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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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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 [REF] 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 [REF, -02], Energy Perspective on Applicability [REF, -01], and most significantly, the Reference Model for Energy Management [REF, -03], The EMAN Applicability statement [REF] 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 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 usually in the same building as the devices being monitored. A building can have zero, one, or many EnMS. A device can be both an EnMS and report 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 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.

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

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.

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. 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. 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

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.

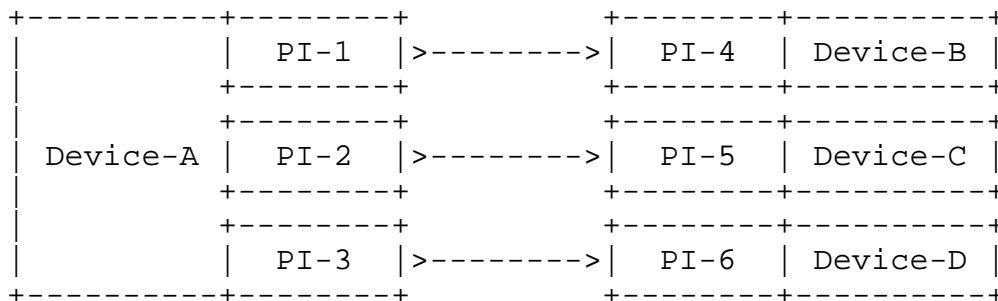


Figure 4: Typical DC wiring topology example

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.

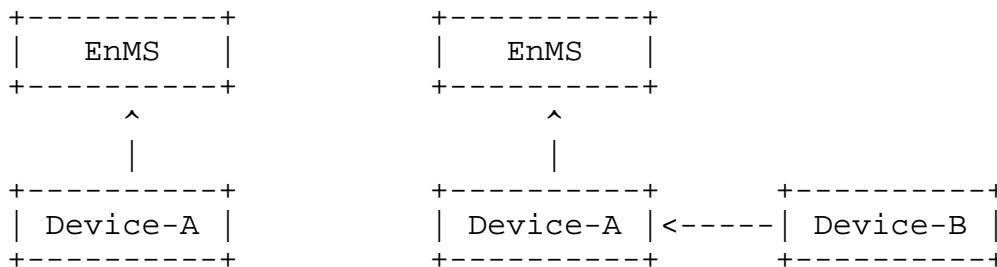


Figure 5: Two basic reporting scenarios

The other EMAN case is non-self-reporting, or other-reporting. The EnMS knows the identity of the device reporting and the identity 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. How the ER Framework Fulfills Basic EMAN Requirements

This section describes how the ER Framework fulfills 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 below are optional to report.

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.

It is not in the requirements, but a widely useful feature for a device would be to report a URL for standard manufacturer data on the brand/model of the device, represented as a string.

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 needed is a text string for the name (5.1.1). The second is a list of keywords, each of which will typically be of the form "name=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.

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. Each device provides 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. An enumeration could indicate this as 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 an error in 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 in the EMAN Framework 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). This representation is suitable. Any 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 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 needed data elements. Note that for a specific implementation, only the first two are required. In the table below, the first column lists which type of energy objects are relevant: device, PI, or component.

EOs	Kind	Data
DPC	Identification	Index (within the device)
DPC		UUID (for unique identification globally)
D		URL for brand/model specifications
DPC	Local Data	Text name
DPC		Keyword list (strings)
D	Power Interfaces	List of PIs in device (UUIDs)
P		List of PIs known to be connected to PI (UUIDs)
P		Timestamp of last change to wiring topology
P	Power, Static	Type of current (AC or DC)
P		Nominal voltage range, AC frequency, AC phases
DPC	Power	Timestamp of power reading
DPC		Numeric value and exponent for power in W
DPC	Power State	List of supported power state series
DPC		Current power state (for each supported series)
DPC	Energy	Timestamp of energy reading
DPC		Numeric value and exponent for energy in Wh
D	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 persistence (4.2), a timestamp of the last entity identifier change (4.3), and a list of strings for additional identifiers, with each having a format of "type: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 (REF) 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 synchronization (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, complex 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 wide 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. Topology Changes

Ideally topology would never change so the EMS need only query it once. A date/time stamp for time of last topology change would enable the EMS to know when it needs to rescan the topology. Section 4.3 proposes adding this.

8.2. 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.

8.3. Fix References

Correctly include the proper reference material.

8.4. EMAN Framework Content

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

8.5. 8.1 Requirements

Are 8.1.2 and 8.1.3 duplicative?

8.6. 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?

9. Security Considerations

This memo currently does not impose any security considerations.

10. IANA Considerations

This memo has no actions for IANA.

11. Acknowledgements

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