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                        Energy Reporting Framework
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Abstract

   Managing energy consumption of devices presents new challenges and
   issues. The EMAN Requirements draft identifies essential
   capabilities needed to accomplish this. This draft describes how an
   energy management system can use EMAN to gather and interpret data
   from individual devices, and how some of the Requirements are
   implemented in the model. This document focuses on Energy Reporting,
   though acknowledges and fully includes the limited control functions
   specified in the Requirements draft. Topics addressed in detail
   include the topology of power distribution, reporting mechanisms, and
   the various roles of devices, power interfaces, and components.

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Table of Contents

1. Introduction

   Managing energy consumption of devices is different from typical
   network management functions because of the special nature of energy
   supply and use. The EMAN Requirements draft [RFC6988] identifies
   necessary capabilities for an energy management standard. This
   document describes how an energy management system (EnMS) uses EMAN
   and how to use and interpret EMAN data.

   In addition to the Requirements draft, this document derives content
   and inspiration from several now-expired drafts: Considerations for
   Power and Energy Management [I-D.norwin-energy-consider], Energy
   Perspective on Applicability [I-D.nordman-eman-energy-perspective],
   and most significantly, the Reference Model for Energy Management
   [I-D.quittek-eman-reference-model]. The EMAN Applicability statement
   [I-D.ietf-eman-applicability-statement] is also informative.

   The current EMAN Framework draft [I-D.ietf-eman-framework] addresses
   some of the requirements in ways suitable for this framework,
   particularly for Advanced capabilities (see Section 5). Those
   requirements are noted below.

   The EMAN requirements are overwhelmingly about the reporting of
   energy data, not about control. The only requirements that address
   control are setting power state (directly and by a proxy) and cutting
   power supply. Thus, while these are fully included in this
   framework, it is titled "Energy Reporting" to match the empirical
   facts about the content of the EMAN requirements.

1.1. Guiding Principles

This presentation, in form and content, takes simplicity as an
overarching goal. Complexity is burdensome for implementation of
EMAN capabilities in individual devices, burdensome for
implementation of management systems, and burdensome for readers and
users of this standard to understand what they need to to accomplish
their goals.

Energy management involves people of many backgrounds and so
documents about it should be accessible to a wide variety of
audiences, from network professionals, to energy professionals, to
building managers, or any person with an interest in energy use.

2. Concepts

At the core of this framework are just a few key concepts. Energy is
used by Devices. Devices have Power Interfaces, which are like
network interfaces, through which power is transferred into or out of
a device. Devices may have internal components with distinct power
consumption or other characteristics. Measurement for devices occurs
at interfaces so that the total or net consumption of a device can be
determined from these. EMAN data are transferred from a device to an
Energy Management System.

2.1. Energy Management System

An Energy Management System (EnMS) is an entity that receives EMAN
data from many devices and interprets it. An EnMS is often in the
same building as the devices being monitored. A building can have
zero, one, or many EnMS. A device can do both, acting as an EnMS and
reporting EMAN data to another EnMS. While the EMAN Requirements
draft does not identify requirements for an EnMS, it is necessary to
understand some of EnMS operation to fully describe how the EMAN
framework operates.

Basic EnMS operations include: discovering relevant devices,
acquiring static data about them, acquiring dynamic data about them
on a periodic basis, processing the resulting data, and implementing
control and/or reporting functions.

2.2. Device

A Device is most commonly a complete product. At any given time, a
device may be drawing electricity in, and may be sending electricity
out. Combining these results in the net energy consumed by a device.

For devices with a single power interface, there is an identity
between data about the interface and about the device as a whole, so
the two can share an identity within EMAN. The power interface
reports some data that a device does not (see Section 2.5) so that in
most cases both will be needed.

2.3. Power Interface

A Power Interface (PI) is an interface on a device through which
power can flow into a device (an inlet) or out of it (an outlet).
Some PIs change over time from being an inlet to being an outlet and
vice versa, however most PIs never change. Most devices have a
single inlet. Devices with multiple inlets often have them connected
to separate power distribution trees. Most devices have no outlets,
but those that do often have many. The only distinction between an
inlet and outlet is the sign of the power value: positive for an
inlet and negative for an outlet. A PI can indicate whether it is
capable of being only an inlet, only an outlet, or can switch between
the two. PIs are all contained (in ENTITY MIB sense) in the device;
a PI is never contained in a component, and a PI cannot contain
anything within it. A PI consumes no power itself. It is always on
the border of a device, never internal.

The flow of electricity within a building is determined by which
power interfaces are connected to each other - the wiring topology.
Thus, a key attribute of a PI is a list of the other interfaces it is
connected to. The power interface term is not new. It is used
similarly by the Power over Ethernet (PoE) standard [IEEE-802.3af]
and [IEEE-802.3at] where a power interface denotes the interface
between a device and the Ethernet transmission medium.

2.4. Component

A component is a distinct part of a device. Components lack some of
the features of devices, such as having power interfaces; instead,
they simply have a net total consumption from the pool of power
available within a device. A component can contain other components,
that draw from the pool of power within the containing component.

2.5. Energy Object

Devices, PIs, and Components are all Energy Objects (EOs). The term
"entity" in the Requirements draft generally corresponds to Energy
Object. The kinds of data available for an EO depends on its type as
shown in Figure 1. Basic data will be implemented by many or most
devices. Most devices are unlikely to implement advanced data.

The total energy and power for a device must match the total of all

of its PIs. PIs dump power into or take power out of the pool of
power in a device. A component draws power from the pool.
Components do not have power interfaces. The sum of all components
in a device may be less than total device consumption as there may be
hardware consuming power that is not part of any modeled component.

```
Device PI Component  Kind
                  Basic
  X    X     X      Identification
  X    X     X      Local data
       X           Power Interfaces
       X           Power, static
  X    X     X      Power
  X    X     X      Power state
  X    X     X      Energy
  X                Reporting
                  Advanced
  X    X           Identification, Advanced
       X           Power, Advanced
             X      Battery``````
  X    X     X      Energy, Advanced
  X    X     X      Time-series data
  X                Reporting, advanced
  X                Proxy control
```

                    Figure 1: Kinds of EMAN data

2.6. Battery

   A battery in a device is a special type of component. EMAN has
   battery-specific data such as battery chemistry and charge state, see
   [I-D.ietf-eman-battery-mib]. A device can report on a battery with
   the battery-specific data, the component data, or both.

3. Topologies

   EMAN covers several distinct topologies, particularly the
   distribution of electricity and the communication of information.
   The ability of EMAN to model power interfaces (PIs) of devices
   enables flexible and powerful capabilities. This section describes
   some of them. With this model an EnMS can query all devices in a
   building for their EMAN data and combine what it receives from each
   into a comprehensive picture of electricity flows and device state.

3.1. Power Distribution

   An EnMS combines all the data it acquires to create as complete a
   picture of power flows as possible; it is not necessary for each

device to have complete information about its connectivity. For
example, terminal devices that only consume power may only know the
identity of the PI from which they draw power. The EnMS then sees
many devices connected to a single outlet PI and can infer that they
are all wired to each other, regardless of whether the supplying PI
knows the identity of the devices it powers. Similarly, a supplying
device may know the identify of the PI it supplies power to and so
can create the map, even if the supplied device does not know where
it draws power from.

For each PI on a device, the group of PIs that are known to be
directly wired to that PI is reported. In Figure 2, Device-A can
report that its PI-1 is wired to PI-2, and Device-B can report that
PI-2 is wired to PI-1. The EnMS knows that PI-1 is part of Device-A
and that PI-2 is part of Device-B. Only one of the PIs needs to know
of the wiring connection for the EnMS to fully understand it. The
drawing shows how a PI is part of a device but is on its periphery.
The line shown is of power flow only.

```
    +---------------+                   +---------------+
    |         +--------+         +--------+         |
    | Device-A |  PI-1  |>-------->|  PI-2  | Device-B |
    |         +--------+         +--------+         |
    +---------------+                   +---------------+
```
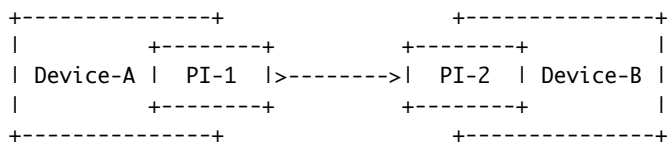
            Figure 2: Simple wiring topology example

Figure 3 shows how wiring is commonly done in AC supply systems, with
Device A being a circuit breaker. In this case, four devices are
wired together. It is possible that all four know of the identity of
all others, but commonly less is known. PI-2, PI-3, and PI-4 may
each know they are wired to PI-1, and PI-1 may know nothing, but the
linkage of all four can be inferred by the EnMS. As another example,
PI-3 and PI-4 may know of the connection to PI-1, with PI-1 knowing
it is connected to PI-2; this also enables construction of the full
set. Finally, PI-1 could know it is connected to PI-2 and PI-3, but
have no knowledge of PI-4; however, it could observe that PI-2 and
PI-3 do not account for all the energy leaving PI-1 and so infer that
at least one other device is also wired to PI-1.

```
                          +--------+----------+
                     ---->|  PI-2  | Device-B |
    +---------------+     |    +--------+----------+
    |         +--------+     |    +--------+----------+
    | Device-A |  PI-1  |>-------->|  PI-3  | Device-C |
```

```
    |         +--------+     |    +--------+----------+
    +---------------+     |    +--------+----------+
                     ---->|  PI-4  | Device-D |
```
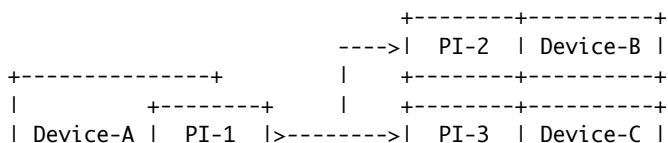
```
                        +--------+---------+
```

Figure 3: Typical AC wiring topology example

Figure 4 shows how wiring is commonly done in DC supply systems, with
Device-A being a PoE switch, USB hub, or similar device. For
technologies which inherently have communication, device identity can
be readily determined.

```
    +----------+--------+          +-------+---------+
    |          | PI-1  |>-------->|  PI-4  | Device-B |
    |          +--------+          +-------+---------+
    |          +--------+          +-------+---------+
    | Device-A |  PI-2  |>-------->|  PI-5  | Device-C |
    |          +--------+          +-------+---------+
    |          +--------+          +-------+---------+
    |          | PI-3  |>-------->|  PI-6  | Device-D |
    +----------+--------+          +-------+---------+
```
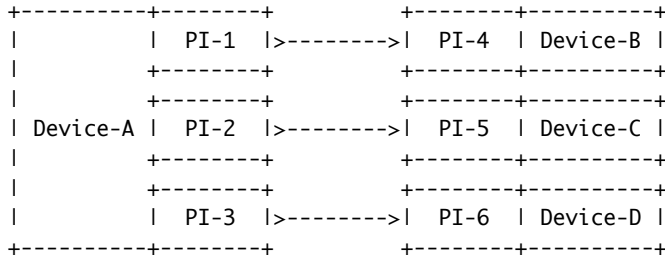
Figure 4: Typical DC wiring topology example

From the capability of each PI (or the direction of power flow on
first report) it is clear which PI is the source. For devices that
provide power (typically a power distribution unit, circuit breaker,
or PoE switch), one can determine which PIs are inlets and which are
outlets. Thus, mapping a traditional tree-structured power
distribution system is a simple process.

Some installations have more complex power distribution, as with more
than one device providing power to a circuit, or PIs that can and do
change the direction of power flow. These can be readily modeled
though require more sophisticated interpretation by the EnMS.

An EnMS may choose to put information it has inferred (principally
about PI connectivity) back into the individual devices, but is not
required to. Doing so is valuable when there is more than one EnMS
present.

With a power distribution map, a management system knows which
devices supply power to which other devices, so that the effect of
switching off a PI (usually at an outlet, but possibly at an inlet)
can be determined. The same applies to metering at PIs, which can
also occur at an outlet or inlet.

   Power source control is accomplished by physically preventing power
   from flowing, or re-enabling it. In contrast, power state control is
   accomplished by communication protocols and not by power distribution
   control so that power state control mechanisms and capabilities have

no required relation to power distribution systems. Power control
for a PI is modeled with power state, with on corresponding with
power able to flow, and off that power cannot flow.

3.2. Reporting

Only devices report data; PIs and components do not. An EMAN device
may report on itself, or on a device other than itself. Self-
reporting is the basic EMAN case and simply involves a device putting
its internal data into the EMAN representation. The EnMS knows the
identity of the device doing the reporting and the identity of the
device being reported on, and these are the same. The left side of
Figure 5 shows this.

```
      +----------+            +----------+
      |   EnMS   |            |   EnMS   |
      +----------+            +----------+
           ^                       ^
           |                       |
      +----------+            +----------+      +----------+
      | Device-A |            | Device-A |<-----| Device-B |
      +----------+            +----------+      +----------+
```
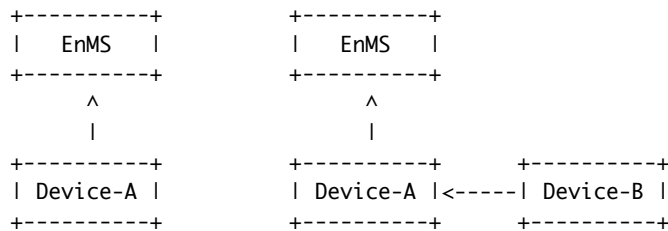
                  Figure 5: Two basic reporting scenarios

The other EMAN case is non-self-reporting, or other-reporting. The
EnMS knows the identity of the device reporting and the identify of
the device being reported on and can see that they are different.
There are three types of other-reporting relationships, where
Device-B is:

a) an IP device (like Device-A) that has the ability to report
   EMAN data to an EnMS,
b) an IP device that does not have the ability to report EMAN data
   to an EnMS, or
c) a non-IP device.

The right side of Figure 5 shows this where the Device-B to Device-A
communication technology depends on which case applies.

Case a) is particularly useful when some amount of collection and/or
summation is done. Summation can be across energy objects, and/or
across time for an individual energy object. The reporting device

may retain the detailed data in case it becomes of interest to an
EnMS later.

Case c) includes circumstances in which some or all of the EMAN data
are communicated over non-IP mechanisms, as well as when the EMAN

device monitors power flowing to the monitored device and may have
access to other information, such as the identity of the device it
provides power to.

Case b) is similar to c) except that the device reported on is an IP
device that is unable to report data in EMAN format.

Practically, the EnMS is indifferent to the distinction between these
cases or even whether the data is self-reported or other-reported; it
only matters what device is being reported on.

The lines shown in Figure 5 are data transfer, not power flow. For
the right side of Figure 5, Device-B could be powered by Device-A, or
have no power relation at all with Device-A (only a reporting
connection). How Device-A obtains the data about Device-B has no
effect on how the data are reported.

4. Fulfilling Basic EMAN Requirements

This section further elaborates the ER Framework and shows how its
features fulfill many of the requirements in the EMAN Requirements
draft. Each subsection includes the relevant requirements,
abbreviated (for the full list see Section 7). Requirement numbers
are noted in the text where the requirement is met. This section
only covers basic requirements that many devices will implement.
More advanced capabilities and requirements are covered in Section 5.

When implementing EMAN capability on a device, only the basic
identification data are required. All other data in Section 4 and
all data in Section 5 are optional to report. In a few cases,
features included that do not derive from specific requirements are
included, and these are always identified as such.

4.1. Identification

  4.1. uniquely identifying entities.

           Figure 6: EMAN Requirement for Identification

There are only two truly mandatory items for an energy object to
implement in EMAN. The first is a unique identity (UUID) (4.1). The
second is an energy object type which can be device, component, power
interface, or aggregate device (see Section 6.3). The EMAN Framework

specifies the UUID and includes an integer as an index for the energy
objects the device can report on.

In addition to the requirements, a widely useful feature for a device
is to report a URL for standard manufacturer data on the brand/model
of the device, represented as a string. Related to this, and also

not derivative of a requirement, is a string for each of the brand
(manufacturer) and model of the device.

4.2. Local Data

   5.1.1. configure, retrieve and report a textual name or a description
   5.1.2. retrieving and reporting context information ..., for example,
         tags associated with an entity that indicate the entity's role.
   5.1.3. retrieving and reporting the significance of entities within
         its context, for example, how important the entity is.
   5.1.4. retrieving and reporting Power priorities of entities. Power
         priorities indicate an order in which Power States of entities
         are changed.
   5.1.5. 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.

                  Figure 7: EMAN Requirements for Local Data

   Local data are those generated at the point of product use and so are
   created for each building individually. The first item is a text
   string for the name (5.1.1). The second is a list of keywords, each
   of which will be a pair of strings, one representing a name or type
   and the other one representing a value (5.1.2, .3, .4, .5). Since
   none of these data types - role, priority, grouping, domain, or
   device type - has been standardized, their representation and
   encoding are determined locally. This flexible mechanism can be used
   for various purposes, as the following examples illustrate using
   different notation styles.

      role="switch"

      powerDownPriority: 6

      "lineofbusiness:Helpdesk"

      <location>South Wing</location>

      domain::office

4.3. Power Interfaces

   5.2.1. monitoring the list of Power Interfaces of a device.
   5.2.2. monitoring the operational mode of a Power Interface which is
         either "Power Inlet" or "Power Outlet".
   5.2.3. identifying the Power Outlet that provides the Power received
         at a Power Inlet.

5.2.4. identifying the list of Power Inlets that receive the Power
        provided at a Power Outlet.
     5.2.5. monitoring the availability of Power at each Power Interface.
        ... indicates whether ... supply is switched on or off.
     5.2.6. monitoring for each Power Interface if it is in actual use.
        ... inlets ... device actually receives Power. ... outlets ...
        Power is actually provided.

                 Figure 8: EMAN Requirements for Power Interfaces

     PIs provide wiring topology and are the source of core energy and
     power data. A device provides PI information as a list of UUIDs of
     PIs it contains (5.2.1). Each PI provides a list of UUIDs of PIs
     that it knows it is wired to (5.2.3, .4). The power mode of a PI is
     indicated by the sign of the power value; positive for power flowing
     in, and negative for power flowing out (5.2.2). The availability of
     power at a PI is shown by its power state (see Section 4.6) (5.2.5).
     Actual flow of power is indicated by the power value being non-zero
     (5.2.6).

     Since wiring topology usually changes only infrequently, it would be
     burdensome for an EnMS to constantly refresh these data. To avoid
     this, a device can provide a timestamp of the last time there was a
     wiring topology change. Only when this changes does an EnMS need to
     rescan the topology. This feature does not arise from a listed
     requirement.

     Another capability not specified by any requirement is what
     directions of power flow a PI is capable of. This is indicated by an
     enumeration value of either inlet-only, outlet-only, or both.

4.4. Power, Static

     5.2.7. reporting the type of current (AC or DC) for each Power
        Interface as well as for a device.
     5.2.8. reporting the nominal voltage range for each Power Interface.
     5.2.9. reporting the nominal AC frequency for each Power Interface.
     5.2.10. reporting the number of AC phases for each Power Interface.

                 Figure 9: EMAN Requirements for Power, Static

     These characteristics of power apply only to PIs and are static.
     They do not change so can be set at the factory. They can be
     represented by an enumeration (5.2.7), two strings (5.2.8, .9), and
     an integers (5.2.10).

     The requirements say that a device should also report its type of
     current, but as some devices support both AC and DC simultaneously on
     different PIs. There is not always a single type of current for a

whole device (as there is for a single PI). This is a shortcoming of
the requirements document, and the situation is covered by single PI
devices (see Section 2.2).

4.5. Power

    5.3.1. reporting the real power for each Power Interface as well as
        for an entity. ... includes ... the direction.
    5.3.2. reporting the corresponding time or time interval for which a
        Power value is reported.

               Figure 10: EMAN Requirements for Power

    Power is represented as an integer and a power-of-ten multiplier and
    the direction of power is by its sign (5.3.1; see Section 4.3). Any
    kind of energy object can report power level data. The time of a
    power reading is indicated by a corresponding timestamp.

4.6. Power State

    5.4.1. reporting the actual Power State of an entity.

               Figure 11: EMAN Requirement for Power State

    The EMAN Framework [I-D.ietf-eman-framework] describes how EMAN
    supports devices to have any number of power state series, and at any
    time, a state can be reported for each. This representation is
    suitable. Each energy object has a list of power state series it
    supports and a corresponding state for each entry in the list
    (5.4.1).

    For PIs, the state indicates whether or not power can flow: 'on'
    means power can flow, 'off' that power unable to flow, and 'sleep'
    that only trickle power is available. Technologies which support
    trickle power include PoE, USB, and UPAMD. Since the IEEE 1621 power
    state series has these three states and only these, it is a natural
    one to use for PIs.

4.7. Energy

    5.5.1. reporting measured values of Energy and the direction of the
        Energy flow received or provided by an entity. ... report the
        Energy passing through each Power Interface.
    5.5.2. reporting the time interval for which an Energy value is
        reported.

               Figure 12: EMAN Requirements for Energy

    Energy is reported as an accumulated meter reading and a timestamp

(5.5.1). An EnMS subtracts one reading/timestamp from a later one to
get an interval of time and the energy flow during that time (5.5.2).
The sign of this energy value indicates whether net energy was
brought into a device or component (a positive value) or sent out of
it (a negative one) (5.5.1).

4.8. Control

   6.1. setting Power States of entities.
   6.2. switching Power supply off or turning Power supply on at Power
        Interfaces.

              Figure 13: EMAN Requirements for Control

   A device or component may accept a command to set the power state
   value to attempt a changing of the power state (6.1). For a PI, this
   turns supply on and off (6.2; see Section 4.6). No new data elements
   are introduced by these requirements.

4.9. Reporting

   7.1. an entity to report information on another entity.
   7.2. reporting the identity of other entities on which information is
        reported. ... For entities that report on one or more other
        entities.
   7.4. reporting the complete list of all those entities on which
        Energy-related information can be reported. ... For entities that
        report on one or more other entities.

              Figure 14: EMAN Requirements for Reporting

   Each device must be able to report the UUIDs of each device it can
   report for, including itself (7.2). An EnMS can request data for any
   listed device (7.1, .4). It can also request data for any PI or
   component of any listed device.

4.10. Data Summary

   The basic requirements above result in the following data elements
   for a fully compliant implementatios. Note that a minimal
   implementation would only require the first two data elements. In
   the table below, the first column lists which type of energy objects
   are relevant: device, PI, or component. The second column lists the
   requirement level, mandatory, recommended, or optional.

   EOs R Kind   Data
   --- - -------------- ---
   DPC m Identification Index (within the device)

```
DPC m              UUID (for unique identification globally)
D   o              URL for brand/model specifications
D C o              Brand, model (strings)
DPC m Local Data   Text name
DPC o              Keyword list (strings)
D   r Power Interf. List of PIs in device (UUIDs)
 P  r              List of PIs known to be connected to PI (UUIDs)
 P  r              Timestamp of last change to wiring topology
 P  m Power, Static Type of current (AC or DC)
 P  m              Nominal voltage range, AC frequency, AC phases
DPC r Power        Timestamp of power reading
DPC r              Numeric value and exponent for power in W
DPC m Power State  List of supported power state series
DPC m              Current power state (for each supported series)
DPC m Energy       Timestamp of energy reading
DPC m              Numeric value and exponent for energy in Wh
D   r Reporting    List of devices that can be reported on (UUIDs)
```

                 Figure 15: Summary of Basic EMAN Data

   A key point about the above table is that it is modest in size and
   minimally burdensome for both implementers and those who use the EMAN
   data in real buildings.

5. How the ER Framework Fulfills Advanced EMAN Requirements

   This section describes how the ER Framework fulfills the rest of the
   requirements in the EMAN Requirements draft. Each subsection begins
   with the requirements listed, abbreviated, as from Section 7. Most
   devices will not implement any of these, and many EnMS may not as
   well. That said, for those devices and buildings where these are
   relevant, these provide important capability. Many readers can skip
   this section entirely. For most of these, content from the EMAN
   Framework draft is suitable.

5.1. Identification, Advanced

   4.2. indicating whether identifiers ... are persistent across a
        re-start.
   4.3. indicate any change of entity identifiers.
   4.4. re-using entity identifiers from existing standards including
        ... the Entity MIB module ... the LLDP MIB module ... the
        LLDP-MED MIB module ... and the ... the Power Ethernet MIB. ...
        Generic means for re-using other entity identifiers must be
        provided.

       Figure 16: EMAN Requirements for Identification, Advanced

These require a flag for identifier persistance (4.2), a timestamp of
the last entity identifier change (4.3), and a list of identifiers
each consisting of a pair of strings, one string representing a type
and the other one representing a value (4.4).

5.2. Power, Advanced

   5.3.3. means to indicate the method how these values have been
      obtained.
   5.3.4. reporting the accuracy of reported Power and Energy values.
   5.3.5. reporting the actual voltage and actual current for each Power
      Interface as well as for a device. In case of AC Power supply ...
      per phase.
   5.3.6. creating notifications if Power values of an entity rise above
      or fall below given thresholds.
   5.3.7. reporting the complex power for each Power Interface and for
      each phase at a Power Interface.
   5.3.8. reporting the actual AC frequency for each Power Interface.
   5.3.9. reporting the Total Harmonic Distortion (THD) of voltage and
      current for each Power Interface.
   5.3.10. reporting the impedance of Power supply for each Power
      Interface. In case of AC Power supply ... per phase.

              Figure 17: EMAN Requirements for Power, Advanced

   The treatment of these requirements in the EMAN Framework draft is
   suitable. Note that 5.3.3, .4, and .6 apply to any energy object,
   but the rest only apply to PIs.

5.3. Power State, Advanced

   5.4.2. retrieving the list of all potential Power States of an
      entity.
   5.4.3. supporting multiple Power State sets simultaneously at an
      entity.
   5.4.4. retrieving the list of all Power State sets supported by an
      entity.

   5.4.5. retrieving the list of all potential Power States of an entity
      for each supported Power State set.
   5.4.6. retrieving the typical Power for each supported Power State.
   5.4.7. 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.
   5.4.8. generating a notification when the actual Power State of an
      entity changes.

                 Figure 18: EMAN Requirements for Power State

   The treatment of these requirements in the EMAN Framework draft is

suitable.

5.4. Energy, Advanced

   5.5.3. reporting the received and provided Energy for each individual
         Power State.

            Figure 19: EMAN Requirement for Energy, Advanced

   The treatment of these requirements in the EMAN Framework draft is
   suitable, except for the notion of distinct values for consumed,
   provided, and net consumption (see Section 6.2).

5.5. Battery

   5.6.1. reporting the current charge ... in units of milliampere hours
   5.6.2. reporting the charging state (charging, discharging, etc.)
   5.6.3. reporting the number of completed charging cycles
   5.6.4. reporting the actual capacity
   5.6.5. reporting the actual temperature
   5.6.6. reporting static properties ... including the nominal
         capacity, the number of cells, the nominal voltage, and the ...
         technology.
   5.6.7. generating a notification when the charge ... decreases
         below a given threshold.
   5.6.8. generating a notification when the number of charging cycles
         ... exceeds a given threshold.
   5.6.9. meeting requirements 5.6.1 to 5.6.8 for each individual
         battery contained in a single entity.

                Figure 20: EMAN Requirements for Batteries

   The treatment of these requirements in the Battery MIB draft
   [I-D.ietf-eman-battery-mib] is suitable.

5.6. Time-series Data

   5.7.1. reporting time series of Energy values. If ... comparison ...
         between multiple entities ... is required, then time
         synchronization ... must be provided.
   5.7.2. supporting alternative interval types. Requirement 5.5.2
         applies to every reported time value.
   5.7.3. should ... reporting the number of values of a time series
         that can be stored.

              Figure 21: EMAN Requirements for Time-series data

   Time-series data is of the same form as single-value data for power

and energy, notably a timestamp plus the relevant value. Thus,
reporting is of a list of these (5.7.1). Every interval type can be
derived from pairs of single-value data, by subtracting the time and
energy values (5.7.2). For sequential windows, adjacent values are
compared; for overlapping windows, non-adjacent values are compared.
The energy object must be able to report the number of available time
series data slots (5.7.3). A device must be able to accept a setting
of time from an EnMS for time syncronization (5.7.1), though for
security purposes, this might affect only EMAN reporting and not
change the global system clock of the device. To implement all this,
a device must be able to accept commands to initiate time-series data
collection, including the requested time interval.

5.7. Reporting, Advanced

   7.3. reporting the list of all entities from which contributions are
        included in an accumulated value.
   7.5. indicating which Energy-related information can be reported for
        which of those entities. ... For entities that report on one or
        more other entities.

              Figure 22: EMAN Requirements for Reporting, Advanced

   This framework includes the concept of an aggregate device (7.3; see
   Section 6.3). No new dta elements are required for this. The method
   to implement 7.5 is TBD.

5.8. Proxy Control

   8.1.1. an Energy Management System to send Power State control
          commands to an entity that concern the Power States of [other]
          entities.
   8.1.2. reporting the identities of the entities for which the
          reporting entity has means to control their Power States.
   8.1.3. an entity to report the list of all entities for which it can

          control the Power State.
   8.1.4. an entity that receives commands controlling its Power State
          from other entities to report the list of all those entities.

                Figure 23: EMAN Requirements for Proxy Control

   Only a device can control the power state of another entity, but any
   energy object can be controlled this way. An energy object that can
   be controlled by a proxy must be able to provide a list of
   controllers (8.1.4). A device must be able to provide a list of
   energy objects that it is capable to control the power state of
   (8.1.2). 8.1.3 appears to be a duplicate of 8.1.2. To use this
   feature, a device receives a power state set command for a UUID that
   it is not itself.

5.9. Security

   9.1. provide privacy, integrity, and authentication mechanisms for
        all actions addressed in Sections 5 - 8. ... must meet the
        security requirements elaborated in Section 1.4 of [RFC3411].
   9.2. allow for isolation of entities that that are not sufficiently
        secure to operate on the public Internet.

                Figure 24: EMAN Requirements for Security

   The treatment of these requirements in the EMAN Framework draft is
   suitable.

6. EnMS Operation

   The full utility and application of EMAN can only be understood with
   some understanding of how an EnMS operates. This section covers
   several of these. This section does not introduce new data items.

6.1. Incomplete data

   Section 3 noted that data on PI connectivity need not be complete to
   be useful, and need not be complete on every device to be
   comprehensive. The ability to report and use incomplete data is
   generic in EMAN. This is particularly valuable for including the
   many legacy devices with few or no EMAN capabilities.

   Note that for the case in the right side of Figure 5, the data
   available from Device-A and Device-B need not be the same. There may
   be a different combination of PIs and components available on them,
   and for each energy object, one of the devices may know and report
   more data than the other.

   Devices may lack power or energy detail for several PIs but still be
   able to report data about the device total.

6.2. Separately Tracking Energy Flows by Direction

   In some cases it may be desired to separately track the flows of
   energy into or out of a device, PI, or component for those that
   support bi-directional power flow. When the direction of power flow
   changes within a reporting period, the opposite flows cancel each
   other out, giving a correct indication of the net flow, but lacking
   the tracking of the total in each direction. Doing this is readily
   accomplished by having two PIs in place of one, or two components in
   place of one. Each is used only for a single direction of power
   flow. In this way, the separate directions are correctly tracked,
   and by summation, the net flow can be calculated. Implementations

which desire this (batteries being a prime example) can do this, and
those that do not simply use a single PI or component. This ability
adds no data fields or complexity to the ER framework.

6.3. Aggregate Devices

An aggregate device is a not a real device, but an information
construct to represent the summation of data across a set of energy
objects. It has a UUID as any device does, has no power interfaces
(since it does not interact with power in the real world), and has
one or more components. Each component of an aggregate device can be
any type of energy object. Commonly, all objects in an aggregate
object will be of the same type (all devices, all PIs, or all
components) but this is not required. A device may or may not report
any data for the UUIDs in the aggregate object components; all that
is required is to have the component UUIDs. The aggregate device
concept introduces no new data items to the EMAN structure.

In producing an aggregate result, EMAN does not define how a
reporting device should treat incomplete data, any mismatch in the
alignment of timestamps among the objects to be aggregated, or
whether power states should be aggregated or how such an aggregation
would be interpreted. A device is free to do whatever it likes in
this regard. The only requirement is that power and energy reported
reflect a summation of all the constituent energy objects. Since
this is an aggregate device and not an aggregate PI, advanced power
data are not reported.

Common examples of aggregate objects might be all servers in a data
center rack, all fans in a data center, all devices in a single room,
all lights in a building, or all devices under the financial
responsibility of a single tenant.

6.4. Proxy Control

Control of the power state of one device by a second device is not
common, but does occur. A prime example is the ability to wake (or
turn on) a sleeping PC with the "Wake On LAN" technology. Another
example would be when the device being controlled is not an IP
device.

6.5. Cloud Devices

Another use of EMAN to accomplish real-world needs is through the use
of "cloud" devices. Like an aggregate device, these are not a single
real-world object (or not necessarily one), but do correspond to real
wiring topology. An example is a tree-structured wiring topology
with circuit breaker panels. An individual circuit breaker, or
collection of them, can be represented as a cloud device. The meter

device shows a PI on it wired to an inlet PI on the cloud device, and individual end-use devices (or downstream circuit breakers) are wired to an outlet PI on the cloud device. The cloud device has a UUID, but is not a device on the network, and no data are reported from the cloud device. Since no data are reported, there is no cloud device of energy object.

What this does is correctly represent the data known about the wiring topology, while hiding some potentially-existing (but unknown) complexity inside the cloud. It adds no complexity to the EMAN model and only adds the creation and use of a single UUID in PIs as appropriate. It is flexible in allowing for a wire variety of topologies of devices, clouds, and devices operating as meters.

6.6. External Power Meters

A device which is only a power meter is modeled exactly as any other device. It is modeled as a device that has an inlet power interface receiving power and one or more outlet power interfaces providing power. The fact that a device may consume none of the energy that passes through it is not relevant to EMAN, and in this case, the quantitative values on both PIs will be identical except of opposite sign.

A DC-powered blade server in a chassis has its own identity on the network and if it reports for itself, it is a separate device, not a component of the chassis. Similarly, a PoE-powered device can be modeled as either a separate device, or a component of the powering device.

7. EMAN Requirements Summary

This section summarizes the content of the EMAN Requirements document, lists all specific requirements. The text is excerpted for brevity, in one case text in [brackets] is added, and "..." indicates text deleted within a requirement. The words "should" and "must" occur in the introductory text; these are often redundant to the actual requirements and so are not included in this list. Requirements generally begin with "The standard must provide means for ..."; this text is omitted. The headings below are not part of the requirements draft.

Requirements: Basic

Identification
4.1. uniquely identifying entities.

Local Data
5.1.1. configure, retrieve and report a textual name or a description

5.1.2. retrieving and reporting context information ..., for example,
       tags associated with an entity that indicate the entity's role.
5.1.3. retrieving and reporting the significance of entities within
       its context, for example, how important the entity is.
5.1.4. retrieving and reporting Power priorities of entities. Power
       priorities indicate an order in which Power States of entities
       are changed.
5.1.5. 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.

Power Interfaces
5.2.1. monitoring the list of Power Interfaces of a device.
5.2.2. monitoring the operational mode of a Power Interface which is
       either "Power Inlet" or "Power Outlet".
5.2.3. identifying the Power Outlet that provides the Power received
       at a Power Inlet.
5.2.4. identifying the list of Power Inlets that receive the Power
       provided at a Power Outlet.
5.2.5. monitoring the availability of Power at each Power Interface.
       ... indicates whether ... supply is switched on or off.
5.2.6. monitoring for each Power Interface if it is in actual use.
       ... inlets ... device actually receives Power. ... outlets ...
       Power is actually provided.

Power, Static
5.2.7. reporting the type of current (AC or DC) for each Power
       Interface as well as for a device.
5.2.8. reporting the nominal voltage range for each Power Interface.
5.2.9. reporting the nominal AC frequency for each Power Interface.
5.2.10. reporting the number of AC phases for each Power Interface.

Power
5.3.1. reporting the real power for each Power Interface as well as
       for an entity. ... includes ... the direction.
5.3.2. reporting the corresponding time or time interval for which a
       Power value is reported.

Power State
5.4.1. reporting the actual Power State of an entity.

Energy
5.5.1. reporting measured values of Energy and the direction of the
       Energy flow received or provided by an entity. ... report the
       Energy passing through each Power Interface.
5.5.2. reporting the time interval for which an Energy value is
       reported.

Control
6.1. setting Power States of entities.

6.2. switching Power supply off or turning Power supply on at Power
     Interfaces.

Reporting
7.1. an entity to report information on another entity.
7.2. reporting the identity of other entities on which information is
     reported. ... For entities that report on one or more other
     entities.
7.4. reporting the complete list of all those entities on which
     Energy-related information can be reported. ... For entities that
     report on one or more other entities.

Requirements: Advanced

Identification, Advanced
4.2. indicating whether identifiers ... are persistent across a
     re-start.
4.3. indicate any change of entity identifiers.
4.4. re-using entity identifiers from existing standards including
     ... the Entity MIB module ... the LLDP MIB module ... the
     LLDP-MED MIB module ... and the ... the Power Ethernet MIB. ...
     Generic means for re-using other entity identifiers must be
     provided.

Power, Advanced
5.3.3. means to indicate the method how these values have been
       obtained.
5.3.4. reporting the accuracy of reported Power and Energy values.
5.3.5. reporting the actual voltage and actual current for each Power
       Interface as well as for a device. In case of AC Power supply ...

       per phase.
5.3.6. creating notifications if Power values of an entity rise above
       or fall below given thresholds.
5.3.7. reporting the complex power for each Power Interface and for
       each phase at a Power Interface.
5.3.8. reporting the actual AC frequency for each Power Interface.
5.3.9. reporting the Total Harmonic Distortion (THD) of voltage and
       current for each Power Interface.
5.3.10. reporting the impedance of Power supply for each Power
        Interface. In case of AC Power supply ... per phase.

Power State
5.4.2. retrieving the list of all potential Power States of an
       entity.
5.4.3. supporting multiple Power State sets simultaneously at an
       entity.
5.4.4. retrieving the list of all Power State sets supported by an
       entity.
5.4.5. retrieving the list of all potential Power States of an entity

for each supported Power State set.
5.4.6. retrieving the typical Power for each supported Power State.
5.4.7. 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.
5.4.8. generating a notification when the actual Power State of an
       entity changes.

Energy, Advanced
5.5.3. reporting the received and provided Energy for each individual
       Power State.

Battery
5.6.1. reporting the current charge ... in units of milliampere hours
5.6.2. reporting the charging state (charging, discharging, etc.)
5.6.3. reporting the number of completed charging cycles
5.6.4. reporting the actual capacity
5.6.5. reporting the actual temperature
5.6.6. reporting static properties ... including the nominal
       capacity, the number of cells, the nominal voltage, and the ...
       technology.
5.6.7. generating a notification when the charge ... decreases
       below a given threshold.
5.6.8. generating a notification when the number of charging cycles
       ... exceeds a given threshold.
5.6.9. meeting requirements 5.6.1 to 5.6.8 for each individual
       battery contained in a single entity.

Time-series data

5.7.1. reporting time series of Energy values. If ... comparison ...
       between multiple entities ... is required, then time
       synchronization ... must be provided.
5.7.2. supporting alternative interval types. Requirement 5.5.2
       applies to every reported time value.
5.7.3. should ... reporting the number of values of a time series
       that can be stored.

Reporting
7.3. reporting the list of all entities from which contributions are
     included in an accumulated value.
7.5. indicating which Energy-related information can be reported for
     which of those entities. ... For entities that report on one or
     more other entities.

Proxy Control
8.1.1. an Energy Management System to send Power State control
       commands to an entity that concern the Power States of [other]
       entities.
8.1.2. reporting the identities of the entities for which the

reporting entity has means to control their Power States.
      8.1.3. an entity to report the list of all entities for which it can
            control the Power State.
      8.1.4. an entity that receives commands controlling its Power State
            from other entities to report the list of all those entities.

      Security
      9.1. provide privacy, integrity, and authentication mechanisms for
            all actions addressed in Sections 5 - 8. ... must meet the
            security requirements elaborated in Section 1.4 of [RFC3411].
      9.2. allow for isolation of entities that that are not sufficiently
            secure to operate on the public Internet.

8.   Outstanding Issues

      The following are questions that need further consideration by the
      EMAN working group.

8.1. How to Address Requirement 7.5

      "7.5. indicating which Energy-related information can be reported for
      which of those entities. ... For entities that report on one or more
      other entities." An EnMS could simply query all data for an energy
      object and observe what are available. A more efficient mechanism
      could be defined. Regardless, any value should have "unknown" as an
      option.

8.2. EMAN Framework Content

      Incorporate details from the EMAN Framework draft and the Battery MIB
      draft where they are to be included substantially as-is.

8.3. Metering

      Add text to section 3 explaining how measurement done at different
      power interfaces leads to conclusions about device metering.

8.4. PI Capability

      Per Section 4.3, should there be a data element to indicate if a PI
      can be only an inlet, only an outlet, or either?

8.5. Data Representation for Section 5.1

      Consider the syntax of the items to be represented and whether the
      proposal for a single text string is sufficient. Possibly provide
      examples.

8.6. Move Requirement Satisfaction Details to Appendix

   Consider whether the details in sections 4 and 5 on how specific
   requirements are satisfied should be moved to an appendix. Sections
   4 and 5 would retain, and possibly expand, their explanation of the
   framework content itself. This would make the document more readable
   (and shorter, not counting the appendix) while retaining
   documentation of the relationships of framework content to
   requirements in the appendix.

9. Security Considerations

   This memo currently does not impose any security considerations.

10. IANA Considerations

   This memo has no actions for IANA.

11. Acknowledgements

   This memo was inspired by discussions with many people, including
   (but not limited to) Juergen Quittek, Rolf Winter, Benoit Claise,
   John Parello, and Mouli Chandramouli.

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