OASIS Collaborative Energy Standards, Facilities, and ZigBee Smart Energy

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Abstract

The enterprise integration-style interfaces and information models in the Organization for the Advancement of Structured Information Systems (OASIS) collaborative energy standards are designed to address information exchange across the smart grid. This paper examines two key types of information exchange to demonstrate the ability of these standards to express this information: block and tier tariff information, and demand response event information.

Our approach analyzes the information that must be communicated at the facility interface to meet the needs of ZigBee Smart Energy Profile 2.0 (SEP2)[1], and demonstrates that this information is represented in a way that can be mapped to SEP2. We show that the OASIS Energy Market Information Exchange (EMIX) information model can express specific tariffs usable to environments such as SEP2, and also describe the information model for demand response events within OASIS Energy Interoperation. This approach of examining information models can be used to show bidirectional mappings between SEP2 and EMIX/Energy Interoperation environments.

1. INTRODUCTION

During a series of National Institute of Standards and Technology (NIST) workshops in 2009, stakeholders called for a two-track approach to addressing demand response standards development [PAP09]. One track, aimed at residential facility Advanced Metering Infrastructure (AMI) implementations, was the ZigBee Smart Energy Profile 2.0, which was working to meet utility energy management goals.

The other track, aimed at commercial and industrial facilities, as well as the full range of markets, aggregators, utilities, and others involved in demand response, was the OASIS collaborative energy [Cox-NISTWS] [CultureOfArchitecture] standards.

The three OASIS collaborative energy standards are:

- Energy Interoperation [EnergyInterop][PAP09], an information model for demand response (DR) and distributed energy resource (DER) event information, as well as messages for DR, market interactions, and price quotes,
- Energy Market Information Exchange [EMIX] [PAP03] for price and product definition, and
- WS-Calendar [WS-Calendar] [PAP04], an information model for schedule and calendar based on Internet Engineering Task Force (IETF) iCalendar [xcal].

These specifications together address information exchanges—in the case of EMIX and WS-Calendar, cutting across the entire Smart Grid [Framework].[2] Rather than combining schedule, price, product definition, DR, and interaction into a single specification, the OASIS work separates schedule, price and product definition, and interoperation/DR into separate specifications. Schedule is separately and broadly applicable across the Smart Grid; likewise price and product definition. Energy Interoperation, which includes demand response, transactive energy interactions, and price quotes, uses concepts and structures from both WS-Calendar and EMIX.

[1] Draft 0.7 – Third Release [SEP2]

[2] The specifications are also cross-cutting in the sense used in the GWAC Stack [GWAC]

One stated goal of the DR and DER signals priority action plan (PAP09) process was to have alignment between Smart Energy Profile and Energy Interoperation by aligning them as much as practicable with the International Electro-technical Commission (IEC) Common Information Model [CIM], and enabled in practice by collaboration between members serving in the development of both standards.

The two track plan had the end goal of a degree of alignment between SEP2 and the OASIS standards and submission of both standards to IEC for international standardization, as planned through IEC Technical Commmittee (TC) 57, the developers of the Common Information Model.

The OASIS collaborative energy standards rely on established standards and specifications in order to meet the needs of cross-domain interactions. These include:

- iCalendar for scheduling [xcal],
- Open Geospatial Consortium's Geographical Markup Language (GML) [OGC] for location,
- OpenADR [OpenADR_1] semantics for Energy Interoperation events,
- Service-Oriented Architecture [SOA-RM] for enterprise scalability,
- Web services [WebServices] for composability of security and reliability
- [CIM] for power domain semantics.

Energy Interoperation standardizes market interactions as well as service provider interactions with customers. Conversely, SEP2 is primarily a residential domain power management protocol based more tightly on the CIM. In late 2010, as the SEP2 and OASIS standards developed, concern was expressed that the data models for price communication were different enough that information flowing cross-domain via Energy Interoperation would arrive at a residence but have no unambiguous mapping to SEP2 inside the facility. This resulted in a call for a focused *Tiger Team* effort to bring SEP2 and OASIS experts together to compare data models and identify any potential misalignment. Since all the specifications were in development, the goal was to address problems early and avoid any misalignment when the standards were completed. The initial focus was on price communication between SEP2 and OASIS EMIX.

The Tiger Team meeting was held in Houston in December 2010. The EMIX and SEP2 data models were discussed and compared, and several issues were identified [Tiger]. That report concluded that price communications could be mapped between standards, except that it was not clear to participants how to communicate block and tier tariffs as implemented in California and elsewhere.

2. BLOCK AND TIER TARIFFS

2.1. Introduction

In this section we describe Block & Tier tariff (BTT) information, and what we call price inflection points that one needs to know to determine prevailing prices. We explore a specific example showing how the example BTT information is expressed in EMIX and in SEP 2.0. We conclude by showing how any application environment that can express BTT price information can also construct that information from an EMIX information exchange.

2.2. Description of the Problem

With Block and Tier tariffs there are two or more Consumption Tiers, determined as a percentage of a baseline number, which in turn is determined by the climate zone of the customer premise, hence known for each premise. In the extended example, and without loss of generality, we assume that the baseline value is 1000 kWh. Four Consumption Tiers are defined as 0 up to 100 %, 100 % up to 150 %, 150 % up to 200 %, and greater than 200 % of the baseline.

Prices vary with time of day (the block) within each Consumption Tier. Price variation might correspond to the time intervals as follows:

- Low 9 pm to 10 am the next day
- Shoulder/Mid 10 am to 2 pm and 6 pm to 9 pm
- High 2 pm to 6 pm

2.3. Information Exchange

EMIX is an integration information model, designed with building blocks to express common characteristics of market information including price.

One cannot assume that all communicating applications will use precisely the same information models, so one must plan for information mapping or transformation where the information is exchanged. And one cannot assume that two parties on either side of an information exchange share the same information modeling approach, or that (even if they do) they change or update their models at exactly the same time.

Service-Oriented Architectures allow for independent evolution on either side of an information exchange interface by limiting the coupling between provider and consumer information models. Complex systems should take advantage of this loosely coupled interface approach to allow independent management of information model developments on either side of the interface.

2.4. Scoping the Problem

To demonstrate mapping to any premise system that can use BTT, it suffices to demonstrate expression of the information model required by those tariffs. We have in effect an array where one dimension is Consumption Tier and the other is time.

Consumption Tiers are defined by the price inflection points and identified by numbers 1, 2, 3, and 4 in Table 1. These correspond to total consumption so far in the billing period. Time of day is broken into different intervals (labeled "Low, Shoulder, and High" in Table 1) corresponding to the times of day and real-time value of electricity.

TABLE 1 EXAMPLE OF BLOCK AND TIER TARIFF

Consumption				
(% baseline)	100%	150%	200%	over
Min (kWh)	0	1000	1500	2000
Max (kWh)	1000	1500	2000	999999
Consumption Tier	**1**	**2**	**3**	**4**
Low ($/kWh)	0.10	0.11	0.12	0.13
Shoulder ($/kWh)	0.20	0.25	0.27	0.32
High ($/kWh)	0.30	0.50	0.60	0.65

This defines a two-dimension array; an application would find where it is in the Consumption Tiers, and then read the price for the current or future time of day. So the key information is exactly that, given the time of day and Consumption Tier, one can tell the BTT aspect of the current price[3].

This array is expressed in EMIX, leveraging the structures for demand charges (industrial in the US, residential and industrial in much of the rest of the world), as follows:

(1a) Each time interval (Low, Shoulder, High) is described as a WS-Calendar Sequence, e.g.,

  a. Low: midnight to 10am and 9pm to midnight (two intervals)
  b. Shoulder: 10am to 2pm and 6pm to 9pm (two intervals)
  c. High: 2pm to 6pm

(1b) Alternatively, a sequence of intervals can be defined with the appropriate tier information attached (starting at midnight, durations of 10 h, 4 h, 4 h, 3 h, 3 h)

(2) Each time interval has a sequence of Consumption Tier inflection points, expressed as maximum energy level of the high point.

(3) Retrieval algorithm: Select the right time interval for time of day; select the correct consumption tier.

[3] Other charges may be in a bill, e.g., usage based or customer based; we are expressing the more complex model for Block & Tier price only.

Applications may choose to, and likely will, express this information differently. For example, an array of 60-minute intervals could point to the Consumption Tier structure for that interval. Moreover, an EMIX artifact could express the information in other ways than what we describe, say with Gluons (which hold data that do not change across the referenced sequence) that respectively reference the Low, Shoulder, and High price tiers.

Clearly this applies only to applications that maintain their own model of a BTT tariff. Since such an application has a means of interpreting the information model (inflection points and time intervals), that application can then describe the mapping from a received EMIX artifact to its own information model.

More complex BTT structures, e.g., ones with different price levels or consumption levels on weekends or holidays, or seasonal differences can be expressed similarly.

2.5. Information Structure for Block and Tier

2.5.1. EMIX Information Structure

The EMIX information structure describes Intervals, each with a list of consumption tiers. See Figure 1. A Gluon references a Sequence [WS-Calendar] and contains inherited information such as currency, units, scale, and what is measured. Thus, common information for each time interval and Consumption Tier is held in the Gluon.[4]

EMIX has a rich expression for price and product information. The mechanisms used for BTT are similar to those used in EMIX to describe so-called ratchet tariffs, where exceeding demand charge thresholds may affect price for months.

2.5.2. SEP 2.0 Information Structure

We describe information structures from SEP2.0 Draft 0.7 – Third Release [SEP2], which represents the Consumption BTT with a list of TimeTariffIntervals, each of which has zero or more ConsumptionTariffIntervals. This expresses the information in Table 1 as shown in Figure 2 with time intervals across the top and the tier values in columns below.[5]

[4] Unless a specific cell needs different information. For example, if many of the prices are 0.30, then that value could be carried in the Gluon and inherited rather than expressed directly. The information model is identical, but the expression may be compressed in this manner for communication.

[5] In this and other examples, optimization may be possible depending on how the application software traverses the structure. Such optimizations do not affect our discussion.

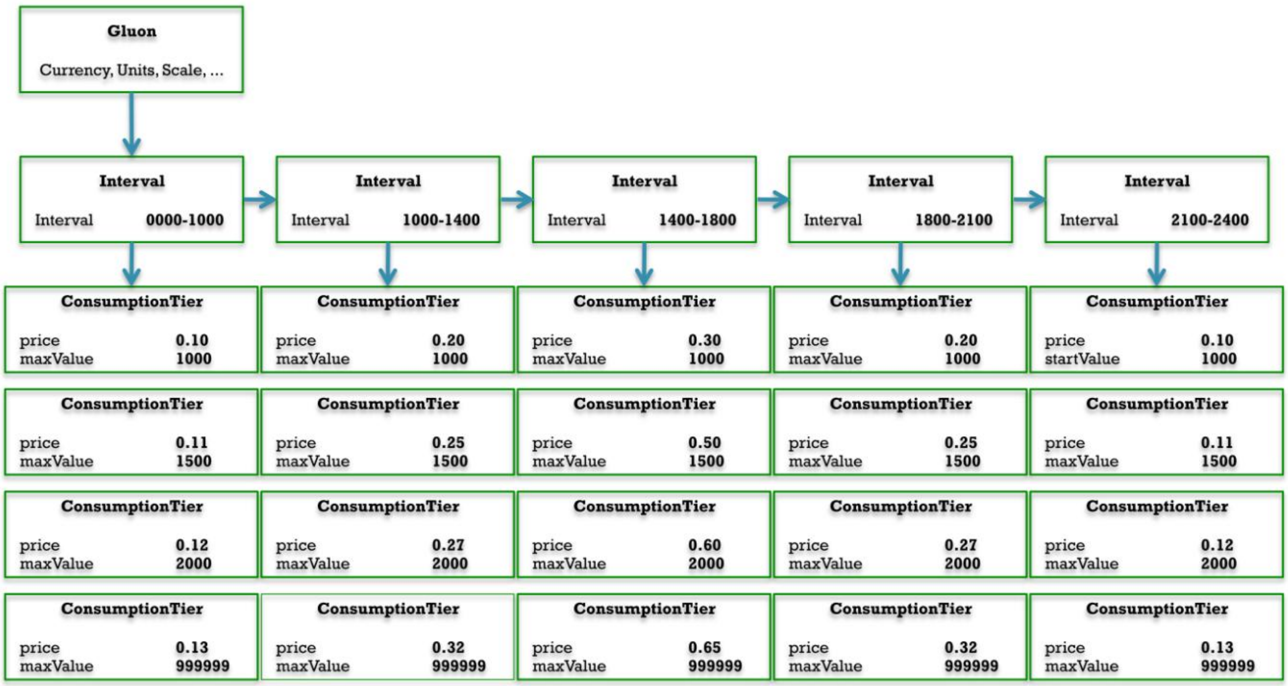

FIGURE 1 EMIX INFORMATION STRUCTURE FOR BLOCK & TIER EXAMPLE

For clarity, Figure 2 omits many details including inherited optional attributes. Consumption Tiers are represented by the minimum usage amount, which is represented as startValue. There is also the powerLimit in the RateComponent object, which is the maximum power permitted by the tariff.

2.5.3. Comparison of EMIX and SEP 2.0 Information Structures

The SEP2 information structure is very similar to the EMIX information structure. Comparing figures 1 and 2, the graphical representation is essentially the same except for attribute names.

The EMIX tiers are identified using the maximum, rather than the minimum levels, so the series in our example would be {1000, 1500, 2000, maximum allowable power}. In contrast, SEP2 tiers have additional information, determined by the Block & Tier inflection point structure, intended for application use, e.g., numPriceLevels that is defined by the price inflection points.

There are other differences. For example, the following information items are represented in the EMIX interchange information in the Gluon, and in the SEP2 application environment are in an instance of the ReadingType class:

- Currency
- Energy
- Multiplier or scale factor

This concludes our analysis of BTT representation in the EMIX and SEP2 information models, demonstrating the ability to map required information from EMIX to SEP2 and back. The next section examines DR event signal information models.

3. DEMAND RESPONSE SIGNALS

The OASIS Energy Interoperation Technical Committee, drawing on experts and the designers of [OpenADR 1], the ISO-RTO Council (IRC) [NAESB_PAP09_2], together with eCommerce and distributed system architects, have defined an information model for DR event signals that is suited to facilities, aggregators, utilities, and others. That model and interaction patterns using it are defined in [EnergyInterop].

3.1. Events and Facilities

The delivery of an event information payload to a facility contains sufficient information so that the facility understands its expected curtailment, and can determine whether the expected response is consistent with the facility's business needs.

The critical elements include when, how much, and for how long? Lawrence Berkeley Laboratory [OpenADR1], the ISO-RTO Council (IRC) business analysis [NAESB_PAP09_2], and the ZigBee Smart Energy Profile [SEP2] all have similar descriptions of events, with the OpenADR 1 definition being reflected in the others.

FIGURE 2 SEP2 INFORMATION STRUCTURE FOR BLOCK & TIER EXAMPLE

Energy Interoperation standardizes and extends the OpenADR 1 event type, with additional attributes defined by the IRC. Any facility that can respond to events defined in that way can therefore use the information in an Energy Interoperation (OpenADR 2.0) event as a basis for that response.

More specifically, if (an) SEP2 (deployment) can respond to a DR event signal, then it can respond to an Energy Interoperation/OpenADR2.0 Event.

It may be convenient to convey additional application-specific information beyond the raw description of an event; Energy Interoperation events have a specific extension point for such information. But this is more a convenience than a different expression of the nature of the event—time, duration, and amount.

3.2. Energy Interoperation and SEP2 Event Information

We discuss the curtailment aspects of events; price representation in [SEP2] and [EMIX] is generally described in Section 2.55.

The SEP2 Application Specification [SEP2] Section 11.4.1 has several key concepts. First, load control events are prepared by and exposed to clients; these are called End Device Controls (EDCs). EDCs carry information that may be generic or directed at particular classes of devices.

"The EDC will also expose necessary attributes that load control client devices will need in order to process an event. These include Start Time and Duration, as well an indication on the need for randomization at the start and/or end of the event." ([SEP2] *op. cit.*) See Figure 3.

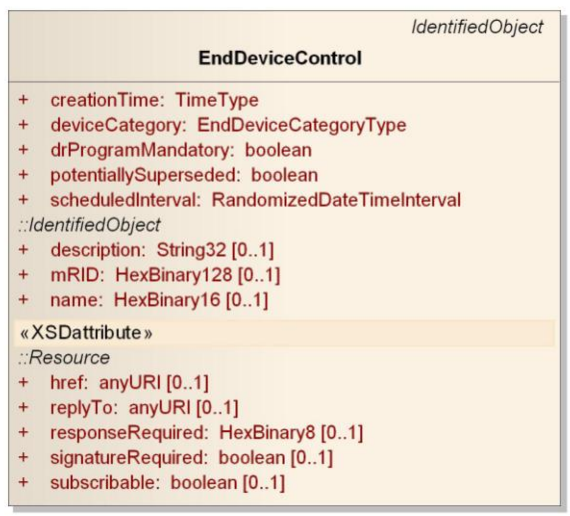

FIGURE 3 SEP2 END DEVICE CONTROL

With respect to randomization, a technique to smooth response, SEP2 defines randomizedDateTimeIntervals that specify randomization at the start or end; or no randomization at all. [EnergyInterop] uses properties in the [WS-Calendar] intervals to convey a superset of that information[6]. Start time and duration within EndDeviceControl are defined in the *scheduledInterval* attribute.

For start time and duration in Energy Interoperation, the EiEvent type carries an Interval with exactly that information. See Figure 4. Start time and duration are defined within the *eiActivePeriod* attribute which is a container for (among other things) time intervals.

The smoothing information is optionally contained in each time interval.

For specific behavior, the [SEP2] EDC has a status (not shown) and optionally a duty cycle, offset, set point, or target reduction. See Figure 5.

These correspond generally to the [EnergyInterop] signal types for each interval within an event including quantity or multiplier, and set point. See Figure 6.

For information that may be needed in a communication to an SEP2 environment, Energy Interoperation includes application-specific extensions as also shown in Figure 6.

3.3. Conclusions on Demand Response Signals

The approach presented here for DR event analysis is similar to that taken in Section 2. Define the key information. Show how it is expressed. Use the fact that the recipient is capable of using information about a particular abstraction (in this case an event; in the previous sections, Block and Tier Tariffs). Conclude that the information available is sufficient for the recipient to apply, as they must apply information on the underlying abstraction.

4. SUMMARY AND CONCLUSIONS

We have shown how EMIX and SEP2 can express the information model of a Block & Tier tariff. Any application that supports such tariffs can take and place the information on price inflection points from an EMIX expression in its own data structures.

A concrete mapping can be made directly for any application environment that describes its mapping of the Block & Tier tariffs. We have described in detail how EMIX and SEP2 express Block & Tier information. More generally, we have demonstrated that such a mapping exists from EMIX to any application that supports Block & Tier tariffs. The same information mapping that the application uses to express Block & Tier information is used to place the necessary price inflection points in that application's internal data structures.

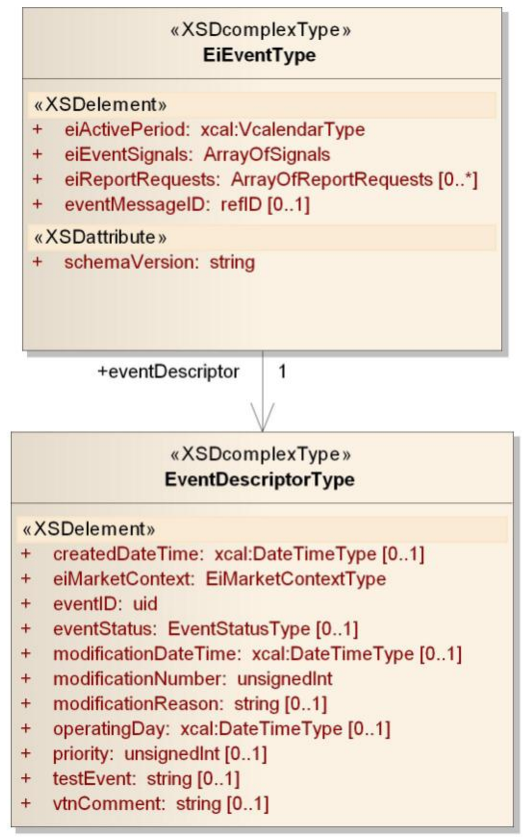

FIGURE 4 ENERGY INTEROPERATION EIEVENT AND DESCRIPTOR

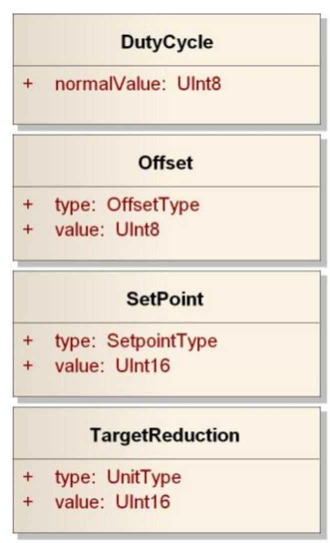

FIGURE 5 SEP2 EDC ASSOCIATED TYPES

[6] The response smoothing in [EnergyInteroperation] need not be symmetric around the start or end point.

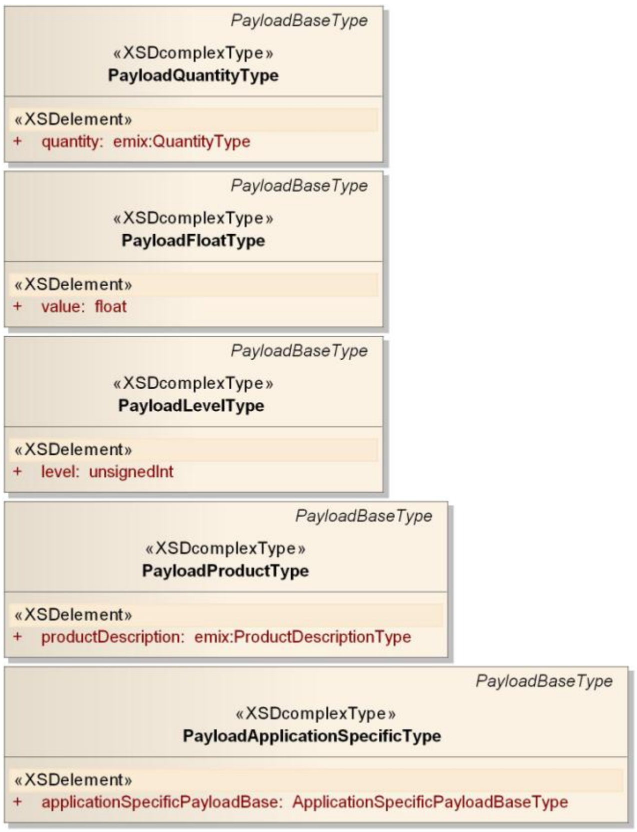

FIGURE 6 ENERGY INTEROPERATION SIGNAL PAYLOADS (NON-PRICE)

For Demand Response events, we have described the data structures and the key information that needs to be used in the application, in this case SEP2, in order to carry out the requested response, and some of the information conveyed in Energy Interoperation signals and SEP2 End Device Controls.

This is the essence of constructing applications using Service Oriented Architectures and integration approaches—the information gets through; how it's maintained internally is the business of the receiving application.

The process demonstrated, of understanding the application model and then mapping the required information in to it, is also replicable for any target data structure that models Block & Tier prices or demand response event signals.

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Biography

William Cox

William Cox is a leader in commercial and open source software definition, specification, design, and development.

He is active in the NIST Smart Grid Interoperability Panel and related activities. He contributed to the NIST conceptual model, architectural guidelines, and the NIST Framework 1.0.

Bill is co-chair of the OASIS Energy Interoperation and Energy Market Information Exchange Technical Committees, past Chair of the OASIS Technical Advisory Board, member of the Smart Grid Architecture Committee, and the WS-Calendar Technical Committee.

Bill has developed enterprise product architectures for Bell Labs, Unix System Labs, Novell, and BEA, and has done related standards work in OASIS, ebXML, the Java Community Process, Object Management Group, and the IEEE, typically working the boundaries between technology and business requirements.

He earned a Ph.D. and M.S. in Computer Sciences from the University of Wisconsin-Madison.

David Holmberg

David Holmberg is a researcher in the Engineering Lab at NIST. His work focuses on building integration into the Smart Grid and, more generally, communication of building-system data to outside partners. David serves as part of the NIST Smart Grid team, leading the Building-to-Grid domain expert working group and serving as NIST lead for a number of customer-interface related priority action plans within the Smart Grid standards effort. He is convener of the BACnet Smart Grid Working Group (SG-WG) of the ASHRAE BACnet committee focused on commercial building automation system interactions with the smart grid. He also co-chairs the OASIS Energy Interoperation technical committee focused on developing a standard for demand response signaling, energy market transactions, energy usage and load communications and other cross-domain energy interactions. Research interests include information modeling to support standards development in addition to novel smart grid aware building control strategies.

David received his PhD from Virginia Tech, and joined NIST in 1997. Since joining the Mechanical Systems and Controls Group, he has addressed BACnet network security, utility interactions, and communication of building data to emergency responders. He is a member of ASHRAE.

Don Sturek

Don Sturek is CTO for Grid2Home, a venture backed startup company focused on development and deployment of SEP 2.0 networking stacks and application layers over all MAC/PHY layers.

Don's Smart Grid related expertise includes:

- Current chair of the ZigBee Core Stack Working Group, responsible for the IP networking stack for SEP 2.0 over IEEE 802.15.4
- Past chair of the UCAiug OpenSG SG-Communications Work Group (responsible for the Smart Grid communications requirements used in NIST SGIP PAP 2)