An Energy Perspective on IoT Data Models

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Energy use and efficiency in buildings is an important application of IoT devices to the extent that IoT can help to cost-effectively improve the delivery of energy services (including to better match them to user desires) and to reduce energy use for the cost and pollution benefits that brings. Energy brings a particular set of concerns and constraints to this topic, as well as a business and technology context that raise challenges to a good outcome. This paper reviews some of those and recommends particular directions to take.

Energy in Buildings Context

Bringing the benefits of modern network and information technology to energy use in buildings has several challenges.

- Many devices and components in buildings are only replaced on a cycle many decades long, so that it takes a long time to get rid of legacy technology, much effort needs to be expended to integrate with old technology, and the entire industry is relatively slow, conservative, and historically has a low level of sophistication about IT.
- The cost of owning and operating a building in general is usually at least an order of magnitude more than the cost of the energy to power it, and for commercial buildings, personnel costs are usually an order of magnitude more than owning and operating; thus, energy concerns are rarely a driving factor in decision-making about building design and operation.
- The buildings sector is highly balkanized, with companies, products, and technologies often significantly different when considering different building types (e.g. residential or commercial), different building sizes, and different countries. Communication technologies that have been developed for buildings have usually not been based on design principles that are well-established in a network context.
- Many companies have business models that rely on technologies that are proprietary and/or require expensive external labor to design, install, and maintain. This impairs deployment of IoT and related technology.

The result of all this is that a good overall technology architecture, and specific implementation details such as a high-quality universal standard data model, are quite unlikely to emerge from the existing buildings/energy industries. The buildings technology industry has invested little in cross-protocol data harmonization, and a recent investigation[1] of data model details for 10 topic areas[2] related to environmental sensing and Energy Reporting found wide diversity in data model coverage, naming, representation, units, and semantic concepts in about twenty protocols and other sources assessed. It also identified several dozen additional sources that also merited assessment, which would likely show even greater diversity of content. New protocols are being introduced at a rate much faster than older ones are retired or harmonized, so the situation for interoperability is only getting worse.

As examples of the findings of the data model analysis, even something as simple as representing the name and model of a device found wide diversity in the name of the fields involved, and in the guidance on what data is to be placed into those fields (see Table 1).

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[1] Bruce Nordman and Iris Cheung, *Data Model Needs for Building Device Interoperation*, Lawrence Berkeley National Laboratory, February 2016. Available at: http://nordman.lbl.gov

[2] Topics covered were: Sensors (identification and units), Unique Identification, General Identification, Classification, Local Data, Energy Reporting, Timestamps, Location, Power States, and Static Power Data.

Table 1. Manufacturer / Model data in various technology standards and other sources

Manufacturer	Model
vendor-identifier (a 2-byte numeric value) and **vendor-name** (BACnet) **Vendor** (FSGIM) **VendorName** (MODbus) **Instrument/Manufacturer** (sMAP) **Vendor name (VT)** **ENERGY STAR Manufacturing Partner and Brand Name** (ENERGY STAR) **Manufacturer and Make** (BEDES) **Manufacturer** (HPXML) **Manufacturer and Brand** (NILM) **Manufacturer** (XMPP) **Manufacturer** (DMTF) **deviceManufacturer** and **deviceVendor** (Haystack) **MakeModel** (CTA 2047)	**model-name** (BACnet, 70) **Model** (FSGIM) **ModelName and ProductCode** (MODbus) **Device model number** (VT) **Instrument/Model** (sMAP) **Model Name and Model Number** (ENERGY STAR) **Model** (DMF and VT) **ModelNumber** (HPXML) **Model** (NILM) **Brand and Product Line / Family Name** (TPEx). **Name** (XMPP) ***Also:* SKUs, UPC codes, retail numbers, descriptions, Global Trade Item Number and version UPC (Universal Product Code), Part Number, …**

Note: Even when two standards have the name for a field, the definition/content are often very different.

With the nature of building construction, operation, and evolution, it is a guarantee that any individual building will have multiple technologies for using communication to coordinate device operation, with few of these IP-based. As such, there is need for gateway devices that can translate between and among them. While some companies today implement proprietary gateways, having such translation be standardized could reduce costs and increase interoperability by having the results of such protocol translation be consistent and known. Having these gateways translate each protocol to and from a neutral common language—*an Esperanto for buildings*—is likely the best route to moving to a common semantic model as protocols would benefit from being consistent with the common language as much as possible, and devices could move to using the common language directly. The question is not whether this is a good approach to the underlying problem—the question is whether there exists a better and plausible approach to follow.

As many buildings devices have user interfaces to adjust device configuration and direct operation, interoperability between human beings and devices is as important as device interoperation. As such, consideration of standards in this area should be conducted in tandem with, or even before, defining data models, so that terminology and metaphors used in both domains can be harmonized[3]. It is better to harmonize device operation to the needs of human beings than vice versa.

Over time, IT networks have developed a suite of services that can be made available in a given network to facilitate interoperability. Examples include DHCP, DNS, file sharing, directory, printing, and time. As we extend networking to physical world devices, an additional set of network services are becoming apparent, each of which has some data model needs. Examples of these include device discovery (taking location into account), occupancy (of people; individually and generically), location (of objects, rooms, and building infrastructure such as HVAC zones), energy reporting (individual devices reporting their own energy use to the local network), and preferences (of people individually and collectively).

[3] Nordman, Bruce 2003. *The Power Control User Interface Standard — Final Report*. prepared for the California Energy Commission, Public Interest Energy Research Program, LBNL-52526. Available at: http://nordman.lbl.gov
Nordman, Bruce, Jessica Granderson, and Kelly Cunningham, "Standardization of user interfaces for lighting controls", *Computer Standards and Interfaces*, October 10, 2011, Vol. 34, pp. 273-279.

Recommendations

Getting to a modern future of widespread IP-based simple interoperability will be slow, but starting this as soon as feasible will have long-term benefits. Steps towards this should include:

- Adopt a goal for energy-using devices in buildings of “universal interoperability” —across building types, device types, people, time, and countries.
- Conduct an extensive survey of data model content in existing standards, to identify content in common use that may need to be represented in a new data model, and any content that merits consideration for usage in the data model directly or with adaptation. This would include: Types of information to be represented, in general; Specific data elements to include; Names for those data elements; and Data encoding (units, enumerations, etc.).
- Design a neutral system architecture mostly from a blank-slate perspective that lacks the many encumbrances present in the existing buildings technologies. Then, legacy technologies can be interfaced to the new system through gateways to enable existing buildings to move into the future. The system should start with the data model and later add a protocol for communicating data about devices. In some cases gaps may be found in semantic data needs and these can be filled directly[4].
- Designate an organization to lead semantic standardization that has the topic as one of its primary activities, and that lacks ties to any particular country, building type, or existing protocol. ISOC and its subsidiary organizations have the requisite independence and skill set to accomplish this. A new organization under ISOC dedicated to this topic area is one possible path to lead progress in this area.
- Once a new standard data model is in place, define the standard translations between it and legacy protocols.
- Ensure that details concerned with managing power availability and distribution are separated from IoT functional concerns. An architecture doing this, Network Power Integration has been proposed[5].
- Determine what network services are needed to respond to physical world issues and create or standards for representing and communicating this data.

Accomplishing the above would likely meet resistance from incumbent companies and organizations in the buildings industry. Their participation in the process should be welcomed so long as it does not compromise the principles on which it is based. Newer organizations (e.g. OCF and Allseen) may be suitable given their lack of existing installed base of devices. Most buildings activities are located in a single country or region and so a process which is intended to have global scope will be unfamiliar to many.

[4] Nordman, Bruce and Iris Cheung, *Basic Device Classification*, report to the Northwest Energy Efficiency Alliance, 2014. Available at: http://nordman.lbl.gov

[5] Nordman, Bruce, and Ken Christensen, *DC Local Power Distribution with Microgrids and Nanogrids*, First International Conference on DC Microgrids, Atlanta, GA, June 2015. Available at: http://nordman.lbl.gov