Energy reporting on networks

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"If you cannot measure it, you cannot improve it"

Lord Kelvin

Summary

The widespread lack of knowledge of how much energy is used by particular devices or end uses in buildings is a well-known barrier to identifying savings opportunities from equipment that is inherently inefficient, performing anomalously, or being operated unnecessarily or inefficiently.

An increasing number of energy-using products are connected to networks for either energy purposes, or (more commonly) reasons unconnected to energy. The coming years should see this rise dramatically. Regardless of the reason, the connectivity can be taken advantage of to enable each device to report data on its own status, power level, and energy use for a variety of management purposes.

The dominant network technology today is the Internet Protocol (IP), so a standard method for IP-connected devices to report their identity and energy (power) is likely to be an essential element in the infrastructure for managing energy use and efficiency in the coming decades. The goal is for every network-connected device in future to use the same protocol for this purpose for maximum benefit and interoperability.

This report documents progress by the Internet Engineering Task Force to establish such a protocol for reporting energy information. This will provide a sound platform for the development of future energy management strategies for inter-dependent devices and could dramatically improve end use energy information as well as demand response.

Introduction

Perhaps no technological developments in the past few decades have had as much affect on our lives and on commerce as those in communications in general and networking in particular. The largest parts of this, the Internet (and its myriad applications), voice communications (including mobile systems), and video distribution are increasingly concentrated on use of the Internet Protocol (IP) as the core medium to distribute information. Systems installed in buildings traditionally have not been networked to any great extent, and for many decades, when communications was required, they used technologies not used elsewhere. In recent times, an increasing number of devices in buildings are gaining rich network connectivity by supporting IP.

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Internet standards have traditionally not engaged the topic of energy consumption and efficiency. Work on sensor networks and mobile networks has been cognizant of the limitations of battery powered devices in energy use, but that has been driven by the lack of mains power rather than concern for mains power consumption. Thus, energy as a central concern is new to Internet standards.

The work documented in this report is one of the first examples of core Internet Protocols dealing with energy use and efficiency issues (or at least facilitating them).

Network Concepts

This discussion only makes sense when some basic facts about network technology are understood. These concepts are not too numerous or complicated, at least to the depth of understanding needed here.

Layers

Modern networks are designed with "layers" of functionality so that details of one layer are only exposed (ideally) to the layers immediately above and below. The abstract "reference model" for networks is the Open System Interconnection Reference Model (OSI), which has seven layers, but for our purposes they can be reduced to three groups: data link (Layers 1 and 2), network (layers 3 and 4, which includes the Internet Protocol), and application (layers 5 to 7). For reference, the seven OSI layers are:

1. Physical
2. Data link
3. Network
4. Transport
5. Application (Session)
6. Application (Presentation)
7. Application

Topology

IP networks have two basic parts: Local Area Networks (LANs) and Wide Area Networks (WANs). Some protocols operate only over LANs. Others, such as those that deliver our email or web pages, operate across the Internet (collection of many interconnected WANs). Most energy information is of interest only within a building and so operates only within a LAN.

Protocols

Communication across a network is embodied in "protocols" which define how the information is encoded and what it means. Protocols exist at every OSI layer, but this discussion does not cover the data link layers of 1 and 2, which relate only to the physical connection properties of each individual data link within the network.

Institutions

The Internet is a "network of networks" that connect with each other by mutual agreement to behave according to standard conventions and technologies. Standards for the lower layers of communication (data link – OSI layers 1 and 2) are defined by hardware-oriented organizations such as the Institute for Electrical and Electronic Engineers (IEEE), such as for Ethernet and Wi-Fi. The middle layers (OSI layers 3 and 4) that enable network functionality are defined by the Internet Engineering Task Force (IETF). A few application layer protocols are defined by the IETF, with the rest of the applications defined by a myriad of organizations. While there are many physical layer technologies and many application layer protocols, the IETF defines a "narrow waist" of protocols that are universal, or at least very widely used.

The IETF is "an organized activity of the Internet Society". The Internet Society (ISoc) is a non-profit organization based outside Washington, DC., originally founded by companies and other organizations that viewed interoperable network technology as critical to their products or mission. Figure 1 shows the relationship of the IETF to the ISoc and related entities. The Internet Research Task Force (IRTF) conducts research on topics that may later end up in IETF work. The Internet Assigned Numbers Authority (IANA) administers various critical sets of numbering and naming that enable key Internet functions. The other entities in the figure are the Internet Architecture Board, the Internet Administrative Support Agency, Internet Area Directors, and the Internet Engineering Steering Group.

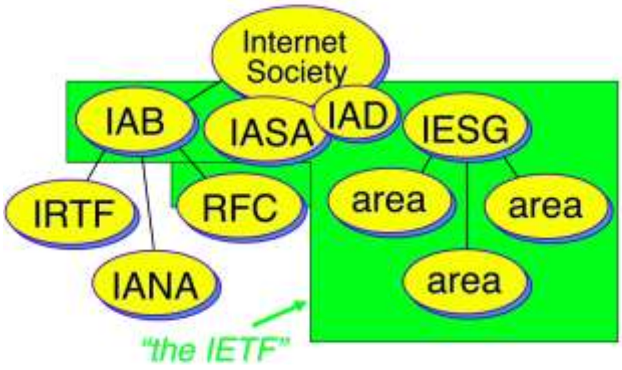

Figure 1. ISoc Entities. *Source: IETF*

The real work of the IETF is accomplished through working groups on particular topics, which are grouped by "area". These are created on an as-needed basis to address a specific topic area, and when finished they either disappear or are given new tasks. An RFC (Request For Comments) is the name that is given to IETF "standards"; there is an intricate process for reviewing and processing RFCs to ensure quality.

The IETF is an extremely open and transparent organization. There are no membership fees or other barriers to participation. Anyone can join any working group email list, and the email traffic for working groups is public and archived. All proposed standard content is always public. There are even facilities for participating remotely into in-person meetings (which happen three times/year in various parts of the world).

The result of all of this is that IETF standards are widely used, robust, generally free of proprietary content, and universally respected. Recently we have seen the exhaustion of the pool of IPv4 addresses handed out to the regional registries around the world that allocate addresses to organizations that need them (e.g. companies and Internet Service Providers). This has brought IPv6 to the fore as a technology that will vastly increase the number of IP addresses available. Not surprisingly, it is the IETF that created IPv4 and IPv6, and has defined mechanisms to manage the transition.

Energy Management

In networks, management is a necessary activity for the network to work at all, work well, be reliable and be efficient. It is a step removed from actual application activity that serves a particular user function or need. One management activity is configuration, to set device behavior and knowledge so that devices are permitted to work. Another function is to track the status of each device connected to the network over time, so that problems or anomalies can be detected and dealt with at the earliest possible stage.

Energy is a classic management topic that has not been included in the primary application functionality for the Internet. It is not the primary function of any device to use energy; energy consumption is just a necessary precondition to many activities. The designers of the Internet did not foresee that information on energy consumption of connected devices was essential to make the Internet work quickly and efficiently. That was true for several decades, but recently it has become clear that it is no longer the case.

Energy management encompasses a variety of activities, some strictly about reporting and analyzing energy status, with others integrated with control functions. Some examples of different purposes are:

- Understanding how much energy (power) different devices and end uses are using in a room or building (at a particular time).
- Tracking energy consumption over time.
- Billing tenants or departments for the energy they use directly.
- Understand energy consumption to know how to manage its consequences such as heat removal.
- Planning for power provisioning and reliability services (e.g. UPS systems).
- Identifying devices that are consuming energy anomalously and so may be malfunctioning or mis-configured.
- Controlling devices to reduce consumption without unduly interfering with the services they deliver.

Control functions usually are involved with the service delivered by the product and so need to take into account product functionality and context. This introduces many complications and so control is likely for the most part to be accomplished by mechanisms other than the reporting one. However, there is no reason to preclude an energy reporting mechanism from part of a reporting protocol.

Since reporting is strictly observational, it is tied little or not at all to the particular characteristics and purpose of a product and so can be generic in the way that the format of a store receipt is generic.

IETF and Energy

For most areas of information technology, energy efficiency was not a topic of great concern until recently, and Internet technology is no exception. In December of 2007, the first plenary presentation was made to IETF 70 (the meetings are numbered) by this author. That presentation gave an overview of energy use in electronics and networks to put them into context, relay activities within other network standards organizations, and identify areas where the IETF might act. There was no immediate result from that presentation, but the energy topic was increasingly of interest to individuals within the IETF and that interest grew over the next year and a half. In 2009, there were explicit discussions in the “opsawg” (Operations Area Working Group) on a possible activity to address energy management in the IETF. In 2010, the first “Internet Drafts” (I-Ds) were posted on the IETF web site (this is the name of all documents reviewed in the IETF, including both those intended to eventually become an RFC — an IETF standard). Finally, in the summer of 2010 a charter for a new working group was proposed, and received final approval in September, 2010, so that its first meeting was at IETF 79 in November, 2010. Benoit Claise of Cisco Systems (based in Belgium) was selected as a co-chair due to his interest in the topic and extended experience in the IETF. This author was selected as the other co-chair to ensure that the “energy perspective" within a policy context was represented, since usually there are no people at IETF meetings whose primary concern is energy use and efficiency.

The charter for the new Energy Management Working Group (eman or EMAN) can be found at `datatracker.ietf.org/wg/eman/charter/` but as it is lengthy it is not reproduced in whole here, but only in excerpts. It begins:

> Energy management is becoming an additional requirement for network management systems due to several factors including the rising and fluctuating energy costs, the increased awareness of the ecological impact of operating networks and devices, and the regulation of governments on energy consumption and production.
>
> The basic objective of energy management is operating communication networks and other equipments with a minimal amount of energy while still providing sufficient performance to meet service level objectives. A discussion of detailed requirements has already started in the OPSAWG, but further exploration in the EMAN WG is needed. Today, most networking and network-attached devices neither monitor nor allow control energy usage as they are mainly instrumented for functions such as fault, configuration, accounting, performance, and security management. These devices are not instrumented to be aware of energy consumption. There are very few means specified in IETF documents for energy management, which includes the areas of power monitoring, energy monitoring, and power state control. The OPSAWG started working on a MIB module for monitoring energy consumption and power states of energy-aware devices and found that more than just a MIB module was needed to manage energy in networks. Rather a new framework for energy management needs to be developed first.

One aspect of this is that the original concern was for energy management of network equipment and network-connected equipment like servers in highly managed environments such as data centers and telecommunications facilities. While the charter does not limit the group's interest to these devices, they are of special interest.

A few items deserve explanation. A "service level" agreement is a specification such as capacity, reliability, delay, etc., that an IT service provider guarantees to a customer. That is, system performance can be variable so long as it does not fall below a threshold. A "MIB module" is a description of a data structure for representing complex information. "Management Information Base" (MIB) is the generic term used in the Internet context for the concept of the data and data structure used for management purposes. It is most well known in being used in the SNMP (Simple Network Management Protocol) protocol for getting and setting such data across the network, but it can be used by other protocols. The module defines variable names, content, meaning, and grouping. A given network device then implements all or a portion of a module.

The charter calls out Power over Ethernet (PoE) powered devices as well as "smart power strips" as of special interest since the measurement and reporting in these cases may be done by a second device, not the device itself. It is also worth noting that the charter uses the term "building network" for how network technology will be applied to energy-using devices that today are not networked. The working group is tasked to produce six documents as follows (headings and other text in the alternate font are quotes from the charter)

1. Requirements for energy management

Capabilities that the defined protocol should enable and support. Control is to be considered.

2. Energy management framework

The structure of the protocol and data structure, including "power and energy monitoring, power states, power state control, and potential power state transitions". Special focus is to be put to "IP-based network equipment (routers, switches, PCs, IP cameras, phones and the like)"[2].

3. Energy-aware Networks and Devices MIB document

This draft will cover "devices identification, context information, and potential relationship between reporting devices, remote devices, and monitoring probes."

4. Power and Energy Monitoring MIB document

"... power states and energy consumption/production. … monitoring of power states … retrieving power states, properties of power states, current power state, power state transitions, and power state statistics. … detailed properties of the actual energy rate (power) and of accumulated energy… electrical power quality". In other words, this draft addresses the energy-specific information, and the previous one data necessary or helpful for interpreting it.

5. Battery MIB document

Information about batteries. This document may be only loosely related to the rest, but was seen as a minor need in the OPS area working group for which the eman WG was the best home.

6. Applicability statement

Where the others are to be used or not used, and how the facility relates to other protocols and standards.

The schedule for the working group specifies that all work is to be completed by the end of the calendar year 2011, though it is common for schedules to slip within the IETF.

Application

The generic model used is that within a building (or subset of a building), there is a management system (either an NMS, "network management system" or an EMS, "energy management system") that asks for and uses the data from individual devices. The process may be assisted by intermediate devices that collect, aggregate, and/or process the data on their way from the end use device to the management system. What the nature of the management system and what it does with the data is outside the scope of the working group. Various organizations will define or implement management systems, either creating new ones, or adding the "eman" functionality to existing network management systems, or existing energy management systems. The standard will enable any management system to talk to any "eman" device so long as both comply with the standard.

While the charter reflects the interest in IETF participants in network (and closely related) equipment, there is no need to limit the standard to those devices. In fact, ANY device that uses energy in a building should be able to use the protocol, so long as either it has an IP connection, or the relevant data can be conveyed to a second device which has an IP connection. Non-building uses of energy such as in industry and transportation are not explicitly mentioned in the charter, though not precluded from using the eman protocol. There are standards organizations for industrial process management that include or are adding energy reporting to their standards.

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[2] In fact, only switches and routers are network equipment; PCs, cameras, and phones are network-attached devices.

Implementation

While other protocols could use the eman MIB modules, the expectation is that SNMP will be the first and dominant protocol used. Today, many information technology (IT) devices implement SNMP, particularly servers, network equipment, personal computers, and printers. The first SNMP standard in the IETF is dated 1990, though it certainly dates back farther in time than that. There are three versions of the standard, as capability and security were added. Thus, there is extensive experience in industry in implementing support for SNMP if they don't already have it, so that devices with Internet Protocol (IP) capability can readily add support for SNMP. Implementing the specific eman functionality is then readily done on top of that. In fact, most products that implement SNMP today are ones that can receive updates to their firmware and software, so that supporting eman on these can be done with a simple software upgrade[3]. So, with the cooperation of equipment manufacturers, millions or billions of existing devices could be upgraded to support the protocol. In any case, over time it will be new products that dominate so ensuring that they support the eman facility is most important. Upgrading of existing products can help make the standard useful more quickly and so gain a critical mass of support.

While the ideal scenario for eman is to use a hardware power meter circuit as the basis for highly accurate power and energy data, many devices can estimate their power consumption (and hence track energy use) from what is known about the basic power consumption patterns for that model, its hardware configuration, and operational states (modes). The fact that the data are estimates and not actual measurements will be noted in the eman reporting, but data that are accurate to within only 5% (for example) are far superior than no data at all. Tracking time is well-established and easy to do in electronics and circuits to do this are already present in many devices. Thus, while there will be a modest hardware cost for the optimal implementation, useful results can be attained with no hardware cost.

Technical Issues

The process within IETF working groups for generating the content in IETF standards (RFCs) is a combination of people submitting and refining Internet Drafts, exchanging ideas on the working group's email list, and discussing issues in the face-to-face meetings held three times per year. All of these activities are documented on the IETF web site. Some progress is made in side conversations among groups of people, but these must be brought into the process through one of the above methods. Those who write a draft will modify it until such a time as a draft is selected as a "working group item" after which the working group has control of edits to the document (an original author may be selected as the editor). A draft being accepted as a working group item does not mean that all the technical issues are resolved — it just means that it is a sufficiently advanced document to work from.

The eman group as of May, 2011 has selected four drafts as working group items, leaving two that are not yet ready for that stage (the Power and Energy Monitoring MIB and the Applicability Statement). There are six other drafts associated with the working group that have been submitted.

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[3] In principle this is possible for IP devices that don't already support SNMP, just a more extensive update.

The IETF works on "rough consensus"; not voting, and not unanimity. People speak for themselves, though of course often reflect the interests of the organization which employs them. Everyone presumably believes that the proposals they make are the best technical solution and direction, but other factors that influence people's opinions include: concern for the special needs of particular product types (e.g. for eman, PoE switches and "smart power strips"), compatibility with other standards, ease of implementation, flexibility, simplicity, universality, and consistency with current product offerings. On this last point, some products implement similar capability to eman's goals through proprietary means, so it is helpful for manufacturers of those products if the difference between them and what eman ultimately produces is as small as possible.

The largest constituency around when the eman scheme was originally conceived (and still to date) is employees of Cisco Systems, so that the charter and several of the working group items reflect that perspective. The most other proposals have come from employees of NEC Research Europe, Cyberswitching Inc., and Lawrence Berkeley National Laboratory. These have been put in the form of Internet Drafts.

Some of the topics raised are not technical issues, but are to do with how the resulting standard is presented. For example, I have been concerned that the documents should begin by stating that "all products are in scope" and not just network equipment and closely related devices. This does not require any changes to the technical content of the drafts, but it is more about how the standard is presented and "marketed". There is already in the drafts the aspect of this of enabling coverage of both IP devices and non-IP devices, and there has been no questioning of that. Related to this is ensuring that there is some eman document which is readily accessible to a wide range of audiences, including people with very little knowledge of networks (most IETF documents are only ever read by people with significant technical background).

An aspect of the intended scope of the standard is the list of "use cases", usage contexts, or scenarios that the working group considered in creating the standard. This is one of the ways to reflect the universal application principle. This is presently being moved into the Applicability Statement document. It seems likely that the working group will fully accept this direction.

One topic that was an ongoing source of disagreement was representation of power states of devices. There were variously proposals for 100, 12, 6, and 3 basic power states that devices would be mapped onto. Reasons to choose particular sets were to enable fine-grained control based on power states, adopting particular series of states from other technology standards, or focusing on states that were truly universal. Ultimately it was agreed that there would be a registry of power states with IANA (the ISoC organisation which manages such data types) to hopefully minimize the number of different state sets, and to seed it with states from the DMTF (a standards organization), ACPI (a technology standard), and the basic states of On/Sleep/Off (and perhaps also Ready).

At the last IETF working group meeting in Prague (Czech Republic), there was a presentation on industrial energy monitoring. The proposal was not to cover industrial devices in the standard, but rather to look for opportunities for harmonization (in both directions), as both groups cover a substantial amount of common territory.

There are some features intended for the eman system that are common to both the current drafts and the alternative "Reference Model" (see below). One is for one device being able to "proxy" for non-IP devices to bring them into the eman system. For example, a heating system for a building might have old proprietary communications including reporting on equipment status and energy use. A “gateway” device can translate that data to the eman system.

Another common feature is accounting for power distribution “domains” though the details of the domain feature are still being discussed.

Details of battery monitoring are coming together and seem to be uncontroversial.

Other technical issues are still being discussed. The major ones include the design model for the MIBs, and the topic of identify.

Reference Model

The current eman drafts take a device-centric view of the system architecture, in defining the various entities in the system and then what they are capable of (REFs). This derives from the model in the Cisco EnergyWise product offering.

An alternative model (the “Reference Model”, *Quittek and Nordman, 2011*) takes a “functional approach” to the architecture, first defining the various functions that need to be performed, and only secondarily noting what devices might implement the various functions (some devices implement multiple functions). This model emerged from conversations between the authors of the model, Juergen Quittek of NEC, and this author. Thus, this discussion is necessarily biased towards the Reference Model.

Some goals for the Reference Model are to be Universal, Simple (as possible), focus only on reporting (though not excluding the possibility of control), and layer on complexity so that simple devices are not burdened by extra features desired by complex devices. Also the reference model takes a more distributed approach (though does not exclude central control) whereas the current drafts are biased to central control.

An example of how the Reference Model focuses on functions first is that the function of distributing power (e.g. in a PoE switch) and the function of aggregating data are separate. They may both be implemented by one device, but that is an implementation choice, not required by the model. The Reference Model also is more explicit in allowing for incomplete solutions that nevertheless provide useful data.

Core functions are: using power, having a battery, supplying power to other devices, and aggregating data from other devices. A key issue at present is whether a reporting device needs to know the identity of the device it is reporting to – and whether there is a single tree of data reporting, or possibly multiple trees of reporting.

The process for coming to a consensus between these two approaches remains to be defined, but all participants sincerely want to come to a sound conclusion.

Identity

A topic this author sees as critical is the notion of “Identity” of a device. This has multiple aspects, some of which already exist. For example, other MIBs have a text string for a human-readable name for a device, e.g. “4th floor switch” or “Mail Server C”, and the IP and MAC addresses of a device uniquely identify a device. What appears to be missing is a more general sense of what a device is, what I have sometimes called “Species” (e.g. switch, server, notebook PC, display, …) and “Origin” (e.g. brand X, model Y, and a URL for the brand/model). The species designation would be modeled on the Linnaean system used in biology to classify species, though with much less complexity (likely just 2 or 3 levels of hierarchy rather than seven, and dozens of types rather than dozens of millions).

At the IETF meeting in March, I presented this to the OPS Area Working Group. A key point of feedback is that identity was likely to be over-interpreted by many people and that "classification" might be a more productive term to use for what I wanted to create.

Other topics

There are some issues that remain to be solved, that either should be resolvable without great difficulty, or can be left for some future version of the standard without greatly reducing its utility.

One of these topics is details of power measurement and estimation such as AC vs DC power, the role of low-power modes (when a device might not be able to report), wire losses, and units (Wh or J). It is expected that accuracy will be variable based on the device and part of what is reported, rather than a fixed sense of accuracy required.

Another topic is devices with multiple power sources. Many aspects of power reporting would be simpler if every device had only one source of power. In fact, the vast majority do, but there are exceptions. A particular reason to do this is to have the sources from separate electrical systems, which further complicates attribution of power consumption. Work on this should continue, but should there be some loose ends or worse, that should not keep the rest of the standard from moving forward. (Note that internal batteries are not a "source" of power for this purpose, or at least I believe that).

Representation of time is a common feature of many information systems (electronic and otherwise). A number of complexities arise in power reporting regarding time. One is that the clock of different systems may be different, so that time stamps need to be implicitly or explicitly tagged with whose time they follow. Reporting purposes may not require a common time, but does require understanding where differences are. Having time that is at least close does help in aggregation.

Portable devices (e.g. notebook computers) also introduce complexity. In the ideal world, there is a static population of devices that have power consumption patterns. When devices move, they accumulate power consumption in different electricity domains and in different buildings, and it can become a policy decision how one wants to account for these.

Ultimately, the first version of the eman protocol[4] will not cover all cases, but should cover the vast majority of IP devices and the vast majority of energy used by IP devices.

Policy implications

Once the eman working group has completed defining its documents, and once there are a few products that have implemented these on the market, policy makers can reasonably begin to require that devices implement the standard, either to obtain voluntary labels (e.g. Energy Star), or in mandatory standards. Since the standards development is in process, policy makers can announce their intention to implement the requirement, but not put the requirement officially into place until the standard and products are more widely available. As an example, a recent discussion document from

[4] EMAN is *not* defining a new protocol, but simply a way to use an existing protocol, along with some data structures. However, it can be useful to refer to it as a protocol in casual language.

the Energy Star program for computers has noted the eman effort as something that could become a requirement.

A key reason for the success of the Internet is its use of protocols that become universal. There should be no need for a competing standard Internet protocol for this purpose for general application. It may be desirable to define standard subsets to the eman MIBs, as well as standard extensions for situations with more complexity. In addition, there may be other protocols than SNMP that could transport the data so that standard alternatives to this could be identified. In all of these cases, they are adaptations of the eman work so that interoperability can be maintained.

Note that there can be an extended time between when a working group completes its work on a standard and when it passes the last milestone in official approval in the IETF process (and sometimes, a widely used standard doesn't even make it to that point in the approval process). While it is theoretically possible for a standard (an RFC) to be rejected or substantially modified along the final approval process, that is not likely, so wide use of the eman standard should not be delayed once the work is "finished".

As the protocol gets wide use, it will become reasonable to consider additional features that should be added to a second version of it, and to bring those to the IETF. In general when this is done, the IETF provides mechanisms for backwards compatibility so that more advanced and earlier systems are interoperable. As an example, there are three versions of SNMP, and systems which implement version 2 can interoperate with version 1 systems. Similarly, version 3 systems can interoperate with those that only have version 1 or 2.

There may be other things that the IETF can do to facilitate saving energy. The eman protocol will be a solid base to build on for such activities.

Next Steps

Work on this protocol development by the Energy Management Working Group in the IETF is scheduled to conclude in late 2011, but could continue into 2012. It is critical that there is ongoing input from an energy policy perspective into the Energy Management Working Group. This will ensure that the resulting protocols are functional and effective for use in future policy developments.

Once the relevant specifications are finalized by the IETF, there are a range of opportunities for implementation in a practical sense. Policies can encourage or require these protocols in future products.

Once the capability for power reporting exists, we need to have some sense as to how it will or could be used. This will vary widely depending on the building type, management style, device, and other factors. For example, it could be used for an *ad hoc* exploration of the behavior of a single device, or for an ongoing system that collects data about all devices it can in a building. It could be used to assess energy efficiency, or simply for billing tenants or others for the energy they use. It also has application when energy resources are limited, either on an ongoing basis, or for emergency or other anomalous conditions.

Another topic is how this facility relates to the Smart Grid. A key question is to what degree building owners want to expose the energy use of individual devices to outsiders like "the grid". In many cases, concern for privacy will dictate not doing this, though also in most cases, there is little rationale argument as to why the grid even needs such information. SNMP is generally implemented only within local area networks. It is likely that any exposing of this information to the outside world will be through some sort of gateway for security and functional reasons. All this aside, one could use eman to implement control based on signals from the grid, but again, it would be through some sort of gateway that would make policy decisions.

Defining these systems and their operation will be an important next step towards the development of a universal energy management and demand response system for buildings in the commercial and residential sectors. This is a significant new area of work and will need vision and dedication to achieve global application.

Conclusions

Energy reporting over the network will be a valuable tool for tracking energy use and efficiency, and will provide many opportunities for coordinated energy management of products within networks. It may also offer a universal interface for communication with the Smart Grid. By using infrastructure installed for other reasons (IP networks), implementing energy reporting and energy management can be very low cost and so will be highly cost-effective. The IETF is the core Internet standards organization and so the logical place to define this capability, and is presently in the process of defining a standard for this purpose. Policy makers will be able to require this functionality for future products as a way to make sure that it gets the widest possible implementation and use.

Once the work of the IETF is completed, work on the development of practical systems to utilize this new, powerful functionality will be needed.

Glossary

4E	IEA Implementing Agreement on Efficient Electrical End-use Equipment
ACPI	Advanced Configuration and Power Interface
AP	Wireless Access Point (AP or WAP)
DMTF	Distributed Management Task Force
EMAN	Energy Management Working Group
EMS	Energy Management System
ES	Energy Star program (US EPA, DOE)
Ethernet	IEEE 802.3 wired network technology
I-D	Internet Draft
IANA	Internet Assigned Numbers Authority
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IT	Information Technology
LAN	Local Area Network
MAC	Media Access Control
MIB	Management Information Base
NMS	Network Management System
OPSAWG	Operations Area Working Group
OSI	Open System Interconnection Model (ISO 7498)
PoE	Power over Ethernet

RFC	Request For Comments
SNMP	Simple Network Management Protocol
WAN	Wide Area Network
Wi-Fi	IEEE 802.11 – wireless network technology
WG	Working Group

References

Nordman, Bruce, Hans-Paul Siderius, Lloyd Harrington, Mark Ellis, and Alan Meier, *Network connectivity and low-power mode energy consumption*, Energy Efficient Domestic Appliances and Lighting, 2009. www.eedal.eu

Harrington, Lloyd, and Bruce Nordman, *Standby Power and Low Energy Networks – issues and directions*, Report for APP and IEA 4E Standby Annex, September 2010

Nordman, Bruce, *Networks, Energy and Energy Efficiency*, IETF70 Vancouver Technical Plenary, December 2007.

J. Quittek, R. Winter, T. Dietz, "Definition of Managed Objects for Battery Monitoring", draft-ietf-eman-battery-mib-00.txt, April 8, 2011

J. Parello, B. Claise, "Energy-aware Networks and Devices MIB", draft-ietf-eman-energy-aware-mib-01, March 10, 2011

B. Claise, J. Parello, B. Schoening, J. Quittek, "Energy Management Framework", draft-ietf-eman-framework-01, March 14, 2011

J. Quittek, R. Winter, T. Dietz, B. Claise, M. Chandramouli, "Requirements for Energy Management", draft-ietf-eman-requirements-01, March 14, 2011

B. Nordman, "Energy perspective on applicability", draft-nordman-eman-energy-perspective-01, March 14, 2011.

J. Quittek, B. Nordman, "Reference Model for Energy Management", draft-quittek-eman-reference-model-01, February 28, 2011.

E. Tychon, M. Laherty, B. Schoening, "Energy Management (EMAN) Applicability Statement", draft-tychon-eman-applicability-statement-01.txt, March 15, 2011

C. Verges, "Energy Monitoring and Management of Networked Entities using SNMP and Role-Specific Sparse Tables", draft-verges-eman-separate-modules-mib-00, February 23, 2011.

M. Chandramouli, B. Schoening, J. Quittek, T. Dietz, B. Claise, "Power and Energy Monitoring MIB", draft-claise-energy-monitoring-mib-08, May 23, 2011.