Requirements for Energy Management

Abstract

   This document defines requirements for standards specifications for
   Energy Management. The requirements defined in this document are
   concerned with monitoring functions as well as control functions.
   Monitoring functions include identifying energy-managed devices and
   their components, as well as monitoring their Power States, Power
   Inlets, Power Outlets, actual power, Power Attributes, received
   energy, provided energy, and contained batteries. Control functions
   include such functions as controlling power supply and Power State of
   energy-managed devices and their components.

   This document does not specify the features that must be implemented
   by compliant implementations but rather lists features that must be
   supported by standards for Energy Management.

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1. Introduction

With rising energy costs and an increasing awareness of the ecological impact of running information technology equipment, Energy Management (EMAN) 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. Energy Management functions focus mainly on devices and their components that receive and provide electrical energy. Devices such as hosts, routers, and middleboxes may have an IP address or may be connected indirectly to the Internet via a proxy with an IP address providing a management interface for the device, for example, devices in a building infrastructure using non-IP protocols and a gateway to the Internet.

These requirements are concerned with 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 on a set of general needs for Energy Management. Requirements for an Energy Management standard are specified in Sections 4 through 8.

Sections 4 through 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 rather 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, which addresses the identification of entities and the granularity of reporting of energy-related information. A standard must support the unique identification of entities, reporting per entire device, and reporting energy-related information on individual components of a device or attached devices.

Section 5 specifies requirements related to the monitoring of entities. This includes general (type, context) information and specific information on Power States, Power Inlets, Power Outlets, power, energy, and batteries. The control of Power State and power supply by 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 only with that entity. When the entity has no instrumentation for determining power, it might still be possible to obtain power values for the entity via communication with other entities in its power distribution tree. A simple example of this would be the retrieval of power values from a power meter at the power line into the entity. A Power Distribution Unit (PDU) and a Power over Ethernet (PoE) switch are common examples. 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 the power supply of an entity that 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 power on or off 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 (sometimes called an Energy Management System or controller). Requirements in this document do not cover the details of these networks and energy devices but specify means for opening IP network management towards them.

These specific issues of Energy Management, as well as other issues, 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 features must, should, or may be implemented by compliant implementations.

2. Terminology

The terms specified in the terminology section are capitalized
throughout the document; the exceptions are the well-known terms
"energy" and "power". These terms are generic and are used in
generated terms such as "energy-saving", "low-power", etc.

Energy

>   Energy is the capacity of a system to do work. As used by
>   electric utilities, it is generally a reference to electrical
>   energy and is measured in kilowatt-hours (kWh) [IEEE-100].

Power

>   Power is the time rate at which energy is emitted, transferred, or
>   received; power is usually expressed in watts (or in joules per
>   second) [IEEE-100]. (The term "power" does not refer to the
>   concept of demand, which is an averaged power value.)

Power Attributes

>   Power Attributes are measurements of electric current, voltage,
>   phase, and frequencies at a given point in an electrical power
>   system (adapted from [IEC.60050]).

>   NOTE: Power Attributes are not intended to be "judgmental" with
>   respect to a reference or technical value and are independent of
>   any usage context.

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 in a
>   manner appropriate to 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.

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
    controlling energy supply and Power State of network elements, as
    well as 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 in turn 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 to operate sets of
   devices using minimal energy, while maintaining a certain level of
   service. [EMAN-STATEMENT] presents the applicability of the EMAN
   framework to a variety of scenarios and also lists use cases and
   target devices.

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 three basic types of Power
   States for an entity or for a whole system:

   o full Power State

   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
   vary considerably. Simple entities may only have the extreme states:
   full Power State and off state. Many devices have three basic Power
   States: on, off, and sleep. However, more finely grained Power
   States can be implemented. Examples are various operational low
   Power States in which a device requires less energy than in the full
   power "on" state, but -- compared to the sleep state -- is still
   operational with reduced performance or functionality.

3.2. Saving Energy versus Maintaining Service Level

   One of the objectives of Energy Management is to reduce energy
   consumption. While this objective is clear, attaining that goal is
   often difficult. In many cases, there is no way to reduce power
   without the consequence of a potential service (performance or
   capacity) degradation. In this case, a trade-off needs to be made
   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 outside 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 in order to set
such policies. Often, this information is best acquired through
monitoring.

Network-wide and local Energy Management methods both have advantages
and disadvantages, and it is often 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 the high or low functional 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 the time of the 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 Attributes

o   setting Power States

Power control is complementary to other energy-saving 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 capable of being uniquely identified within the
context of the management system. This includes entities that are
components of managed devices as well as entire devices.

Entities that report on or control other entities must identify the
entities they report on or control: see Section 7 or Section 8,
respectively, for the detailed requirements.

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.
The ability to control individual components to save energy may be
required. 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 Link Layer Discovery Protocol
(LLDP) MIB module [IEEE-802.1AB] and the Link Layer Discovery
Protocol -- Media Endpoint Discovery (LLDP-MED) MIB module
[ANSI-TIA-1057] for devices, and the Entity MIB module [RFC6933] and
the power Ethernet MIB [RFC3621] for components of devices. Energy
Management needs a means to link energy-related information to such
identifiers.

Instrumentation for measuring the 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 restart of the entity.

4.3. Change of Identifiers

The standard must provide means to indicate any change of entity
identifiers.

4.4. Using Entity Identifiers of Existing MIB Modules

The standard must provide means for reusing entity identifiers from
existing standards, including at least the following:

o the entPhysicalIndex in the Entity MIB module [RFC6933]

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 reusing 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. The 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, understanding the role and context of an
entity may be required. 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 mission-critical 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, assign them to domains, or assign device types to them.

5.2. Power Interfaces

A Power Interface is an interface at which a device is connected to a
power transmission medium, at which it can in turn receive power,
provide power, or both.

A Power Interface is either an inlet or an outlet. Some Power
Interfaces change over time from being an inlet to being an outlet
and vice versa. However, most Power Interfaces never change.

Devices have Power Inlets at which they are supplied with electric
power. Most devices 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 a device, the availability of power at inlets, and which
inlets are actually in use.

Devices can have one or more Power Outlets for supplying other
devices with electric power.

For identifying and potentially controlling the source of power
received at an inlet, identifying the Power Outlet of another device
at which the received power is provided may be required.
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 devices.

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. Note that the nominal
voltage is often not a single value but a voltage range, such as, for
example, (100V-120V), (100V-240V), (100V-120V,220V-240V).

5.2.1. List of Power Interfaces

The standard must provide means for monitoring the list of Power
Interfaces of a device.

5.2.2. Operational Mode of Power Interfaces

The standard must provide means for monitoring the operational mode
of a Power Interface, which is either "Power Inlet" or "Power
Outlet".

5.2.3. Corresponding Power Outlet

The standard must provide means for identifying the Power Outlet that
provides the power received at a Power Inlet.

5.2.4. Corresponding Power Inlets

The standard must provide means for identifying the list of Power
Inlets that receive the power provided at a Power Outlet.

5.2.5. Availability of Power

If the Power States allow it, the standard must provide means for
monitoring the availability of power at each Power Interface. This
includes indicating whether a power supply at a Power Interface is
switched on or off.

5.2.6. Use of Power

The standard must provide means for monitoring each Power Interface
if it is actually in use. For inlets, this means that the device
actually receives power at the inlet. For outlets, this means that
power is actually provided from the outlet to one or more devices.

5.2.7. 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 a device.

5.2.8. Nominal Voltage Range

The standard must provide means for reporting the nominal voltage
range for each Power Interface.

5.2.9. Nominal AC Frequency

The standard must provide means for reporting the nominal AC
frequency for each Power Interface.

5.2.10. 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 dedicated metering hardware is required. Entities without the
ability to measure with high accuracy their power, received energy,
and provided energy 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 a 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 power supplied to a device are also of
interest. For AC power supply in particular, several Power
Attributes beyond the real power are of potential interest to Energy
Management Systems. The set of these properties includes the complex
Power Attributes (apparent power, reactive power, and phase angle of
the current or power factor) as well as the actual voltage, the
actual AC frequency, the Total Harmonic Distortion (THD) of voltage
and current, and the impedance of an AC phase or of the DC supply. A
new standard for monitoring these Power Attributes should be in line
with already-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 / Power Factor

The standard must provide means for reporting the real power for each
Power Interface as well as for an 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 used to obtain
these values. 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, 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 a device. For
   AC power supply, means must be provided for reporting the actual
   voltage and actual current per phase.

5.3.6. High-Power/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 / Power Factor

   The standard must provide means for reporting the complex power for
   each Power Interface and for each phase at a Power Interface. In
   addition to the real power, at least two of the following three
   quantities need to be reported: apparent power, reactive power, and
   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.
   For 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 a
   power supply for each Power Interface. For 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 to
   provide the 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 that possibly use different Power State sets while
   simultaneously interfacing with a particular entity, the Energy
   Management System must provide means for supporting multiple Power
   State sets used simultaneously at an entity.

   Power States have parameters that describe their properties. It is
   required to have a standardized means for reporting some key
   properties, such as the typical power of an entity in a certain
   state.

   There is also a need to report statistics on Power States, including
   the time spent as well as 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. Typical Power Per Power State

   The standard must provide means for retrieving the typical power for
   each supported Power State.

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 the
requirements in Section 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

The 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 timestamps 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 Measurement

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
requirements on Power State statistics described in Section 5.4.7.

5.6. Battery State

Batteries are special entities that supply power. 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 through 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, its
temperature, and additional 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, in units of milliampere-hours (mAh).

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. Actual Battery Temperature

The standard must provide means for reporting the actual temperature
of a battery.

5.6.6. 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.

5.6.7. Low Battery Charge Notification

The standard must provide means for generating a notification when the charge of a battery decreases below a given threshold. Note that the threshold may depend on the battery technology.

5.6.8. Battery Replacement Notification

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

5.6.9. Multiple Batteries

If the battery technology allows, the standard must provide means for meeting requirements in Sections 5.6.1 through 5.6.8 for each individual battery contained in a single entity.

5.7. Time Series of Measured Values

For some network management tasks, obtaining time series of measured values from entities, such as power, energy, battery charge, etc., is required.

In general, time series measurements could be obtained in many different ways. 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 the 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 timestamps or, alternatively, by mean values for
these quantities averaged between two (consecutive) timestamps 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 IP Flow Information Export (IPFIX) protocol [RFC7011]
[RFC7012]. The Simple Network Management Protocol (SNMP) [RFC3411]
is an example of 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. If the comparison of time series between multiple entities
is required, then time synchronization between those entities must be
provided (for example, with the Network Time Protocol [RFC5905]).

5.7.2. Time Series Interval Types

The standard must provide means for supporting alternative interval
types. The requirement in Section 5.5.2 applies to every reported
time value.

5.7.3. Time Series Storage Capacity

The 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.

A power supply is typically not self-managed by devices, and control
of a power supply is typically not conducted as an interaction
between an Energy Management System and the device itself. It is
rather an interaction between the management system and a device
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 device.

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 a power supply off or
turning a power supply on at Power Interfaces providing power to one
or more devices.

7. Reporting on Other Entities

As discussed in Section 5, not all energy-related information may be
available at the entity in question. Such information may be
provided by other entities. This section covers only the reporting
of information. 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 the entities
belonging to that set need to be identified.

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 Information 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. Note that, in some situations, a
   manual configuration might be required to populate this information.

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 Information 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 what type or types of energy-
   related information can be reported, and for which entities.

8. Controlling Other Entities

   This section specifies requirements for controlling Power States and
   power supply of entities by communicating with other entities that
   have the means for doing that control.

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 the 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, a way to make
   this control accessible to the Energy Management System is needed.

   In addition, it is required that an entity that has its state
   controlled by other entities has the 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 controls the
Power States of entities other than the entity to which the command
was sent.

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 the means to control
their Power States. Note that, in some situations, a manual
configuration might be required to populate this information.

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 the requirement in Section 6.2.

In addition, it is required that an entity that has its supply
controlled by other entities has the means to report the list of
these other entities. This need is already addressed by requirements
in Sections 5.2.3 and 5.2.4.

9. Security Considerations

Controlling Power State and power supply of entities are considered
highly sensitive actions, since they can significantly affect the
operation of directly and indirectly connected devices. Therefore,
all control actions addressed in Sections 6 and 8 must be
sufficiently protected through authentication, authorization, and
integrity protection mechanisms.

Entities that are not sufficiently secure to operate directly on the public Internet do exist and can be a significant cause of risk, for example, if the remote control functions described in Sections 6 and 8 can be exercised on those devices from anywhere on the Internet. The standard needs to provide means for dealing with such cases. One solution is providing means that allow the isolation of such devices, e.g., behind a sufficiently secured gateway. Another solution is to allow compliant implementations to disable sensitive functions, or to not implement such functions at all.

The monitoring of energy-related quantities of an entity as addressed in Sections 5 through 8 can be used to derive more information than just the received and provided energy; therefore, monitored data requires protection. This protection includes authentication and authorization of entities requesting access to monitored data as well as confidentiality protection during transmission of monitored data. Privacy of stored data in an entity must be taken into account. 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 through 8. The security mechanisms must meet the security requirements detailed in Section 1.4 of [RFC3411].

9.2. Isolation of Insufficiently Secure Entities

The standard must provide means to allow the isolation of entities that are not sufficiently secure to operate on the public Internet, e.g., behind a gateway that implements sufficient security that the vulnerable entities are not directly exposed to the Internet.

9.3. Optional Restriction of Functions

The standard must allow compliant implementations to disable sensitive functions, or to not implement such functions at all, when operating in environments that are not sufficiently secured. This applies particularly to the control functions described in Sections 6 and 8.

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