENTITY MIB related managed objects, in addition to `entPhysicalIndex`, `entPhysicalName`, and `entPhysicalUris` [RFC4133] MAY be implemented. For example, to understand the relationship between Energy Object Components and Energy Objects, the ENTITY-MIB physical containment tree [RFC4133] MUST be implemented.

A second example deals with one of the ENTITY-MIB extensions: if the Energy Object temperature is required, the managed objects from the ENTITY-SENSOR-MIB [RFC3433] should be supported.

When an Energy Object Parent acts as a Power Aggregator or a Power Proxy, the Energy Object Parent and its Energy Object Child/Children MUST be members of the same Energy Management Domain, specified by the eoDomainName MIB Object.

Each Energy Object MUST belong to a single Energy Management Domain or in other words, an Energy Object cannot belong to more than one Energy Management Domain. Refer to the "Energy Management Domain" section in [EMAN-FMWK] for background information. The eoDomainName, which is an element of the eoTable, is a read-write MIB object. The Energy Management Domain should map 1-1 with a metered or sub-metered portion of the network. The Energy Management Domain MUST be configured on the Energy Object Parent. The Energy Object Children MAY inherit the some of the domain parameters (possibly domain name, some of the context information such as role or keywords, importance) from the Energy Object Parent or the Energy Management Domain MAY be configured directly in an Energy Object Child.

5.2 Energy Object Context

Refer to the "Energy Object Context" section in [EMAN-FMWK] for background information.

An Energy Object must provide a value for eoImportance in the range of 1..100 to help differentiate the use or relative value of the device. The importance range is from 1 (least important) to 100 (most important). The default importance value is 1.

An Energy Object can provide a set of eoKeywords. These keywords are a list of tags that can be used for grouping and summary reporting within or between Energy Management Domains.

An Energy Object can be classified based on the physical properties of the Energy Object. That Energy Object can be classified as consuming power or supplying power to other devices or that Energy Object can perform both of those functions and finally, an Energy Object can be a passive meter.

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Additionally, an Energy Object can provide an eoRoleDescription string that indicates the purpose the Energy Object serves in the network.

5.3 Links to Other Identifiers

While the entPhysicalIndex is the primary index for all MIB objects in the ENERGY-OBJECT-CONTEXT-MIB module, the Energy Management Systems (EnMS) must be able to make the link with the identifier(s) in other supported MIB modules.

If the Energy Object is a PoE port, and if the Power over Ethernet MIB [RFC3621] is supported by the Energy Object SNMP agent, then the Energy Object eoethPortIndex and eoethPortGrpIndex MUST contain the values of pethPsePortIndex and pethPsePortGroupIndex [RFC3621].

The Energy Object eoLldpPortNumber MUST contain the lldpLocPortNum from the LLDP MIB [LLDP-MIB], if the LLDP-MED MIB is supported on the Energy Object SNMP agent.

The intent behind the links to the other MIB module identifier(s) is to correlate the instances in the different MIB modules. This will allow the ENERGY-OBJECT-CONTEXT-MIB MIB module to reference other MIB modules in cases where the Power over Ethernet and the LLDP MIB modules are supported by the SNMP agent. Some use cases may not implement any of these two MIB modules for the Energy Objects. However, in situation where any of these two MIB modules are implemented, the EnMS must be able to correlate the instances in the different MIB modules.

The eoAlternateKey alternate key object specifies a manufacturer defined string that can be used to identify the Energy Object. Since EnMS may need to correlate objects across management systems, this alternate key is provided to facilitate such a link. This optional value is intended as a foreign key or alternate identifier for a manufacturer or EnMS to use to correlate the unique Energy Object Id in other systems or namespaces. If an alternate key is not available or is not applicable then the value is the zero-length string.

5.4 Child: Energy Object Relationships

Refer to the "Energy Object Parent and Child" section in [EMAN-FMWK] for the definition and background information.

In order to link the Energy Object Child and the Energy Object Parent, a separate table (eoRelationTable) has been introduced in this MIB module. The following relationships between Energy objects have been considered in the eoRelationTable.

Metering Relationship -> meteredby , metering

Power Source Relationship -> poweredby , powering

Aggregation Relationship -> aggregatedby , aggregating

Proxy Relationship -> proxyby , proxying

Each Energy object can have one or more Energy Object relationships with other Energy Objects. Depending on the direction of the relationship, an Energy Object can be considered as an Energy Object Parent or an Energy Object Child. The relationship between the Energy Objects is specified with an arbitrary index and the UUID of the remote Energy Object. The UUID MUST comply to the RFC 4122 specifications. It is important to note that it is possible that an Energy Object may not have an Energy Object relationship with other Energy Objects.

Proxy is a special relationship, and the Energy Object can designate another Energy Object that can have the proxy capabilities such as energy reporting, power state configurations, non physical wake capabilities (such as Wake-on-LAN)), or any combination of capabilities.

The eoProxyAbilities object is specific to the Proxy Relationship. This object describes the capabilities of the Energy Object Parent for the Energy Object Child represented by the entPhysicalIndex. The possible capabilities are: report, configuration, and/or wakeonlan. This object only applies to an Energy Object Child.

Since the communication between the Energy Object Parent and Energy Object Child may not be via SNMP (as defined in EMAN-FMWK), an Energy Object Child can have additional MIB objects that can be used for easier identification by the EnMS. The optional objects eoMgmtMacAddress, eoMgmtAddressType, eoMgmtDNSName can be used to help identify the relationship between the child and other NMS objects. These objects can be

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used as an alternate key to help link the Energy Object with
other keyed information that may be stored within the EnMS(s).

5.5 Parent: Energy Object Relationships

When the Energy Object is an Energy Object Parent, the relationship table specifies the relationships to every Energy Object children. The explicit relationship between the Energy Object parent and each Energy Object child can be powering, metering, proxying and aggregating.

5.6 Energy Object Identity Persistence

In some situations, the Energy Object identity information should be persistent even after a device reload. For example, in a static setup where a switch monitors a series of connected PoE phones, there is a clear benefit for the EnMS if the Energy Object Identification and all associated information persist, as it saves a network discovery. However, in other situations, such as a wireless access point monitoring the mobile user PCs, there is not much advantage to persist the Energy Object Information. The identity information of an Energy Object should be persisted and there is value in the writable MIB objects persisted.

6. MIB Definitions

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

```
ENERGY-OBJECT-CONTEXT-MIB DEFINITIONS ::= BEGIN
```

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

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mib-2,
Integer32
 FROM SNMPv2-SMI
TEXTUAL-CONVENTION, MacAddress, TruthValue
 FROM SNMPv2-TC
MODULE-COMPLIANCE,
OBJECT-GROUP
 FROM SNMPv2-CONF
SnmAdminString
 FROM SNMP-FRAMEWORK-MIB
InetAddressType, InetAddress
 FROM INET-ADDRESS-MIB
entPhysicalIndex
 FROM ENTITY-MIB;

energyAwareMIB MODULE-IDENTITY
LAST-UPDATED "201207100000Z"
ORGANIZATION "IETF EMAN Working Group"
CONTACT-INFO
 "WG Charter:
 <http://datatracker.ietf.org/wg/eman/charter/>

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

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 IN
 Phone: +91 80 4426 3947
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DESCRIPTION

"This MIB is used for describing the identity and the
context information of Energy Objects"

REVISION

"201207100000Z"

DESCRIPTION

"Initial version, published as RFC XXXX."

::= { mib-2 xxxxx }

energyAwareMIBNotifs OBJECT IDENTIFIER

::= { energyAwareMIB 0 }

energyAwareMIBObjects OBJECT IDENTIFIER

::= { energyAwareMIB 2 }

energyAwareMIBConform OBJECT IDENTIFIER

::= { energyAwareMIB 3 }

-- Textual Conventions

PethPsePortIndexOrZero ::= TEXTUAL-CONVENTION

DISPLAY-HINT "d"

STATUS current

DESCRIPTION

"This textual convention is an extension of the
pethPsePortIndex convention, which defines a greater than
zero value used to identify a power Ethernet PSE port.
This extension permits the additional value of zero. The
semantics of the value zero are object-specific and must,
therefore, be defined as part of the description of any
object that uses this syntax. Examples of the usage of
this extension are situations where none or all physical
entities need to be referenced."

PethPsePortGroupIndexOrZero ::= TEXTUAL-CONVENTION
DISPLAY-HINT "d"
STATUS current
DESCRIPTION
 "This textual convention is an extension of the
 pethPsePortGroupIndex convention from the Power Over
 Ethernet MIB [RFC3621], which defines a greater than zero
 value used to identify group containing the port to which
 a power Ethernet PSE is connected. This extension
 permits the additional value of zero. The semantics of
 the value zero are object-specific and must, therefore,
 be defined as part of the description of any object that
 uses this syntax. Examples of the usage of this
 extension are situations where none or all physical
 entities need to be referenced."
SYNTAX Integer32 (0..2147483647)

LldpPortNumberOrZero ::= TEXTUAL-CONVENTION
DISPLAY-HINT "d"
STATUS current
DESCRIPTION
 "This textual convention is an extension of the
 LldpPortNumber convention specified in the LLDP MIB,
 which defines a greater than zero value used to uniquely
 identify each port contained in the chassis (that is
 known to the LLDP agent) by a port number. This
 extension permits the additional value of zero. The
 semantics of the value zero are object-specific and must,
 therefore, be defined as part of the description of any
 object that uses this syntax. Examples of the usage of
 this extension are situations where none or all physical
 entities need to be referenced."
SYNTAX Integer32(0..4096)

EnergyObjectUUID ::= TEXTUAL-CONVENTION
STATUS current
DESCRIPTION
 "An arbitrary value that uniquely identifies the Energy
 Object. The object contains a single URI and, therefore,
 the syntax of this object must conform to IETF RFC

REFERENCE

"RFC 3986, Uniform Resource Identifiers (URI): Generic Syntax, section 2, August 1998.

RFC 4122, Uniform Resource Identifier (UUID) URN Namespace, July 2005."

SYNTAX OCTET STRING (SIZE (0..65535))

EnergyObjectKeywordList ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"A list of keywords that can be used to group Energy Objects for reporting or searching. If multiple keywords are present, then this string will contain all the keywords separated by the ',' character. All alphanumeric characters and symbols (other than a comma), such as #, (, \$, !, and &, are allowed. White spaces before and after the commas are excluded, as well as within a keyword itself.

For example, if an Energy Object were to be tagged with the keyword values 'hospitality' and 'guest', then the keyword list will be 'hospitality,guest'."

SYNTAX OCTET STRING (SIZE (0..2048))

EnergyRelations ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"This object specifies relationship between Energy Objects. For example, poweredby relationship indicates, Energy Object A is powered by Energy Object B. From the point of view of Energy Object B, it is powering Energy Object A. "

SYNTAX BITS {
none (0), --
poweredby(1), -- power relationship
powering(2),
meteredby(3), -- meter relationship
metering(4),
proxyby(5), -- proxy relationship

```
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                  proxying(6),
                  aggregatedby(7), -- aggregation relationship
                  aggregating(8)
                  }
```

-- Objects

```
eoTablePersistence OBJECT-TYPE
    SYNTAX      TruthValue
    MAX-ACCESS   read-write
    STATUS      current
    DESCRIPTION
        "This object enables/disables persistence re-
        initializations of the local management subsystem for
        all entries in the eoTable, eoRelationsTable and
        eoProxyTable. A value of true(1) enables the persistence,
        while a value of false(2) disables the persistence."
    ::= { energyAwareMIBObjects 1 }
```

```
eoTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF EoEntry
    MAX-ACCESS   not-accessible
    STATUS      current
    DESCRIPTION
        "This table lists Energy Objects."
    ::= { energyAwareMIBObjects 2 }
```

```
eoEntry OBJECT-TYPE
    SYNTAX      EoEntry
    MAX-ACCESS   not-accessible
    STATUS      current
    DESCRIPTION
        "An entry describes the attributes of an Energy Object.
        Whenever a new Energy Object is added or an existing
        Energy Object is deleted, a row in the eoTable is added
        or deleted."

    INDEX      {entPhysicalIndex }
    ::= { eoTable 1 }
```

```

EoEntry ::= SEQUENCE {
    eoEthPortIndex          PethPsePortIndexOrZero,
    eoEthPortGrpIndex       PethPsePortGroupIndexOrZero,
    eoLldpPortNumber        LldpPortNumberOrZero,
    eoMgmtMacAddress         MacAddress,
    eoMgmtAddressType        InetAddressType,
    eoMgmtAddress            InetAddress,
    eoMgmtDNSName            SnmpAdminString,
    eoDomainName             SnmpAdminString,
    eoRoleDescription        SnmpAdminString,
    eoKeywords               EnergyObjectKeywordList,
    eoImportance              Integer32,
    eoPowerCategory          INTEGER,
    eoAlternateKey            SnmpAdminString
}

```

```

eoEthPortIndex    OBJECT-TYPE
    SYNTAX          PethPsePortIndexOrZero
    MAX-ACCESS      read-only
    STATUS           current
    DESCRIPTION
        "This variable uniquely identifies the power Ethernet
        port to which the attached device is connected [RFC3621].
        In addition, PoE MIB should be instantiated on the
        device. If such a power Ethernet port cannot be specified
        or is not known then the object is zero."
    ::= { eoEntry 1 }

```

```

eoEthPortGrpIndex OBJECT-TYPE
    SYNTAX          PethPsePortGroupIndexOrZero
    MAX-ACCESS      read-only
    STATUS           current
    DESCRIPTION
        "This variable uniquely identifies the group containing
        the port to which a power Ethernet PSE is connected
        [RFC3621]. In addition, PoE MIB should be instantiated on
        the device. If such a group cannot be specified or is not
        known then the object is zero."
    ::= { eoEntry 2 }

```

```

eoLldpPortNumber  OBJECT-TYPE
    SYNTAX          LldpPortNumberOrZero
    MAX-ACCESS      read-only
    STATUS           current
    DESCRIPTION

```

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 "This variable uniquely identifies the port component
 (contained in the local chassis with the LLDP agent) as
 defined by the lldpLocPortNum in the [LLDP-MIB] and
 [LLDP-MED-MIB]. In addition, LLDP MIB should be
 instantiated on the device If such a port number cannot
 be specified or is not known then the object is zero."
::= { eoEntry 3 }

eoMgmtMacAddress OBJECT-TYPE
 SYNTAX MacAddress
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This object specifies a MAC address of the Energy
 Object. This object typically only applies to Energy
 Object Children. This object can be used as an alternate
 key to help link the Energy Object with other keyed
 information that may be stored within the EnMS(s). The
 eoMgmtMacAddress MIB object SHOULD be implemented for
 Energy Object Children, and MAY be implemented for Energy
 Object Parents."
::= { eoEntry 4 }

eoMgmtAddressType OBJECT-TYPE
 SYNTAX InetAddressType
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This object specifies the eoMgmtAddress type, i.e. an
 IPv4 address or an IPv6 address. This object MUST be
 populated when eoMgmtAddress is populated. The
 eoMgmtAddressType MIB object SHOULD be implemented for
 Energy Object Children, and MAY be implemented for Energy
 Object Parents."
::= { eoEntry 5 }

eoMgmtAddress OBJECT-TYPE
 SYNTAX InetAddress
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This object specifies the management address as an IPv4
 address or IPv6 address of Energy Object. The IP address
 type, i.e. IPv4 or IPv6, is determined by the
 eoMgmtAddressType value. This object can be used as an
 alternate key to help link the Energy Object with other

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keyed information that may be stored within the EnMS(s).
The eoMgmtAddress MIB object SHOULD be implemented for
Energy Object Children, and MAY be implemented for Energy
Object Parents."
::= { eoEntry 6 }

eoMgmtDNSName OBJECT-TYPE
SYNTAX SnmpAdminString
MAX-ACCESS read-only
STATUS current
DESCRIPTION
 "This object specifies the DNS name of the eoMgmtAddress.
 This object can be used as an alternate key to help link
 the Energy Object with other keyed information that may
 be stored within the EnMS(s). The eoMgmtDNSName MIB
 objects SHOULD be implemented for Energy Object Children,
 and MAY be implemented for Energy Object Parents."

::= { eoEntry 7 }

eoDomainName OBJECT-TYPE
SYNTAX SnmpAdminString
MAX-ACCESS read-write
STATUS current
DESCRIPTION
 "This object specifies the name of an Energy Management
 Domain for the Energy Object. This object specifies a
 zero-length string value if no Energy Management Domain
 name is configured. The value of eoDomainName must remain
 constant at least from one re-initialization of the
 Energy Objects local management system to the next re-
 initialization."

::= { eoEntry 8 }

eoRoleDescription OBJECT-TYPE
SYNTAX SnmpAdminString
MAX-ACCESS read-write
STATUS current
DESCRIPTION
 "This object specifies an administratively assigned name
 to indicate the purpose an Energy Object serves in the
 network.

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

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This object specifies the value is the zero-length string
value if no role description is configured."

::= { eoEntry 9 }

eoKeywords OBJECT-TYPE

SYNTAX EnergyObjectKeywordList
MAX-ACCESS read-write
STATUS current

DESCRIPTION

"This object specifies a list of keywords that can be used to group Energy Objects for reporting or searching. The value is the zero-length string if no keywords have been configured. If multiple keywords are present, then this string will contain all the keywords separated by the ',' character. For example, if an Energy Object were to be tagged with the keyword values 'hospitality' and 'guest', then the keyword list will be 'hospitality,guest'.

If write access is implemented and a value is written into the instance, the agent must retain the supplied value in the eoKeywords instance associated with the same physical entity for as long as that entity remains instantiated. This includes instantiations across all re-initializations/reboots of the local management agent. eoKeywords shall be persistent independent of eoTablePersistence. "

::= { eoEntry 10 }

eoImportance OBJECT-TYPE

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

DESCRIPTION

"This object specifies a ranking of how important the Energy Object is (on a scale of 1 to 100) compared with other Energy Objects in the same Energy Management Domain. The ranking should provide a business or operational context for the Energy Object as compared to other similar Energy Objects. This ranking could be used as input for policy-based network management.

Although network managers must establish their own ranking, the following is a broad recommendation:


```
90 to 100 Emergency response
80 to 90 Executive or business critical
70 to 79 General or Average
60 to 69 Staff or support
40 to 59 Public or guest
1 to 39 Decorative or hospitality"
DEFVAL { 1 }
 ::= { eoEntry 11 }
```

eoPowerCategory OBJECT-TYPE

```
SYNTAX INTEGER {
    consumer(0),
    producer(1),
    consumerproducer(2),
    meter(3)
}
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object describes the Energy Object category, which indicates the expected behavior or physical property of the Energy Object, based on its design. An Energy Object can be a consumer(0), producer(1), or consumerproducer(2) or meter (3).

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

In some cases, a meter is required to measure the power consumption. In such a case, this meter Energy Object category is meter(3). "

```
 ::= { eoEntry 12 }
```

eoAlternateKey OBJECT-TYPE

```
SYNTAX SnmpAdminString
```

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object specifies a manufacturer defined string that can be used to identify the Energy Object. Since Energy Management Systems (EnMS) and Network Management Systems (NMS) may need to correlate objects across management systems, this alternate key is provided to provide such a link. This optional value is intended as a foreign key or alternate identifier for a manufacturer or EnMS/NMS to use to correlate the unique Energy Object Id in other

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 systems or namespaces. If an alternate key is not
 available or is not applicable then the value is the
 zero-length string."

::= { eoEntry 13 }

eoRelationTable OBJECT-TYPE

 SYNTAX SEQUENCE OF EoRelationEntry

 MAX-ACCESS not-accessible

 STATUS current

 DESCRIPTION

 "This table describes the relationships between Energy Objects."

::= { energyAwareMIBObjects 3 }

eoRelationEntry OBJECT-TYPE

 SYNTAX EoRelationEntry

 MAX-ACCESS not-accessible

 STATUS current

 DESCRIPTION

 "An entry in this table describes the relationship between
 Energy objects."

 INDEX { entPhysicalIndex, eoRelationIndex }

::= { eoRelationTable 1 }

EoRelationEntry ::= SEQUENCE {

 eoRelationIndex Integer32,

 eoRelationID EnergyObjectUUID,

 eoRelationship EnergyRelations

}

eoRelationIndex OBJECT-TYPE

 SYNTAX Integer32 (0..2147483647)

 MAX-ACCESS not-accessible

 STATUS current

 DESCRIPTION

 "This object is an arbitrary index to identify the Energy Object
 related to another Energy Object"

::= { eoRelationEntry 1 }

eoRelationID OBJECT-TYPE

 SYNTAX EnergyObjectUUID

 MAX-ACCESS read-only

 STATUS current

 DESCRIPTION

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 "This object specifies the Universally Unique Identifier (UUID)
 of the peer (other) Energy Object. The UUID must comply to the
 RFC 4122 specifications. "
 ::= { eoRelationEntry 2 }

eoRelationship OBJECT-TYPE
 SYNTAX EnergyRelations
 MAX-ACCESS read-write
 STATUS current
 DESCRIPTION

"This object describes the relations between Energy objects. For
 each Energy object, the relations between the other Energy
 objects are specified using the bitmap. If the Energy Object is
 a Parent and has no other relations, none(0) is specified."
 ::= { eoRelationEntry 3 }

eoProxyTable OBJECT-TYPE
 SYNTAX SEQUENCE OF EoProxyEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION

"This table describes the proxy capabilities of a Energy
 Object Parent for a specific local Energy Object Child. "
 ::= { energyAwareMIBObjects 4 }

eoProxyEntry OBJECT-TYPE
 SYNTAX EoProxyEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION
 "An entry describes the attributes of an Energy Object.
 Whenever a new Energy Object is added or deleted, a row
 in the eoProxyTable is added or deleted."
 INDEX { entPhysicalIndex, eoProxyIndex }
 ::= { eoProxyTable 1 }

EoProxyEntry ::= SEQUENCE {
 eoProxyIndex Integer32,
 eoProxyID EnergyObjectUUID,
 eoProxyAbilities BITS
 }

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

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DESCRIPTION

 "This object is an arbitrary index for an Energy Object."

 ::= { eoProxyEntry 1 }

eoProxyID OBJECT-TYPE

 SYNTAX EnergyObjectUUID

 MAX-ACCESS read-only

 STATUS current

 DESCRIPTION

 "This object describes the Universally Unique Identifier (UUID) of the Energy Object Parent.

 The UUID must comply to the RFC 4122 specifications.

 The object contains an URI and, therefore, the syntax of this object must conform to RFC 3986, section 2."

REFERENCE

 "RFC 3986, Uniform Resource Identifiers (URI): Generic Syntax, section 2, August 1998.

 RFC 4122, Uniform Resource Identifier (UUID) URN Namespace, July 2005."

 ::= { eoProxyEntry 2 }

eoProxyAbilities OBJECT-TYPE

 SYNTAX BITS {

 none(0),

 report(1),

 configuration(2),

 wakeonlan(3)

 }

 MAX-ACCESS read-only

 STATUS current

 DESCRIPTION

 "This object describes the proxy capabilities of the Energy Object Parent for the local Energy Object Child specified in the EoRelationTable. none (0) is be used when the Energy Object Parent does not have any proxy abilities regarding the Energy Object Child. report(1) indicates that the Energy Object Parent reports the usage for the Energy Object Child. configuration(2) indicates that the Energy Object Parent can configure the Power Level for the Energy Object Child.

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wakeonlan(3) indicates that the Energy Object Parent can
wake up the Energy Object Child (the mechanism is
unspecified)."
 ::= { eoProxyEntry 3 }

-- Conformance

energyAwareMIBCompliances OBJECT IDENTIFIER
 ::= { energyAwareMIBObjects 5 }

energyAwareMIBGroups OBJECT IDENTIFIER
 ::= { energyAwareMIBObjects 6 }

energyAwareMIBFullCompliance MODULE-COMPLIANCE
 STATUS current
 DESCRIPTION
 "When this MIB is implemented with support for
 read-write, then such an implementation can
 claim full compliance. Such devices can then
 be both monitored and configured with this MIB.
 The entPhysicalIndex, entPhysicalName, and
 entPhysicalUris [RFC4133] MUST be implemented."

MODULE -- this module
MANDATORY-GROUPS {
 energyAwareMIBTableGroup,
 energyAwareRelationTableGroup
 }

GROUP energyAwareOptionalMIBTableGroup
 DESCRIPTION
 "A compliant implementation does not have to
 implement. The entPhysicalIndex,
 entPhysicalName, and entPhysicalUris [RFC4133]
 MUST be implemented. "

GROUP energyAwareProxyTableGroup
 DESCRIPTION "A compliant MIB implementation does
 not have to implement. The entPhysicalIndex,
 entPhysicalName, and entPhysicalUris [RFC4133]
 MUST be implemented."

::= { energyAwareMIBCompliances 1 }

```

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energyAwareMIBReadOnlyCompliance MODULE-COMPLIANCE
    STATUS          current
    DESCRIPTION
        "When this MIB is implemented without support for
        read-write (i.e. in read-only mode), then such an
        implementation can claim read-only compliance.  Such a
        device can then be monitored but cannot be configured
        with this MIB. The entPhysicalIndex, entPhysicalName,
        and entPhysicalUris [RFC4133] MUST be implemented."
    MODULE          -- this module

    MANDATORY-GROUPS {
        energyAwareMIBTableGroup,
        energyAwareRelationTableGroup
    }

GROUP energyAwareOptionalMIBTableGroup
    DESCRIPTION
        "A compliant implementation does not have to implement
        the managed objects in this GROUP. Thee entPhysicalIndex,
        entPhysicalName, and entPhysicalUris [RFC4133] MUST be
        implemented. "

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

::= { energyAwareMIBCompliances 2 }

-- Units of Conformance

energyAwareMIBTableGroup OBJECT-GROUP
    OBJECTS          {
        eoTablePersistence,
        eoDomainName,
        eoRoleDescription,
        eoAlternateKey,
        eoKeywords,
        eoImportance,
        eoPowerCategory

```

```

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                  }
STATUS            current
DESCRIPTION
    "This group contains the collection of all the objects
    related to the EnergyObject. The entPhysicalIndex,
    entPhysicalName, and entPhysicalUris [RFC4133]
    MUST be implemented."
 ::= { energyAwareMIBGroups 1 }

energyAwareOptionalMIBTableGroup OBJECT-GROUP
OBJECTS
    {
        eoEthPortIndex,
        eoEthPortGrpIndex,
        eoLldpPortNumber,
        eoMgmtMacAddress,
        eoMgmtAddressType,
        eoMgmtAddress,
        eoMgmtDNSName
    }
STATUS            current
DESCRIPTION
    "This group contains the collection of all the objects
    related to the Energy Object."
 ::= { energyAwareMIBGroups 2 }

energyAwareRelationTableGroup OBJECT-GROUP
OBJECTS
    {
        -- Note that object eoRelationIndex is not
        -- included since it is not-accessible

        eoRelationID,
        eoRelationship
    }
STATUS            current
DESCRIPTION
    "This group contains the collection of all objects
    specifying the relationship between Energy Objects."
 ::= { energyAwareMIBGroups 3 }

energyAwareProxyTableGroup OBJECT-GROUP
OBJECTS
    {
        -- Note that object eoProxyIndex is not
        -- included since it is not-accessible

```

STATUS	current
--------	---------

END

7. 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 eoDomainName, entPhysicalName, eoRoleDescription, eoKeywords, and/or eoImportance MAY disrupt power and energy collection, and therefore any predefined policies defined in the network.

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

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

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

8. IANA Considerations

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

Descriptor -----	OBJECT IDENTIFIER value -----
energyAwareMIB	{ mib-2 xxx }

Additions to this MIB module are subject to Expert Review
[RFC5226], i.e., review by one of a group of experts designated
by an IETF Area Director. The group of experts MUST check the
requested MIB objects for completeness and accuracy of the
description. Requests for MIB objects that duplicate the
functionality of existing objects SHOULD be declined. The
smallest available OID SHOULD be assigned to a new MIB objects.
The specification of new MIB objects SHOULD follow the structure
specified in Section 6 and MUST be published using a well-
established and persistent publication medium.

9. Acknowledgement

We would like to thank Juergen Quittek and Juergen Schoenwalder
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draft.

OPEN ISSUE 1: Do we need global persistence with the object eoTablePersistence; some objects in the eoTable are read-only objects.

OPEN ISSUE 2: Can we have persistence of entPhysicalIndex or entPhysicalUris. That implies persistence of Entity MIB objects. How about persistence of PoE MIB objects ?

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Power and Energy Monitoring MIB
draft-ietf-eman-energy-monitoring-mib-03

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Abstract

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

Conventions used in this document

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

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1. Introduction

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

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for Energy Management are discussed in Energy Management
Applicability Statement [EMAN-AS].

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

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

2. The Internet-Standard Management Framework

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

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

3. Use Cases

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

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"Energy Management (EMAN) Applicability Statement" [EMAN-AS]. An
illustrative example scenario is presented in Section 8.

4. Terminology

Please refer to [EMAN-FRAMEWORK] for the definitions of the
following terminology used in this draft.

Device

Component

Energy Management

Energy Management System (EnMS)

ISO Energy Management System

Energy

Power

Demand

Power Characteristics

Electrical Equipment

Non-Electrical Equipment (Mechanical Equipment)

Energy Object

Electrical Energy Object

Non-Electrical Energy Object

Energy Monitoring

Energy Control

Provide Energy:

Receive Energy:

Power Interface

Power Outlet

Energy Management Domain

Energy Object Identification

Energy Object Context

Energy Object Relationship

Aggregation Relationship

Metering Relationship

Power Source Relationship

Proxy Relationship

Energy Object Parent

Energy Object Child

Power State

Power State Set

Nameplate Power

5. Architecture Concepts Applied to the MIB Module

This section describes the concepts specified in the Energy Management Framework [EMAN-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 powerCharMIB is focused on Power Characteristics measurements.

The energyObjectMib MIB module consists of four tables. The first table eoPowerTable is indexed by entPhysicalIndex. The second table eoPowerStateTable indexed by entPhysicalIndex,

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and eoPowerStateIndex. The eoEnergyParametersTable is indexed
by eoEnergyParametersIndex. The eoEnergyTable is indexed by
eoEnergyParametersIndex and eoEnergyCollectionStartTime.

```

eoMeterCapabilitiesTable(1)
|
+--- eoMeterCapabilitiesEntry(1)  [entPhysicalIndex]
|
|   +---r-n  BITS                                eoMeterCapability
|
|
eoPowerTable(1)
|
+---eoPowerEntry(1) [entPhysicalIndex]
|
|   +---r-n Integer32                            eoPower(1)
|   +---r-n Integer32                            eoPowerNamePlate(2)
|   +---r-n UnitMultiplier                       eoPowerUnitMultiplier(3)
|   +---r-n Integer32                            eoPowerAccuracy(4)
|   +---r-n INTEGER                             eoMeasurementCaliber(5)
|   +---r-n INTEGER                             eoPowerCurrentType(6)
|   +---r-n INTEGER                             eoPowerOrigin(7)
|   +---r-n Integer32                            eoPowerAdminState(8)
|   +---r-n Integer32                            eoPowerOperState(9)
|   +---r-n OwnerString                          eoPowerStateEnterReason(10)
|
+---eoPowerStateTable(2)
|
|   +---eoPowerStateEntry(1)
|   |   [entPhysicalIndex,
|   |   eoPowerStateIndex]
|   |
|   +--- --n IANAPowerStateSet  eoPowerStateIndex(1)
|   +--- r-n Integer32          eoPowerStateMaxPower (2)
|   +--- r-n UnitMultiplier
|   |   eoPowerStatePowerUnitMultiplier (3)
|   +--- r-n TimeTicks          eoPowerStateTotalTime(4)
|   +--- r-n Counter32          eoPowerStateEnterCount(5)
|
+eoEnergyParametersTable(1)
+---eoEnergyParametersEntry(1) [eoEnergyParametersIndex]
|
|
|   +--- --n PhysicalIndex          eoEnergyObjectIndex (1)
|   +   r-n Integer32               eoEnergyParametersIndex (2)
|   +--- r-n TimeInterval

```

```

|               eoEnergyParametersIntervalLength (3)
|   +--- r-n Integer32
|               eoEnergyParametersIntervalNumber (4)
|   +--- r-n Integer32
|               eoEnergyParametersIntervalMode (5)
|   +--- r-n TimeInterval
|               eoEnergyParametersIntervalWindow (6)
|   +--- r-n Integer32
|               eoEnergyParametersSampleRate (7)
|   +--- r-n RowStatus  eoEnergyParametersStatus (8)
|
|+eoEnergyTable (1)
|+---eoEnergyEntry(1) [ eoEnergyParametersIndex,
eoEnergyCollectionStartTime]
|
|   +--- r-n TimeTicks      eoEnergyCollectionStartTime (1)
|   +--- r-n Integer32      eoEnergyConsumed (2)
|   +--- r-n Integer32      eoEnergygyProduced (3)
|   +--- r-n Integer32      eoEnergyNet (4)
|   +--- r-n UnitMultiplier
|               eoEnergyUnitMultiplier (5)
|   +--- r-n Integer32      eoEnergyAccuracy(6)
|   +--- r-n Integer32      eoEnergyMaxConsumed (7)
|   +--- r-n Integer32      eoEnergyMaxProduced (8)
|   +--- r-n TimeTicks
|               eoEnergyDiscontinuityTime(9)
|   +--- r-n RowStatus      eoEnergyParametersStatus (10)

```

The powerCharacteristicsMIB consists of four tables.
 eoACPwrCharTable is indexed by entPhysicalIndex.
 eoACPwrCharPhaseTable is indexed by entPhysicalIndex and
 eoPhaseIndex. eoACPwrCharWyePhaseTable and
 eoACPwrCharDelPhaseTable are indexed by entPhysicalIndex and
 eoPhaseIndex.

```

eoACPwrCharTable(1)
|
|+---eoACPwrCharEntry (1) [ entPhysicalIndex]
|
|   +---r-n INTEGER      eoACPwrCharConfiguration (1)
|   +--- r-n Integer32    eoACPwrCharAvgVoltage (2)
|   +--- r-n Integer32    eoACPwrCharAvgCurrent (3)
|   +--- r-n Integer32    eoACPwrCharFrequency (4)
|   +--- r-n UnitMultiplier
|               eoACPwrCharPowerUnitMultiplier (5)
|   +--- r-n Integer32    eoACPwrCharPowerAccuracy (6)

```

```

|   +-- r-n Integer32    eoACPwrCharTotalActivePower (7)
|   +-- r-n Integer32
|       eoACPwrCharTotalReactivePower (8)
|   +-- r-n Integer32    eoACPwrCharTotalApparentPower (9)
|   +-- r-n Integer32    eoACPwrCharTotalPowerFactor(10)
|   +-- r-n Integer32    eoACPwrCharThdAmperes (11)
|
|   +eoACPwrCharPhaseTable (1)
|   +---EoACPwrCharPhaseEntry(1)[ entPhysicalIndex,
|                                   eoPhaseIndex]
|       |
|       +-- r-n Integer32  eoPhaseIndex (1)
|       +-- r-n Integer32
|           eoACPwrCharPhaseAvgCurrent (2)
|       +-- r-n Integer32
|           eoACPwrCharPhaseActivePower (3)
|       +-- r-n Integer32
|           eoACPwrCharPhaseReactivePower (4)
|       +-- r-n Integer32
|           eoACPwrCharPhaseApparentPower (5)
|       +-- r-n Integer32
|           eoACPwrCharPhasePowerFactor (6)
|       +-- r-n Integer32
|           eoACPwrCharPhaseImpedance (7)
|
|   +eoACPwrCharDelPhaseTable (1)
|   +-- eoACPwrCharDelPhaseEntry(1)
|       |
|       |
|       +-- r-n Integer32
|           eoACPwrCharDelPhaseToNextPhaseVoltage (1)
|       +-- r-n Integer32
|           eoACPwrCharDelThdPhaseToNextPhaseVoltage (2)
|       +-- r-n Integer32  eoACPwrCharDelThdCurrent (3)
|
|   +eoACPwrCharWyePhaseTable (1)
|   +-- eoACPwrCharWyePhaseEntry (1)
|       |
|       |
|       |
|       +-- r-n Integer32
|           eoACPwrCharWyePhaseToNeutralVoltage (1)
|       +-- r-n Integer32
|           eoACPwrCharWyePhaseCurrent (2)
|       +-- r-n Integer32
|           eoACPwrCharWyeThdPhaseToNeutralVoltage (3)
|
|   .

```

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

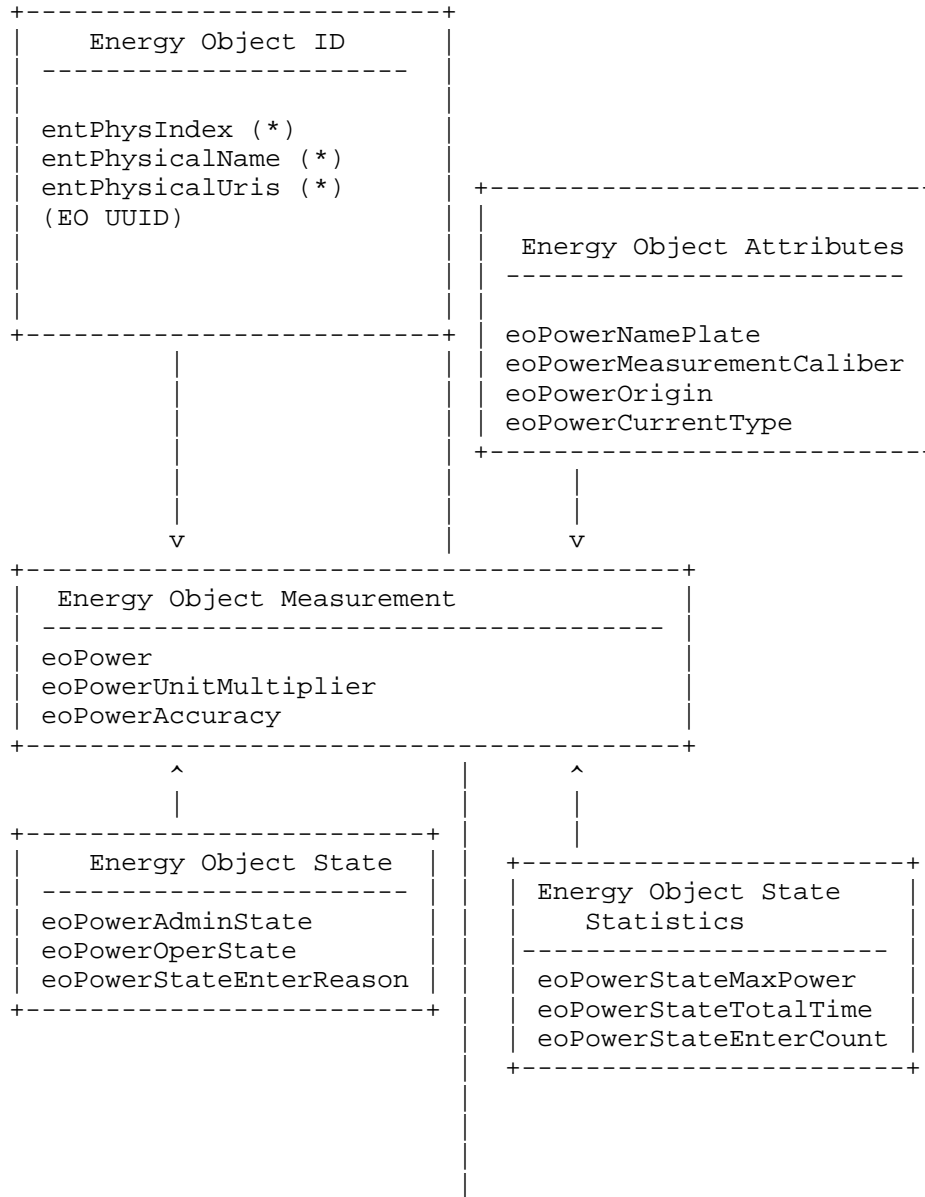
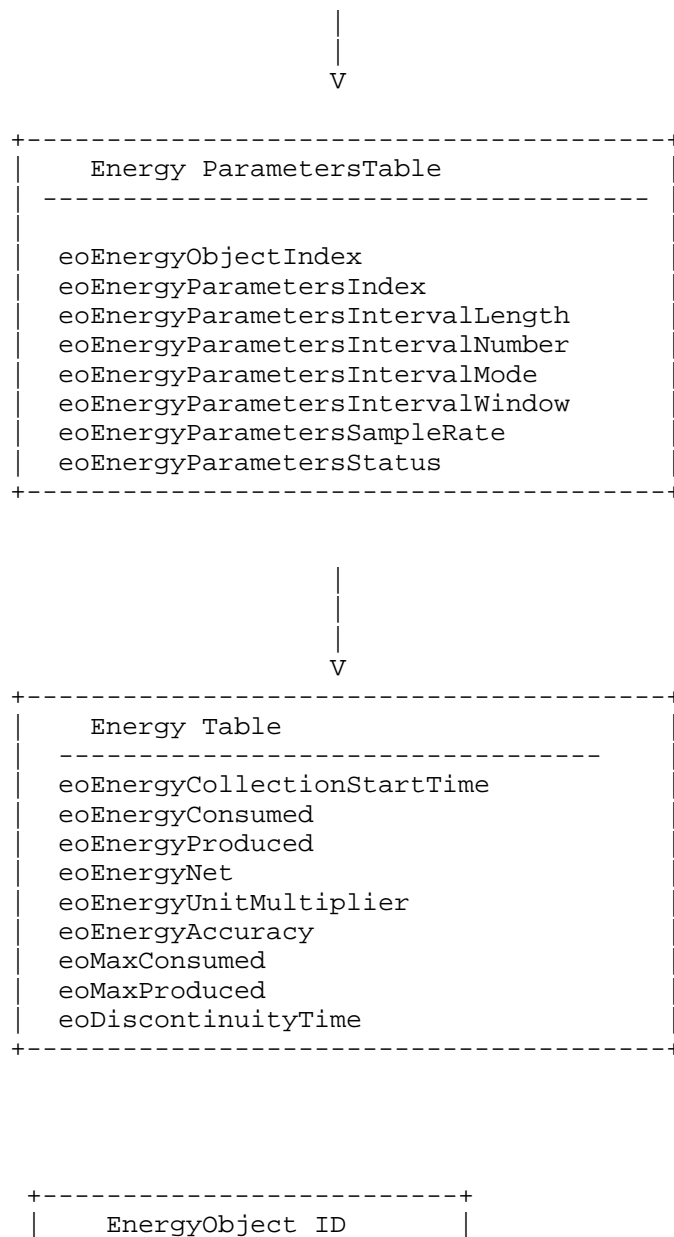
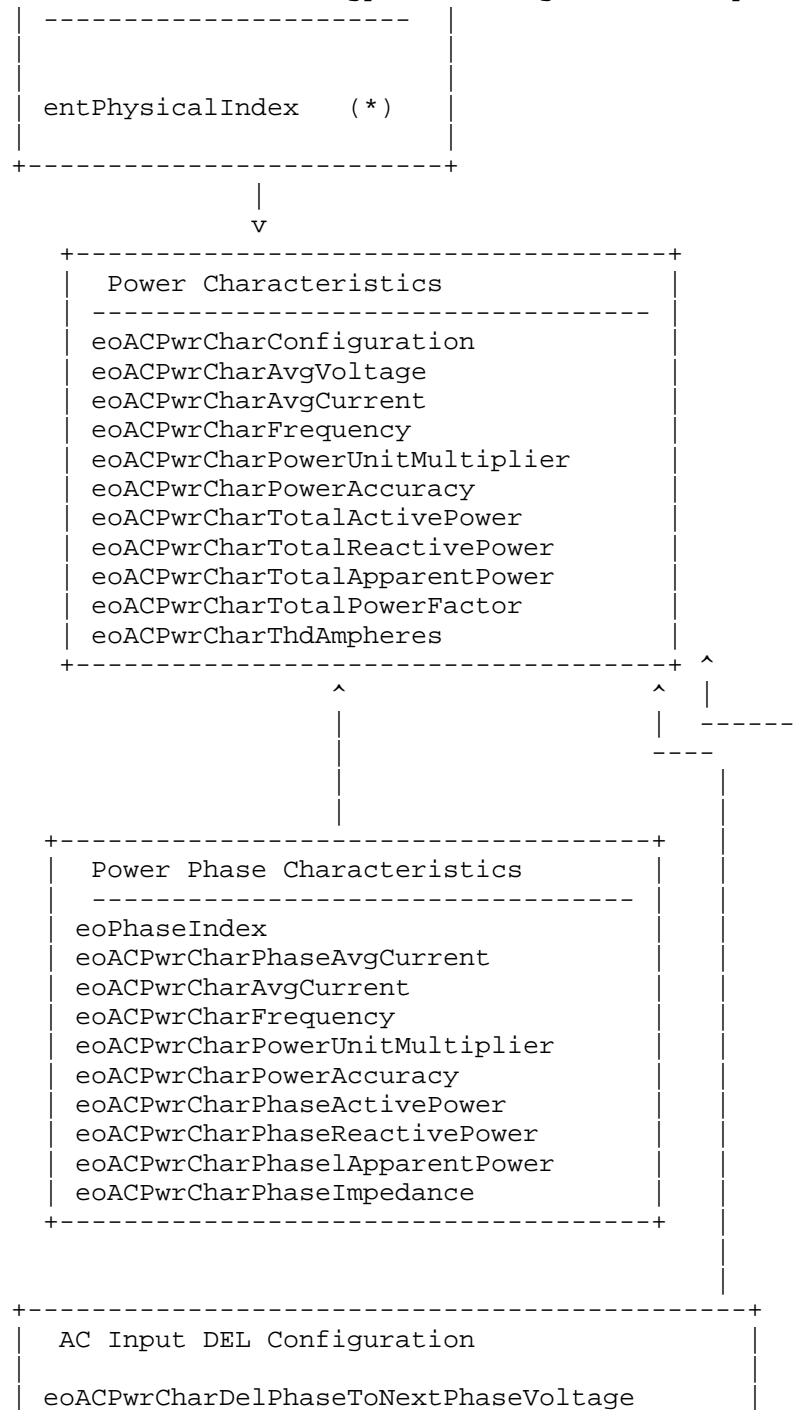


Figure 1:UML diagram for powerMonitor MIB

(*) Link with the ENTITY-MIB





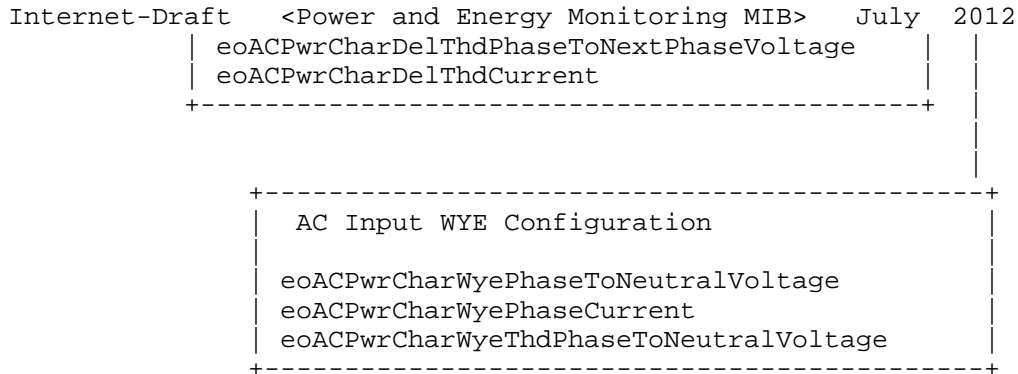


Figure 2: UML diagram for the powerCharacteristicsMIB

(*) Link with the ENTITY-MIB

5.1. Energy Object Information

Refer to the "Energy Object Information" section in [EMAN-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 entPhysicalUris and entPhysicalIndex. The ENERGY-AWARE-MIB module returns the relationship (parent/child) between Energy Objects. There are several possible relationships between Parent and Child as defined in [EMAN-AWARE-MIB] such as MeteredBy, PoweredBy, AggregatedBy and ProxiedBy.

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.

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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

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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

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

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

ready(6)      : No entity features are available, except
                for out-of-band management, for example
                wake-up mechanisms. This mode is
                analogous to hot-standby. The entity can
                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

```

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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, eoEnergyUnitMultiplier, and eoACPwrCharPowerUnitMultiplier.

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

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describes whether the measurements were made at the device itself or from a remote source. The eoPowerMeasurementCaliber describes the method that was used to measure the power and can distinguish actual or estimated values. There may be devices in the network, which may not be able to measure or report power consumption. For those devices, the object eoPowerMeasurementCaliber shall report that measurement mechanism is "unavailable" and the eoPower measurement shall be "0".

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

5.4. Optional Power Usage Characteristics

Refer to the "Optional Power Usage Characteristics" section in [EMAN-FRAMEWORK] for background information.

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

The powerCharacteristicsMIB MIB module contains a primary table, the eoACPwrCharTable table, that defines Power Characteristics measurements for supported entPhysicalIndex entities, as a sparse extension of the eoPowerTable (with entPhysicalIndex as primary index). This eoACPwrCharTable 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 eoACPwrCharPhaseTable additional table is populated with Power Characteristics measurements per phase (so double indexed by the entPhysicalIndex and eoPhaseIndex). This table, which describes attributes common to both WYE and DEL configurations, contains the average current, active/reactive/apparent power, power factor, and impedance.

In case of 3-phase power with a DEL configuration, the eoACPwrCharDelPhaseTable table describes the phase-to-phase Power Characteristics measurements, i.e., voltage and current.

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

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.

The eoEnergyParametersTable consists of the parameters defining eoEnergyParametersIndex, an index of that specifies the setting for collection of energy measurements for an Energy Object, eoEnergyObjectIndex, linked to the entPhysicalIndex of the Energy Object, the duration of measurement intervals in seconds, (eoEnergyParametersIntervalLength), the number of successive intervals to be stored in the eoEnergyTable, (eoEnergyParametersIntervalNumber), the type of measurement technique (eoEnergyParametersIntervalMode), and a sample rate used to calculate the average (eoEnergyParametersSampleRate). Judicious choice of the sampling rate will ensure accurate measurement of energy while not imposing an excessive polling burden.

There are three eoEnergyParametersIntervalMode types used for energy measurement collection: period, sliding, and total. The choices of the the three different modes of collection are based on IEC standard 61850-7-4. Note that multiple eoEnergyParametersIntervalMode types MAY be configured simultaneously. It is important to note that for a given Energy Object, multiple modes (periodic, total, sliding window) of energy measurement collection can be configured with the use of eoEnergyParametersIndex. However, simultaneous measurement in multiple modes for a given Energy Object depends on the Energy Object capability.

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

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

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

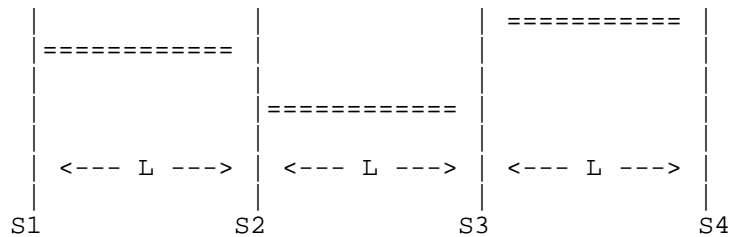
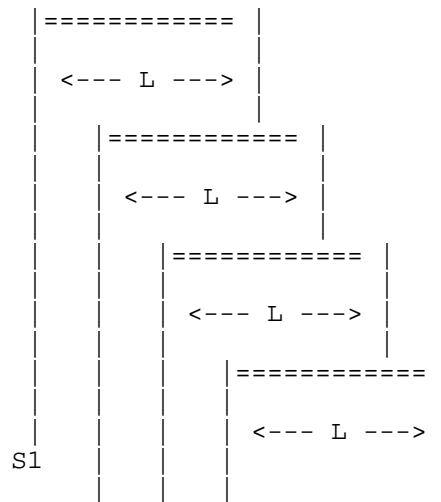


Figure 4 : Period eoEnergyParametersIntervalMode

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



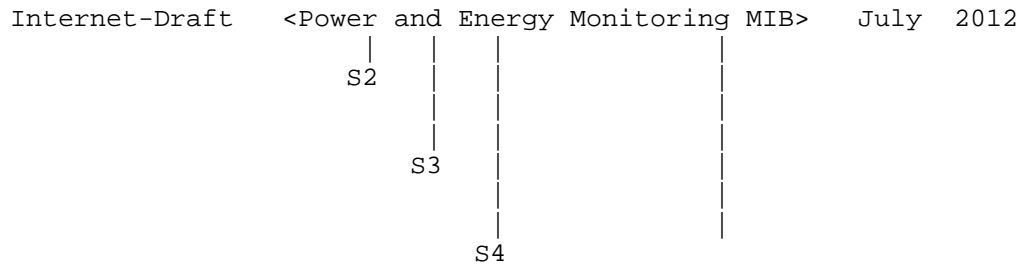


Figure 5 : Sliding eoEnergyParametersIntervalMode

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

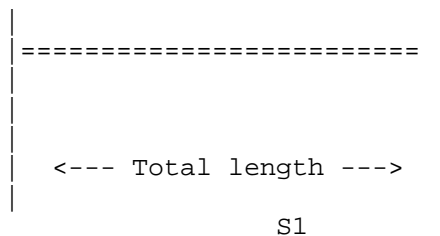


Figure 6 : Total eoEnergyParametersIntervalMode

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 eoEnergyConsumed, eoEnergyProduced and eoEnergyNet, the units of the measured energy eoEnergyUnitMultiplier, and the maximum observed energy within a window, eoEnergyMaxConsumed, eoEnergyMaxProduced.

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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 `eoEnergyDiscontinuityTime` is provided for indicating the time of the last interruption of total energy measurement. `eoEnergyDiscontinuityTime` 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 `eoEnergyParametersIndex` which identifies the index for the setting of energy measurement collection Energy Object, and `eoEnergyCollectionStartTime`, which denotes the start time of the energy measurement interval based on `sysUpTime` [RFC3418]. The value of `eoEnergyConsumed` is the measured energy consumption over the time interval specified (`eoEnergyParametersIntervalLength`) based on the Energy Object internal sampling rate (`eoEnergyParametersSampleRate`). While choosing the values for the `eoEnergyParametersIntervalLength` and `eoEnergyParametersSampleRate`, it is recommended to take into consideration either the network element resources adequate to process and store the sample values, and the mechanism used to calculate the `eoEnergyConsumed`. The units are derived from `eoEnergyUnitMultiplier`. For example, `eoEnergyConsumed` can be "100" with `eoEnergyUnitMultiplier` equal to 0, the measured energy consumption of the Energy Object is 100 watt-hours. The `eoEnergyMaxConsumed` is the maximum energy observed and that can be "150 watt-hours".

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

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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

It is foreseen that most Energy Objects will require the implementation of the ENERGY-AWARE MIB [EMAN-AWARE-MIB] as a prerequisite for this MIB module. In such a case, eoPowerTable of the EMAN-MON-MIB is a sparse extension of the eoTable of ENERGY-AWARE-MIB. Every Energy Object MUST implement entPhysicalIndex, entPhysicalUris and entPhysicalName from the ENTITY-MIB [RFC4133]. As the index for the primary Energy Object, entPhysicalIndex is used.

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

If an implementation of the ENERGY-AWARE-MIB module is available in the local SNMP context, for the same Energy Object, the entPhysicalIndex value (EMAN-AWARE-MIB) shall be used. The entPhysicalIndex characterizes the Energy Object in the energyObjectMib and the powerCharacteristicsMIB MIB modules (this document).

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

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

Finally, the NMS can monitor the Power Characteristics thanks to the powerCharacteristicsMIB MIB module, which reuses the entPhysicalIndex to index the Energy Object.

7. Link with the other IETF MIBs

7.1. Link with the ENTITY-MIB and the ENTITY-SENSOR MIB

RFC 4133 [RFC4133] defines the ENTITY-MIB module that lists the physical entities of a networking device (router, switch, etc.) and those physical entities indexed by entPhysicalIndex. From an energy-management standpoint, the physical entities that consume or produce energy are of interest.

RFC 3433 [RFC3433] defines the ENTITY-SENSOR MIB module that provides a standardized way of obtaining information (current value of the sensor, operational status of the sensor, and the data units precision) from sensors embedded in networking devices. Sensors are associated with each index of entPhysicalIndex of the ENTITY-MIB [RFC4133]. While the focus of the Power and Energy Monitoring MIB is on measurement of power usage of networking equipment indexed by the ENTITY-MIB, this MIB proposes a customized power scale for power measurement and different power state states of networking equipment, and functionality to configure the power state states.

When this MIB module is used to monitor the power usage of devices like routers and switches, the ENTITY-MIB and ENTITY-SENSOR MIB SHOULD be implemented. In such cases, the Energy

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Objects are modeled by the entPhysicalIndex through the
entPhysicalEntity MIB object specified in the eoTable in the
ENERGY-AWARE-MIB MIB module [EMAN-AWARE-MIB].

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

Power measurements specifying the qualifier 'UNITS' for each
measured value in watts are used in the LLDP-EXT-MED-MIB, POE
[RFC3621], and UPS [RFC1628] MIBs. The same 'UNITS' qualifier
is used for the power measurement values.

One cannot assume that the ENTITY-MIB and ENTITY-SENSOR MIB are
implemented for all Energy Objects that need to be monitored. A
typical example is a converged building gateway, monitoring
several other devices in the building, doing the proxy between
SNMP and a protocol like BACNET. Another example is the home
energy controller. In such cases, the eoPhysicalEntity value
contains the zero value, thanks to PhysicalIndexOrZero textual
convention.

The eoPower is similar to entPhySensorValue [RFC3433] and the
eoPowerUnitMultiplier is similar to entPhySensorScale.

7.2. Link with the ENTITY-STATE MIB

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

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

7.3. Link with the POWER-OVER-ETHERNET MIB

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

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

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

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

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

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.

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 [EMAN-AWARE-MIB]. The switch has the following attributes, entPhysicalIndex "1", 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 entPhysicalIndex "3", 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 have an entPhysicalIndex, and 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.

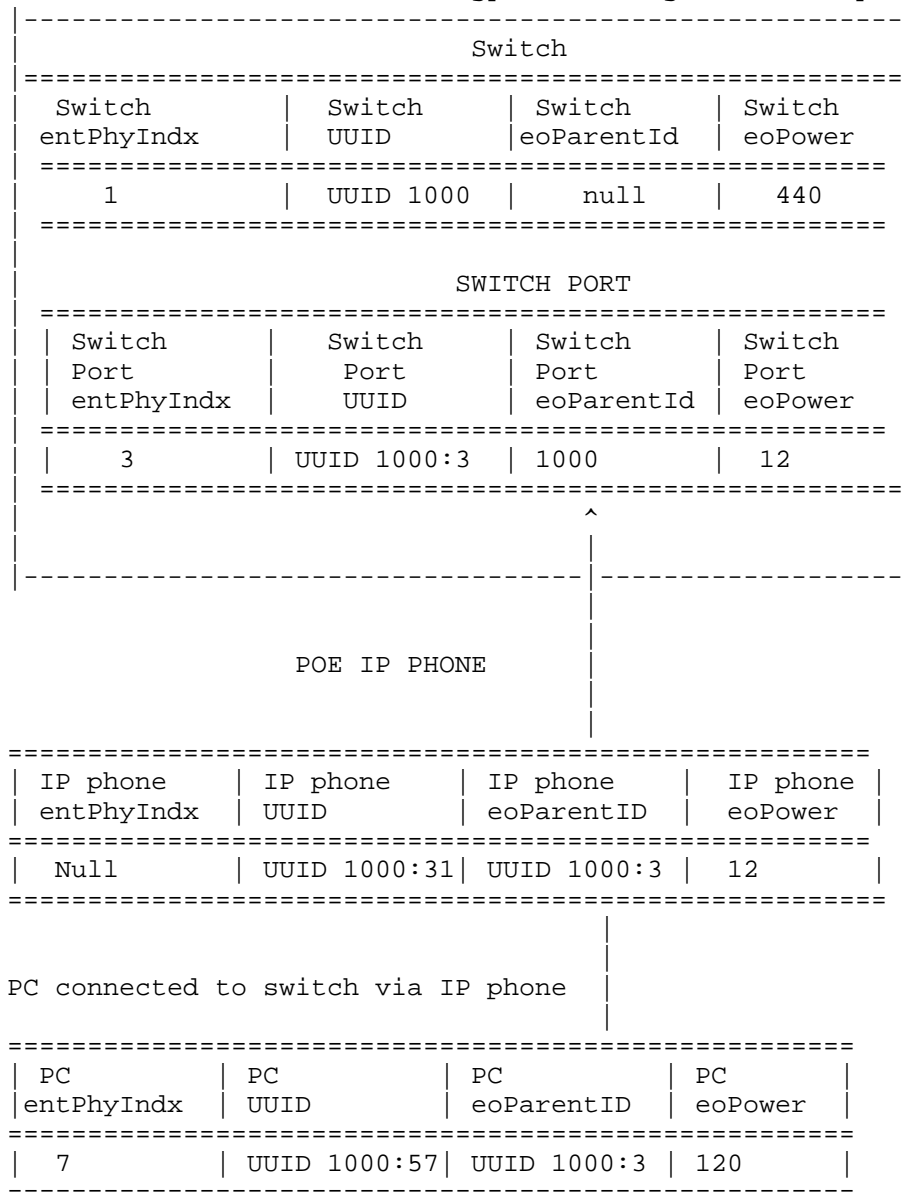


Figure 1: Example scenario

The primary MIB object in this MIB module is the energyObjectMibObject. The eoPowerTable table of energyObjectMibObject describes the power measurement attributes of an Energy Object entity. The notion of identity of the device in terms of uniquely identification of the Energy Object and its relationship to other entities in the network are addressed in [EMAN-AWARE-MIB].

Logically, this MIB module is a sparse extension of the [EMAN-AWARE-MIB] module. Thus the following requirements which are applied to [EMAN-AWARE-MIB] are also applicable. As a requirement for this MIB module, [EMAN-AWARE-MIB] should be implemented and the three MIB objects from ENTITY-MIB (entPhysicalIndex, entPhysicalName and entPhysicalUris) MUST be implemented.

eoMeterCapabilitiesTable is useful to enable applications to determine the capabilities supported by the local management agent. This table indicates the energy monitoring MIB groups that are supported by the local management system. By reading the value of this object, it is possible for applications to know which tables contain the information and are usable without walking through the table and querying every element which involves a trial-and-error process.

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

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

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

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

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

ENERGY-OBJECT-MIB DEFINITIONS ::= BEGIN

IMPORTS

```
    MODULE-IDENTITY,  
    OBJECT-TYPE,  
    NOTIFICATION-TYPE,  
    mib-2,  
    Integer32, Counter32, TimeTicks  
        FROM SNMPv2-SMI  
    TEXTUAL-CONVENTION, DisplayString, RowStatus, TimeInterval,  
    TimeStamp  
        FROM SNMPv2-TC  
    MODULE-COMPLIANCE, NOTIFICATION-GROUP, OBJECT-GROUP  
        FROM SNMPv2-CONF  
    OwnerString  
        FROM RMON-MIB  
    entPhysicalIndex, PhysicalIndex  
        FROM ENTITY-MIB;
```

```
energyObjectMib MODULE-IDENTITY  
    LAST-UPDATED      "201207110000Z"      -- 11 July 2012  
  
    ORGANIZATION      "IETF EMAN Working Group"  
    CONTACT-INFO  
        "WG charter:  
        http://datatracker.ietf.org/wg/eman/charter/  
  
        Mailing Lists:  
        General Discussion: eman@ietf.org  
  
        To Subscribe:  
        https://www.ietf.org/mailman/listinfo/eman
```

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

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DESCRIPTION

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

This table sparse extension of the eoTable from the ENERGY-AWARE-MIB. As a requirement [EMAN-AWARE-MIB] should be implemented and three MIB objects from ENTITY-MIB (entPhysicalIndex, entPhysicalName and entPhysicalUris) MUST be implemented. "

REVISION

"201207110000Z" -- 11 July 2012

DESCRIPTION

"Initial version, published as RFC XXXX."

::= { mib-2 xxx }

energyObjectMibNotifs OBJECT IDENTIFIER

::= { energyObjectMib 0 }

energyObjectMibObjects OBJECT IDENTIFIER

::= { energyObjectMib 1 }

energyObjectMibConform OBJECT IDENTIFIER

::= { energyObjectMib 2 }

-- Textual Conventions

IANAPowerStateSet ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

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

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

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in the Power State S, the named number with the value S * 256
+ X + 1 is allocated to represent the power state."

REFERENCE

"<http://www.iana.org/assignments/eman>

RFC EDITOR NOTE: please change the previous URL if this is
not the correct one after IANA assigned it."

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

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

    dmtf(512),        -- indicates DMTF set
    dmtfOn(513),
    dmtfSleepLight(514),
    dmtfSleepDeep(515),
    dmtfOffHard(516),
    dmtfOffSoft(517),
    dmtfHibernate(518),
    dmtfPowerOffSoft(519),
    dmtfPowerOffHard(520),
    dmtfMasterBusReset(521),
    dmtfDiagnosticInterrupt(522),
    dmtfOffSoftGraceful(523),
    dmtfOffHardGraceful(524),
    dmtfMasterBusResetGraceful(525),
    dmtfPowerCycleOffSoftGraceful(526),
    dmtfPowerCycleHardGraceful(527),

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

UnitMultiplier ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"The Unit Multiplier is an integer value that represents the IEEE 61850 Annex A units multiplier associated with the integer units used to measure the power or energy.

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

eoMeterCapabilitiesTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoMeterCapabilitiesEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table is useful for helping applications determine the monitoring capabilities supported by the local management agents. It is possible for applications to know which tables are usable without going through a trial-and-error process."

::= { energyObjectMibObjects 1 }

eoMeterCapabilitiesEntry OBJECT-TYPE

SYNTAX EoMeterCapabilitiesEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry describes the metering capability of an Energy Object."

INDEX { entPhysicalIndex }

::= { eoMeterCapabilitiesTable 1 }

EoMeterCapabilitiesEntry ::= SEQUENCE {

eoMeterCapability BITS

}

eoMeterCapability OBJECT-TYPE

SYNTAX BITS {

none(0),

powermetering(1), -- power measurement

energymetering(2), -- energy measurement

powercharacteristics(3) -- Power Characteristics

}

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"An indication of the Energy monitoring capabilities supported by this agent. This object use a BITS syntax and indicate the MIB groups supported by the probe. By reading the value of this object, it is possible to determine the MIB tables supported. "

::= { eoMeterCapabilitiesEntry 1 }

eoPowerTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoPowerEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table lists Energy Objects."

::= { energyObjectMibObjects 2 }

eoPowerEntry OBJECT-TYPE

SYNTAX EoPowerEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

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"An entry describes the power usage of an Energy Object."

```
INDEX            { entPhysicalIndex }  
::= { eoPowerTable 1 }
```

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

eoPower OBJECT-TYPE

```
SYNTAX           Integer32  
UNITS             "Watts"  
MAX-ACCESS        read-only  
STATUS            current
```

DESCRIPTION

"This object indicates the power measured for the Energy Object. For alternating current, this value is obtained as an average over fixed number of AC cycles. . This value is specified in SI units of watts with the magnitude of watts (milliwatts, kilowatts, etc.) indicated separately in eoPowerUnitMultiplier. The accuracy of the measurement is specified in eoPowerAccuracy. The direction of power flow is indicated by the sign on eoPower. If the Energy Object is consuming power, the eoPower value will be positive. If the Energy Object is producing power, the eoPower value will be negative.

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

The eoPowerMeasurementCaliber object specifies how the usage value reported by eoPower was obtained. The eoPower value must report 0 if the eoPowerMeasurementCaliber is

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 'unavailable'. For devices that can not measure or
 report power, this option can be used."
::= { eoPowerEntry 1 }

eoPowerNameplate OBJECT-TYPE
 SYNTAX Integer32
 UNITS "Watts"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This object indicates the rated maximum consumption for
 the fully populated Energy Object. The nameplate power
 requirements are the maximum power numbers and, in almost
 all cases, are well above the expected operational
 consumption. The eoPowerNameplate is widely used for
 power provisioning. This value is specified in either
 units of watts or voltage and current. The units are
 therefore SI watts or equivalent Volt-Amperes with the
 magnitude (milliwatts, kilowatts, etc.) indicated
 separately in eoPowerUnitMultiplier."
::= { eoPowerEntry 2 }

eoPowerUnitMultiplier OBJECT-TYPE
 SYNTAX UnitMultiplier
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "The magnitude of watts for the usage value in eoPower
 and eoPowerNameplate."
::= { eoPowerEntry 3 }

eoPowerAccuracy OBJECT-TYPE
 SYNTAX Integer32 (0..10000)
 UNITS "hundredths of percent"
 MAX-ACCESS read-only
 STATUS current
 DESCRIPTION
 "This object indicates a percentage value, in 100ths of a
 percent, representing the assumed accuracy of the usage
 reported by eoPower. For example: The value 1010 means
 the reported usage is accurate to +/- 10.1 percent. This
 value is zero if the accuracy is unknown or not
 applicable based upon the measurement method.

ANSI and IEC define the following accuracy classes for
power measurement:

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

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 ANSI C12.20 class 0.2, 0.5"
 ::= { eoPowerEntry 4 }

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

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

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

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

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

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

```
::= { eoPowerEntry 5 }
```

eoPowerCurrentType OBJECT-TYPE

```
SYNTAX      INTEGER {  
                ac(1),  
                dc(2),  
                unknown(3)  
            }
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates whether the eoUsage for the Energy Object reports alternative current AC(1), direct current DC(2), or that the current type is unknown(3)."

```
::= { eoPowerEntry 6 }
```

eoPowerOrigin OBJECT-TYPE

```
SYNTAX      INTEGER {  
                self (1),  
                remote (2)  
            }
```

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates the source of power measurement and can be useful when modeling the power usage of attached devices. The power measurement can be performed by the entity itself or the power measurement of the entity can be reported by another trusted entity using a protocol extension. A value of self(1) indicates the measurement is performed by the entity, whereas remote(2) indicates that the measurement was performed by another entity."

```
::= { eoPowerEntry 7 }
```

eoPowerAdminState OBJECT-TYPE

```
SYNTAX      IANAPowerStateSet
```

MAX-ACCESS read-write

STATUS current

DESCRIPTION

"This object specifies the desired Power State and the Power State Set for the Energy Object. Note that other(0) is not a Power State Set and unknown(255) is not a Power State as such, but simply an indication that the Power State of the Energy Object is unknown. Possible values of eoPowerAdminState within the Power State Set are registered at IANA."

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A current list of assignments can be found at

<<http://www.iana.org/assignments/eman>>

RFC-EDITOR: please check the location after IANA"

::= { eoPowerEntry 8 }

eoPowerOperState OBJECT-TYPE

SYNTAX IANAPowerStateSet

MAX-ACCESS read-only

STATUS current

DESCRIPTION

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

Possible values of eoPowerAdminState within the Power State Set are registered at IANA.

A current list of assignments can be found at

<<http://www.iana.org/assignments/eman>>

RFC-EDITOR: please check the location after IANA"

::= { eoPowerEntry 9 }

eoPowerStateEnterReason OBJECT-TYPE

SYNTAX OwnerString

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"This string object describes the reason for the eoPowerAdminState transition Alternatively, this string may contain with the entity that configured this Energy Object to this Power State."

DEFVAL { "" }

::= { eoPowerEntry 10 }

eoPowerStateTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoPowerStateEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table enumerates the maximum power usage, in watts, for every single supported Power State of each Energy Object.

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

::= { energyObjectMibObjects 3 }

eoPowerStateEntry OBJECT-TYPE

SYNTAX EoPowerStateEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"A eoPowerStateEntry extends a corresponding
 eoPowerEntry. This entry displays max usage values at
 every single possible Power State supported by the Energy
 Object.

For example, given the values of a Energy Object
 corresponding to a maximum usage of 11W at the
 state 1 (mechoff), 6 (ready), 8 (mediumMinus), 12 (High):

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

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

INDEX { entPhysicalIndex,
 eoPowerStateIndex
 }

::= { eoPowerStateTable 1 }

EoPowerStateEntry ::= SEQUENCE {

eoPowerStateIndex

IANAPowerStateSet,

eoPowerStateMaxPower

Integer32,

eoPowerStatePowerUnitMultiplier

UnitMultiplier,

eoPowerStateTotalTime

TimeTicks,

```

    eoPowerStateEnterCount      Counter32
}

```

eoPowerStateIndex OBJECT-TYPE

```

SYNTAX      IANAPowerStateSet
MAX-ACCESS  not-accessible
STATUS      current
DESCRIPTION

```

"
This object specifies the index of the Power State of the Energy Object within a Power State Set. The semantics of the specific Power State can be obtained from the Power State Set definition."

```
 ::= { eoPowerStateEntry 1 }
```

eoPowerStateMaxPower OBJECT-TYPE

```

SYNTAX      Integer32
UNITS       "Watts"
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION

```

"This object indicates the maximum power for the Energy Object at the particular Power State. This value is specified in SI units of watts with the magnitude of the units (milliwatts, kilowatts, etc.) indicated separately in eoPowerStatePowerUnitMultiplier. If the maximum power is not known for a certain Power State, then the value is encoded as 0xFFFF."

For Power States not enumerated, the value of eoPowerStateMaxPower might be interpolated by using the next highest supported Power State."

```
 ::= { eoPowerStateEntry 2 }
```

eoPowerStatePowerUnitMultiplier OBJECT-TYPE

```

SYNTAX      UnitMultiplier
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION

```

"The magnitude of watts for the usage value in eoPowerStateMaxPower."

```
 ::= { eoPowerStateEntry 3 }
```

eoPowerStateTotalTime OBJECT-TYPE

```

SYNTAX      TimeTicks
MAX-ACCESS  read-only
STATUS      current

```

DESCRIPTION

"This object indicates the total time in hundreds of seconds that the Energy Object has been in this power state since the last reset, as specified in the sysUpTime."

::= { eoPowerStateEntry 4 }

eoPowerStateEnterCount OBJECT-TYPE

SYNTAX Counter32

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"This object indicates how often the Energy Object has entered this power state, since the last reset of the device as specified in the sysUpTime."

::= { eoPowerStateEntry 5 }

eoEnergyParametersTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoEnergyParametersEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table is used to configure the parameters for Energy measurement collection in the table eoEnergyTable. This table allows the configuration of different measurement settings on the same Energy Object."

::= { energyObjectMibObjects 4 }

eoEnergyParametersEntry OBJECT-TYPE

SYNTAX EoEnergyParametersEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry controls an energy measurement in eoEnergyTable."

INDEX { eoEnergyParametersIndex }

::= { eoEnergyParametersTable 1 }

EoEnergyParametersEntry ::= SEQUENCE {

eoEnergyObjectIndex	PhysicalIndex,
eoEnergyParametersIndex	Integer32,
eoEnergyParametersIntervalLength	TimeInterval,
eoEnergyParametersIntervalNumber	Integer32,
eoEnergyParametersIntervalMode	Integer32,
eoEnergyParametersIntervalWindow	TimeInterval,

```
        eoEnergyParametersSampleRate    Integer32,
        eoEnergyParametersStatus        RowStatus
    }
```

```
eoEnergyObjectIndex OBJECT-TYPE
    SYNTAX                PhysicalIndex
    MAX-ACCESS            read-create
    STATUS                current
    DESCRIPTION
        "The unique value, to identify the specific Energy Object
        on which the measurement is applied, the same index used
        in the eoPowerTable to identify the Energy Object."
    ::= { eoEnergyParametersEntry 1 }
```

```
eoEnergyParametersIndex OBJECT-TYPE
    SYNTAX                Integer32 (0..2147483647)
    MAX-ACCESS            read-create
    STATUS                current
    DESCRIPTION
        "This object specifies the index of the Energy
        Parameters setting for collection of energy measurements
        for an Energy Object. An Energy Object can have multiple
        eoEnergyParametersIndex, depending on the capability of
        the Energy Object"
    ::= { eoEnergyParametersEntry 2 }
```

```
eoEnergyParametersIntervalLength OBJECT-TYPE
    SYNTAX                TimeInterval
    MAX-ACCESS            read-create
    STATUS                current
    DESCRIPTION
        "This object indicates the length of time in hundredth of
        seconds over which to compute the average
        eoEnergyConsumed measurement in the eoEnergyTable table.
        The computation is based on the Energy Object's internal
        sampling rate of power consumed or produced by the Energy
        Object. The sampling rate is the rate at which the Energy
        Object can read the power usage and may differ based on
        device capabilities. The average energy consumption is
        then computed over the length of the interval."
    DEFVAL { 90000 }
    ::= { eoEnergyParametersEntry 3 }
```

```
eoEnergyParametersIntervalNumber OBJECT-TYPE
    SYNTAX                Integer32
    MAX-ACCESS            read-create
    STATUS                current
```

"The number of intervals maintained in the eoEnergyTable. Each interval is characterized by a specific eoEnergyCollectionStartTime, used as an index to the table eoEnergyTable. Whenever the maximum number of entries is reached, the measurement over the new interval replacesthe oldest measurement. There is one exception to this rule: when the eoEnergyMaxConsumed and/or eoEnergyMaxProduced are in (one of) the two oldest measurement(s), they are left untouched and the next oldest measurement is replaced."

DEFVAL { 10 }

::= { eoEnergyParametersEntry 4 }

eoEnergyParametersIntervalMode OBJECT-TYPE

SYNTAX INTEGER {
 period(1),
 sliding(2),
 total(3)
 }

MAX-ACCESS read-create

STATUS current

DESCRIPTION

"A control object to define the mode of interval calculation for the computation of the average eoEnergyConsumed or eoEnergyProduced measurement in the eoEnergyTable table.

A mode of period(1) specifies non-overlapping periodic measurements.

A mode of sliding(2) specifies overlapping sliding windows where the interval between the start of one interval and the next is defined in eoEnergyParametersIntervalWindow.

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

::= { eoEnergyParametersEntry 5 }

eoEnergyParametersIntervalWindow OBJECT-TYPE

SYNTAX TimeInterval

MAX-ACCESS read-create

STATUS current

DESCRIPTION

```

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    "The length of the duration window between the starting
    time of one sliding window and the next starting time in
    hundredth of seconds, in order to compute the average of
    eoEnergyConsumed, eoEnergyProduced measurements in the
    eoEnergyTable table. This is valid only when the
    eoEnergyParametersIntervalMode is sliding(2). The
    eoEnergyParametersIntervalWindow value should be a multiple
    of eoEnergyParametersSampleRate."
    ::= { eoEnergyParametersEntry 6 }

eoEnergyParametersSampleRate OBJECT-TYPE
    SYNTAX          Integer32
    UNITS            "Milliseconds"
    MAX-ACCESS       read-create
    STATUS           current
    DESCRIPTION
        "The sampling rate, in milliseconds, at which the Energy
        Object should poll power usage in order to compute the
        average eoEnergyConsumed, eoEnergyProduced measurements
        in the table eoEnergyTable. The Energy Object should
        initially set this sampling rate to a reasonable value,
        i.e., a compromise between intervals that will provide
        good accuracy by not being too long, but not so short
        that they affect the Energy Object performance by
        requesting continuous polling. If the sampling rate is
        unknown, the value 0 is reported. The sampling rate
        should be selected so that
        eoEnergyParametersIntervalWindow is a multiple of
        eoEnergyParametersSampleRate."
    DEFVAL { 1000 }
    ::= { eoEnergyParametersEntry 7 }

eoEnergyParametersStatus OBJECT-TYPE
    SYNTAX          RowStatus
    MAX-ACCESS       read-create
    STATUS           current
    DESCRIPTION
        "The status of this row. The eoEnergyParametersStatus is
        used to start or stop energy usage logging. An entry
        status may not be active(1) unless all objects in the
        entry have an appropriate value. If this object is not
        equal to active(1), all associated usage-data logged into
        the eoEnergyTable will be deleted. The data can be
        destroyed by setting up the eoEnergyParametersStatus to
        destroy(2)."
    ::= {eoEnergyParametersEntry 8 }

```

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

```
eoEnergyEntry OBJECT-TYPE
    SYNTAX      EoEnergyEntry
    MAX-ACCESS   not-accessible
    STATUS       current
    DESCRIPTION
        "An entry describing energy measurements."
    INDEX { eoEnergyParametersIndex,
eoEnergyCollectionStartTime }
    ::= { eoEnergyTable 1 }
```

```
EoEnergyEntry ::= SEQUENCE {
    eoEnergyCollectionStartTime    TimeTicks,
    eoEnergyConsumed               Integer32,
    eoEnergyProduced              Integer32,
    eoEnergyNet                   Integer32,
    eoEnergyUnitMultiplier        UnitMultiplier,
    eoEnergyAccuracy              Integer32,
    eoEnergyMaxConsumed           Integer32,
    eoEnergyMaxProduced           Integer32,
    eoEnergyDiscontinuityTime     TimeStamp
}
```

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


eoEnergyConsumed OBJECT-TYPE

SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates the energy consumed in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.) indicated separately in eoEnergyUnitMultiplier."

::= { eoEnergyEntry 2 }

eoEnergyProduced OBJECT-TYPE

SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates the energy produced in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.) indicated separately in eoEnergyUnitMultiplier."

::= { eoEnergyEntry 3 }

eoEnergyNet OBJECT-TYPE

SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates the resultant of the energy consumed and energy produced for an energy object in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.) indicated separately in eoEnergyUnitMultiplier."

::= { eoEnergyEntry 4 }

eoEnergyUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object is the magnitude of watt-hours for the energy field in eoEnergyConsumed, eoEnergyProduced,

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 eoEnergyNet, eoEnergyMaxConsumed, and eoEnergyMaxProduced
 ."
 ::= { eoEnergyEntry 5 }

eoEnergyAccuracy OBJECT-TYPE

SYNTAX Integer32 (0..10000)
UNITS "hundredths of percent"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object indicates a percentage value, in 100ths of a percent, representing the presumed accuracy of Energy usage reporting. eoEnergyAccuracy is applicable to all Energy measurements in the eoEnergyTable.

For example: 1010 means the reported usage is accurate to +/- 10.1 percent.

This value is zero if the accuracy is unknown."

 ::= { eoEnergyEntry 6 }

eoEnergyMaxConsumed OBJECT-TYPE

SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object is the maximum energy ever observed in eoEnergyConsumed since the monitoring started. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.) indicated separately in eoEnergyUnitMultiplier."

 ::= { eoEnergyEntry 7 }

eoEnergyMaxProduced OBJECT-TYPE

SYNTAX Integer32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"This object is the maximum energy ever observed in eoEnergyEnergyProduced since the monitoring started. This value is specified in the units of watt-hours with the magnitude of watt-hours (kW-Hr, MW-Hr, etc.) indicated separately in eoEnergyEnergyUnitMultiplier."

eoEnergyDiscontinuityTime OBJECT-TYPE

SYNTAX TimeStamp

MAX-ACCESS read-only

STATUS current

DESCRIPTION

"The value of sysUpTime [RFC3418] on the most recent occasion at which any one or more of this entity's energy counters in this table suffered a discontinuity: eoEnergyConsumed, eoEnergyProduced or eoEnergyNet. If no such discontinuities have occurred since the last re-initialization of the local management subsystem, then this object contains a zero value."

::= { eoEnergyEntry 9 }

-- Notifications

eoPowerStateChange NOTIFICATION-TYPE

OBJECTS {eoPowerAdminState, eoPowerOperState,
eoPowerStateEnterReason}

STATUS current

DESCRIPTION

"The SNMP entity generates the eoPowerStateChange when the value(s) of eoPowerAdminState or eoPowerOperState, in the context of the Power State Set, have changed for the Energy Object represented by the entPhysicalIndex."

::= { energyObjectMibNotifs 1 }

-- Conformance

energyObjectMibCompliances OBJECT IDENTIFIER

::= { energyObjectMib 3 }

energyObjectMibGroups OBJECT IDENTIFIER

::= { energyObjectMib 4 }

energyObjectMibFullCompliance MODULE-COMPLIANCE

STATUS current

DESCRIPTION

"When this MIB is implemented with support for read-create, then such an implementation can claim full compliance. Such devices can then be both monitored and configured with this MIB. The entPhysicalIndex, entPhysicalName, and

```

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    entPhysicalUris [RFC4133] MUST be implemented."
MODULE            -- this module
MANDATORY-GROUPS {
    energyObjectMibTableGroup,
    energyObjectMibStateTableGroup,
    energyObjectMibNotifGroup
}

GROUP            energyObjectMibEnergyTableGroup

    DESCRIPTION "A compliant implementation does not
    have to implement. The entPhysicalIndex,
    entPhysicalName, and entPhysicalUris [RFC4133]
    MUST be implemented."

GROUP            energyObjectMibEnergyParametersTableGroup

    DESCRIPTION "A compliant implementation does not
    have to implement. The entPhysicalIndex,
    entPhysicalName, and entPhysicalUris [RFC4133]
    MUST be implemented."

GROUP            energyObjectMibMeterCapabilitiesTableGroup

    DESCRIPTION "A compliant implementation does not
    have to implement. The entPhysicalIndex,
    entPhysicalName, and entPhysicalUris [RFC4133]
    MUST be implemented."

::= { 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. The entPhysicalIndex,
    entPhysicalName, and entPhysicalUris from [RFC4133]
    MUST be implemented. "
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
    {
        eoEnergyObjectIndex,
        eoEnergyParametersIndex,
```

```

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

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

    eoEnergyConsumed,
    eoEnergyProduced,
    eoEnergyNet,
    eoEnergyUnitMultiplier,
    eoEnergyAccuracy,
    eoEnergyMaxConsumed,
    eoEnergyMaxProduced,
    eoEnergyDiscontinuityTime
    }
STATUS            current
DESCRIPTION
    "This group contains the collection of all the objects
    related to the Energy Table."
 ::= { energyObjectMibGroups 4 }

energyObjectMibMeterCapabilitiesTableGroup OBJECT-GROUP
OBJECTS           {
    eoMeterCapability
    }
STATUS            current
DESCRIPTION
    "This group contains the object indicating the
    capability of the Energy Object"
 ::= { energyObjectMibGroups 5 }

energyObjectMibNotifGroup NOTIFICATION-GROUP

```

```

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

END

```

```

-- *****
--
-- This MIB module is used to monitor Power Characteristics of
-- networked devices with measurements.
--
-- This MIB module is an extension of energyObjectMib module.
--
-- *****

```

```

POWER-CHARACTERISTICS-MIB DEFINITIONS ::= BEGIN

```

```

IMPORTS
    MODULE-IDENTITY,
    OBJECT-TYPE,
    mib-2,
    Integer32
        FROM SNMPv2-SMI
    MODULE-COMPLIANCE,
    OBJECT-GROUP
        FROM SNMPv2-CONF
    UnitMultiplier
        FROM ENERGY-OBJECT-MIB
    OwnerString
        FROM RMON-MIB
    entPhysicalIndex
        FROM ENTITY-MIB;

```

```

powerCharacteristicsMIB MODULE-IDENTITY

```

```

    LAST-UPDATED      "201207110000Z"    -- 11 July 2012

    ORGANIZATION      "IETF EMAN Working Group"
    CONTACT-INFO

```

Internet-Draft <Power and Energy Monitoring MIB> July 2012
"WG charter:
<http://datatracker.ietf.org/wg/eman/charter/>

Mailing Lists:

General Discussion: eman@ietf.org

To Subscribe:

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

Archive:

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

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Internet-Draft <Power and Energy Monitoring MIB> July 2012
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DESCRIPTION

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

As a requirement for this MIB module, [EMAN-AWARE-MIB] should be implemented and three MIB objects from ENTITY-MIB (entPhysicalIndex, entPhysicalName and entPhysicalUris) MUST be implemented. "

REVISION

"201207110000Z" -- 11 July 2012

DESCRIPTION

"Initial version, published as RFC YYY."

::= { mib-2 yyy }

powerCharacteristicsMIBConform OBJECT IDENTIFIER
 ::= { powerCharacteristicsMIB 0 }

powerCharacteristicsMIBObjects OBJECT IDENTIFIER
 ::= { powerCharacteristicsMIB 1 }

-- Objects

eoACPwrCharTable OBJECT-TYPE
 SYNTAX SEQUENCE OF EoACPwrCharEntry
 MAX-ACCESS not-accessible
 STATUS current
 DESCRIPTION

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"This table defines Power Characteristics measurements
for supported entPhysicalIndex entities. It is a sparse
extension of the eoPowerTable."

::= { powerCharacteristicsMIBObjects 1 }

eoACPwrCharEntry OBJECT-TYPE

SYNTAX EoACPwrCharEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This is a sparse extension of the eoPowerTable with
entries for Power Characteristics measurements or
configuration. Each measured value corresponds to an
attribute in IEC 61850-7-4 for non-phase measurements
within the object MMUX."

INDEX {entPhysicalIndex }

::= { eoACPwrCharTable 1 }

EoACPwrCharEntry ::= SEQUENCE {

eoACPwrCharConfiguration	INTEGER,
eoACPwrCharAvgVoltage	Integer32,
eoACPwrCharAvgCurrent	Integer32,
eoACPwrCharFrequency	Integer32,
eoACPwrCharPowerUnitMultiplier	UnitMultiplier,
eoACPwrCharPowerAccuracy	Integer32,
eoACPwrCharTotalActivePower	Integer32,
eoACPwrCharTotalReactivePower	Integer32,
eoACPwrCharTotalApparentPower	Integer32,
eoACPwrCharTotalPowerFactor	Integer32,
eoACPwrCharThdAmperes	Integer32,
eoACPwrCharThdVoltage	Integer32

}

eoACPwrCharConfiguration 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)

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."

::= { eoACPwrCharEntry 1 }

eoACPwrCharAvgVoltage 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'"

::= { eoACPwrCharEntry 2 }

eoACPwrCharAvgCurrent 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'"

::= { eoACPwrCharEntry 3 }

eoACPwrCharFrequency 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'."

::= { eoACPwrCharEntry 4 }

eoACPwrCharPowerUnitMultiplier OBJECT-TYPE

SYNTAX UnitMultiplier
MAX-ACCESS read-only
STATUS current
DESCRIPTION

"The magnitude of watts for the usage value in
eoACPwrCharTotalActivePower,
eoACPwrCharTotalReactivePower
and eoACPwrCharTotalApparentPower measurements.
For 3-phase power systems, this will include
eoACPwrCharPhaseActivePower,
eoACPwrCharPhaseReactivePower and
eoACPwrCharPhaseApparentPower"

::= { eoACPwrCharEntry 5 }

eoACPwrCharPowerAccuracy 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"

::= { eoACPwrCharEntry 6 }

eoACPwrCharTotalActivePower 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'."

::= { eoACPwrCharEntry 7 }

eoACPwrCharTotalReactivePower OBJECT-TYPE

SYNTAX Integer32
UNITS "volt-amperes reactive"
MAX-ACCESS read-only
STATUS current

DESCRIPTION

"A measured value of the reactive portion of the
apparent power. IEC 61850-7-4 attribute 'TotVAr'."

::= { eoACPwrCharEntry 8 }

eoACPwrCharTotalApparentPower OBJECT-TYPE

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

"A measured value of the voltage and current which determines the apparent power. The apparent power is the vector sum of real and reactive power.

Note: watts and volt-amperes are equivalent units and may be combined. IEC 61850-7-4 attribute 'TotVA'."

::= { eoACPwrCharEntry 9 }

eoACPwrCharTotalPowerFactor 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'."

::= { eoACPwrCharEntry 10 }

eoACPwrCharThdAmperes 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'."

::= { eoACPwrCharEntry 11 }

eoACPwrCharThdVoltage 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'."

::= { eoACPwrCharEntry 12 }

eoACPwrCharPhaseTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoACPwrCharPhaseEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table describes 3-phase Power Characteristics measurements. It is a sparse extension of the eoACPwrCharTable."

::= { powerCharacteristicsMIBObjects 2 }

eoACPwrCharPhaseEntry OBJECT-TYPE

SYNTAX EoACPwrCharPhaseEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"An entry describes common 3-phase Power Characteristics measurements."

This optional table describes 3-phase Power Characteristics measurements, with three entries for each supported entPhysicalIndex entity. Entities having single phase power shall not have any entities.

This table describes attributes common to both WYE and DEL. Entities having single phase power shall not have any entries here. It is a sparse extension of the eoACPwrCharTable.

These attributes correspond to IEC 61850-7.4 MMXU phase measurements."

INDEX { entPhysicalIndex, eoPhaseIndex }

::= { eoACPwrCharPhaseTable 1 }

EoACPwrCharPhaseEntry ::= SEQUENCE {

eoPhaseIndex Integer32,

eoACPwrCharPhaseAvgCurrent Integer32,

eoACPwrCharPhaseActivePower Integer32,

eoACPwrCharPhaseReactivePower Integer32,

eoACPwrCharPhaseApparentPower Integer32,

eoACPwrCharPhasePowerFactor Integer32,

eoACPwrCharPhaseImpedance Integer32

}

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

eoACPwrCharPhaseAvgCurrent 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'"
::= { eoACPwrCharPhaseEntry 2 }

eoACPwrCharPhaseActivePower 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'"
::= { eoACPwrCharPhaseEntry 3 }

eoACPwrCharPhaseReactivePower 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'"
::= { eoACPwrCharPhaseEntry 4 }

eoACPwrCharPhaseApparentPower OBJECT-TYPE
SYNTAX Integer32
UNITS "volt-amperes"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A measured value of the voltage and current determines the apparent power. Active plus reactive power equals the total apparent power."

Internet-Draft <Power and Energy Monitoring MIB> July 2012
Note: Watts and volt-amperes are equivalent units and
may be combined. IEC 61850-7-4 attribute 'VA'."
::= { eoACPwrCharPhaseEntry 5 }

eoACPwrCharPhasePowerFactor 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."
::= { eoACPwrCharPhaseEntry 6 }

eoACPwrCharPhaseImpedance 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'."
::= { eoACPwrCharPhaseEntry 7 }

eoACPwrCharDelPhaseTable OBJECT-TYPE
SYNTAX SEQUENCE OF EoACPwrCharDelPhaseEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
 "This table describes DEL configuration phase-to-phase
 Power Characteristics measurements. This is a sparse
 extension of the eoACPwrCharPhaseTable."
::= { powerCharacteristicsMIBObjects 3 }

eoACPwrCharDelPhaseEntry OBJECT-TYPE
SYNTAX EoACPwrCharDelPhaseEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
 "An entry describes Power Characteristics attributes of
 a phase in a DEL 3-phase power system. Voltage
 measurements are provided both relative to each other
 and zero."

Internet-Draft <Power and Energy Monitoring MIB> July 2012
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 { entPhysicalIndex, eoPhaseIndex }  
 ::= { eoACPwrCharDelPhaseTable 1 }
```

```
EoACPwrCharDelPhaseEntry ::= SEQUENCE {  
    eoACPwrCharDelPhaseToNextPhaseVoltage      Integer32,  
    eoACPwrCharDelThdPhaseToNextPhaseVoltage    Integer32,  
    eoACPwrCharDelThdCurrent                    Integer32  
}
```

eoACPwrCharDelPhaseToNextPhaseVoltage 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'."  
 ::= { eoACPwrCharDelPhaseEntry 2 }
```

eoACPwrCharDelThdPhaseToNextPhaseVoltage OBJECT-TYPE

```
SYNTAX      Integer32 (0..10000)  
UNITS       "hundredths of percent"  
MAX-ACCESS  read-only  
STATUS      current  
DESCRIPTION  
    "A calculated value for the voltage total harmonic  
    distortion for phase to next phase. Method of calculation  
    is not specified. IEC 61850-7-4 attribute 'ThdPPV'."  
 ::= { eoACPwrCharDelPhaseEntry 3 }
```

eoACPwrCharDelThdCurrent OBJECT-TYPE

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

"A calculated value for the voltage total harmonic distortion (THD) for phase to phase. Method of calculation is not specified.

IEC 61850-7-4 attribute 'ThdPPV'."

::= { eoACPwrCharDelPhaseEntry 4 }

eoACPwrCharWyePhaseTable OBJECT-TYPE

SYNTAX SEQUENCE OF EoACPwrCharWyePhaseEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table describes WYE configuration phase-to-neutral Power Characteristics measurements. This is a sparse extension of the eoACPwrCharPhaseTable."

::= { powerCharacteristicsMIBObjects 4 }

eoACPwrCharWyePhaseEntry OBJECT-TYPE

SYNTAX EoACPwrCharWyePhaseEntry

MAX-ACCESS not-accessible

STATUS current

DESCRIPTION

"This table describes measurements of WYE configuration with phase to neutral Power Characteristics attributes. Three entries are required for each supported entPhysicalIndex entry. Voltage measurements are relative to neutral.

This is a sparse extension of the eoACPwrCharPhaseTable.

Each entry describes Power Characteristics attributes of one phase of a WYE 3-phase power system.

Measured values are from IEC 61850-7-2 MMUX and THD from MHAI objects."

INDEX { entPhysicalIndex, eoPhaseIndex }

::= { eoACPwrCharWyePhaseTable 1 }

EoACPwrCharWyePhaseEntry ::= SEQUENCE {

eoACPwrCharWyePhaseToNeutralVoltage Integer32,

eoACPwrCharWyePhaseCurrent Integer32,

eoACPwrCharWyeThdPhaseToNeutralVoltage Integer32

}

eoACPwrCharWyePhaseToNeutralVoltage 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'."

::= { eoACPwrCharWyePhaseEntry 1 }

eoACPwrCharWyePhaseCurrent OBJECT-TYPE

SYNTAX Integer32
UNITS "0.1 amperes AC"
MAX-ACCESS read-only
STATUS current

DESCRIPTION

"A measured value of phase currents. IEC 61850-7-4 attribute 'A'."

::= { eoACPwrCharWyePhaseEntry 2 }

eoACPwrCharWyeThdPhaseToNeutralVoltage 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'."

::= { eoACPwrCharWyePhaseEntry 3 }

-- Conformance

powerCharacteristicsMIBCompliances OBJECT IDENTIFIER

::= { powerCharacteristicsMIB 2 }

powerCharacteristicsMIBGroups OBJECT IDENTIFIER

::= { powerCharacteristicsMIB 3 }

powerCharacteristicsMIBFullCompliance MODULE-COMPLIANCE

STATUS current

DESCRIPTION

"When this MIB is implemented with support for read-create, then such an implementation can claim full compliance. Such devices can then be both monitored and configured with this MIB. The entPhysicalIndex, entPhysicalName, and entPhysicalUris [RFC4133] MUST be implemented."

MODULE -- this module

MANDATORY-GROUPS {
 powerACPwrCharMIBTableGroup

"A compliant implementation does not have to implement."

"A compliant implementation does not have to implement."

"A compliant implementation does not have to implement."

"A compliant implementation does not have to implement."

```
::= { powerCharacteristicsMIBCompliances 1 }
```

-- Units of Conformance

```
-- Note that object entPhysicalIndex is NOT
-- included since it is not-accessible
```

```
eoACPwrCharAvgVoltage,  
eoACPwrCharAvgCurrent,  
eoACPwrCharFrequency,  
eoACPwrCharPowerUnitMultiplier,  
eoACPwrCharPowerAccuracy,  
eoACPwrCharTotalActivePower,  
eoACPwrCharTotalReactivePower,  
eoACPwrCharTotalApparentPower,  
eoACPwrCharTotalPowerFactor  
} STATUS
```

current	DESCRIPTION

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 "This group contains the collection of all the Power
 Characteristics objects related to the Energy Object."
 ::= { powerCharacteristicsMIBGroups 1 }

powerACPwrCharOptionalMIBTableGroup OBJECT-GROUP
 OBJECTS {
 eoACPwrCharConfiguration,
 eoACPwrCharThdAmperes,
 eoACPwrCharThdVoltage
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all the Power
 Characteristics objects related to the Energy Object."
 ::= { powerCharacteristicsMIBGroups 2 }

powerACPwrCharPhaseMIBTableGroup OBJECT-GROUP
 OBJECTS {
 -- Note that object entPhysicalIndex is NOT
 -- included since it is not-accessible
 eoACPwrCharPhaseAvgCurrent,
 eoACPwrCharPhaseActivePower,
 eoACPwrCharPhaseReactivePower,
 eoACPwrCharPhaseApparentPower,
 eoACPwrCharPhasePowerFactor,
 eoACPwrCharPhaseImpedance
 }
 STATUS current
 DESCRIPTION
 "This group contains the collection of all 3-phase Power
 characteristics objects related to the Power State."
 ::= { powerCharacteristicsMIBGroups 3 }

powerACPwrCharDelPhaseMIBTableGroup OBJECT-GROUP
 OBJECTS {
 -- Note that object entPhysicalIndex and
 -- eoPhaseIndex are NOT included
 -- since they are not-accessible
 eoACPwrCharDelPhaseToNextPhaseVoltage ,
 eoACPwrCharDelThdPhaseToNextPhaseVoltage,
 eoACPwrCharDelThdCurrent
 }
 STATUS current
 DESCRIPTION

```

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    "This group contains the collection of all power
    characteristic attributes of a phase in a DEL 3-phase
    power system."
    ::= { powerCharacteristicsMIBGroups 4 }

powerACPwrCharWyePhaseMIBTableGroup OBJECT-GROUP
    OBJECTS          {
        -- Note that object entPhysicalIndex and
        -- eoPhaseIndex are NOT included
        -- since they are not-accessible
        eoACPwrCharWyePhaseToNeutralVoltage,
        eoACPwrCharWyePhaseCurrent,
        eoACPwrCharWyeThdPhaseToNeutralVoltage
    }
    STATUS            current
    DESCRIPTION
        "This group contains the collection of all WYE
        configuration phase-to-neutral Power Characteristics
        measurements."
    ::= { powerCharacteristicsMIBGroups 5 }

END

```

11. Security Considerations

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

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

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

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

12. IANA Considerations

12.1. IANA Considerations for the MIB Modules

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

Descriptor	OBJECT IDENTIFIER value
-----	-----
energyObjectMib	{ mib-2 xxx }
powerCharacteristicsMIB	{ mib-2 yyy }

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

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 list in 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.

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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.

12.3. Updating the Registration of Existing Power State Sets

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>

With the evolution of standards, over time, it may be important to deprecate some of the existing the Power State Sets or some of the states within a Power State Set.

The registrant shall publish an Internet-draft or an individual submission with the clear specification on deprecation of Power State Sets or Power States registered with IANA. The deprecation shall be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The process should also allow for a mechanism for cases where others have significant objections to claims on deprecation of a registration. In cases, where the registrant cannot be reached, IESG can designate an Expert to modify the IANA registry for the deprecation.

12. Contributors

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

John Parello

Rolf Winter

Dominique Dudkowski

13. Acknowledgment

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14. Open Issues

OPEN ISSUE 1 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 2 check if all the requirements from [EMAN-REQ] are covered.

OPEN ISSUE 3 IANA Registered Power State Sets deferred to [EMAN-FRAMEWORK]

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Energy Management Framework
draft-ietf-eman-framework-05

Status of this Memo

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Abstract

This document defines a framework for providing Energy Management for devices within or connected to communication networks, and components thereof. The framework defines an Energy Management Domain as a set of Energy Objects, for which each Energy Object is identified, classified and given context. Energy Objects can be monitored and/or controlled with respect to Power, Power State, Energy, Demand, Power Quality, and battery. Additionally the framework models relationships and capabilities between Energy Objects.

<Claise, et. Al>

Expires Mar 12,2013

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OPEN ISSUES:

- The UML must be aligned with the latest [EMAN-AWARE-MIB] and [EMAN-AWARE-MIB] document versions.
- The document must aligned with the latest latest [EMAN-REQ] version

EDITORS NOTE: Authors would like to revise for grammar and consolidation after extensive merging with other documents for this version.

1. Introduction

Network management is divided into the five main areas defined in the ISO Telecommunications Management Network model: Fault, Configuration, Accounting, Performance, and Security Management (FCAPS) [X.700]. Absent from this management model is any consideration of Energy Management, which is now becoming a critical area of concern worldwide as seen in [ISO50001].

Note that Energy Management has particular challenges in that a power distribution network is responsible for the supply of energy to various devices and components, while a separate communication network is typically used to monitor and control the power distribution network.

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

The identified device or identified components within a device can then be monitored for Energy Management by obtaining measurements for Power, Energy, Demand and Power Quality. If a device contains batteries, they can be also be monitored and managed. An Energy Object state can be monitored or controlled by providing an interface expressed as one or more Power State Sets. The most basic example of Energy Management is a single Energy Object reporting information about itself. However, in many cases, energy is not measured by the Energy

Object itself, but by a meter located upstream in the power distribution tree. An example is a power distribution unit (PDU) that measures energy received by attached devices and may report this to an Energy Management System (EnMS). Therefore, Energy Objects are recognized as having relationships to other devices in the network from the point of view of Energy Management. These relationships include Aggregation Relationship, Metering Relationship, Power Source Relationship, and Proxy Relationship.

1.1. Energy Management Document Overview

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

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

other frameworks.

The Energy-aware Networks and Devices MIB [EMAN-AWARE-MIB] specifies objects for addressing Energy Object Identification, classification, context information, and relationships from the point of view of Energy Management.

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

Further, the battery monitoring MIB [EMAN-BATTERY-MIB] defines managed objects that provide information on the status of batteries in managed devices.

2. Terminology

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

EDITOR'S NOTE:

All terms are copied over from the version 6 of the [EMAN-TERMINOLOGY] draft.

Device

A piece of electrical or non-electrical equipment.

Reference: Adapted from [IEEE100]

Component

A part of an electrical or non-electrical equipment
(Device).

Reference: Adapted from [ITU-T-M-3400]

Energy Management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization.

Reference: Adapted from [ITU-T-M-3400]

Example: A set of computer systems that will poll electrical meters and store the readings

NOTES:

1. Energy management refers to the activities, methods, procedures and tools that pertain to measuring, modeling, planning, controlling and optimizing the use of energy in networked systems [NMF].
2. Energy Management is a management domain which is congruent to any of FCAPS areas of management in the ISO/OSI Network Management Model [TMN]. Energy Management for communication networks and attached devices is a subset or part of an organization's greater Energy Management Policies.

Energy Management System (EnMS)

An Energy Management System is a combination of hardware and software used to administer a

network with the primary purpose being Energy Management.

Reference: Adapted from [1037C]

Example: A single computer system that polls data from devices using SNMP

NOTES:

1. An Energy Management System according to [ISO50001] (ISO-EnMS) is a set of systems or procedures upon which organizations can develop and implement an energy policy, set targets,

action plans and take into account legal requirements related to energy use. An EnMS allows organizations to improve energy performance and demonstrate conformity to requirements, standards, and/or legal requirements.

2. Example ISO-EnMS: Company A defines a set of policies and procedures indicating there should exist multiple computerized systems that will poll energy from their meters and pricing / source data from their local utility. Company A specifies that their CFO should collect information and summarize it quarterly to be sent to an accounting firm to produce carbon accounting reporting as required by their local government.
3. For the purposes of EMAN, the definition from [1037C] is the preferred meaning of an Energy Management System (EnMS). The definition from [ISO50001] can be referred to as ISO Energy Management System (ISO-EnMS).

ISO Energy Management System

Energy Management System as defined by [ISO50001]

Energy

That which does work or is capable of doing work. As used by electric utilities, it is generally a reference to electrical energy and is measured in kilo-watt hours (kWh).

Reference: [IEEE100]

NOTES

1. Energy is the capacity of a system to produce external activity or perform work [ISO50001]

Power

The time rate at which energy is emitted,

transferred, or received; usually expressed in watts (or in joules per second).
Reference: [IEEE100]

Demand

The average value of power or a related quantity over a specified interval of time. Note: Demand is expressed in kilowatts, kilovolt-amperes, kilovars, or other suitable units.

Reference: [IEEE100]

NOTES:

1. Typically kilowatts.
2. Energy providers typically bill by Demand measurements as well as for maximum Demand per billing periods. Power values may spike during short-terms by devices, but Demand measurements recognize that maximum Demand does not equal maximum Power during an interval.

Power Characteristics

Measurements of the electrical current, voltage, phase and frequencies at a given point in an electrical power system.

Reference: Adapted from [IEC60050]

NOTES:

1. Power Characteristics is not intended to be judgmental with respect to a reference or technical value and are independent of any usage context.

Power Quality

Characteristics of the electric current, voltage, phase and frequencies at a given point in an electric power system, evaluated against a set of reference technical parameters. These parameters might, in some cases, relate to the compatibility between electricity supplied in an electric power system and the loads connected to that electric power

system.

Reference: [IEC60050]

NOTES:

1. Electrical characteristics representing power quality information are typically required by customer facility energy management systems. It is not intended to satisfy the detailed requirements of power quality monitoring. Standards typically also give ranges of allowed values; the information attributes are the raw measurements, not the "yes/no" determination by the various standards.

Reference: [ASHRAE-201]

Electrical Equipment

A general term including materials, fittings, devices, appliances, fixtures, apparatus, machines, etc., used as a part of, or in connection with, an electric installation.

Reference: [IEEE100]

Non-Electrical Equipment (Mechanical Equipment)

A general term including materials, fittings, devices appliances, fixtures, apparatus, machines, etc., used as a part of, or in connection with, non-electrical power installations.

Reference: Adapted from [IEEE100]

Energy Object

An Energy Object (EO) is a piece of equipment
that is part of or attached to a communications

network that is monitored, controlled, or aids in the management of another device for Energy Management.

Electrical Energy Object

An Electrical Energy Object (EEO) is an Energy Object that is a piece of Electrical Equipment

Non-Electrical Energy Object

A Non-Electrical Energy Object (NEEO) an Energy Object that is a piece of Non-Electrical Equipment.

Energy Monitoring

Energy Monitoring is a part of Energy Management that deals with collecting or reading information from Energy Objects to aid in Energy Management.

NOTES:

1. This could include Energy, Power, Demand, Power Quality, Context and/or Battery information.

Energy Control

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

NOTES:

1. Typically in order to optimize or ensure its efficiency.

Internet-Draft

<EMAN Framework>

July 2012

Provide Energy:

An Energy Object "provides" energy to another Energy Object if there is an energy flow from this Energy Object to the other one.

Receive Energy:

An Energy Object "receives" energy from another Energy Object if there is an energy flow from the other Energy Object to this one.

Power Interface

A Power Interface (or simply interface) is an interconnection among devices or components where energy can be provided, received or both.

Power Inlet

A Power Inlet (or simply inlet) is an interface at which a device or component receives energy from another device or component.

Power Outlet

A Power Outlet (or simply outlet) is an interface at which a device or component provides energy to another device or component.

Energy Management Domain

An Energy Management Domain is a set of Energy Objects where all objects in the domain are considered one unit of management.

For example, power distribution units and all of the attached Energy Objects are part of the same Energy Management Domain.

For example, all EEO's drawing power from the same distribution panel with the same AC voltage within a building, or all EEO's in a building for which there is one main meter, would comprise an Energy Management Domain.

NOTES:

1. Typically, this set will have as members all EO's that are powered from the same source.

Energy Object Identification

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

Energy Object Context

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

NOTES:

1. The classification could contain the use and/or the ranking of the Energy Object as compared to other Energy Objects in the Energy Management Domain.

Energy Object Relationship

An Energy Object Relationship is a functional association among Energy Objects

NOTES

1. Relationships can be named and could include Aggregation, Metering, Power Source, and Proxy.
2. The Energy Object is the noun or entity in the relationship with the relationship described as the verb.

Example: If EO x is a piece of Electrical Equipment and EO y is an electrical meter clamped onto x's power cord, then x and y have a Metering Relationship. It follows that y meters x and that x is metered by y.

Reference: Adapted from [CHEN]

Aggregation Relationship

An Aggregation Relationship is an Energy Object Relationship where one Energy Object aggregates the Energy Management information of one or more other Energy Objects. These Energy Objects are referred to as having an Aggregation Relationship.

NOTES:

Aggregate values may be obtained by reading values from multiple Energy Objects and producing a single value of more significant meaning such as average, count, maximum, median, minimum, mode and most commonly sum [SQL].

Metering Relationship

A Metering Relationship is an Energy Object Relationship where one Energy Object measures the Power or Energy of one or more other Energy Objects. These Energy Objects are referred to as having a Metering Relationship.

Example: a PoE port on a switch measures the Power it provides to the connected Energy Object.

Power Source Relationship

A Power Source Relationship is an Energy Object Relationship where one Energy Object is the source of or distributor of Power to one or more other Energy Objects. These Energy Objects are referred to as having a Power Source Relationship.

Example: a PDU provides power for a connected device.

Proxy Relationship

A Proxy Relationship is an Energy Object Relationship where one Energy Object provides the Energy Management capabilities on behalf of one or more other Energy Objects. These Energy Objects are referred to as having a Proxy Relationship.

Example: a protocol gateways device for Building Management Systems (BMS) with subtended devices.

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

Example: in a Metering Relationship, the Energy Object that is metering is called the Energy Object Parent, while the Energy Object that is metered is called the Energy Object Child.

Energy Object Child

An Energy Object Child is an Energy Object that participates in an Energy Object Relationships and is considered as receiving the capabilities in the relationship.

Example: in a Metering Relationship, the Energy Object that is metering is called the Energy Object Parent, while the Energy Object that is metered is called the Energy Object Child.

Power State

A Power State is a condition or mode of a device that broadly characterizes its capabilities, power consumption, and responsiveness to input.

Reference: Adapted from [IEEE1621]

NOTES:

1. A Power State can be seen as a power setting of an Energy Object that influences the power consumption, the available functionality, and the responsiveness of the Energy Object.
2. A Power State can be viewed as one method for Energy Control

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

Example: The states {on, off, and sleep} as defined in [IEEE1621], or the 16 power states as defined by the [DMTF] can be considered two different Power State Sets.

Nameplate Power

The Nameplate Power is the maximal (nominal) Power that a device can support.

NOTES:

1. This is typically determined via load testing and is specified by the manufacturer as the maximum value required for operating the device. This is sometimes referred to as the worst-case Power. The actual or average Power may be lower. The Nameplate Power is typically used for provisioning and capacity planning.

3. Requirements & Use Cases

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

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

Target devices for Energy Management are all Energy Objects that can directly or indirectly be monitored or controlled by

an Energy Management System (EnMS) using the Internet protocol, for example:

- Simple electrical appliances / fixtures
- Hosts, such as a PC, a datacenter server, or a printer
- Routers
- Switches
- A component within devices, such as a battery inside a PC, a line card inside a switch, etc...
- Power over Ethernet (PoE) endpoints
- Power Distribution Units (PDU)
- Protocol gateway devices for Building Management Systems (BMS)
- Electrical meters
- Sensor controllers with subtended sensors

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

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

This is the first version of the IETF Energy Management framework. Though it already covers a wide range of use cases, there are still a lot of potential ones that are not covered, yet. A simple example is the limitation to discrete power states without parameters. Some devices have energy-related properties that not well described with discrete power states, for example a dimmer with a continuous power range from 0%-100%. Other devices may have even more parameters than just a single percentage value.

This framework defines an information model containing various values that are measured on a device for the purpose of monitor and control. The framework does not cover setting bounds or conditions for these values for the purpose of policy management - for example specifying that power MUST NOT exceed a limit. While implementations can set bounds and notification when exceeding those bounds while monitored, physically preventing a device to not exceed the bound is beyond the scope of this framework. It is up to future updates of this document to select more of such use-cases and to cover them by extensions or revisions of the present framework.

4. Energy Management Issues

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

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

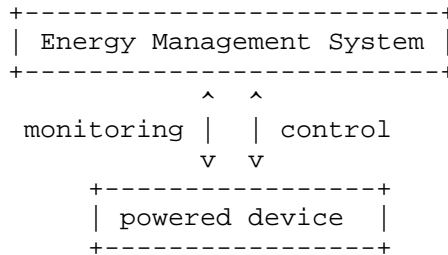


Figure 1: Basic energy management scenario

The powered device may have local energy control mechanisms, for example putting itself into a sleep mode when appropriate, and it may receive energy control commands for similar purposes from the EnMS. Information reported from a powered device to the EnMS includes at least the Power State of the powered device (on, sleep, off, etc.).

This and similar cases are well understood and likely to become very common for Energy Management. They can be handled with well established and standardized management procedures. The only missing components today are standardized information and data models for reporting and configuration, such as, for example, energy-specific MIB modules [RFC2578] and YANG modules [RFC6020].

However, the nature of energy supply and use introduces some issues that are special to Energy Management. The following subsections address these issues and illustrate them by extending the basic scenario in Figure 1.

A powered device may supply itself with power. Sensors, for example, commonly have batteries or harvest Energy. However, most powered devices that are managed by an EnMS receive external power.

While a huge number of devices receive Power from unmanaged supply systems, the number of manageable power supply devices is increasing.

In datacenters, many Power Distribution Units (PDUs) allow the EnMS to switch power individually for each socket and also to measure the provided Power. Here there is a big difference to many other network management tasks: In such and similar cases, switching power supply for a powered device or monitoring its power is not done by communicating with the actual powered device, but with an external power supply device (in this case, the PDU). Note that those external power supply devices may be an external power meter).

Consequently, a standard for Energy Management must not just cover the powered devices that provide services for users, but also the power supply devices (which are powered devices as well) that monitor or control the power supply for other powered devices.

A very simple device such as a plain light bulb can be switched on or off only by switching its power supply. More complex devices may have the ability to switch off themselves or to bring themselves to states in which they consume very little power. For these devices as well, it is desirable to monitor and control their power supply.

This extends the basic scenario from Figure 1 by a power supply device, see Figure 2.

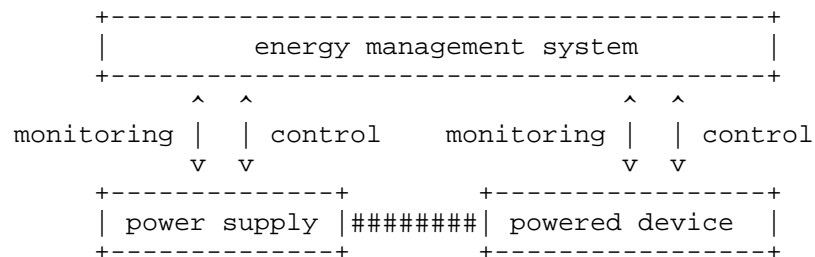


Figure 2: Power Supply

The power supply device can be as simple as a plain power switch. It may offer interfaces to the EnMS to monitor and to control the status of its power outlets, as with PDUs and Power over Ethernet (PoE) [IEEE-802.3at] switches.

The relationship between supply devices and the powered devices they serve creates several problems for managing power supply:

- o Identification of corresponding devices
 - * A given powered device may need to identify the supplying power supply device.
 - * A given power supply device may need to identify the corresponding supplied powered device(s).
- o Aggregation of monitoring and control for multiple powered devices
 - * A power supply device may supply multiple powered devices with a single power supply line.
- o Coordination of power control for devices with multiple power inlets
 - * A powered device may receive power via multiple power lines controlled by the same or different power supply devices.

4.1.1 Identification of Power Supply and Powered Devices

When a power supply device controls or monitors power supply at one of its power outlets, the effect on other devices is not always clear without knowledge about wiring of power lines. The same holds for monitoring. The power supplying device can report that a particular socket is powered, and it may even be able to measure power and conclude that there is a consumer drawing power at that socket, but it may not know which powered device receives the provided power.

In many cases it is obvious which other device is supplied by a certain outlet, but this always requires additional (reliable) information about power line wiring. Without knowing which device(s) are powered via a certain outlet, monitoring data are of limited value and the consequences of switching power on or off may be hard to predict.

Even in well organized operations, powered devices' power cords can be plugged into the wrong socket, or wiring plans changed without updating the EnMS accordingly.

For reliable monitoring and control of power supply devices, additional information is needed to identify the device(s) that receive power provided at a particular monitored and controlled socket.

This problem also occurs in the opposite direction. If power supply control or monitoring for a certain device is needed, then the supplying power supply device has to be identified.

To conduct Energy Management tasks for both power supply devices and other powered devices, sufficiently unique identities are needed, and knowledge of their power supply relationship is required.

4.1.2 Multiples Devices Supplied by a Single Power Line

The second fundamental problem is the aggregation of monitoring and control that occurs when multiple powered devices are supplied by a single power supply line. It is often required that the EnMS has the full list of powered devices connected to a single outlet as in Figure 3.

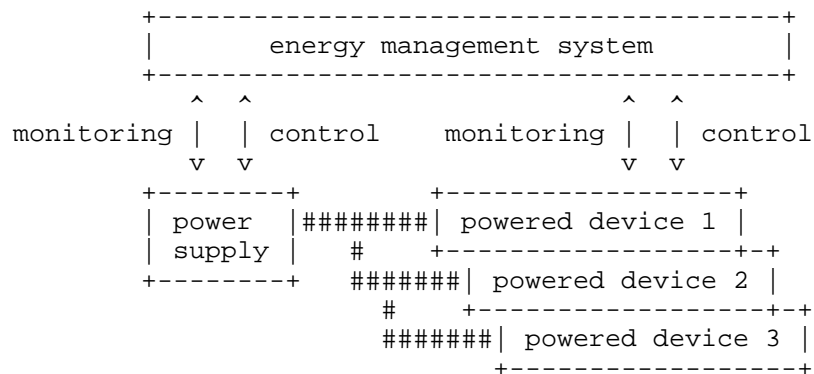


Figure 3: Multiple Powered Devices Supplied by Single Power Line

With this list, the single status value has clear meaning and is the sum of all powered devices. Control functions are limited by the fact that supply for the concerned devices can only be switched on or off for all of them at once. Individual control at the supply is not possible.

If the full list of devices powered by a single supply line is not known by the controlling power supply device, then control of power supply is problematic, because the consequences of control actions can only be partially known.

4.1.3 Multiple Power Supply for a Single Powered Device

The third problem arises from the fact that there are devices with multiple power supplies. Some have this for redundancy of power supply, some for just making internal power converters (for example, from AC mains power to DC internal power) redundant, and some because the capacity of a single supply line is insufficient.

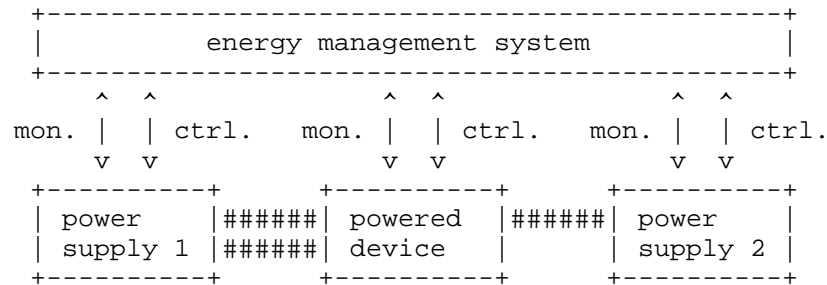


Figure 4: Multiple Power Supply for Single Powered Device

The example in Figure 4 does not necessarily show a real world scenario, but it shows the two cases to consider:

- o multiple power supply lines between a single power supply device and a powered device
- o different power supply devices supplying a single powered device

In any such case there may be a need to identify the supplying power supply device individually for each power inlet of a powered device.

Without this information, monitoring and control of power supply for the powered device may be limited.

4.1.4 Bidirectional Power Interfaces

Low wattage DC systems may allow power to be delivered bi-directionally. Energy stored in batteries on one device can be delivered back to a power hub which redirects the current to power another device. In this situation, the interface can function as both an inlet and outlet.

The framework for Energy Management introduces the notion of Power Interface, which can model a power inlet and a power outlet, depending on the conditions. The Power Interface reports power direction, as well as the energy received, supplied and the net result.

4.1.5 Relevance of Power Supply Issues

In some scenarios, the problems with power supply do not exist or can be sufficiently solved. With Power over Ethernet (PoE) [IEEE-802.3at], there is always a one-to-one relationship between a Power Sourcing Equipment (PSE) and a Powered Device (PD). Also, the Ethernet link on the line used for powering can be used to identify the two connected devices.

For supply of AC mains power, the three problems described above cannot be solved in general. There is no commonly available protocol or automatic mechanism for identifying endpoints of a power line.

And, AC power lines support supplying multiple powered devices with a single line and commonly do.

4.1.6 Remote Power Supply Control

There are three ways for an energy management system to change the Power State of an powered devices. First is for the EnMS to provide policy or other useful information (like the electricity price) to the powered device for it to use in determining its Power State. The second is sending the powered devices a command to switch to another Power State. The third is to utilize an upstream device (to the powered device) that has capabilities to switch on and off power at its outlet.

Some Energy Objects do not have capabilities for receiving commands or changing their Power States by themselves. Such Energy Objects may be controlled by switching on and off the power supply for them and so have particular need for the third method.

In Figure 4, the power supply can switch on and off power at its power outlet and thereby switch on and off power supply for the connected powered device.

4.2. Power and Energy Measurement

Some devices include hardware to directly measure their Power and Energy consumption. However, most common networked devices do not provide an interface that gives access to Energy and Power measurements. Hardware instrumentation for this kind of measurements is typically not in place and adding it incurs an additional cost.

With the increasing cost of Energy and the growing importance of Energy Monitoring, it is expected that in future more devices will include instrumentation for power and energy measurements, but this may take quite some time.

4.2.1 Local Estimates

One solution to this problem is for the powered device to estimate its own Power and consumed Energy. For many Energy Management tasks, getting an estimate is much better than not getting any information at all.

Estimates can be based on actual measured activity level of a device or it can just depend on the power state (on, sleep, off, etc.).

The advantage of estimates is that they can be realized locally and with much lower cost than hardware instrumentation. Local estimates can be dealt with in traditional ways. They don't need an extension of the basic scenarios above. However, the powered device needs an energy model of itself to make estimates.

4.2.2 Management System Estimates

Another approach to the lack of instrumentation is estimation by the EnMS. The EnMS can estimate Power based on basic information on the powered device, such as the type of device, or also its brand/model and functional characteristics.

Energy estimates can combine the typical power level by Power State with reported data about the Power State.

If the EnMS has a detailed energy model of the device, it can produce better estimates including the actual power state and actual activity level of the device. Such information can be obtained by monitoring the device with conventional means of performance monitoring.

4.3. Reporting Sleep and Off States

Low power modes pose special challenges for energy reporting because they may preclude a device from listening to and responding to network requests. Devices may still be able to reliably track energy use in these modes, as power levels are usually static and internal clocks can track elapsed time in these modes.

Some devices do have out-of-band or proxy abilities to respond to network requests in low-power modes. Others could use proxy abilities in an energy management protocol to improve this reporting, particularly if the powered device sends out notifications of power state changes.

4.4. Device and Device Components

While the primary focus of energy management is entire powered Devices, sometimes it is necessary or desirable to manage Components such as line cards, fans, disks, etc.

The concept of a Power Interface may not apply to Components since they may receive Energy from a pool available from the encompassing device. For example, a DC-powered blade server in a chassis may have its own identity on the network and be managed as a single device but its energy may be received from a shared power source among all blades in the chassis.

4.5. Non-Electrical Equipment

The primary focus of this framework is for the management of Electrical Equipment. Some Non-Electrical Equipment may be connected to a communication networks and could have their energy managed if normalize to the electrical units for power and energy.

Some examples of Non-Electrical Equipment that may be connected to a communication network are:

- 1) A controller for compressed air. The controller is electrical only for its network connection. The controller is fueled by natural gas and produces compressed air. The energy transferred via compressed air is distributed to devices on a factory floor via a Power Interface: tools (drills, screwdrivers, assembly line conveyor belts). The energy measured is non-electrical (compressed air).
EDITOR'S NOTE: Note that, in such as case, some might argue that the "energy interface" term might be more accurate than Power Interface. To be discussed.
- 2) A controller for steam. The controller is electrical for its network attachment but it burns tallow and produces steam to subtended boilers. The energy is non-electrical (steam).
- 3) A controller or regulator for gas. The controller is electrical for its network attachment but it has physical non-electrical components for control. The energy is non-electrical (BTU).

5. Energy Management Reference Model

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

In this section we will describe the topologies that can exist when describing a device, components and the relationships among them in an Energy Management Domain.

We will then generalize those topologies by using an information model based upon relationships. The most abstract and general relationship between devices is a Parent and Child relationship. Specific types of relationships are defined and used in concert to describe the topologies of an Energy Management Domain.

5.1. Reference Topologies

The reference model defines physical and logical topologies of devices and the relationship among them in a communication network.

The physical topology defined by the model defines relationships between devices that reflect provisioning, transfer of energy, and aid in management.

Logical topologies concern monitoring and controlling devices and covers metering of energy and power, reporting information relevant for energy management, and energy-related control of devices.

5.1.1 Power Source Topology

As described in Section 4, it is important for energy management, which devices provides power to which other device. The energy management reference model addresses this by a "Power Source"Relationship. This is a relationship among devices providing energy and devices receiving energy.

A simple example is a PoE PSE, for example, an Ethernet switch, providing power to a PoE PD, for example, a desktop phone. Here the switch provides energy and the phone receives energy. Their relationship can be illustrated as shown in the figure below.

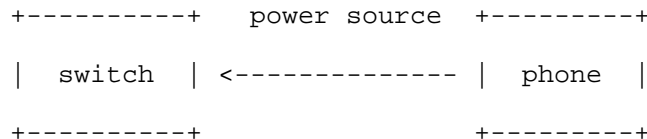


Figure 5: Simple Power Source

A single power provider can act as power source of multiple power receivers. An example is a power distribution unit (PDU) providing AC power for multiple switches.

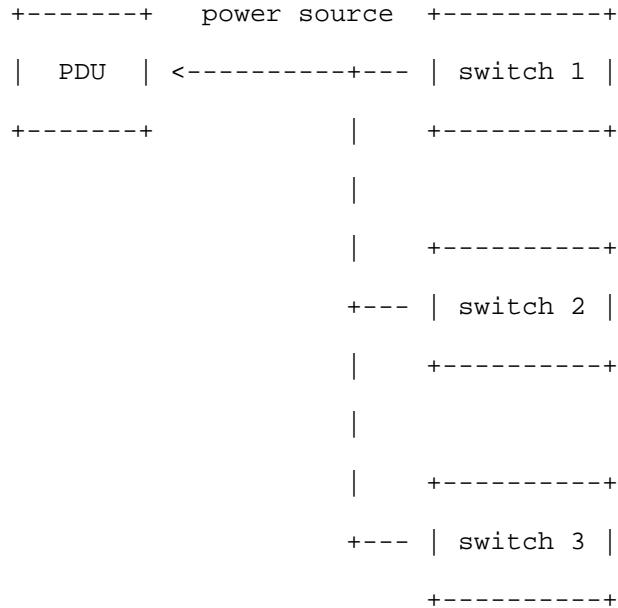


Figure 6: Multiple Power Source

This level of modeling is sufficient if there is no need to distinguish in monitoring and control between the individual receivers at the switch.

However, if there is a need to monitor or control power supply for individual receivers at the power provider, then a more detailed level of modeling is needed.

Devices receive or provide energy at power interfaces connecting them to a transmission medium. . The Power Source relationship can be used also between power interfaces at the power provider side as well as at the power receiver side. The example below shows a power providing device with a power interface (PI) per connected receiving device.

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	+-----+-----+	power source	+-----+
	PI 1	<-----	switch 1
	+-----+		+-----+
	+-----+	power source	+-----+
PDU	PI 2	<-----	switch 2
	+-----+		+-----+
	+-----+	power source	+-----+
	PI 3	<-----	switch 3
	+-----+-----+		+-----+

Figure 7: Power Source with Power interfaces

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

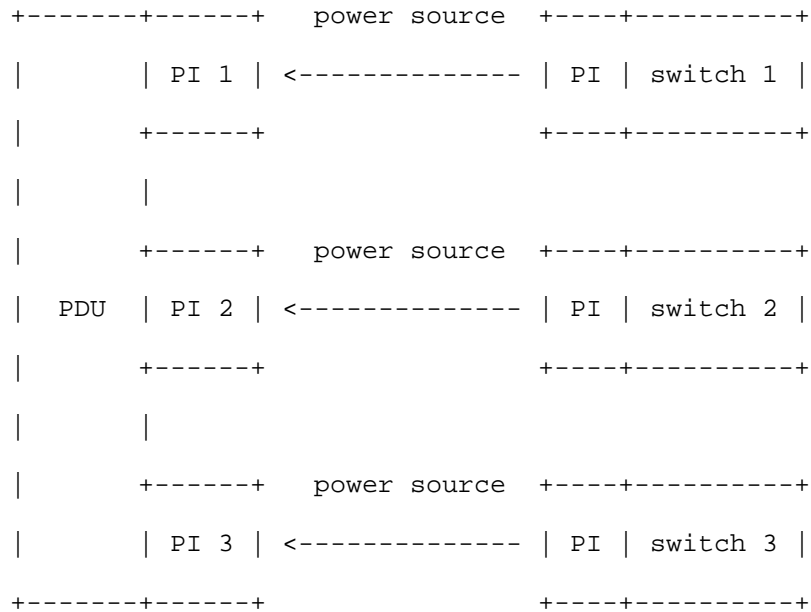


Figure 8: Power Interfaces at Receiving Device

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

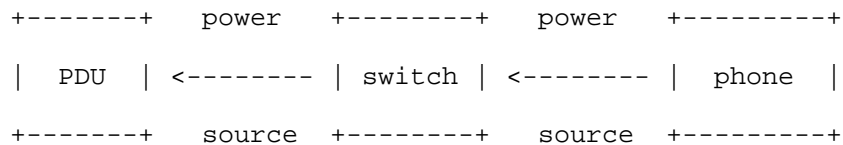


Figure 9: Power Source Non-Transitive

Power Source Relationships are between the PDU and the switch and between the switch and the phone.

Power Source Relationships are between the PDU and the switch and between the switch and the phone. Consequently, there is logically exists a power source relation between the PDU and the phone.

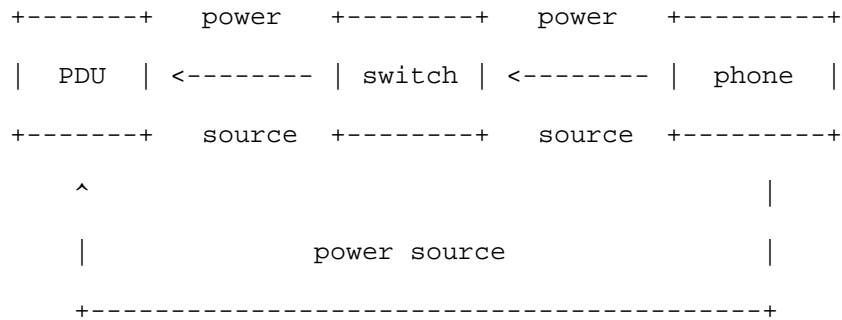


Figure 10: Power Source Transitive

5.1.2 Metering Topology

Metering Between Two Device

The power metering topology between two devices is closely related to the power source topology. It is based on the assumption that in many cases the power provided and the power received is the same for both peers of a power source relationship. Then power measured at one end can be taken as the actual power value at the other end. Obviously, the same applies to energy at both ends.

We define in this case a Power Metering Relationship between two devices or power interfaces of devices that have a power source relationship. Power and energy values measured at one peer of the power source relationship are reported for the other peer as well.

The Power Metering Relationship is independent of the direction of the Power source Relationship. The more common case is that values measured at the power provider are reported for the power receiver, but also the reverse case is

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

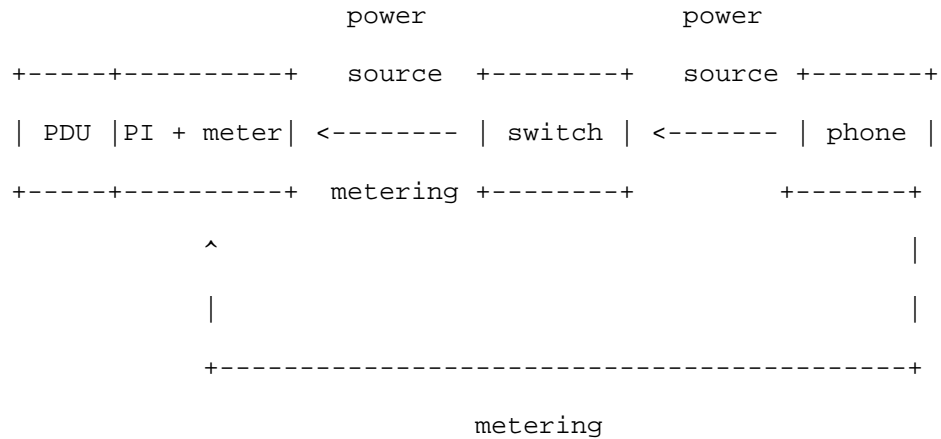


Figure 11: Direct and One Hop Metering

Metering At a Point in Power Distribution

A Sub-meter in a power distribution system can logically measure the power or energy for all devices downstream from the meter in the power distribution system. As such a Power metering relationship can be seen as a relationship between a meter and all of the devices downstream from the meter.

We define in this case a Power Metering relationship between a metering device and devices downstream from the meter.

In cases where the Power Source topology cannot be discovered or derived from the information available in the Energy Management Domain, the Metering Topology can be used to relate the upstream meter to the downstream devices in the absence of specific power source relationships.

A metering relationship can occur between devices that are not directly connected as shown by the figure below.

An analogy to communication networks would be modeling connections between servers (meters) and clients (devices) when the complete Layer 2 topology between the servers and clients is not known.

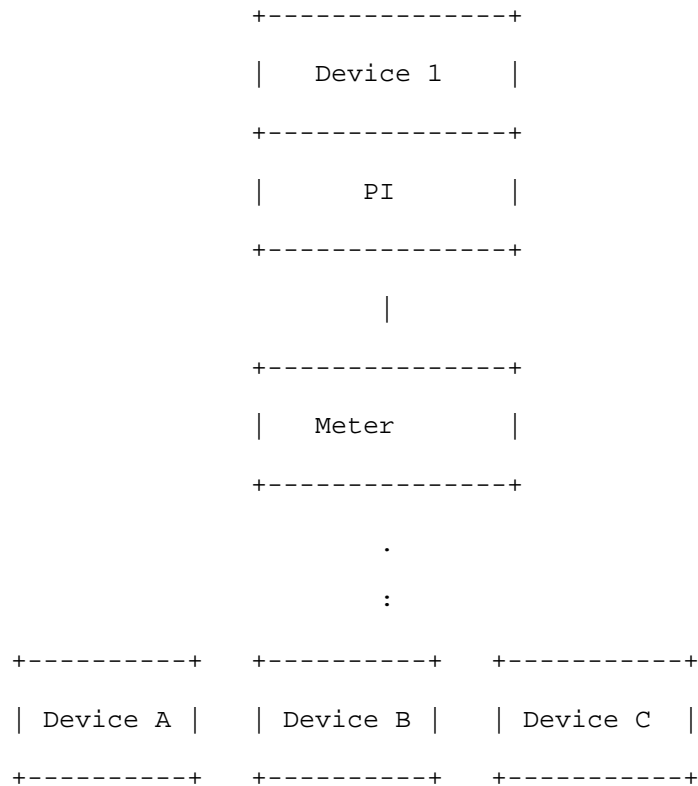


Figure 12: Complex Metering Topology

5.1.3 Proxy Topology

Some devices may provide energy management capabilities on behalf of other devices. For example a controller may logically model power interfaces but the physical topology may require that the controller communicate to another device using a BMS protocol. These subtended devices that are represented as power interfaces may be directly connected or may be controlled over a communication network with no direct connection.

While the EnMS may look at the logical representation of the controller as a device with power interfaces, it may require to report the physical topology and relationship to the subtended devices. To model this we define a proxy relationship to provide this visibility.

```
+-----+-----+
|          | PI 1 |
|          +-----+
|          |
|          +-----+
| PDU      | PI 2 |
|          +-----+
|          |
|          +-----+
|          | PI 3 |
+-----+-----+
```

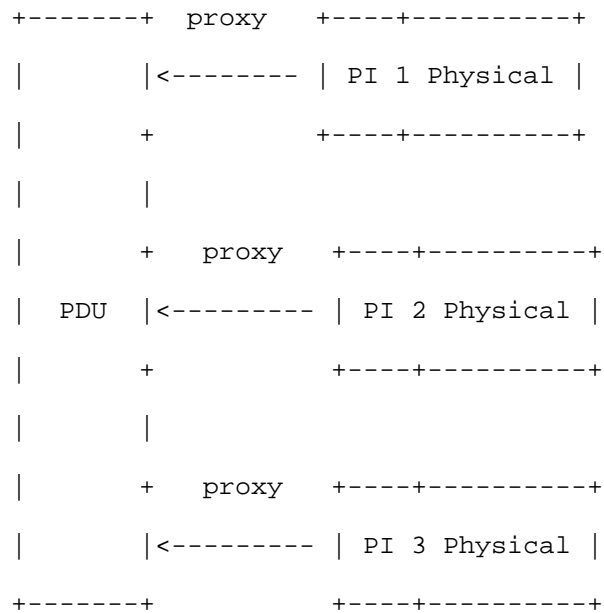


Figure 13: Proxy Relationship Virtual and Physical

5.1.4 Aggregation Topology

Some devices in a domain can act as aggregation points for other devices. For example a PDU controller device may contain the summation of power and energy readings for many PDU devices. The PDU controller will have aggregate values for power and energy for a group of PDU devices.

This aggregation is independent of the physical power or communication topology.

We define in this case an Aggregation Relationship between a device containing aggregate values for arbitrary groups of other devices.

While any power or energy values monitored from a device/power interface can be seen as a summation for all devices downstream from the monitoring device, the aggregation relationship is used to represent a summation when it is not

obvious from the powering topology or a device to component containment.

5.2. Generalized Relationship Model

As displayed in Figure 5, the most basic energy management reference model is composed of an EnMS that obtains Energy Management information from Energy Objects. The Energy Object (EO) returns information for Energy Management directly to the EnMS.

The protocol of choice for Energy Management is SNMP, as three MIBs are specified for Energy Management: the energy-aware MIB [EMAN-AWARE-MIB], the energy monitoring MIB [EMAN-MON-MIB], and the battery MIB [EMAN-BATTERY-MIB]. However, the EMAN requirement document [EMAN-REQ] also requires support for a push model distribution of time series values. The following diagrams mention IPFIX [RFC5101] as one possible solution for implementing a push mode transfer, however this is for illustration purposes only. The EMAN standard does not require the use of IPFIX and acknowledges that other alternative solutions may also be acceptable.

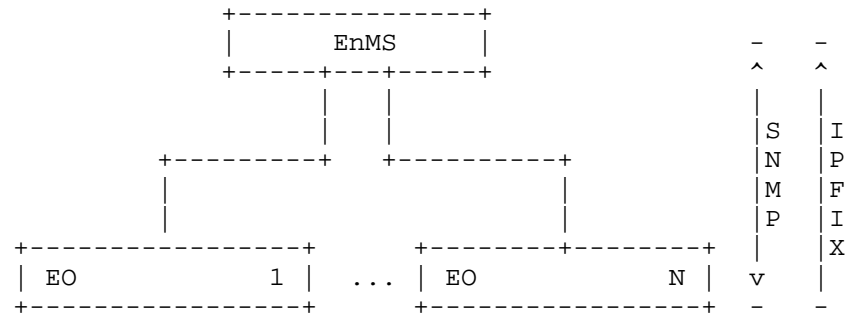


Figure 14: Simple Energy Management

As displayed in the Figure 5, a more complex energy reference model includes Energy Managed Object Parents and Children. The Energy Managed Object Parent returns information for themselves as well as information according to the Energy Managed Object Relationships.

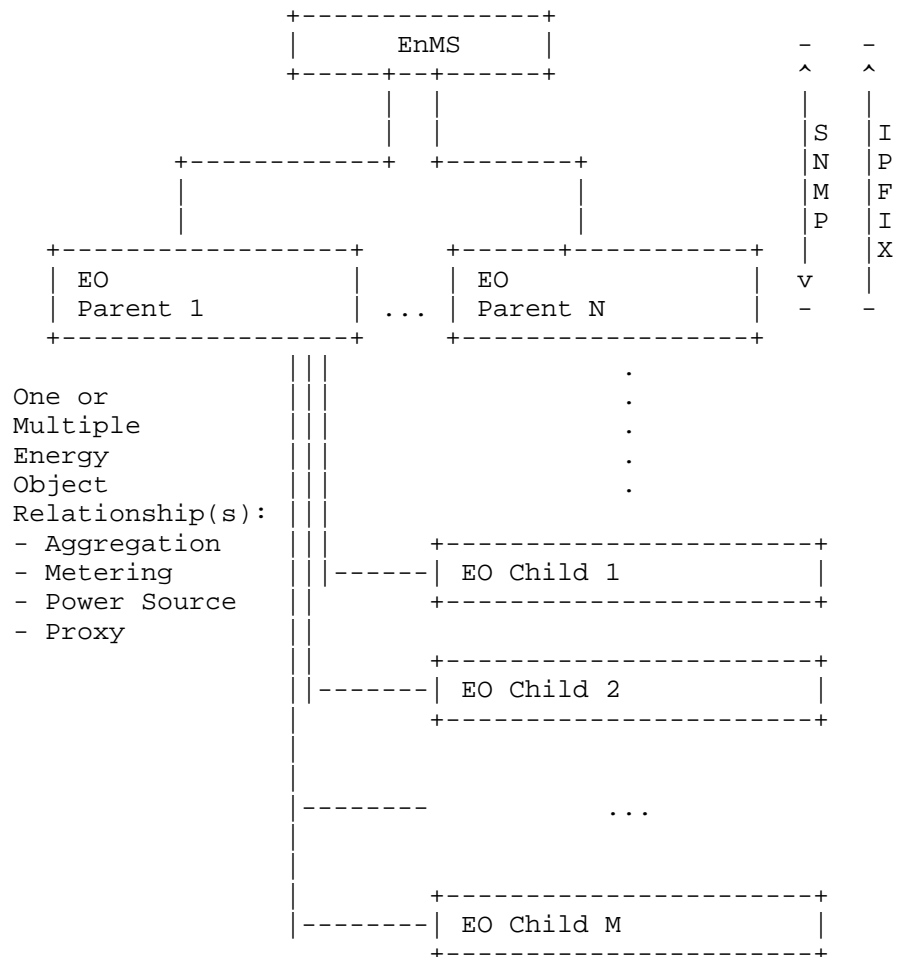


Figure 15: Complex Energy Management Model

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

Given the pattern in Figure 6, the complex relationships between Energy Objects can be modeled (refer also to section 5.3):

- A PoE device modeled as an Energy Object Parent with the Power Source, Metering, and Proxy Relationships for one or more Energy Object Children
- A PDU modeled as an Energy Object Parent with the Power Source and Metering Relationships for the plugged in Electrical Equipment (the Energy Object Children)
- Building management gateway, used as proxy for non IP protocols, is modeled as an Energy Object Parent with the Proxy Relationship, and potentially the Aggregation Relationship to the managed Electrical Equipment
- Etc.

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

5.3. Energy Object, Energy Object Components and Containment Tree

The framework for Energy Management manages two different types of Energy Objects: Devices and Components. A typical example of an Device is a switch. However, a port within the switch, which provides Power to one end point, is also an Energy Object if it meters the power provided. A second example is PC, which is a typical Device, while the battery inside the PC is a Component, managed as an individual Energy Object. Some more examples of Components: power supply within a router, an outlet within a smart PDU, etc...

In the [EMAN-AWARE-MIB], each Energy Object is managed with an unique value of the entPhysicalIndex index from the ENTITY-MIB [RFC4133]

The ENTITY-MIB [RFC4133] specifies the notion of physical containment tree, as:

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

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

6. Framework High Level Concepts and Scope

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

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

While an EnMS may be a central point for corporate reporting, cost, environmental impact, and regulatory compliance, Energy Management in this framework excludes Energy procurement and the environmental impact of energy use. As such the framework does not include:

- Manufacturing costs of an Energy Object in currency or environmental units
- Embedded carbon or environmental equivalences of an Energy Object
- Cost in currency or environmental impact to dismantle or recycle an Energy Object
- Supply chain analysis of energy sources for Energy Object deployment
- Conversion of the usage or production of energy to units expressed from the source of that energy (such as the greenhouse gas emissions associated with 1000kW from a diesel source).

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

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

6.1. Energy Object and Energy Management Domain

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

An Energy Management Domain should map 1:1 with a metered or sub-metered portion of the site. An Energy Object is part of a single Energy Management Domain. The Energy Management Domain MAY be configured on an Energy Object: the default value is a zero-length string.

If all Energy Objects in the physical containment tree (see ENTITY-MIB) are part of the same Energy Management Domain, then it is safe to state that the Energy Object at the root of that containment tree is in that Energy Management Domain.

An Energy Object Child may inherit the domain value from an Energy Object Parent or the Energy Management Domain may be configured directly in an Energy Object Child.

6.2. Power Interface

There are some similarities between Power Interfaces and network interfaces. A network interface can be used in different modes, such as sending or receiving on an attached line. The Power Interface can be receiving or providing power.

Most Power Interfaces never change their mode, but as the mode is simply a recognition of the current direction of electricity flow, there is no barrier to a mode change.

A power interface can have capabilities for metering power and other electric quantities at the shared power transmission medium.

This capability is modeled by an association to a power meter.

In analogy to MAC addresses of network interfaces, a globally unique identifier is assigned to each Power Interface.

Physically, a Power Interface can be located at an AC power

6.3. Energy Object Identification and Context

6.2.1 Energy Object Identification

Energy Objects MUST be associated with a value that uniquely identifies the Energy Object among all the Energy Management Domains within an EnMS. A Universal Unique Identifier (UUID) [RFC4122] MUST be used to uniquely and persistently identify an Energy Object.

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

6.2.2 Context in General

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

6.2.3 Context: Importance

An Energy Object can provide an importance value in the range of 1 to 100 to help rank a device's use or relative value to the site. The importance range is from 1 (least important) to 100 (most important). The default importance value is 1.

For example: A typical office environment has several types of phones, which can be rated according to their business impact. A public desk phone has a lower importance (for example, 10) than a business-critical emergency phone (for example, 100). As another example: A company can consider that a PC and a phone for a customer-service engineer is more important than a PC and a phone for lobby use.

Although EnMS and administrators can establish their own ranking, the following is a broad recommendation:

- . 90 to 100 Emergency response
- . 80 to 90 Executive or business-critical
- . 70 to 79 General or Average
- . 60 to 69 Staff or support
- . 40 to 59 Public or guest
- . 1 to 39 Decorative or hospitality

6.2.4 Context: Keywords

An Energy Object can provide a set of keywords. These keywords are a list of tags that can be used for grouping, summary reporting within or between Energy Management Domains, and for searching. All alphanumeric characters and symbols (other than a comma), such as #, (, \$, !, and &, are allowed. Potential examples are: IT, lobby, HumanResources, Accounting, StoreRoom, CustomerSpace, router, phone, floor2, or SoftwareLab. There is no default value for a keyword.

Multiple keywords can be assigned to a device. White spaces before and after the commas are excluded, as well as within a keyword itself. In such cases, the keywords are separated by commas and no spaces between keywords are allowed. For example, "HR,Bldg1,Private".

6.2.5 Context: Role

An Energy Object can provide a "role description" string that indicates the purpose the Energy Object serves in the EnMS. This could be a string describing the context the device fulfills in deployment.

Administrators can define any naming scheme for the role of a device. As guidance a two-word role that combines the service the device provides along with type can be used [IPENERGY]

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Example types of devices: Router, Switch, Light, Phone,
WorkStation, Server, Display, Kiosk, HVAC.

Example Services by Line of Business:

Line of Business	Service
Education	Student, Faculty, Administration, Athletic
Finance	Trader, Teller, Fulfillment
Manufacturing	Assembly, Control, Shipping
Retail	Advertising, Cashier
Support	Helpdesk, Management
Medical	Patient, Administration, Billing

Role as a two-word string: "Faculty Desktop", "Teller Phone",
"Shipping HVAC", "Advertising Display", "Helpdesk Kiosk",
"Administration Switch".

6.4. Energy Object Relationships

Two Energy Objects MAY establish an Energy Object Relationship. Within a relationship one Energy Object becomes an Energy Object Parent while the other becomes an Energy Object Child.

The Power Source Relationship gives the view the wiring topology. For example: a data center server receiving power from two specific Power Interfaces from two different PDUs.

The Metering Relationship gives the view of the metering topology. Standalone meters can be placed anywhere in a power distribution tree. For example, utility meters monitor and report accumulated power consumption of the entire building. Logically, the metering topology overlaps with the wiring topology, as meters are connected to the wiring topology. A typical example is meters that clamp onto the existing wiring.

The Proxy Relationship allows software objects to be inserted into the wiring or metering topology to aid in managing (monitoring and/or control) the Energy Domain.

From a EnMS management point of view, this implies that there is yet another management topology that EnMS will need to be aware of.

In the ideal situation, the wiring, the metering, and the management topologies overlap. For Example: A Power-over-Ethernet (PoE) device (such as an IP phone or an access point) is attached to a switch port. The switch port is the source of power for the attached device, so the Energy Object Parent is the switch port, which acts as a Power Interface, and the Energy Object Child is the device attached to the switch. This Energy Object Parent (the switch) has three Energy Object Relations with this Energy Object Child (the remote Energy Object): Power Source Relationship, Metering Relationship, and Proxy Relationship.

However, the three topologies (wiring, metering, and management) don't always overlap. For example, when a protocol gateways device for Building Management Systems (BMS) controls subtended devices, which themselves receive Power from PDUs or wall sockets.

Note: The Aggregation Relationship is slightly different compared to the other relationships (Power Source, Metering, and Proxy Relationships) as this refers more to a management function.

The communication between the parent and child for monitoring or collection of power data is left to the device manufacturer. For example: A parent switch may use LLDP to communicate with a connected child, and a parent lighting controller may use BACNET to communicate with child lighting devices.

The Energy Object Child MUST keep track of its Energy Object Parent(s) along with the Energy Object Relationships type(s). The Energy Object Parent MUST keep track of its Energy Object Child(ren), along with the Energy Object Relationships type(s).

6.4.1 Energy Object Children Discovery

There are multiple ways that the Energy Object Parent can discover its Energy Object Children: :

- . In case of PoE, the Energy Object Parent automatically discovers an Energy Object Child when the Child requests power.
- . The Energy Object Parent and Children may run the Link Layer Discovery Protocol [LLDP], or any other discovery protocol, such as Cisco Discovery Protocol (CDP). The Energy Object Parent might even support the LLDP-MED MIB [LLDP-MED-MIB], which returns extra information on the Energy Object Children.
- . The Energy Object Parent may reside on a network connected to a facilities gateway. A typical example is a converged building gateway, monitoring several other devices in the building, and serving as a proxy between SNMP and a protocol such as BACNET.
- . A different protocol between the Energy Object Parent and the Energy Object Children. Note that the communication specifications between the Energy Object Parent and Children is out of the scope of this document.

However, in some situations, it is not possible to discover the Energy Object Relationships, and they must be set manually. For example, in today's network, an administrator must assign the connected Energy Object to a specific PDU Power Interface, with no means of discovery other than that manual connection.

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

6.4.2 Energy Object Relationship Conventions and Guidelines

This Energy Management framework does not impose many "MUST" rules related to Energy Object Relationships. There are always corner cases that could be excluded with too strict specifications of relationships. However, this Energy Management framework proposes a series of guidelines, indicated with "SHOULD" and "MAY".

Aggregation

Aggregation relationships are intended to identify when one device is used to accumulate values from other devices. Typically this is for energy or power values among devices and not for Components or Power Interfaces on the same device. The intent of Aggregation relationships is to indicate when one device is providing aggregate values for a set of other devices when it is not obvious from the power source or simple containment within a device.

Establishing aggregation relationships within the same device would make modeling more complex and the aggregated values can be implied from the use of Power Inlets, outlet and Energy Object value on the same device.

Additionally since an EnMS is naturally a point of aggregation for information in an Energy Management Domain it is not necessary to model aggregation for an EnMS(s).

Aggregation SHOULD be used for power and energy. It MAY be used for aggregation of other values from the information model for example but the rules and logical ability to aggregated each attribute is out of scope for this document.

- A Device SHOULD NOT establish an Aggregation Relationship with a Component.
- A Device SHOULD NOT establish an Aggregation Relationship with the Power Interfaces contained on the same device.
- A Device SHOULD NOT establish an Aggregation Relationship with the an EnMS.
- Aggregators SHOULD log or provide notification in the case of errors or missing values while performing aggregation.

Power Source

Power Source relationships are intended to identify the connections between Power Interfaces. This is analogous to a Layer 2 connection in networking devices (a "one hop" connection).

The preferred modeling would be for Power Interfaces to participate in Power Source Relationships.

It may happen that the some Energy Objects may not have the capability to model Power Interfaces. Therefore, it may happen that a Power Source Relationship is established between two Energy Objects or two non-connected Power Interfaces.

While strictly speaking Components and Power Interfaces on the same device do provide or receive energy from each other the Power Source relationship is intended to show energy transfer between Devices. Therefore relationship is implied on the same Device.

- An Energy Object SHOULD NOT establish a Power Source Relationship with a Component.
- A Power Source Relationship SHOULD be established with next known Power Interface in the wiring topology.
- Transitive Power Source relationships SHOULD be avoided. For examples if an Energy Object A has a Power Source Relationship "Poweredby" with the Energy Object B, and if the Energy Object B has a Power Source Relationship "Poweredby" with the Energy Object C, then the Energy Object A SHOULD NOT have a Power Source Relationship "PoweredBby" the Energy Object C.

Metering Relationship

Metering Relationships are intended to show when one Device is measuring the power or energy at a point in a power distribution system. Since one point of a power distribution system may cover many Devices with a complex wiring topology, this relationship type can be seen as an arbitrary set.

Additionally, Devices may include metering hardware for components and Power Interfaces or for the entire Device.

For example some PDUs may have the ability to measure Power for each Power Interface (metered by outlet). Others may only be able to control power at each Power Interface but only measure Power at the Power Inlet and a total for all Power Interfaces (metered by device).

In such cases a Device SHOULD be modeled as an Energy Object that meters all of its Power Outlets and each Power Outlet MAY be metered by the Energy Object representing the Device.

- A Meter Relationship MAY be established with any other Energy Object, Component, or Power Interface.
- Transitive Meter relationships MAY be used.

Proxy

A Proxy relationship is intended to show when one Device is providing the Energy Object capabilities for another Device typically for protocol translations. Strictly speaking a Component of a Device may provide the Energy Object capabilities for that Device (and vice versa) this relationship is intended to model relationships between Devices.

- A Proxy relationship SHOULD be limited when possible to Energy Objects of different Devices.

6.5. Energy Monitoring

For the purposes of this framework energy will be limited to electrical energy in watt hours. Other forms of Energy Objects that use or produce non-electrical energy may be part of an Energy Management Domain (See Section 4.5.) but MUST provide information converted to and expressed in watt hours.

An analogy for understanding power versus energy measurements can be made to speed and distance in automobiles. Just as a speedometer indicates the rate of change of distance, a power meter indicates the rate of transfer of energy. The odometer in an automobile measures the cumulative distance traveled and an energy meter indicates the accumulate energy transferred. So a less formal statement of the analogy is that power meters measures "speed" while energy meters measure "distance".

Each Energy Object will have information that describes power information, along with how that measurement was obtained or derived (actual measurement, estimated, or presumed). For Energy Objects that can report actual power readings, an optional energy measurement can be provided.

Optionally, an Energy Object can further describe the Power information with Power Quality information reflecting the electrical characteristics of the measurement.

Optionally, an Energy Object that can report actual power readings can have energy meters that provide the energy used, produced, and net energy in kWh. These values are energy meters that accumulate the power readings. If energy values are returned then the three energy meters must be provided along with a description of accuracy.

Optionally, an Energy Object can provide demand information over time.

6.5.1 Power Measurement

A power measurement MUST be qualified with the units, magnitude, direction of power flow, and SHOULD be qualified by what means the measurement was made (ex: Root Mean Square versus Nameplate).

In addition, the Energy Object should describe how it intends to measure power as one of consumer, producer or meter of usage. Given the intent, readings can be summarized or analyzed by an EnMS. For example metered usage reported by a meter and consumption usage reported by a device connected to that meter may naturally measure the same usage. With the two measurements identified by intent a proper summarization can be made by an EnMS.

Power measurement magnitude should conform to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure. Measured values are represented in SI units obtained by $\text{BaseValue} * (10^{\text{Scale}})$. For example, if current power usage of an Energy Object is 3, it could be 3 W, 3 mW, 3 KW, or 3 MW, depending on the value of the scaling factor. 3W implies that the BaseValue is 3 and Scale = 0, whereas 3mW implies BaseValue = 3 and ScaleFactor = -3.

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

In addition to knowing the usage and magnitude, it is useful to know how an Energy Object usage measurement was obtained:

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

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

An EnMS can use this information to account for the accuracy and nature of the reading between different implementations.

The EnMS can use the Nameplate Power for provisioning, capacity planning and potentially billing.

6.5.2 Optional Power Quality

Given a power measurement, it may in certain circumstances be desirable to know the Power Quality associated with that measurement. The information model must adhere to the IEC 61850 7-2 standard for describing AC measurements. Note that the Power Quality includes two sets of characteristics: characteristics as received from the utility, and characteristics depending on how the power is used.

In some Energy Management Domains, the power quality may not be needed, available, or relevant to the EnMS.

Optional Demand

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

Optional Battery

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

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

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

When an individual Power State is configured from a specific Power State Set, an Energy Object may be busy at the request time. The Energy Object will set the desired state and then update the actual Power State when the priority task is finished. This mechanism implies two different Power State variables: actual versus desired

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

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

IEEE1621 - [IEEE1621]

DMTF - [DMTF]

EMAN - Specified here

6.5.1 IEEE1621 Power State Series

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

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

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

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

6.5.2 DMTF Power State Series

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

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

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

Figure 7: DMTF / ACPI Power State Mapping

6.5.3 EMAN Power State Set

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

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

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

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

softoff(2) : Similar to mechoff(1), but some components remain powered or receive trace power so that the Energy Object can be awakened from its off state. In softoff(2), no context is saved and the device typically requires a complete boot when awakened. This corresponds to ACPI state G2. hibernate(3): No Energy Object features are available. The Energy Object may be awakened without requiring a complete boot, but the time for availability is longer than sleep(4). An example for state hibernate(3) is a save to-disk state where DRAM context is not maintained. Typically, energy consumption is zero or close to zero. This corresponds to state G1, S4 in ACPI.

sleep(4) : No Energy Object features are available, except for out-of-band management, such as wake-up mechanisms. The time for availability is longer than standby(5). An example for state sleep(4) is a save-to-RAM

state, where DRAM context is maintained. Typically, energy consumption is close to zero. This corresponds to state G1, S3 in ACPI.

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

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

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

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

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

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

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

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

The Figure 8 displays the mappings from the IEEE1621 Power State Series to the EMAN Power State Series, showing that the EMAN twelve Power States expand on [IEEE1621] on, sleep and off.

Non-operational states:

Power(off)	MechOff(1)
Power(off)	SoftOff(2)
Power(sleep)	Hibernate(3)
Power(sleep)	Sleep(4)
Power(sleep)	Standby(5)
Power(sleep)	Ready(6)

Operational states:

Power(on)	LowMinus(7)
Power(on)	Low(8)
Power(on)	MediumMinus(9)
Power(on)	Medium(10)
Power(on)	HighMinus(10)
Power(on)	High(11)

Figure 8: DMTF / ACPI Power State Mapping

6.7. Energy Objects Relationship Extensions

This framework for Energy Management, is based on four Energy Objects Relationships: Aggregation Relationship, Metering Relationship, Power Source Relationship, and Proxy Relationship.

This framework is defined with possible extension of new Energy Objects Relationships in mind. For example, a Power Distribution Unit (PDU) that allows physical entities like outlets to be "ganged" together as a logical entity for simplified management purposes, could be modeled with a future extension based on "gang relationship", whose semantic would specify the Energy Objects grouping.

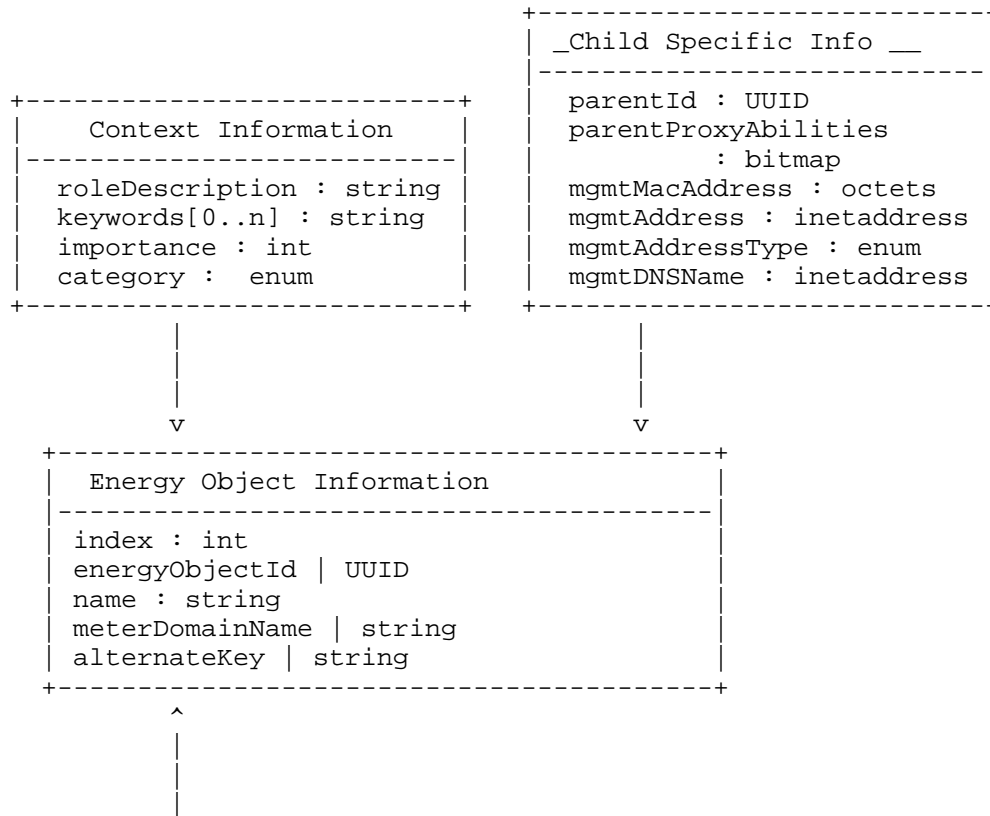
7. Structure of the Information Model: UML Representation

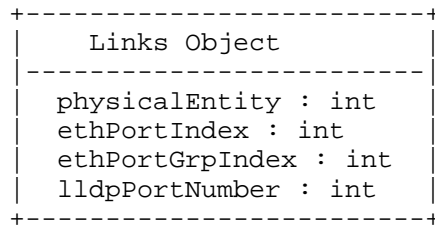
The following basic UML represents an information model expression of the concepts in this framework. This information model, provided as a reference for implementers, is represented as a MIB in the different related IETF Energy Monitoring documents. However, other programming structure with different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

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

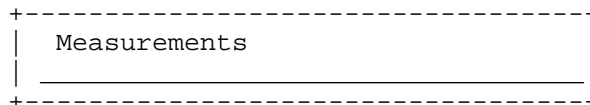
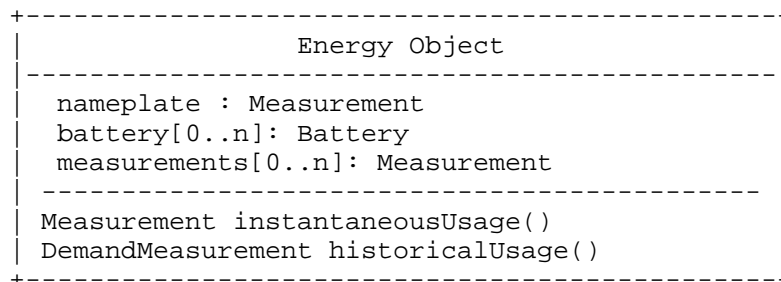
EDITOR'S NOTE: the first part of the UML must be aligned with the latest [EMAN-AWARE-MIB] document version. Also, received the following comment referring to the arrows in the following figure: "It is not clear to me what UML relationships are being specified here in the ASCIIified UML relationships. Please provide a legend to make your conventions for mapping to UML clear."

EO RELATIONSHIPS AND CONTEXT

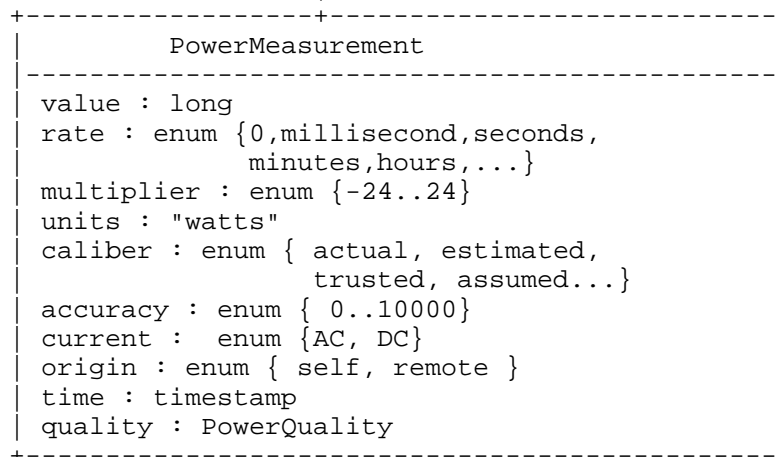


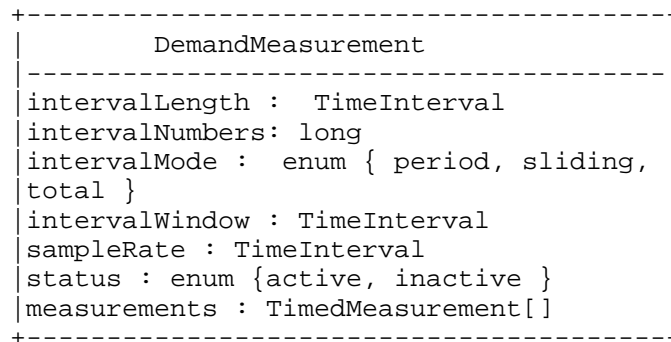
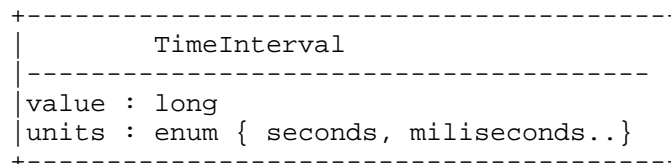
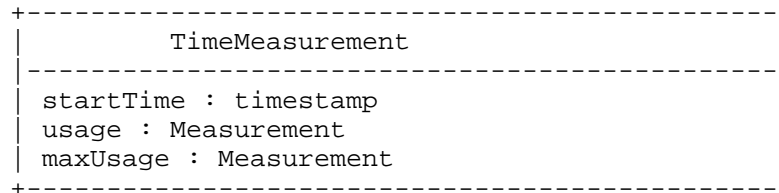
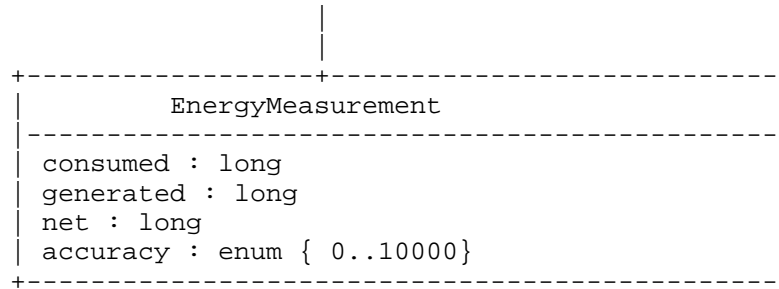


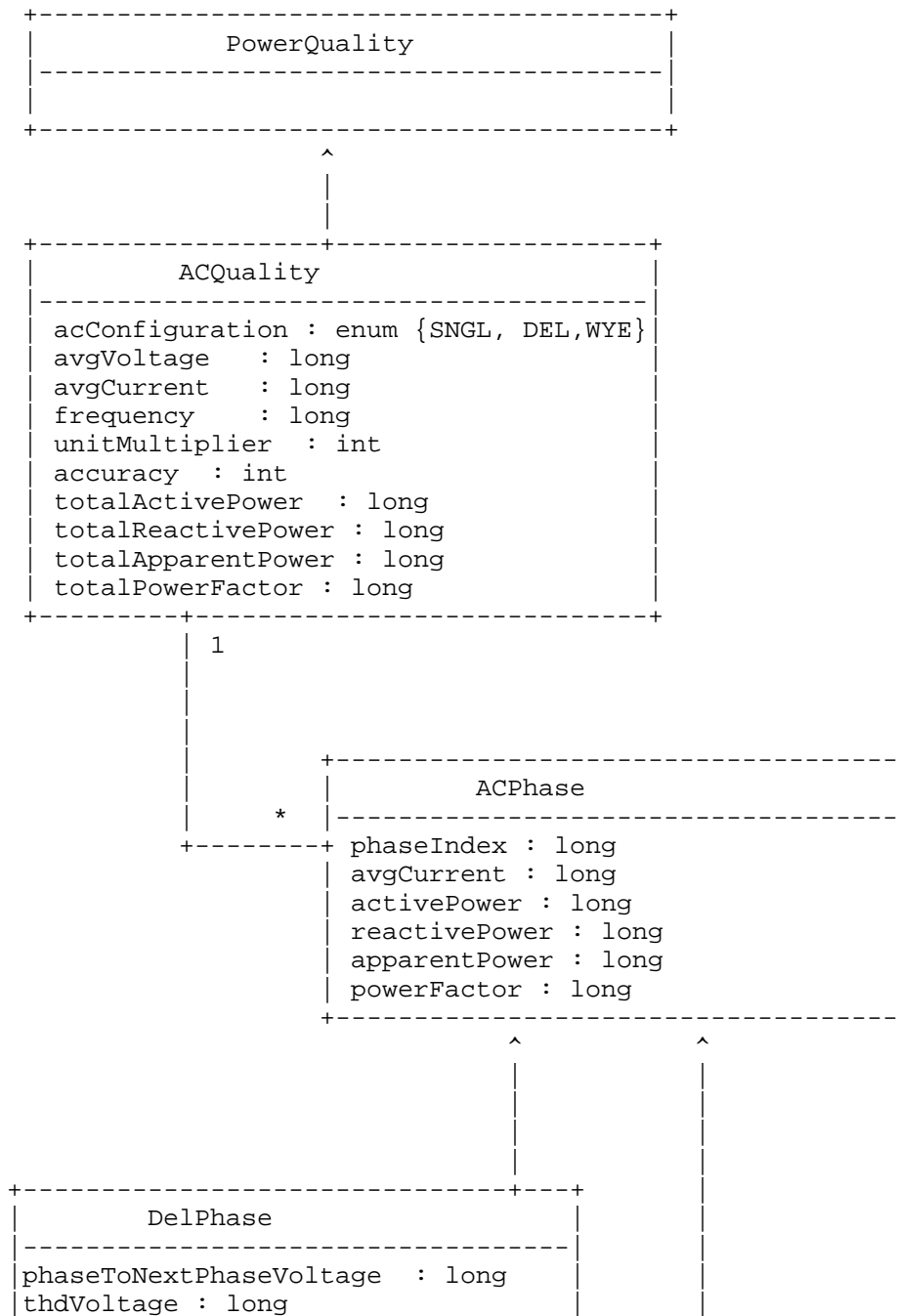
EO AND MEASUREMENTS

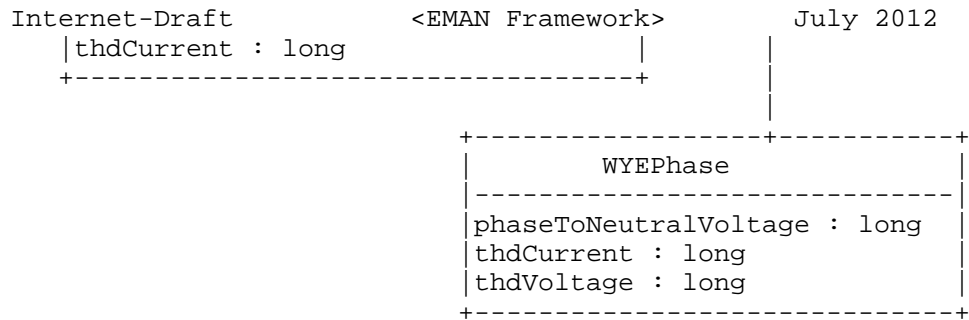


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EO & STATES

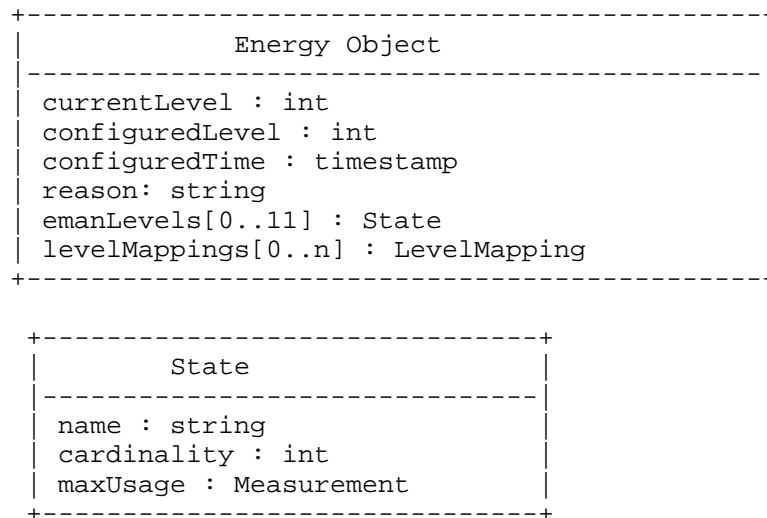


Figure 16: Information Model UML Representation

8. Configuration

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

- . Energy Object name: A unique printable name for the Energy Object.
- . Energy Object role: An administratively assigned name to indicate the purpose an Energy Object serves in the network.
- . Energy Object importance: A ranking of how important the Energy Object is, on a scale of 1 to 100, compared with other Energy Objects in the same Energy Management Domain.
- . Energy Object keywords: A list of keywords that can be used to group Energy Objects for reporting or searching.
- . Energy Management Domain: Specifies the name of an Energy Management Domain for the Energy Object.
- . Energy Object Power State: Specifies the current Power State for the Energy Object.
- . Demand parameters: For example, which interval length to report the Demand over, the number of intervals to keep, etc.
- . Assigning an Energy Object Parent to an Energy Object Child
- . Assigning an Energy Object Child to an Energy Object Parent.

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

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

9. Fault Management

[EMAN-REQ] specifies some requirements about Power States such as "the current state - the time of the last change", "the

total time spent in each state", "the number of transitions to each state", etc. Such requirements are fulfilled via the pmPowerStateChange NOTIFICATION-TYPE [EMAN-MON-MIB]. This SNMP notification is generated when the value(s) of Power State has changed for the Energy Object.

Regarding high and low thresholding mechanism, the RMON alarm and event [RFC2819] allows to periodically takes statistical samples from Energy Object variables, compares them to previously configured thresholds, and to generate an event (i.e. an SNMP notification) if the monitored variable crosses a threshold. The RMON alarm can monitor variables that resolve to an ASN.1 primitive type of INTEGER (INTEGER, Integer32, Counter32, Counter64, Gauge32, or TimeTicks), so basically most the variables in [EMAN-MON-MIB].

10. Examples

In this section we will give examples of how to use the Energy Management framework. In each example we will show how it can be applied when Devices have the capability to model Power Interfaces. We will also show in each example how the framework can be applied when devices cannot support Power Interfaces but only monitor information or control the Device as a whole. For instance a PDU may only be able to measure power and energy for the entire unit without the ability to distinguish among the inlets or outlet.

Together these examples show how the framework can be adapted for Devices with different capabilities (typically hardware) for Energy Management.

Given for all Examples:

Device W: A computer with one power supply. Power interface 1 is an inlets for Device W.

Device X: A computer with two power supplies. Power interface 1 and power interface 2 are both inlets for Device X.

Device Y: A PDU with multiple Power Interfaces numbered 0..10, Power interface 0 is an inlet and power interface 1..10 are outlets.

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Device Z: A PDU with multiple Power Interfaces numbered 0..10,
Power interface 0 is an inlet and power interface 1..10 are
outlets.

Example I: Simple Device with one Source

Topology:

Device W inlet 1 is plugged into Device Y outlet 8.

With Power Interfaces:

Device W has an Energy Object representing the computer
itself as well as one Power Interface defined as an inlet.

Device Y would have an Energy Object representing the PDU
itself (the Device) with a Power Interface 0 defined as an
inlet and Power Interfaces 1..10 defined as outlets.

The interfaces of the devices would have a Power Source
Relationship such that:

Device W inlet 1 is powered by Device Y outlet 8

Without Power Interfaces:

In this case Device W has an Energy Object representing the
computer. Device Y would have an Energy Object representing
the PDU.

The devices would have a Power Source Relationship such
that:

Device W is powered by Device Y.

Example II: Multiple Inlets

Topology:

Device X inlet 1 is plugged into Device Y outlet 8.

Device X inlet 2 is plugged into Device Y outlet 9.

With Power Interfaces:

Device X has an Energy Object representing the computer
itself. It contains two Power Interface defined as inlets.

Device Y would have an Energy Object representing the PDU
itself (the Device) with a Power Interface 0 defined as an
inlet and Power Interface 1..10 defined as outlets.

The interfaces of the devices would have a Power Source Relationship such that:

Device X inlet 1 is powered by Device Y outlet 8

Device X inlet 2 is powered by Device Y outlet 9

Without Power Interfaces:

In this case Device X has an Energy Object representing the computer. Device Y would have an Energy Object representing the PDU.

The devices would have a Power Source Relationship such that:

Device X is powered by Device Y.

Example III: Multiple Sources

Topology:

Device X inlet 1 is plugged into Device Y outlet 8.

Device X inlet 2 is plugged into Device Z outlet 9

With Power Interfaces:

Device X has an Energy Object representing the computer itself. It contains two Power Interface defined as inlets.

Device Y would have an Energy Object representing the PDU itself (the Device) with a Power Interface 0 defined as an inlet and Power Interface 1..10 defined as outlets.

Device Z would have an Energy Object representing the PDU itself (the Device) with a Power Interface 0 defined as an inlet and Power Interface 1..10 defined as outlets.

The interfaces of the devices would have a Power Source Relationship such that:

Device X inlet 1 is powered by Device Y outlet 8

Device X inlet 2 is powered by Device Z outlet 9

Without Power Interfaces:

In this case Device X has an Energy Object representing the computer. Device Y and Z would both have respective Energy Objects representing each entire PDU.

The devices would have a Power Source Relationship such that:

Device X is powered by Device Y and powered by Device Z.

11. Relationship with Other Standards Development Organizations

11.1. Information Modeling

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

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

Specific examples include:

- . The scaling factor, which represents Energy Object usage magnitude, conforms to the IEC 61850 definition of unit multiplier for the SI (System International) units of measure.
- . The electrical characteristic is based on the ANSI and IEC Standards, which require that we use an accuracy class for power measurement. ANSI and IEC define the following accuracy classes for power measurement:
 - . IEC 62053-22 60044-1 class 0.1, 0.2, 0.5, 1 3.
 - . ANSI C12.20 class 0.2, 0.5
- . The electrical characteristics and quality adheres closely to the IEC 61850 7-2 standard for describing AC measurements.
- . The power state definitions are based on the DMTF Power State Profile and ACPI models, with operational state extensions.

12. Security Considerations

Regarding the data attributes specified here, some or all may be considered sensitive or vulnerable in some network environments. Reading or writing these attributes without

proper protection such as encryption or access authorization may have negative effects on the network capabilities.

12.1. Security Considerations for SNMP

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

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

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

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

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

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

13. IANA Considerations

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

14. Acknowledgments

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Requirements for Energy Management
draft-ietf-eman-requirements-08

Abstract

This document defines requirements for standards specifications for energy management. The requirements defined in this document concern monitoring functions as well as control functions. In detail, the focus of the requirements is on the following features: identification of energy-managed devices and their components, monitoring of their Power State, power inlets, power outlets, actual power, power properties, received energy, provided energy, and contained batteries. Further requirements are included to enable control of their power supply and Power State. This document does not specify the features that must be implemented by compliant implementations but rather features that must be supported by standards for energy management.

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1. Introduction

With rising energy cost and with an increasing awareness of the ecological impact of running IT equipment, energy management functions and interfaces are becoming an additional basic requirement for network management systems and devices connected to a network.

This document defines requirements for standards specifications for energy management, both monitoring functions and control functions. Subject of energy management are entities in the network. An entity is either a device or one of a device's components that is subject to individual energy monitoring or control or both.

In detail, the requirements listed are focused on the following features: identification of entities, monitoring of their Power State, power inlets, power outlets, actual power, power properties, received energy, provided energy, and contained batteries. Further included is control of entities' power supply and Power State.

The main subject of energy management are devices and their components that receive and provide electric energy. Devices may have an IP address, such as hosts, routers, and middleboxes, or they are connected indirectly to the Internet via a proxy with an IP address providing a management interface for the device. An example are devices in a building infrastructure using non-IP protocols and a gateway to the Internet.

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

Section 3 elaborates a set of general needs for energy management. Requirements for an energy management standard are specified in Sections 4 to 8.

Sections 4 to 6 contain conventional requirements specifying information on entities and control functions.

Sections 7 and 8 contain requirements specific to energy management. Due to the nature of power supply, some monitoring and control functions are not conducted by interacting with the entity of interest, but with other entities, for example, entities upstream in a power distribution tree.

1.1. Conventional Requirements For Energy Management

The specification of requirements for an energy management standard starts with Section 4 addressing the identification of entities and the granularity of reporting of energy-related information. A standard must support unique identification of entities, reporting per entire device, and reporting energy-related information on individual components of a device or subtended devices.

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

1.2. Specific Requirements for Energy Management

While the conventional requirements summarized above seem to be all that would be needed for energy management, there are significant differences between energy management and most well known network management functions. The most significant difference is the need for some devices to report on other entities. There are three major reasons for this.

- o For monitoring a particular entity it is not always sufficient to communicate with the entity only. When the entity has no instrumentation for determining power, it might still be possible to obtain power values for the entity by communication with other entities in its power distribution tree.
A simple example is retrieving power values from a power meter at the power line into the entity. Common examples are a Power Distribution Unit (PDU) and a Power over Ethernet (PoE) switch. Both supply power to other entities at sockets or ports, respectively, and are often instrumented to measure power per socket or port.
- o Similar considerations apply to controlling power supply of a entity which often needs direct or indirect communications with another entity upstream in the power distribution tree. Again, a PDU and a PoE switch are common examples, if they have the capability to switch on or off power at their sockets or ports, respectively.
- o Energy management often extends beyond entities with IP network interfaces, to non-IP building systems accessed via a gateway. Requirements in this document do not cover details of these networks, but specify means for opening IP network management towards them.

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

The requirements in these sections need a new energy management framework that deals with the specific nature of energy management. The actual standards documents, such as MIB module specifications, address conformance by specifying which feature must, should, or may be implemented by compliant implementations.

2. Terminology

Energy

That which does work or is capable of doing work. As used by electric utilities, it is generally a reference to electrical energy and is measured in kilo-watt hours (kWh) [IEEE-100].

Power

The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or in joules per second) [IEEE-100].

Energy management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization [ITU-M.3400].

Energy management system

An Energy Management System is a combination of hardware and software used to administer a network with the primary purpose being energy management [Fed-Std-1037C].

Energy monitoring

Energy monitoring is a part of energy management that deals with collecting or reading information from network elements and attached devices and their components to aid in energy management.

Energy control

Energy control is a part of energy management that deals with directing influence over network elements and attached devices and their components.

Power Interface

A Power Interface is an interface at which a device is connected to a power transmission medium at which it can receive power, provide power, or both.

Power inlet

A power inlet is a Power Interface at which a device can receive power from other devices.

Power outlet

A power outlet is a Power Interface at which a device can provide power to other devices.

Power State

A Power State is a condition or mode of a device that broadly characterizes its capabilities, power consumption, and responsiveness to input [IEEE-1621].

3. General Considerations Related to Energy Management

The basic objective of energy management is operating sets of devices with minimal energy, while maintaining a certain level of service. Use cases for energy management can be found in [I-D.ietf-eman-applicability-statement].

3.1. Power States

entities can be set to an operational state that results in the lowest power level that still meets the service level performance objectives. In principle, there are four basic types of Power States for an entity or for a whole system:

- o full Power State
- o reduced Power States (e.g. lower clock rate for processor, lower data rate on a link, etc.)
- o sleep state (not functional, but immediately available)
- o off state (may require significant time to become operational)

In specific devices, the number of Power States and their properties varies considerably. Simple entities may just have only the extreme states, full power and off state. Many devices have three basic Power States: on, off, and sleep. However, more finely grained Power States can be implemented.

3.2. Saving Energy versus Maintaining Service Level Agreements

While the general objective of energy management is quite clear, the way to attain that goal is often difficult. In many cases there is no way of reducing power without the consequence of a potential performance, service, or capacity degradation. Then a trade-off needs to be dealt with between service level objectives and energy minimization. In other cases a reduction of power can easily be achieved while still maintaining sufficient service level performance, for example, by switching entities to lower Power States when higher performance is not needed.

3.3. Local Versus network-Wide energy Management

Many energy saving functions are executed locally by an entity; it monitors its usage and dynamically adapts its power according to the required performance. It may, for example, switch to a sleep state when it is not in use or out of scheduled business hours. An energy management system may observe an entity's power state and configure its power saving policies.

Energy savings can also be achieved with policies implemented by a network management system that controls Power States of managed entities. Information about the power received and provided by entities in different Power States may be required to set policies. Often this information is acquired best through monitoring.

Both methods, network-wide and local energy management, have advantages and disadvantages and often it is desirable to combine them. Central management is often favorable for setting Power States of a large number of entities at the same time, for example, at the beginning and end of business hours in a building. Local management is often preferable for power saving measures based on local observations, such as high or low load of an entity.

3.4. Energy Monitoring Versus Energy Saving

Monitoring energy, power, and Power States alone does not reduce the energy needed to run an entity. In fact, it may even increase it slightly due to monitoring instrumentation that needs energy. Reporting measured quantities over the network may also increase energy use, though the acquired information may be an essential input to control loops that save energy.

Monitoring energy and Power States can also be required for other purposes including:

- o investigating energy saving potential
- o evaluating the effectiveness of energy saving policies and measures
- o deriving, implementing, and testing power management strategies
- o accounting for the total power received and provided by an entity, a network, or a service
- o predicting an entity's reliability based on power usage
- o choosing time of next maintenance cycle for an entity

3.5. Overview Of Energy Management Requirements

The following basic management functions are required:

- o monitoring Power States
- o monitoring power (energy conversion rate)
- o monitoring (accumulated) received and provided energy
- o monitoring power properties
- o setting Power States

Power control is complementary to other energy savings measures such as low power electronics, energy saving protocols, energy-efficient device design (for example, low-power modes for components), and energy-efficient network architectures. Measurement of received and provided energy can provide useful data for developing these technologies.

4. Identification Of Entities

Entities must be uniquely identified. This includes entities that are components of managed devices as well as entire devices.

For entities that report on or control other entities it is important to identify the entities they report on or control, see Section 7 or Section 8, respectively.

An entity may be an entire device or a component of it. Examples of components of interest are a hard drive, a battery, or a line card. It may be required to be able to control individual components to save energy. For example, server blades can be switched off when the overall load is low or line cards at switches may be powered down at night.

Identifiers for devices and components are already defined in standard MIB modules, such as the LLDP MIB module [IEEE-802.1AB] and the LLDP-MED MIB module [ANSI-TIA-1057] for devices and the Entity MIB module [RFC4133] and the Power Ethernet MIB [RFC3621] for components of devices. Energy management needs means to link energy-related information to such identifiers.

Instrumentation for measuring received and provided energy of a device is typically more expensive than instrumentation for retrieving its Power State. Many devices may provide Power State information for all individual components separately, while reporting the received and provided energy only for the entire device.

4.1. Identifying entities

The standard must provide means for uniquely identifying entities. Uniqueness must be preserved such that collisions of identities are avoided at potential receivers of monitored information.

4.2. Persistence of identifiers

The standard must provide means for indicating whether identifiers of entities are persistent across a re-start of the entity.

4.3. Using entity identifiers of other MIB modules

The standard must provide means for re-using entity identifiers from other standards including at least the following:

- o the entPhysicalIndex in the Entity MIB module [RFC4133]
- o the LldpPortNumber in the LLDP MIB module [IEEE-802.1AB] and in the LLDP-MED MIB module [ANSI-TIA-1057]
- o the pethPsePortIndex and the pethPsePortGroupIndex in the Power Ethernet MIB [RFC3621]

Generic means for re-using other entity identifiers must be provided.

5. Information On Entities

This section describes information on entities for which the standard must provide means for retrieving and reporting.

Required information can be structured into seven groups.

Section 5.1 specifies requirements for general information on entities, such as type of entity or context information.

Requirements for information on power inlets and power outlets of entities are specified in Section 5.2. Monitoring of power and energy is covered by Sections 5.3 and 5.5, respectively. Section 5.4 covers requirements related to entities' Power States. Section 5.6 specifies requirements for monitoring batteries. Finally, the reporting of time series of values is covered by Section 5.7.

5.1. General Information On Entities

For energy management it may be required to understand the role and context of an entity. An energy management system may aggregate

values of received and provided energy according to a defined grouping of entities. When controlling and setting Power States it may be helpful to understand the grouping of the entity and role of an entity in a network, for example, it may be important to exclude some vital network devices from being switched to lower power or even from being switched off.

5.1.1. Type of entity

The standard must provide means to configure, retrieve and report a textual name or a description of an entity.

5.1.2. Context of an entity

The standard must provide means for retrieving and reporting context information on entities, for example, tags associated with an entity that indicate the entity's role.

5.1.3. Significance of entities

The standard must provide means for retrieving and reporting the significance of entities within its context, for example, how important the entity is.

5.1.4. Power priority

The standard must provide means for retrieving and reporting power priorities of entities. Power priorities indicate an order in which Power States of entities are changed, for example, to lower Power States for saving power.

5.1.5. Grouping of entities

The standard must provide means for grouping entities. This can be achieved in multiple ways, for example, by providing means to tag entities, to assign them to domains, or to assign device types to them.

5.2. Power Interfaces

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

entities have power inlets at which they are supplied with electric power. Most entities have a single power inlet, while some have multiple inlets. Different power inlets on a device are often connected to separate power distribution trees. For energy

monitoring, it is useful to retrieve information on the number of inlets of an entity, the availability of power at inlets and which of them are actually in use.

Entities can have one or more power outlets for supplying other entities with electric power.

For identifying and potentially controlling the source of power received at an inlet, it may be required to identify the power outlet of another entity at which the received power is provided. Analogously, for each outlet it is of interest to identify the power inlets that receive the power provided at a certain outlet. Such information is also required for constructing the wiring topology of electrical power distribution to entities.

Static properties of each Power Interface are required information for energy management. Static properties include the kind of electric current (AC or DC), the nominal voltage, the nominal AC frequency, and the number of AC phases.

5.2.1. Lists of Power Interfaces

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

5.2.2. Corresponding power outlet

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

5.2.3. Corresponding power inlets

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

5.2.4. Availability of power

The standard must provide means for monitoring the availability of power at each Power Interface. This indicates whether at a Power Interfaces power supply is switched on or off.

5.2.5. Use of power

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

5.2.6. Type of current

The standard must provide means for reporting the type of current (AC or DC) for each Power Interface as well as for an entire entity.

5.2.7. Nominal voltage

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

5.2.8. Nominal AC frequency

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

5.2.9. Number of AC phases

The standard must provide means for reporting the number of AC phases for each Power Interface.

5.3. Power

Power is measured as an instantaneous value or as the average over a time interval.

Obtaining highly accurate values for power and energy may be costly if it requires dedicated metering hardware. Entities without the ability to measure their power and received and provided energy with high accuracy may just report estimated values, for example based on load monitoring, Power State, or even just the entity type.

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

Further properties of the supplied power are also of interest. For AC power supply, power attributes beyond the real power to be reported include the apparent power, the reactive power, and the phase angle of the current or the power factor. For both AC and DC power the power characteristics are also subject of monitoring. Power parameters include the actual voltage, the actual frequency, the Total Harmonic Distortion (THD) of voltage and current, the impedance of an AC phase or of the DC supply. Power monitoring should be in line with existing standards, such as [IEC.61850-7-4].

For some network management tasks it is desirable to receive notifications from entities when their power value exceeds or falls below given thresholds.

5.3.1. Real power

The standard must provide means for reporting the real power for each Power Interface as well as for an entire entity. Reporting power includes reporting the direction of power flow.

5.3.2. Power measurement interval

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

5.3.3. Power measurement method

The standard must provide means to indicate the method how these values have been obtained. Based on how the measurement was conducted, it is possible to associate a certain degree of confidence with the reported power value. For example, there are methods of measurement such as direct power measurement, or by estimation based on performance values, or hard coding average power values for an entity.

5.3.4. Accuracy of power and energy values

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

5.3.5. Actual voltage and current

The standard must provide means for reporting the actual voltage and actual current for each power interface as well as for an entire entity. In case of AC power supply, means must be provided for reporting the actual voltage and actual current per phase.

5.3.6. High/low power notifications

The standard must provide means for creating notifications if power values of an entity rise above or fall below given thresholds.

5.3.7. Complex power

The standard must provide means for reporting the complex power for each Power Interface and for each phase at a Power Interface.

Besides the real power, at least two out of the following three quantities need to be reported: apparent power, reactive power, phase angle. The phase angle can be substituted by the power factor.

5.3.8. Actual AC frequency

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

5.3.9. Total harmonic distortion

The standard must provide means for reporting the Total Harmonic Distortion (THD) of voltage and current for each Power Interface. In case of AC power supply, means must be provided for reporting the THD per phase.

5.3.10. Power supply impedance

The standard must provide means for reporting the impedance of power supply for each Power Interface. In case of AC power supply, means must be provided for reporting the impedance per phase.

5.4. Power State

Many entities have a limited number of discrete Power States.

There is a need to report the actual Power State of an entity, and means for retrieving the list of all supported Power States.

Different standards bodies have already defined sets of Power States for some entities, and others are creating new Power State sets. In this context, it is desirable that the standard support many of these power state standards. In order to support multiple management systems possibly using different Power State sets, while simultaneously interfacing with a particular entity, the energy management standard must provide means for supporting multiple Power State sets used simultaneously at an entity.

Power States have parameters that describe its properties. It is required to have standardized means for reporting some key properties, such as average power and maximum power of an entity in a certain state.

There also is a need to report statistics on Power States including the time spent and the received and provided energy in a Power State.

5.4.1. Actual Power State

The standard must provide means for reporting the actual Power State of an entity.

5.4.2. List of supported Power States

The standard must provide means for retrieving the list of all potential Power States of an entity.

5.4.3. Multiple Power State sets

The standard must provide means for supporting multiple Power State sets simultaneously at an entity.

5.4.4. List of supported Power State sets

The standard must provide means for retrieving the list of all Power State sets supported by an entity.

5.4.5. List of supported Power States within a set

The standard must provide means for retrieving the list of all potential Power States of an entity for each supported Power State set.

5.4.6. Maximum and average power per Power State

The standard must provide means for retrieving the maximum power and the average power for each supported Power State. These values may be static.

5.4.7. Power State statistics

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

5.4.8. Power State changes

The standard must provide means for generating a notification when the actual Power State of an entity changes.

5.5. Energy

Monitoring of electrical energy received or provided by an entity is a core function of energy management. Since energy is an accumulated quantity, it is always reported for a certain interval of time. This can be, for example, the time from the last restart of the entity to the reporting time, the time from another past event to the reporting time, the last given amount of time before the reporting time, or a certain interval specified by two time stamps in the past.

It is useful for entities to record their received and provided energy per Power State and report these quantities.

5.5.1. Energy

The standard must provide means for reporting measured values of energy and the direction of the energy flow received or provided by an entity. The standard must also provide the means to report the energy passing through each Power Interface.

5.5.2. Time intervals

The standard must provide means for reporting the time interval for which an energy value is reported.

5.5.3. Energy per Power State

The standard must provide means for reporting the received and provided energy for each individual power state. This extends the requirement 5.4.7 on Power State statistics.

5.6. Battery State

Many entities contain batteries that supply them with power when disconnected from electrical power distribution grids. The status of these batteries is typically controlled by automatic functions that act locally on the entity and manually by users of the entity. There is a need to monitor the battery status of these entities by network management systems.

Devices containing batteries can be modeled in two ways. The entire device can be modeled as a single entity on which energy-related information is reported or the battery can be modeled as an individual entity for which energy-related information is monitored individually according to requirements in Sections 5.1 to 5.5.

Further information on batteries is of interest for energy management, such as the current charge of the battery, the number of

completed charging cycles, the charging state of the battery, and further static and dynamic battery properties. It is desirable to receive notifications if the charge of a battery becomes very low or if a battery needs to be replaced.

5.6.1. Battery charge

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

5.6.2. Battery charging state

The standard must provide means for reporting the charging state (charging, discharging, etc.) of a battery.

5.6.3. Battery charging cycles

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

5.6.4. Actual battery capacity

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

5.6.5. Static battery properties

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

5.6.6. Low battery charge notification

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

5.6.7. Battery replacement notification

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

5.6.8. Multiple batteries

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

5.7. Time Series Of Measured Values

For some network management tasks, it is required to obtain time series of measured values from entities, such as power, energy, battery charge, etc.

In general time series measurements could be obtained in many different ways. It should be avoided that such time series can only be obtained through regular polling by the energy management system. Means should be provided to either push such values from the location where they are available to the management system or to have them stored locally for a sufficiently long period of time such that a management system can retrieve full time series.

The following issues are to be considered when designing time series measurement and reporting functions:

1. Which quantities should be reported?
2. Which time interval type should be used (total, delta, sliding window)?
3. Which measurement method should be used (sampled, continuous)?
4. Which reporting model should be used (push or pull)?

The most discussed and probably most needed quantity is energy. But a need for others, such as power and battery charge can be identified as well.

There are three time interval types under discussion for accumulated quantities such as energy. They can be reported as total values, accumulated between the last restart of the measurement and a certain timestamp. Alternatively, energy can be reported as delta values between two consecutive timestamps. Another alternative is reporting values for sliding windows as specified in [IEC.61850-7-4].

For non-accumulative quantities, such as power, different measurement methods are considered. Such quantities can be reported using values sampled at certain time stamps or alternatively by mean values for these quantities averaged between two (consecutive) time stamps or over a sliding window.

Finally, time series can be reported using different reporting models, particularly push-based or pull-based. Push-based reporting can, for example, be realized by reporting power or energy values using the IPFIX protocol [RFC5101],[RFC5102]. SNMP [RFC3411] is an example for a protocol that can be used for realizing pull-based reporting of time series.

For reporting time series of measured values the following requirements have been identified. Further decisions concerning

issues discussed above need to be made when developing concrete energy management standards.

5.7.1. Time series of energy values

The standard must provide means for reporting time series of energy values.

5.7.2. Time series storage capacity

The management standard should provide means for reporting the number of values of a time series that can be stored for later reporting.

6. Control Of Entities

Many entities control their Power State locally. Other entities need interfaces for an energy management system to control their Power State.

Power supply is typically not self-managed by entities. And controlling power supply is typically not conducted as interaction between energy management system and the entity itself. It is rather an interaction between the management system and an entity providing power at its power outlets. Similar to Power State control, power supply control may be policy driven. Note that shutting down the power supply abruptly may have severe consequences for the entity.

6.1. Controlling Power States

The standard must provide means for setting Power States of entities.

6.2. Controlling power supply

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

7. Reporting On Other Entities

As discussed in Section 5, not all energy-related information may be available at the concerned entity. Such information may be provided by other entities. This section covers reporting of information only. See Section 8 for requirements on controlling other entities.

There are cases where a power supply unit switches power for several entities by turning power on or off at a single power outlet or where

a power meter measures the accumulated power of several entities at a single power line. Consequently, it should be possible to report that a monitored value does not relate to just a single entity, but is an accumulated value for a set of entities. All of these entities belonging to that set need to be identified.

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

7.1. Reports on other entities

The standard must provide means for an entity to report information on another entity.

7.2. Identity of other entities on which is reported

For entities that report on one or more other entities, the standard must provide means for reporting the identity of other entities on which information is reported.

7.3. Reporting quantities accumulated over multiple entities

The standard must provide means for reporting the list of all entities from which contributions are included in an accumulated value.

7.4. List of all entities on which is reported

For entities that report on one or more other entities, the standard must provide means for reporting the complete list of all those entities on which energy-related information can be reported.

7.5. Content of reports on other entities

For entities that report on one or more other entities, the standard must provide means for indicating which energy-related information can be reported for which of those entities.

7.6. Indicating source of remote information

For an entity that has one or more other entities reporting on its behalf, the standard must provide means for the entity to indicate which information is available at which other entity.

8. Controlling Other Entities

This section specifies requirements for controlling Power States and power supply of entities by communicating with other entities that have means for controlling Power State or power supply of others.

8.1. Controlling Power States Of Other Entities

Some entities have control over Power States of other entities. For example a gateway to a building system may have means to control the Power State of entities in the building that do not have an IP interface. For this scenario and other similar cases means are needed to make this control accessible to the energy management system.

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

8.1.1. Control of Power States of other entities

The standard must provide means for an energy management system to send Power State control commands to an entity that concern the Power States of other entities than the one the command was sent to.

8.1.2. Identity of other Power State controlled entities

The standard must provide means for reporting the identities of the entities for which the reporting entity has means to control their Power States.

8.1.3. List of all Power State controlled entities

The standard must provide means for an entity to report the list of all entities for which it can control the Power State.

8.1.4. List of all Power State controllers

The standard must provide means for an entity that receives commands controlling its Power State from other entities to report the list of all those entities.

8.2. Controlling Power Supply

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

is already addressed by requirement 6.2.

In addition, it is required that an entity that has its supply controlled by other entities has means to report the list of these other entities. This need is already addressed by requirements 5.2.2 and 5.2.3.

9. Security Considerations

Controlling Power State and power supply of entities are highly sensitive actions since they can significantly affect the operation of directly and indirectly affected devices. Therefore all control actions addressed in 6 and 8 must be sufficiently protected through authentication, authorization, and integrity protection mechanisms.

Monitoring energy-related quantities of an entity addressed in Sections 5 - 8 can be used to derive more information than just the received and provided energy, so monitored data requires privacy protection. Monitored data may be used as input to control, accounting, and other actions, so integrity of transmitted information and authentication of the origin may be needed.

9.1. Secure energy management

The standard must provide privacy, integrity, and authentication mechanisms for all actions addressed in Sections 5 - 8. The security mechanisms must address all threats listed in Section 1.4 of [RFC3411].

10. IANA Considerations

This document has no actions for IANA.

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Appendix A. Existing Standards

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

A.1. Existing IETF Standards

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

A.1.1. ENTITY MIB

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

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

Yet another example, is smart-PDUs, which can report the energy provided to the device attached to the power outlet of the PDU. In some cases, the device can be attached to multiple to power outlets. Thus, the energy measured at multiple outlets need to be aggregated to determine the energy provided to a single device. From mapping

perspective, between the PDU outlets and the device this is a many-to-one mapping. It is not clear if such a many-to-one mapping is feasible within the ENTITY-MIB framework.

A.1.2. ENTITY STATE MIB

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

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

A.1.3. ENTITY SENSOR MIB

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

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

However, there is no unit available for reporting energy quantities, such as, for example, watt seconds or kilowatt hours, and the ENTITY SENSOR MIB module does not support reporting accuracy of measurements according to the IEC / ANSI accuracy classes, which are commonly in use for electric power and energy measurements. The ENTITY SENSOR

MIB modules only provides a coarse-grained method for indicating accuracy by stating the number of correct digits of fixed point values.

A.1.4. UPS MIB

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

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

A.1.5. POWER ETHERNET MIB

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

The POWER ETHERNET MIB does not report power and energy on a per port basis, but can report aggregated values for groups of ports. It does not use objects of the ENTITY MIB module for identifying entities, although this module existed already when the POWER ETHERNET MIB modules was standardized.

A.1.6. LLDP MED MIB

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

A.2. Existing standards of other bodies

A.2.1. DMTF

The DMTF has defined a Power State management profile [DMTF.DSP1027] that is targeted at computer systems. It is based on the DMTF's Common Information Model (CIM) and it is rather an entity profile than an actual energy monitoring standard.

The Power State management profile is used to describe and to manage the Power State of computer systems. This includes e.g. means to change the Power State of an entity (e.g. to shutdown the entity) which is an aspect of but not sufficient for active energy management.

A.2.2. ODVA

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

A.2.3. IEEE-ISTO Printer WG

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

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Nanogrids
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Abstract

A nanogrid is a very small electricity domain that is distinct from any other grid it is connected to in voltage, reliability, quality, or price. Nanogrids could form the basis of a future electricity system built on a bottom-up, decentralized, and distributed network model rather than the top-down centralized grid we have today in most parts of the world. This document introduces the idea of a nanogrid to the IETF community for two purposes -- to inform the work on energy management presently underway in the EMAN working group, and to describe how future communications within and between grids could be accomplished with protocols that are the product of the IETF. There appears to be no fundamental conflict between the nanogrid concept and the current drafts in the EMAN working group.

Status of this Memo

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1. Overview

A nanogrid is a very small electricity domain that is distinct from any other grid it is connected to in voltage, reliability, quality, or price [CIGRE] (also [NG-2009]). Nanogrids could form the basis of a future electricity system built on a bottom-up, decentralized, and distributed network model rather than the top-down centralized grid we have today in most parts of the world. Central to nanogrids is the ability to communicate electricity price and availability to enable matching demand with varying supply of electricity. For the remainder of this document, we use "nanogrid" to refer to those which use price to manage supply and demand. Nanogrids bring an Internet approach and architecture to our electricity system.

2. How Nanogrids Work

A nanogrid must have at least one load or sink of power (which could be electricity storage) and at least one gateway to the outside. Electricity storage may or may not be present. Electricity sources are not part of the nanogrid, but often a source will be connected only to a single nanogrid. Interfaces to other power entities are through gateways within the nanogrid controller. Nanogrids implement power distribution only and not any functional aspects of the devices (or loads) that connect to the nanogrid. Thus, the components of a nanogrid are a controller, loads, storage (optional), and gateways. Figure 1 is a schematic of a nanogrid. A nanogrid manages the power distributed to its loads. All power flows are accompanied by communications and all communications are bi-directional. Communication - either wired or wireless - is used to mediate local electricity supply and demand using price, both within the nanogrid and in exchanges across the gateways. The nanogrid controller receives requests for power, grants or revokes them, measures or estimates power, and sets the local price. Loads take the price into account in deciding how to operate. Controllers negotiate with each other across gateways to buy or sell power. Battery storage is optional - batteries can increase the reliability and stability of a

nanogrid.

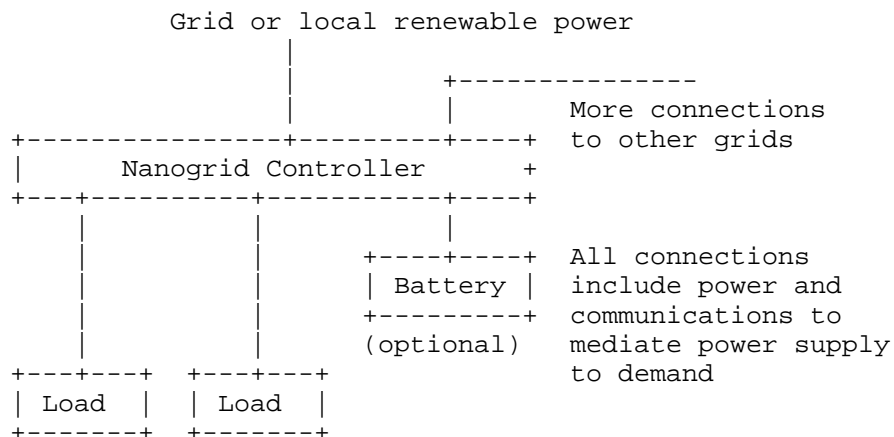


Figure 1: Conceptual diagram of a nanogrid

Controllers may resemble existing Power over Ethernet (PoE) switches, however unlike PoE they need not be limited to one device per port. To set the local price, the controller takes into account the price of any utility grid electricity it has access to, as well as the quantity and price of any local power sources. A nanogrid can exchange power with other nanogrids or with microgrids whenever mutually beneficial (as indicated by relative price). This enables optimal allocation of scarce and/or expensive power among loads and among local grids. A price will typically be a current price and non-binding forecast of future prices, up to one day in advance.

Devices that connect to a nanogrid will ship with default price preference functions that make sense given typical grid prices. When a nanogrid is connected to the grid, the grid price will be a strong influence on the local price, though local generation and storage can dramatically change that dependency. When not grid-connected, the local price will reflect the local supply/demand condition, the estimated replacement cost for battery power (which may be future grid power), and an assessment of battery capacity. Nanogrid policies establish the local price and load policies establish the price a given load is willing to pay.

A core principle is to separate power distribution technologies from functional control technology. Power distribution is envisioned to have three layers: layer 1 is power; layer 2 is power coordination; and layer 3 is device functionality. Nanogrids implement layer 2 to improve the efficiency and flexibility of power distribution and use (layer 1), and isolate power distribution from device functionality

(layer 3). Separating power coordination from functionality has several purposes. In future usage, devices that are in the same room or otherwise need to coordinate functionally will often be powered differently, and devices that share a power infrastructure may not have functional relationships. Separating power distribution into different functional layers allows each function to evolve separately, greatly easing and simplifying the development of new technologies and deploying them alongside existing products.

To develop useful nanogrid technology we need standards for communication internal to nanogrids, and for communication between them via gateways.

Nanogrids use price to mediate their internal supply and demand with attached loads, and to determine how power is acquired from external grids and exchanged between nanogrids. They require energy price information, common communications protocols and interfaces, and standardized semantics.

3. Benefits

Nanogrids could offer many benefits, broadly including:

- o Local Renewables
- o Storage and Reliability
- o Security, Privacy, and Reliability
- o System Reliability
- o Demand Response
- o Smart Grid
- o New Electricity Users
- o Disaster Relief
- o Military Applications
- o Reduced Capital Costs
- o Reduced Energy Use
- o Mobile and Off-Grid

Nanogrids could provide smart grid benefits at the small (local) scale, a capability we lack today; smart grid efforts only address grid connected and large scale contexts. Nascent nanogrids are common today in digitally managed forms (technologies including USB and Power over Ethernet (PoE)), and unmanaged ones (vehicles, emergency circuits, etc.). However, they all lack the ability to use price as the core prioritization mechanism and lack the ability to exchange power with each other; a fully functioning "managed" nanogrid can do both. Such future nanogrids could be connected in arbitrary and dynamic networks to each other, to microgrids, and to the utility grid.

Nanogrids are a new mechanism for managing power at the local level, useful in a wide variety of applications. They particularly enable more and better use of local generation (including intermittent renewables) and local storage, as well as facilitate "Direct DC" - powering loads with local renewable power without converting to and from AC. Recent studies have estimated 5-13% electricity savings from Direct DC in residences [DIRECTDC], and local renewables also avoid transmission system losses. Many people value local renewable energy more than grid power and value the reliability and certainty of local storage and off-grid capability.

Nanogrids offer the possibility of moving to a less reliable large-scale grid, providing increased quality and reliability locally, and saving capital and energy in a distributed, bottom-up manner. While the smart grid will better match supply and demand at the large scale, we lack mechanisms to do this at small scales. Nanogrids fill this gap. Microgrids are important and necessary, but lack near-term potential for dramatic scale-up of deployment, lack standards-based plug-and-play technologies, lack comprehensive visibility into individual loads, and lack pervasive use of price. Nanogrids build on standard semiconductor and communications technologies already produced at mass-scale, and can be deployed incrementally and at low capital and installation cost. This will enable them to spread rapidly and quickly become a standard fixture in buildings.

While existing nanogrid technologies enable only relatively small loads, there is no power limit to nanogrid loads or controllers. While nanogrids work best with communicating loads, for legacy devices, with one device per port, the controller can implement the load control function itself for on/off loads, as well as variable loads like lights and motors.

By being directly and correctly responsive to the most local conditions of energy supply, storage, and demand, nanogrids can provide price and other control abilities not possible with other technologies which treat electricity distribution at a more aggregated and abstracted level. Nanogrids are also inherently more flexible and should be less capital-intensive than alternatives, and provide a more nimble infrastructure for local generation and storage.

4. Implications for EMAN

The concept of power interface in the current EMAN drafts is consistent with the interfaces that nanogrids have, both those from controllers to loads, and those at gateways between nanogrids. A load could report via EMAN protocols directly, or a controller could

report information about loads on their behalf; these are both basic EMAN functions. The role that batteries play in nanogrids is consistent with EMAN's treatment of them.

Nanogrids enable bi-directional exchange of power between grids; recent versions of EMAN documents acknowledge this as a possibility and support it (of course, the power flows in only one direction at any given time). Two existing power distribution technologies, UPAMD and HDBaseT, support bi-directional power flows.

Nanogrids have two characteristics that could be challenging for EMAN to handle and deserve further consideration. The first is that grids can be arranged in any topology and may lack a single "root" as the utility grid generally provides. The second is that connections among grids and connections to loads may be intermittent and dynamic. Accommodating these does not seem contrary to the goals of EMAN, but EMAN semantics could be defined in a way which makes doing so difficult or impossible.

5. Other Implications

Communication internal to a nanogrid will be specific to the particular physical layer technology. USB, for example, could add nanogrid capability by simply extending the existing protocols it provides for coordinating power distribution on USB links. For PoE, it would be possible to do this with LLDP, or with some higher-layer protocol. Communication between nanogrids will require standards for gateways between them that cover both electrical and communications aspects. IEEE is a likely choice for at least most of this. Some of these may benefit from using IETF protocols, though core to the concept of local power distribution is that it only requires communication between immediately adjacent (electrically-connected) grids - just one hop.

Whether or not the IETF is involved in power distribution protocols, most of the devices in future that are on nanogrids, and the controllers themselves, will likely also implement IETF protocols, so that semantic consistency between the two domains would be extremely beneficial. Just as EMAN provides visibility into device power (measurement and control) at the network level, the IETF may want to in future support management protocols for small (microgrid or smaller) grids (that is, not intruding into the utility grid space where other standards organizations are active).

6. Terminology

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

7. Security Considerations

This mechanism introduces no information security vulnerabilities. A security advantage of nanogrids is that they only need to communicate with other grids (or power sources) to which they are directly electrically connected. This requirement for physical connection greatly reduces their vulnerability, and is in sharp contrast to many grid architectures which require communication across many network links.

8. Privacy Considerations

Nanogrid gateways need only communicate information about the price and quantity of electricity, not about their internal structure or electricity-consuming loads. This makes them exceptionally protective of privacy.

9. References

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Abstract

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

<parello>

Expires September 2012

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1. Introduction

Within Energy Management there are terms that may seem obvious to a casual reader but in fact require a rigorous and sourced definition. To avoid any confusion in terms among the working group drafts, one glossary / lexicon of terms should exist that all drafts can refer to. This will avoid a review of terms multiplied across drafts.

This draft will contain a glossary of definitions of terms that can be agreed upon by the working group outside of the context of drafts and then included in or sourced to this draft.

Each term will contain a definition(s), a normative or informative reference, an optional example, an optional comment(s) listed a note(s).

All terms should be rooted with a well-known reference. If a definition is taken verbatim from a reference then the source is listed in square brackets. If a definition is derived from a well-known reference then the source is listed as "Adapted from" with the reference listed in square brackets. If a defined term is newly defined here the reference will indicate as such by stating "herein" and if applicable list any composing terms from this document.

When applicable the [IEEE100] was used as the

preferred source. If a term was not available from [IEEE100], then [IEC60050] was used. When these were multiple items from [IEEE100], [IEC60050] or [ISO50001], there were all included.

2. Terminology

Device

A piece of electrical or non-electrical equipment.

Reference: Adapted from [IEEE100]

Component

A part of an electrical or non-electrical equipment (Device).

Reference: Adapted from [ITU-T-M-3400]

Energy Management

Energy Management is a set of functions for measuring, modeling, planning, and optimizing networks to ensure that the network elements and attached devices use energy efficiently and is appropriate for the nature of the application and the cost constraints of the organization.

Reference: Adapted from [ITU-T-M-3400]

Example: A set of computer systems that will poll electrical meters and store the readings

NOTES:

1. Energy management refers to the activities, methods, procedures and tools that pertain to measuring, modeling, planning, controlling and optimizing the use of energy in networked systems [NMF].
2. Energy Management is a management domain which is congruent to any of FCAPS areas of management in the ISO/OSI Network Management Model [TMN]. Energy Management for communication networks and attached

devices is a subset or part of an organization's greater Energy Management Policies.

Energy Management System (EnMS)

An Energy Management System is a combination of hardware and software used to administer a network with the primary purpose being Energy Management.

Reference: Adapted from [1037C]

Example: A single computer system that polls data from devices using SNMP

NOTES:

1. An Energy Management System according to [ISO50001] (ISO-EnMS) is a set of systems or procedures upon which organizations can develop and implement an energy policy, set targets, action plans and take into account legal requirements related to energy use. An EnMS allows organizations to improve energy performance and demonstrate conformity to requirements, standards, and/or legal requirements.
2. Example ISO-EnMS: Company A defines a set of policies and procedures indicating there should

exist multiple computerized systems that will poll energy from their meters and pricing / source data from their local utility. Company A specifies that their CFO should collect information and summarize it quarterly to be sent to an accounting firm to produce carbon accounting reporting as required by their local government.

3. For the purposes of EMAN, the definition from [1037C] is the preferred meaning of an Energy Management System (EnMS). The definition from [ISO50001] can be referred to as ISO Energy Management System (ISO-EnMS).

ISO Energy Management System

Energy Management System as defined by [ISO50001]

Reference: herein

Energy

That which does work or is capable of doing work. As used by electric utilities, it is generally a reference to electrical energy and is measured in kilo-watt hours (kWh).

Reference: [IEEE100]

NOTES

1. Energy is the capacity of a system to produce external activity or perform work [ISO50001]

Power

The time rate at which energy is emitted, transferred, or received; usually expressed in watts (or in joules per second).

Reference: [IEEE100]

Demand

The average value of power or a related quantity over a specified interval of time. Note: Demand is expressed in kilowatts, kilovolt-amperes, kilovars, or other suitable units.

Reference: [IEEE100]

NOTES:

1. typically kilowatts

2. Energy providers typically bill by Demand measurements as well as for maximum Demand per billing periods. Power values may spike during short-terms by devices, but Demand measurements recognize that maximum Demand does not equal maximum Power during an interval.

Power Characteristics

Measurements of the electrical current, voltage and frequencies at a given point in an electrical power system.

Reference: Adapted from [IEC60050]

NOTES:

1. Power Characteristics is not intended to be judgmental with respect to a reference or technical value and are independent of any usage context.

Power Quality

Characteristics of the electric current, voltage and frequencies at a given point in an electric power system, evaluated against a set of reference technical parameters. These parameters might, in some cases, relate to the compatibility between electricity supplied in an electric power system and the loads connected to that electric power system.

Reference: [IEC60050]

NOTES:

1. Electrical characteristics representing power quality information are typically required by customer facility energy management systems. It is not intended to satisfy the detailed requirements of power quality monitoring. Standards typically also give ranges of allowed values; the information attributes are the raw measurements, not the "yes/no" determination by the various standards.

Reference: [ASHRAE-201]

Electrical Equipment

A general term including materials, fittings, devices, appliances, fixtures, apparatus, machines, etc., used as a part of, or in connection with, an electric installation.

Reference: [IEEE100]

Non-Electrical Equipment (Mechanical Equipment)

A general term including materials, fittings, devices, appliances, fixtures, apparatus, machines, etc., used as a part of, or in connection with, non-electrical power installations.

Reference: Adapted from [IEEE100]

Energy Object

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

Reference: herein

Electrical Energy Object

An Electrical Energy Object (EEO) is an Energy Object that is a piece of Electrical Equipment

Reference: herein, Electrical Equipment

Non-Electrical Energy Object

A Non-Electrical Energy Object (NEEO) an Energy Object that is a piece of Non-Electrical Equipment.

Reference: herein, Non-Electrical Equipment.

Energy Monitoring

Energy Monitoring is a part of Energy Management that deals with collecting or reading information from Energy Objects to aid in Energy Management.

Reference: herein

NOTES:

1. This could include Energy, Power, Demand, Power Quality, Context and/or Battery information.

Energy Control

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

Reference: herein

NOTES:

1. Typically in order to optimize or ensure its efficiency.

Provide Energy:

An Energy Object "provides" energy to another Energy Object if there is an energy flow from this Energy Object to the other one.
Reference: herein

Receive Energy:

An Energy Object "receives" energy from another Energy Object if there is an energy flow from the other Energy Object to this one.
Reference: herein

Power Interface

A Power Interface (or simply interface) is an interconnection among devices or components where energy can be provided, received or both.

Reference: herein

Power Inlet

A Power Inlet (or simply inlet) is an interface at which a device or component receives energy from another device or component.

Reference: herein

Power Outlet

A Power Outlet (or simply outlet) is an interface at which a device or component provides energy to another device or component.

Reference: herein

Energy Management Domain

An Energy Management Domain is a set of Energy Objects where all objects in the domain are considered one unit of management.

Reference: herein

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

NOTES:

1. Typically, this set will have as members all EO's that are powered from the same source.

Energy Object Identification

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

Reference: herein

Energy Object Context

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

Reference: herein

NOTES:

1. The classification could contain the use and/or the ranking of the Energy Object as compared to other Energy Objects in the Energy Management Domain.

Energy Object Relationship

An Energy Object Relationship is a functional association among Energy Objects

NOTES

1. Relationships can be named and could include Aggregation, Metering, Power Source, and Proxy.
2. The Energy Object is the noun or entity in the relationship with the relationship described as the verb.

Example: If EO x is a piece of Electrical Equipment and EO y is an electrical meter clamped onto x's power cord, then x and y have a Metering Relationship. It follows that y meters x and that x is metered by y.

Reference: Adapted from [CHEN]

Aggregation Relationship

An Aggregation Relationship is an Energy Object Relationship where one Energy Object aggregates the Energy Management information of one or more other Energy Objects.
These Energy Objects are referred to as having an Aggregation Relationship.

Reference: herein

NOTES:

1. Aggregate values may be obtained by reading values from multiple Energy Objects and producing a single value of more significant meaning such as average,

count, maximum, median, minimum, mode and most commonly sum [SQL].

Metering Relationship

A Metering Relationship is an Energy Object Relationship where one Energy Object measures the Power or Energy of one or more other Energy Objects.

These Energy Objects are referred to as having a Metering Relationship.

Reference: herein

Example: a PoE port on a switch measures the Power it provides to the connected Energy Object.

Power Source Relationship

A Power Source Relationship is an Energy Object Relationship where one Energy Object is the source of or distributor of Power to one or more other Energy Objects.

These Energy Objects are referred to as having a Power Source Relationship.

Reference: herein

Example: a PDU provides power for a connected device.

Proxy Relationship

A Proxy Relationship is an Energy Object Relationship where one Energy Object provides the Energy Management capabilities on behalf of one or more other Energy Objects.

These Energy Objects are referred to as having a Proxy

Relationship.

Reference: herein

Example: a protocol gateways device for Building Management Systems (BMS) with subtended devices.

Energy Object Parent

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

Example: in a Metering Relationship, the Energy Object that is metering is called the Energy Object Parent, while the Energy Object that is metered is called the Energy Object Child.

Reference: herein

Energy Object Child

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

Example: in a Metering Relationship, the Energy Object that is metering is called the Energy Object Parent, while the Energy Object that is metered is called the Energy Object Child.

Reference: herein

Power State

A Power State is a condition or mode of a device that

broadly characterizes its capabilities, power consumption, and responsiveness to input.

Reference: Adapted from [IEEE1621]

NOTES:

1. A Power State can be seen as a power setting of an Energy Object that influences the power consumption, the available functionality, and the responsiveness of the Energy Object.
2. A Power State can be viewed as one method for Energy Control

Power State Set

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

Reference: herein

Example: The states {on, off, and sleep} as defined in [IEEE1621], or the 16 power states as defined by the [DMTF] can be considered two different Power State Sets.

Nameplate Power

The Nameplate Power is the maximal (nominal) Power that a device can support.

Reference: herein

NOTES:

1. This is typically determined via load testing and is specified by the manufacturer as the maximum value required for operating the device. This is

sometimes referred to as the worst-case Power. The actual or average Power may be lower. The Nameplate Power is typically used for provisioning and capacity planning.

3. Security Considerations

None

4. IANA Considerations

None

5. Acknowledgments

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A Framework and Requirements for Energy Aware Control Planes
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Abstract

There has been, for several years, a rising concern over the energy usage of large scale networks. This concern is strongly focused on campus, data center, and other highly concentrated deployments of network infrastructure. Given the steadily increasing demand for higher network speeds, always-on service models, and ubiquitous network coverage, it is also of growing importance for telecommunication networks both local and wide area in scope. One of the issues in moving forward to reduce energy usage is to ensure that the network can still meet the performance specifications required to support the applications running over it.

This document provides an overview of the various areas of concern in the interaction between network performance and efforts at energy aware control planes, as a guide for those working on modifying current control planes or designing new control planes to improve the energy efficiency of high density, highly complex, network deployments.

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1. Introduction

As energy prices continue to increase, and energy awareness becomes a watchword for most large companies, places where the network infrastructure used a good deal of power have come under increased scrutiny for savings. There is a concern, however, in saving energy at the cost of network operations --to reduce performance along with energy consumption, negatively impacting the operation of a network and the applications reliant on that network. This concern is primarily focused on the network control plane, but will necessarily apply to network performance and energy usage overall.

This document provides a background, a framework for understanding and managing the tradeoffs between modifications made to network protocols to conserve energy and network performance metrics and requirements, and a set of requirements for protocol designers to consider in proposals for new control plane protocols or modifications to existing control plane protocols. It is intended to encourage work on mechanisms that will reduce network energy usage while providing perspective on balancing energy usage against performance. The ultimate goal is to provide the tools and knowledge necessary for protocol designers to modify network protocols to best balance efficiency against performance, and to provide the background information network operators will need to intelligently deploy and use protocol modifications to network protocols.

The document is organized as follows. Section 3 provides material the reader needs to understand to appreciate the challenges inherent in balancing energy reduction with effective network performance. This section includes subsections considering the application and business requirements that are the basis of the rest of the document. Section 4 provides a framework for understanding mechanisms common to all energy management schemes proposed to date in general terms. Section 5 provides an analysis of the areas highlighted, including an explanation of how the specific area interacts with energy management, and example of the interaction, and, finally, a set of requirements protocol designers SHOULD consider when proposing either new protocols or modifications to existing protocols to reduce energy usage.

2. Requirements Language

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

3. Background

The background covered here describes the underlying business and application drivers for the consideration and requirements sections below. This section also contains a small example network used throughout the remainder of this document for explaining various mechanisms and technical points.

3.1. Scope

The reader should differentiate between radio based and wireline (or rather, "plugged in"), networks. Radio based networks designed for rapid deployment for highly mobile users (often called Mobile Ad Hoc Networks, or MANETs [MANET]), and sensor networks designed for low power, processing, and memory (such as those described in [ROLL]), are not the target of this document. Readers should refer to the groups working within those areas for energy management requirements based on those specialized environment. While protocol developers for those environments may draw useful information from this document, this work is not intended to address those specialized networks specifically. Mobile cellular networks however are similarly affected by excess energy consumption as wireline networks and seek to save energy by methods as described in the following (see e.g. [3GPP]).

The reader should also differentiate between intradomain and interdomain applications. Interdomain applications require more work in policy than in technical and business considerations, and therefore fall outside the scope of this document. Intradomain control planes are (intuitively) where most energy savings will be attained, at any rate. Most high concentrations of routers, such as data centers and campus networks, are under a single administrative domain. Therefore, placing interdomain control planes outside the scope of this document does not limit its usefulness in any meaningful way.

The reader should further differentiate between the components of an energy management system, namely energy monitoring and energy control. Energy monitoring deals with the collection of information related to energy utilization and characteristics, as described in [EMAN]. Energy control relates to directly influencing the optimization and/or efficiency of devices in the network. The focus of this document is on understanding the tradeoffs between modifications made to network protocols to conserve energy and network performance metrics and requirements, not on the functions, steps or procedures required for energy monitoring.

3.2. Business Drivers

Networks are primarily built to support both broad and narrow business requirements. Broad business requirements might include general communication requirements, such as providing email service between internal and external personnel, or providing general access to the World Wide Web for research and business support. Narrow requirements would relate to specific applications, such as supporting a particular financial application in the case of a bank or other financial enterprise, or supporting customer traffic in the case of a service provider. Application requirements will be considered in greater detail in the next section.

Another class of requirements business place on networks can be called operational requirements. These include (but are not limited to), capital expense, operational expense, and the restrictions the network architecture places on the growth and operation of the business itself. These, in turn, drive requirements such as change management, total uptime (availability), and the ability of the network to be easily and quickly modified to meet new business demands, or to shed old business demands. Operational expense is the primary area this document covers in relation to business requirements, because this is where energy management most obviously overlaps with network performance.

3.3. Application Drivers

Applications drivers provide the background for each of the technical sections below. When approaching a specific application, there are only a small number of questions network and protocol designers need to fully understand to shape networks and protocols so a specific application can be supported. The first two questions revolve around bandwidth; how much bandwidth will the application consume, and is this bandwidth consumption fairly steady, or highly variable? For instance, applications such as streaming video tend to have long lasting flows with high bandwidth requirements, file transfers tend to produce shorter flows requiring high bandwidth, and HTML traffic tends to be bursty, with much lower bandwidth requirements.

The next question a protocol or network designer might ask about a specific application is it's tolerance to jitter. Real time applications, such as voice and video conferencing, have a very low toleration for jitter. File transfers and streaming video, on the other hand, can often handle large variations in packet arrival times. If packets are delayed long enough, the application may actually time out, shutting down sessions. Users will often "hang up" after a short period of time, as well, causing loss of revenue and productivity.

Delay is another crucial factor in the performance of many applications. Many server virtualization protocols, for instance, have very low tolerance for delay, having been written with a short wire local broadcast segment in mind. Applications such as stock and commodity trading, remote medical, and collaborative video editing also exhibit very little tolerance for delay.

These last two application drivers, jitter and delay, are normally the result of two underlying causes within a network's control plane: stretch and convergence. Stretch (defined more fully in the section considering stretch below) causes longer paths to be taken through the network. Each hop in the network path adds serialization into and out of a set of queues in device memory, along with the delays of various queuing mechanisms implemented on that device. Each hop in the network increases delay directly, and has the potential to increase jitter as packets pass into and out of the additional devices.

Network convergence will also show up as jitter in an application's stream; if packets are held up or looped for hundreds of milliseconds during a network convergence event, applications running over the converging topology will see this convergence time as a massive jitter event, or a short term delay in the delivery of packets.

Jitter and delay can also be introduced directly into the packet stream by reducing the throughput of individual links, or putting devices and/or links into energy reduced modes for very short periods of time (microsleeps). If a link is asleep when the first and third packets from a flow arrive at the head end of the link, and not when the second packet from that same flow arrives, each packet is going to be processed differently, and hence will have a different delay across the path.

The specific technical problems addressed in the following sections, then, are bandwidth reduction, increasing stretch, network convergence, and introducing jitter through microsleeps.

4. Framework

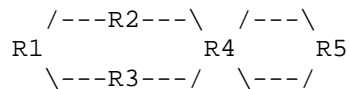
4.1. Modes of Reducing Energy Usage

Regardless of whether the control plane is centralized (such as some form of centrally computed traffic engineering or software defined network), or distributed (traditional routing protocols), there are four primary ways in which energy usage can be reduced:

- o Removing redundant links from the network topology
- o Removing redundant network equipment from the network topology
- o Reducing the amount of time equipment or links are operational
- o Reducing the link speed or processing rate of equipment

4.1.1. Example Network

To illustrate the impacts of link and device removal throughout the rest of this document, the following network is used.



This network is overly simplistic so the impact of removing various links and devices from the topology can be more clearly illustrated. More complex topologies will often exhibit these same impacts without being so obvious.

4.1.2. Examples of Energy Reduction

In the example network above, several different modes of energy reduction might be:

- o Shutting down one of the two links between R4 and R5
- o Shutting down one of the two links between R4 and R5, and shutting down any line cards (or part of the nodes themselves) associated with the removal of these links
- o Shutting down R2 or R3, since these represent alternate paths to reach the same set of destinations
- o Shutting down the link between R2 and R4, since similar connectivity is provided through R1->R3->R4
- o Shutting down all links and devices for fractions of time in a coordinated fashion
- o Shutting down individual links as traffic or the control plane permits for fractions of time (here the momentary shutdown of various links is not coordinated, but undertaken hop by hop)
- o Reducing the speed of all links and devices for fractions of time in a coordinated fashion

- o Reducing the speed of individual links as traffic or the control plane permits for fractions of time (here the momentary slowdown of various links is not coordinated, but undertaken hop by hop)

4.2. Global Verses Local Decisions

Independent of whether the control plane is centralized or distributed, the scope considered when making a decision about energy efficiency may affect the result and effectiveness of the system. There are clearly two extreme options when looking at the scope of the information used to make decisions. The first extreme is that of every device in the network considering only local conditions, and determining the proper local state from that information. An example of this mode of operation might be a local link where the devices on either side of that link measure the link utilization, and independently decide to automatically shut the link down when utilization reaches a specific threshold. An example of the other end of the spectrum might be a network control plane in which all the nodes involved agree before taking a specific action; in the case of two parallel links, the devices on each end not only would have similar configured policies, but would coordinate if one of the links was to be turned off. It is outside the scope of this document to determine which of these two options may be optimal or "best."

There are some considerations and tradeoffs which need to be outlined in considering the global versus local decisions in relation to energy efficiency. System designers SHOULD take note of the difficulties with preventing pathological conditions when purely localized decisions are made. For instance, in the example network, assume R1 determines to put the R1->R2 link into an energy saving mode, while R4 determines to put the R4->R3 link into an energy saving mode. In this case, no path will remain available through the network. It is also possible for the opposite to occur, that is for no links or devices to be placed into a reduced energy state because R1 and R4 don't agree through the control plane which links and devices should be removed from the topology.

Protocol designers SHOULD consider these tradeoffs in proposals for energy aware control planes.

5. Considerations and Requirements

5.1. Energy Efficiency and Bandwidth Reduction

Bandwidth is an important consideration in high density networks; most data centers are designed to provide a specific amount of bandwidth into and out of each server and to facilitate virtual

server movement among physical devices. In campus and core networks bandwidth is finely coupled with quality of service guarantees for applications and services. It should be obvious that removing links or devices from a network topology will adversely affect the amount of available bandwidth, which could, in turn, cause well thought out quality of service mechanisms to degrade or fail.

What might not be so obvious is the relationship between available bandwidth and jitter, or other network quality of service measures. If higher speed links are removed from the topology in order to continue using lower speed (and therefore presumably lower power) links, then serialization delays will have a larger impact on traffic flow. Longer serialization delays can cause input queues to back up, which impacts not only delay but jitter, and possibly even traffic delivery.

5.1.1. An Example of Lowered Bandwidth

In the network illustrated above, one of the two links between R4 and R5 could be an obvious candidate for removal from the network. Especially if the network load can easily be transferred to the remaining link without failure, and without serious consequences for delay or jitter in the network, there is a strong case to be made for doing so --particularly if the accompanying line cards could also be shut down to add to the energy savings.

5.1.2. Requirements

Modifications to control plane protocols to achieve network energy efficiency SHOULD provide the ability to set the minimal bandwidth, jitter, and delay through the network, and not shut down links or devices that would violate those minimal requirements.

5.2. Energy Efficiency and Stretch

In any given network, there is a shortest path between any source and any destination. Network protocols discover these paths from the destination's perspective --routing draws traffic along a path, rather than driving along a path. Along with the shortest path, there are a number of paths that can also carry traffic from a given source to a given destination without the packets passing along the same logical link, or through the same logical device, more than once. These are considered loop-free alternate [RFC5714] paths.

The primary difference between the shortest path and the loop-free alternate paths is the total cost of using the path. In simple terms, this difference can be calculated as the number of links and devices a packet must pass through when being carried from the source

to the destination --the hop count. While most networks use much more sophisticated metrics based on bandwidth, congestion, and other factors, the hop count will stand in as the only metric used throughout this document.

When the control plane causes traffic to pass from the source to the destination along a path which is longer than the shortest path, the network is said to have stretch (see [Krioukov] for a more in depth explanation of network stretch). To measure stretch, simply subtract the metric of the shortest path from the metric of the longer path. For example, in hop count terms, if the best path is three hops, and the current path is four hops, the network exhibits a stretch of 1.

5.2.1. An Example of Stretch

In the network illustrated above, if a modification is made to the control plane in order to remove the link between R1 and R4 in order to save energy, all the destinations shown in the diagram remain reachable. However, from the perspective of R1, the best path available to reach R2 has increased in length by two hops. The original path is R1->R2, the new path is R1->R3->R4->R2. This represents a stretch of 2.

Along with this increased stretch will most likely also come increased delay through the network; each hop in the network represents a measurable amount of delay. This increased stretch might also represent an increased amount of jitter, as there are more queues and more serialization events in the path of each packet carried. There will also be the modifications in jitter as the network switches between the optimal performance configuration and an energy efficient configuration.

5.2.2. Requirements

Designers who propose modifications to control plane protocols to achieve network energy efficiency SHOULD analyze the impact of their mechanisms on the stretch in typical network topologies, and SHOULD include such analysis when explaining the applicability of their proposals. This analysis may include an examination of the absolute, or maximum, stretch caused by the modifications to the control plane as well as analysis at the 95th percentile, the average stretch increase in a given set of topologies, and/or the mean increase in stretch.

Mechanisms that could impact the stretch of a network SHOULD provide the ability for the network administrator to limit the amount of stretch the network will encounter when moving into a more energy efficient mode.

5.3. Energy Efficiency and Fast Recovery

A final area where modifications to the control plane for energy efficiency is fast convergence or fast recovery. Many networks are now designed to recover from failures quickly enough to only cause a handful of traffic to be lost; recovery on the order of half a second is not an uncommon goal. It should be obvious that removing redundant links and devices from the network to reduce energy consumption could adversely affect these goals.

5.3.1. An Example of Impact on Fast Recovery

In the network shown, assume R2 and its associated links are removed from the topology in order to save energy. Rather than this second path being available for immediate recovery on the failure of the R1->R3 link, some process must be followed to bring R2 and its associated links back up, reinject them into the topology, and finally begin routing traffic across this path.

In many situations, only links and devices which are a "third point of failure" may be acceptable as removal candidates in order to conserve energy.

5.3.2. Requirements

Modifications to the control plane in order to remove links or nodes to conserve energy should entail the ability to choose the level of redundancy available after the network topology has been trimmed. For instance, it might be acceptable in some situations to move to single points of failure throughout the network, or in specific sections of the network, for certain periods of time. In other situations, it may only be acceptable to reduce the network to a double point of failure, and never to a single point of failure.

The complete removal of nodes or links from the network topology has several impacts on the control plane which must be considered. In these cases, the control plane must:

- o Modify the network topology so removed links or devices are not used to forward traffic
- o Remember that such links exist, possibly including the neighbors and destinations reachable through those links or devices

5.4. Introducing Jitter Through Microsleeps

One proposed mechanism to reduce energy usage in a network is to sleep links or devices for very short periods of time, called microsleeps. For instance, if a particular link is only used at 50% of the actual available bandwidth, it should be possible to place the link in some lower power state for 50% of the time, thus reducing energy usage by something percentage.

Such schemes introduce delay and jitter into the network path directly; if a packet arrives while the link to the next hop, or the next hop itself, is in a reduced energy state, the packet must wait until the link or next hop device enter a normal operational mode before it can be forwarded. Most of the time the proposed sleep states are so small as to be presumably inconsequential on overall packet delay, but multiple packets crossing a series of links, each encountering different links in different states, could take very different amounts of time to pass along the path.

One possible way to resolve this somewhat random accrual of delays on a per packet basis is to coordinate these sleep states such that packets accepted at the entry of the network are consistently passed through the network when all links and devices are in a normal operating mode, and simply delaying all packets at the entry point into the network while the devices in the network are in some energy reduced state. This solution still introduces some amount of jitter; some packets will be delayed by the sleep state at the edge of the network, while others will not. This solution also requires coordinated timers at the speed of forwarding itself to effectively control the sleep and wake cycles of the network.

5.4.1. An Example of Microsleeps to Reduce Energy Usage

In the example network, assume the bandwidth utilization along the path R1->R2->R4->R5 is 50% of the actual available bandwidth along this path. It is possible to consider a scheme where R1->R2, R2->R4, and R4->R5 are all put into some energy reduced operational mode 50% of the time, since packets are only available to send 50% of the time. A packet entering at R1 may encounter a short delay at R1->R2, at R2->R4, and at R4->R5, or it might not. Even if these delays are very small, say 200ms at each hop, the accumulated delay through the network due to sleep states may be 0ms (all links and devices awake) or 600ms (all links and devices asleep) as the packet passes through the network.

As network paths lengthen to more realistic path lengths in real deployments, the jitter introduced varies more widely, which could cause problems for the operation of a number of applications.

5.4.2. Requirements

Protocol designers SHOULD analyze the impact of accumulated jitter when proposing mechanisms that rely on microsleeps in either equipment or links. This analysis SHOULD include both worst case and best case scenarios, as well as an analysis of how coordinated clocks are to be handled in the case of coordinated sleep states.

5.5. Other Operational Aspects

Modification of the network topology in order to save energy needs to consider the operational needs of the network as well as application requirements. Change management, operational downtime, and business usage of the network need to be considered when determining which links and nodes should be placed into a low energy state. Energy provisions have to be assigned and changed for nodes and links, optimally according to network usage profiles over the time of day.

Control plane protocol operation, in terms of operational efficiency on the wire, also needs to be considered when modifying protocol parameters. Any changes that negatively impact the operation of the protocol, in terms of the amount of traffic, the size of routing information transmitted over the network, and interaction with network management operations need to be carefully analyzed for scaling and operational implications.

5.5.1. An Example of Operational Impact

Time of day is an important consideration in business operations. During normal operational hours, the network needs to be fully available, including all available redundancy and bandwidth. During holidays, night hours, and other times when a campus might not be used, or when there are lower traffic and resiliency demands on the network, network elements can be removed to reduce energy usage.

5.5.2. Requirements

Protocol designers SHOULD analyze operational requirements, such as time of day and network traffic load considerations, and explain how proposed protocols or modifications to protocols will interact with these types of requirements. Protocol designers SHOULD analyze increases in network traffic and the operational efficiency impact of proposed changes or protocols.

6. Security Considerations

None.

7. Acknowledgements

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Green Usage Monitoring Information Base
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Abstract

This memo defines a portion of the Management Information Base (MIB), the GreenUsage MIB, for use with network management protocols in the Internet community. In particular, the GreenUsage MIB can be used to monitor the power-on/power-off status of electrical devices.

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1. The Internet-Standard Management Framework

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

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP).

Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies a MIB module that is compliant to the SMIV2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].

2. Overview

2.1. The GreenUsage monitoring concept

Monitor the power-on/power-off status of electrical devices. If a device is in power-on state beyond business hours, it is wasteful usage of electricity. The GreenUsage concept aims to monitor and reduce this wastage.

This document defines a set of managed objects (MOs) that can be used to monitor the power-on/power-off status of electrical devices.

2.2. Terminology

Electrical device: a device that consumes electricity. Power-on/power-off status indicates whether the device is powered on or not. Often it is not possible to get a direct indication of whether a device is powered on or not. But indirect means may be used to infer the power-on/power-off status of a device. For example, if a device shows some network activity, it can be inferred that the device is powered on. Note that it is difficult to infer that a device is powered off. Also, there may be several states between power-on and power-off e.g. sleep state, power-saving state etc.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14, RFC 2119 [RFC2119].

3. GreenUsage Monitoring Requirements

Multiple mechanisms may be used to determine whether a device is powered on or not. The mechanisms will depend on the nature of the device. Since the number of devices may be very large, the identification, usage type, and location of devices needs to be addressed with care.

4. MIB Design

The basic principle has been to keep the MIB as simple as possible and at the same time to make it effective enough so that the essential needs of monitoring are met.

The GreenUsage-MIB is composed of the following

- device Table: a list of the devices that will be monitored
- deviceStatus Table: the power-on/power-off status of the devices

5. MIB Definitions

5.1 The GreenUsage MIB

```
GREENUSAGE-MIB DEFINITIONS ::= BEGIN
    IMPORTS
        MODULE-IDENTITY, mib-2, Unsigned32, OBJECT-TYPE
            FROM SNMPv2-SMI -- RFC 2578
        TimeStamp, MacAddress, TEXTUAL-CONVENTION
            FROM SNMPv2-TC -- RFC 2579
        MODULE-COMPLIANCE, OBJECT-GROUP
            FROM SNMPv2-CONF -- RFC 2580
        SnmpAdminString
            FROM SNMP-FRAMEWORK-MIB
    ;

greenUsageMIB MODULE-IDENTITY
    LAST-UPDATED "201207070000Z" -- 7th July, 2012
    ORGANIZATION "PREDICT Working Group"
    CONTACT-INFO
        "
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"

DESCRIPTION

"This MIB module is for monitoring the power-on/power-off
status of electrical devices.

Copyright (C) The IETF Trust (2012). This version of
this MIB module is part of RFC XXXX; see the RFC itself for
full legal notices.

"

-- RFC Ed.: replace XXXX with the actual RFC number & remove this
-- note

```
REVISION "201207070000Z"      -- 7th July, 2012
DESCRIPTION
    "The initial version, published as RFC XXXX."

-- RFC Ed.: replace XXXX with the actual RFC number & remove this
-- note

 ::= { mib-2 YYY1 }          -- Will be assigned by IANA

-- IANA Reg.: Please assign a value for "YYY1" under the
-- 'mib-2' subtree and record the assignment in the SMI
-- Numbers registry.

-- RFC Ed.: When the above assignment has been made, please
--           remove the above note
--           replace "YYY1" here with the assigned value and
--           remove this note.

-- -----
-- Textual Conventions
-- -----

GumStatusDetectionMethod ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
        "The object specifies the technology which is used
        to detect the power-on/power-off status of a device.
        The enumerated values and the corresponding
        technology are as follows:
        reserved                (0): reserved (Not used)
        arpSensing              (1): arp packets from the
                                device
        neighborDiscoverySensing (2): neighbor discovery
                                packets from the device
        icmpEchoProbing         (3): ICMP echo packets
        switchMonitoring        (4): switch monitoring

    "
    SYNTAX      INTEGER
    {
        reserved                (0),
        arpSensing              (1),
        neighborDiscoverySensing (2),
        icmpEchoProbing         (3),
```

```

        switchMonitoring          (4)
    }

GumDeviceStatus ::= TEXTUAL-CONVENTION
    STATUS current
    DESCRIPTION
        "The object represents the power-on/power-off
        status of a monitored device.
        unknown          (0)
        powerOn          (1): device is powered on
        powerOff         (2): device is powered off
        sleepMode        (3): device is in sleep mode
        powerSavingMode  (4): device is in
                        powersaving mode
    "
    SYNTAX INTEGER
    {
        unknown          (0),
        powerOn          (1),
        powerOff         (2),
        sleepMode        (3),
        powerSavingMode  (4)
    }

```

-- The GREENUSAGE MIB has the following 3 primary groups

```

gumNotifications    OBJECT IDENTIFIER ::= { greenUsageMIB 0 }
gumObjects          OBJECT IDENTIFIER ::= { greenUsageMIB 1 }
gumConformance      OBJECT IDENTIFIER ::= { greenUsageMIB 2 }

gumDeviceTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF GumDeviceEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This table models the device list

        Entries in this table are required to survive
        a reboot of the managed entity.
    "
    ::= { gumObjects 1 }

gumDeviceEntry OBJECT-TYPE
    SYNTAX      GumDeviceEntry

```

```
MAX-ACCESS    not-accessible
STATUS        current
DESCRIPTION
    "This entry represents a conceptual row in the
    gumDevice table. It represents a device that
    will be monitored for power-on/power-off status.
    "
INDEX { gumDeviceID }
 ::= { gumDeviceTable 1 }

GumDeviceEntry ::=
SEQUENCE {
    gumDeviceID             Unsigned32,
    gumDeviceName           SnmpAdminString,
    gumDeviceMacAddress     MacAddress,
    gumDeviceType           SnmpAdminString,
    gumDeviceLocation       SnmpAdminString
}

gumDeviceID OBJECT-TYPE
SYNTAX         Unsigned32
MAX-ACCESS     not-accessible
STATUS         current
DESCRIPTION
    "A unique arbitrary identifier for this device."
 ::= { gumDeviceEntry 1 }

gumDeviceName OBJECT-TYPE
SYNTAX         SnmpAdminString (SIZE(1..64))
MAX-ACCESS     read-create
STATUS         current
DESCRIPTION
    "Administratively assigned textual name of this
    device."
 ::= { gumDeviceEntry 2 }

gumDeviceMacAddress OBJECT-TYPE
SYNTAX         MacAddress
MAX-ACCESS     read-only
STATUS         current
DESCRIPTION
    "MAC Address of this device.
    If there is no MAC address, this object will be
    inaccessible."
 ::= { gumDeviceEntry 3 }
```

```
gumDeviceType OBJECT-TYPE
    SYNTAX      SnmpAdminString (SIZE(1..64))
    MAX-ACCESS  read-create
    STATUS      current
    DESCRIPTION
        "Administratively assigned textual description about
         usage type of this device."
    ::= { gumDeviceEntry 4 }

gumDeviceLocation OBJECT-TYPE
    SYNTAX      SnmpAdminString (SIZE(1..64))
    MAX-ACCESS  read-create
    STATUS      current
    DESCRIPTION
        "Administratively assigned textual location
         name of this device."
    ::= { gumDeviceEntry 5 }

gumDevUsageTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF GumDevUsageEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This table models the device usage status

        Entries in this table are required to survive
        a reboot of the managed entity.
        "
    ::= { gumObjects 2 }

gumDevUsageEntry OBJECT-TYPE
    SYNTAX      GumDevUsageEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "This entry represents a conceptual row in the
         gumDevUsage table. It represents a power-on/power-off
         status of a monitored device.
        "
    INDEX { gumDeviceID, gumDevUsageDetID }
    ::= { gumDevUsageTable 1 }

GumDevUsageEntry ::=
    SEQUENCE {
        gumDevUsageDetID          GumStatusDetectionMethod,
```

```
        gumDevUsageDetStatus      GumDeviceStatus,
        gumDevUsageDetTimeStamp   TimeStamp
    }

gumDevUsageDetID OBJECT-TYPE
    SYNTAX      GumStatusDetectionMethod
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "The detection method by which the usage status is
         computed."
    ::= { gumDevUsageEntry 1 }

gumDevUsageDetStatus OBJECT-TYPE
    SYNTAX      GumDeviceStatus
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "the usage status of the device."
    ::= { gumDevUsageEntry 2 }

gumDevUsageDetTimeStamp OBJECT-TYPE
    SYNTAX      TimeStamp
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "the time at which the usage status of the
         device was computed."
    ::= { gumDevUsageEntry 3 }

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

gumObjectsGroup OBJECT-GROUP
    OBJECTS {
        gumDeviceName,
        gumDeviceMacAddress,
        gumDeviceType,
        gumDeviceLocation,
        gumDevUsageDetStatus,
        gumDevUsageDetTimeStamp
    }
    STATUS      current
    DESCRIPTION
```

```
        " A collection of objects for basic GreenUsage
          monitoring."
      ::= { gumGroups 1 }

-- Compliance statements
gumCompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "The compliance statement for SNMP entities
         which implement the GREENUSAGE-MIB
        "
    MODULE -- this module
        MANDATORY-GROUPS { gumObjectsGroup
                           }
    ::= { gumCompliances 1 }

END
```


6. Security Considerations

There are no management objects defined in this MIB module with a MAX-ACCESS clause of read-write. Some of the readable objects in this MIB module (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control even GET and/or NOTIFY access to these objects and possibly to even encrypt the values of these objects when sending them over the network via SNMP. These are the tables and objects and their sensitivity/vulnerability:

- gumDeviceName,
- gumDeviceMacAddress,
- gumDeviceType,
- gumDeviceLocation,
- gumDevUsageDetStatus,
- gumDevUsageDetTimeStamp

The above objects may be used to identify users and their activities. Thus these objects may be considered to be particularly sensitive and/or private.

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

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

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

7. IANA Considerations

IANA should assign

1. a base arc in the 'mib-2' (standards track) OID tree for the 'greenUsageMIB' MODULE-IDENTITY defined in the

GREENUSAGE-MIB.

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