

IEEE 2030.5™-2013 (Smart Energy Profile 2.0)

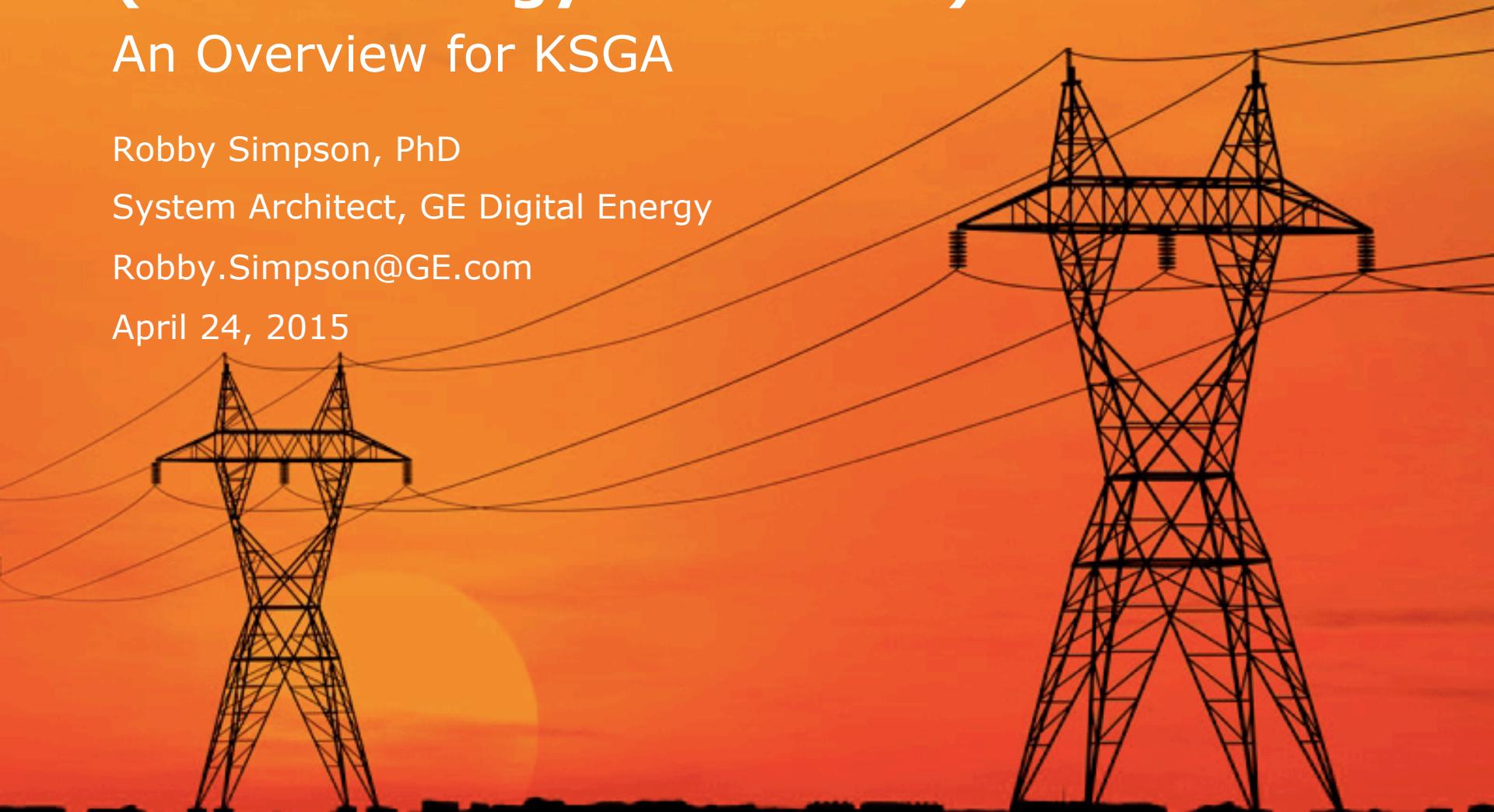
An Overview for KSGA

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Agenda

Time	Program	Activity
10:00~10:30	Registration	KSGA
10:30~12:00	IEEE 2030.5: Motivation, Example Applications	Bill Ash Robby Simpson, PhD
12:00~13:30	Lunch	
13:30~14:30	IEEE 2030.5: Relationship to other Smart Grid Standards, Testing and Certification	Bill Ash Robby Simpson, PhD
14:30~14:50	Break	
14:50~16:50	IEEE 2030.5: Technical Overview	Bill Ash Robby Simpson, PhD
16:50~17:00	Conclusion	

IEEE 2030.5: Motivation, Example Applications

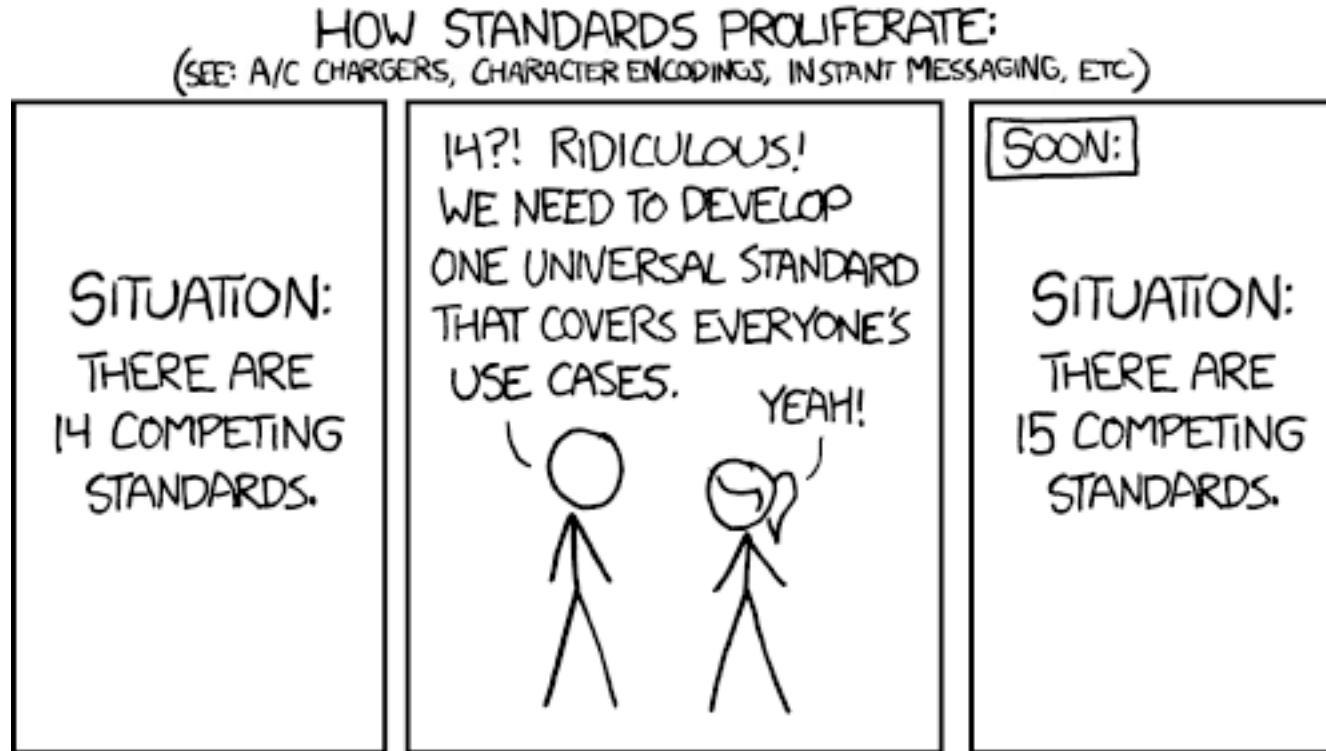


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Smart Grid Home Area Network (HAN)

- An addition to existing consumer HANs
- The integration of consumer devices into the smart grid
- Serves two general purposes:
 - **Inform** the consumer (e.g., energy usage, pricing)
 - Request **actions** to assist the grid (e.g., thermostat changes, plug-in electric vehicle charging)
- Focus on communications related to efficiency, usage, price, demand response and load control, and service provider messages
- One or more Energy Services Interfaces (ESI) serve as the gateway – the utility / service provider “voice” into the home
 - Often, but not always, a smart meter

An Analogy



Example Devices for the Smart Grid HAN

- Smartphone
- Tablet
- Television
- Computer
- Thermostat
- Smart Meter
- Pool Pump
- Water Heater
- Smart Appliance
- Cloud Server
- Plug-in Electric Vehicle
- Solar Inverter
- Energy Management System
- Building Management System

Background / History of IEEE 2030.5 (SEP 2)



- Evolution of ZigBee Smart Energy 1.x
 - A widely deployed standard for the Smart Grid HAN
 - Provides most, if not all, of the needed application information (more on that in a moment)
 - Robust testing and certification program with a certification mark
 - 60+ million meters currently deployed or under contract, from a variety of manufacturers
 - ~550 Certified Products
 - However, limited to the ZigBee PRO technology (802.15.4 at 2.4 GHz running the ZigBee PRO stack)

Motivations for a New Version: Multiple Link Layers

- Link layer (MAC/PHYs) technologies have different strengths and weaknesses (e.g., Wi-Fi, HomePlug, Ethernet)
- Internetworking!
- Consumers may already have various link layer technologies
 - Smartphone with Wi-Fi and/or Bluetooth
 - TV with Ethernet and/or Wi-Fi
- Desire to enable multi-dwelling units (MDUs) and other scenarios where a single wireless technology may not be feasible

Motivations for a New Version: Widely-Adopted Technologies

- Encourage a vast ecosystem
- Allow consumers to use existing devices
- Rapid development and adoption – enable “guy in a garage”
- Use commercial off-the-shelf products, existing software libraries, etc.
- Vast labor pool
- Wisdom of large community
- Long-life / Forwards compatibility
- Already mature
- Intellectual property better understood

Motivations for a New Version: A True “Profile”

- Options and configurations selected for interoperability
- “Standards Selecting” instead of “Standards Defining”
 - Nothing new – a collection of widely-adopted standards
 - All pieces of IEEE 2030.5 sourced from standards developing organizations (SDOs)

Motivations for a New Version: Range of Backhaul Technologies

- Not all consumers have broadband Internet access
- Not all consumers have Advanced Metering Infrastructure (AMI)
- Some jurisdictions require capability when consumer has no Internet access
- Range of bandwidths:
 - Broadband Internet: 10s of Mbps
 - Cellular AMI: 100s of Kbps
 - Mesh AMI: 10s of Kbps
 - And some PLC AMI are < 1 bps!
- Desire to enable all, while taking advantage of higher bandwidths where possible

Motivations for a New Version: Range of Device Constraints

- Embedded devices often have limited hardware resources
 - 10s of KB of RAM
 - 100s of KB of Flash
 - See RFC 7228
- Smart Grid HAN devices often have strict energy constraints
 - Gas and water meter may need a single battery to last 10-20 years!
 - Many thermostats are battery-powered

Motivations for a New Version: Secure!

- Security and privacy concerns paramount
- Cybersecurity attacks on smart grid can have significant consequences in the physical world
- Smart Grid HAN one piece of consumer's network
 - Cannot be weak link
 - Rest of consumer network may be insecure
- Little to no physical protection
- Devices need to last decades
- Many governments have cybersecurity guidelines and requirements

And New Partners!



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Key Technology Decisions

- Internet Protocol (IP)
- RESTful HTTP
- TLS 1.2 (HTTPS)
- IEC 61968 (CIM)

More on protocols in the Technical Overview...

Why IP?

- Internetworking – mixing various link layer technologies
- Use routers instead of application layer gateways
 - No knowledge of Smart Energy required in the router
 - Allows for end-to-end security
- Easily connect consumers' existing devices
- Eases convergence and architecture changes
- As an example, allows smart phone, using Wi-Fi, to speak directly and seamlessly to electricity meter, using ZigBee, as well as a plug-in electric vehicle, using HomePlug

Why HTTP?

- The web protocol we all know and love
- Long life, particularly when compared to alternatives – reduced risk of stranded assets
- Familiar to consumers and developers – larger ecosystem
- Eases ability to also provide web pages – code reuse

Why TLS 1.2 (HTTPS)?

- Same security used and proven in Internet banking
- Desire to meet US NIST requirements (Suite B)
- Facilitate end-to-end security

Why IEC 61968 (CIM)?

- Smart Grid “dictionary”
- Reuse of knowledge of smart grid industry
- Same data used in home as used in utility backoffice and smart meter networks – less risk of translation errors

A Variety of Architectures

- In-home only
- Via smart meter
- Via Internet
- Cloud-based ESI
- Combinations of the above

The use of IP eases convergence and architecture changes

High-Level Design

- Divided into “**Function Sets**” – independent sets of functionality
- Any device can be a **server** and/or a **client** for a function set – servers provide the data, clients use the data
- Can have multiple servers for a function set – allows for multiple service providers
- If desired, clients can be assigned to servers
- Not restricted to energy – supports **multiple commodities** (water, natural gas, steam, etc.)

Some IEEE 2030.5 Functionality

- Price Communication
- Demand Response and Load Control
- Energy Usage Information (e.g., meter data)
- Service Provider Messaging
- Prepayment Metering
- Distributed Energy Resources
- Electric Vehicle
- Billing Communication
- File Download / Update

Price Communication

- Information only
- Support for many types of tariffs
 - Time-based
 - Consumption-based
 - Combinations
- Bi-directional support (feed-in tariffs)
- Can even communicate alternative costs such as carbon emissions or percentage of energy generated cleanly

Price Communication (continued)

- Example clients:
 - Could be as simple as a device that **displays** current price (TV, for example)
 - Or devices can **act** on the price:
 - Refrigerator can shift defrost cycle to optimal time
 - HVACs can pre-cool and pre-heat homes
 - Plug-in electric vehicles can select optimal time to charge
 - Clothes dryers can use lower heat setting
 - Solar panels can intelligently feed back to grid
 - Many others
- Example servers:
 - Smart Meter
 - Standalone ESI
 - Cloud-based ESI

Demand Response and Load Control

- Typically provided as utility / service provider programs
- Events can be high-level:
 - Request to shed a certain amount of Watts
- Events can be more detailed (load control):
 - Thermostat setpoints or offsets
 - Duty cycle
- May address specific devices and device types (e.g., water heater)
- Allows devices to shed load or simply shift load
- Devices may advertise their ability to shed
- Devices may respond with details regarding their actions

Demand Response and Load Control (continued)

- Example clients:
 - Could be as simple as a device that **displays** the requested event
 - Or devices that **act** on the event:
 - Thermostat
 - Pool pump
 - Smart appliance
 - Water heater
 - Electric vehicle
 - Many others
- Example servers:
 - Smart meter
 - Standalone ESI
 - Cloud-based ESI

Energy Usage Information

- Variety of measurements (more on that during Technical Overview)
- Variety of commodities (e.g., electricity, natural gas, water)
- Near real-time
- Unlimited number of usage points
- Mirroring capability for “sleepy” devices such as gas meters
- Bidirectional

Energy Usage Information (continued)

- Example clients:
 - A device that displays usage data
 - A device that stores usage data for historical analysis
 - A device that alerts or makes suggestions based on usage data
- Example servers:
 - Smart electricity meter
 - Smart gas meter
 - Cloud-based server
 - Smart appliance with metering capability
 - Any device capable of measuring usage!

Service Provider Messaging

- Freeform text messages
- UTF-8: support for a variety of characters and languages
- Example applications:
 - Reverse-911
 - Weather alerts
 - Tsunami warnings
 - Billing messages
 - Energy saving tips
- Can request read receipt

Distributed Energy Resources

- Support for both generation and storage
- Immediate and curve-based controls
- “Nameplate rating” and settings
- Targeted at loosely-coupled, occasionally connected, small scale PV
- Many of the previous functionalities useful:
 - Pricing
 - Energy usage (monitoring)
- IEEE 2030.5 enables higher penetration of grid-tied PV systems and new non-utility resources
- Deployments at MECO and PEPCO (Maui, New Jersey, Washington DC, Maryland)
- In addition to remote monitoring and control, allows increased customer engagement and information

Electric Vehicles

- Many of the previous functionalities useful:
 - Pricing
 - Demand Response and Load Control
 - Energy Usage
 - Distributed Energy Resource – Vehicle-to-Grid capability
- As well as “Flow Reservation”
 - Ability to schedule charging times

Announcement: IEEE 2030.5 (SEP 2) Symposium and Product Expo

- When: **June 30, 2015**
- Where: **EPRI, Palo Alto, CA**
- Cost: **Free**

Supported by:



And now... Lunch!



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IEEE 2030.5: Relationship to other Smart Grid Standards, Testing and Certification

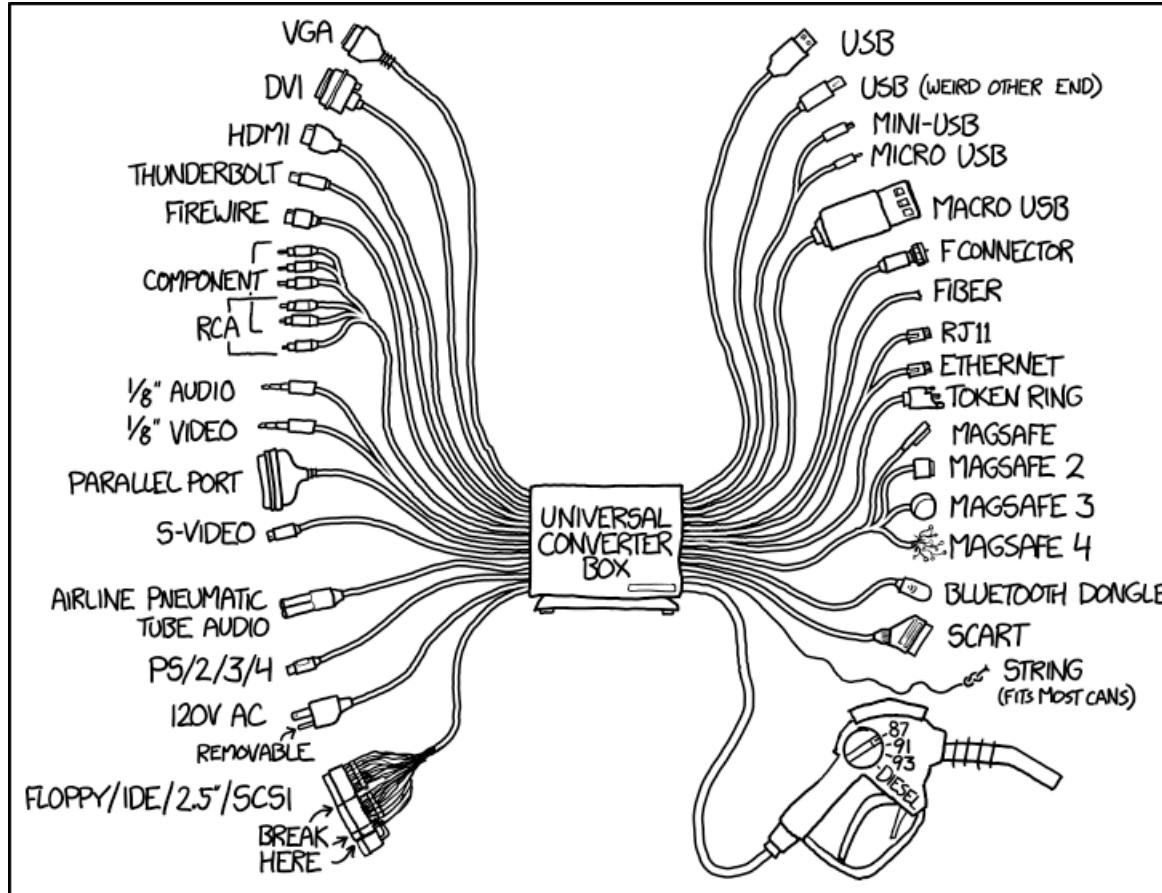


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Relationship to Other Standards

- As a profile, IEEE 2030.5 has much in common with other standards (intentionally)
- As such, there is often confusion on when to use IEEE 2030.5 or another standard
- IEEE 2030.5 is often complementary to other, similar standards

Relationship to other Standards: IEC 61968 (CIM) and IEC 61850



- IEC 61968 can be thought of as the Smart Grid “dictionary”
- IEC 61968 was the required information model for IEEE 2030.5
- Where gaps existed, relevant information elements from IEC 61850 were included
- IEEE 2030.5 profiled these information elements to make them useful for the Smart Grid HAN

Relationship to other Standards: SunSpec



- DER function set based on SunSpec Alliance Inverter Control Model, derived from IEC 61850-90-7 and EPRI work
- Worked closely with SunSpec Alliance to adapt to RESTful HTTP
- SunSpec has traditionally focused on Modbus
- The two standards work quite well together, often with SunSpec Modbus controls being utilized locally and IEEE 2030.5 being used for communication
- Working together to enable smart microinverters in California per Rule 21

Relationship to other Standards: OpenADR

- OpenADR is a standard for demand response – an “interface between electricity markets and customers”
- Of course, opinions differ – this is mine
- OpenADR has traditionally been used to communicate with an entire premises
- OpenADR has traditionally focused on commercial and industrial customers
- IEEE 2030.5 has traditionally focused on residential customers
- OpenADR has a more focused scope (DR) than IEEE 2030.5
- The two standards can work together quite well, for example, using OpenADR to communicate from the utility to an ESI, and then using IEEE 2030.5 to communicate from the ESI into the home

Relationship to other Standards: Green Button



- Green Button is a standard for accessing energy usage data from a utility as well as sharing energy usage data with third parties
- Green Button and IEEE 2030.5 have worked closely together and use the same information model for energy usage (a subset of IEC 61968)
- Green Button focuses on authorized connections via the Internet, not within a home
- Green Button has a more focused scope (energy usage) than IEEE 2030.5
- The two standards can work together quite well, with Green Button providing aggregate data via the Internet and to authorized third parties and IEEE 2030.5 providing real-time data within the home

Relationship to other Standards: the Internet of Things

- “Internet of Things” (IoT) is not a particular standard, but rather a vision
- While the term was not yet popular when IEEE 2030.5 was begun, IEEE 2030.5 is certainly an “Internet of Things” standard
- Many IEEE 2030.5 participants worked within various standards bodies such as IEEE and IETF to make certain IoT standards were in place for use by IEEE 2030.5 and others
- More details regarding specific IoT standards used by IEEE 2030.5 will be provided in the Technical Overview

Testing and Certification: Why?

- Standards (even profiles) are often subject to interpretation
- Out-of-the-box interoperability is particularly important in the consumer space and with IoT devices that have little to no user interface
- Interoperability testing provides a means to discover issues
- Certification provides assurance to consumers that the product has been tested and will be interoperable



- A collaboration focused on developing consistent test and certification programs across multiple communications media to run IEEE 2030.5
- Structure for multiple industries to advance adoption and support best user experience
- Developed common test specification, PICS, test harness, security certificates, etc. for use by the various alliances
- Conducted several interoperability events – typically once per month
- Testing also occurs over the Internet (the beauty of IP!)

<http://csep.org>



Certification

- Executed by any CSEP Sponsor with the authority to qualify test laboratories to perform certifications according to the test materials
- Qualified test houses able to certify equipment and use Consortium certification mark(s) to denote IEEE 2030.5 (SEP 2) interoperability
- Must use test materials (test specification, PICS, test harness) from CSEP
- Allows each CSEP Sponsor (currently Wi-Fi, HomePlug, ZigBee, and Bluetooth) to continue to operate independently, but consistently

Additional CSEP Participation

- CSEP Sponsor membership is open to other industry groups
- Questionnaire, membership agreements, and other CSEP governing documents available on the CSEP website (<http://csep.org>)
- Questions can be directed to admin@csep.org
- *Note: CSEP membership is not open to individuals or commercial corporations (they must participate through industry groups like the Wi-Fi Alliance, HomePlug Alliance, ZigBee Alliance, and Bluetooth SIG).*



CSEP Test Harness

- After extensive testing during interoperability events and evaluation, CSEP selected test harness software from **QualityLogic** in January 2015
- Products can now use this test harness as part of the certification process

<https://www.qualitylogic.com/>

Consortium for Smart Energy Profile 2 Interoperability (CSEP) Approves Test Harness Software from QualityLogic

New Test Harness is the First Authorized for Testing Products Implementing the IEEE Standard 2030.5 (SEP 2) IP-based Application Profile for Smart Energy Management

January 28, 2015 08:00 AM Eastern Standard Time

Break!



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IEEE 2030.5: Technical Overview



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Artifacts

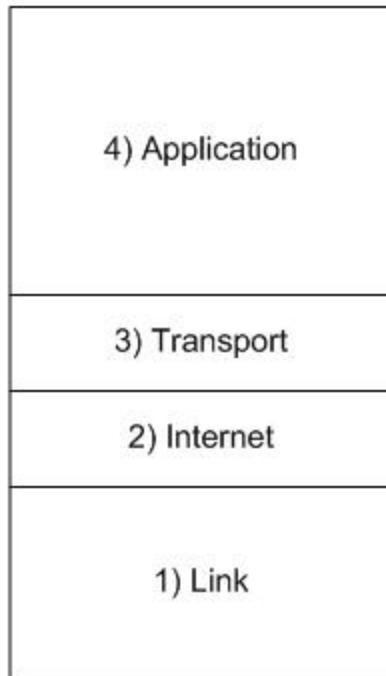
- Normative
 - Specification – the text
 - Schema (XSD) – the objects
 - WADL – the methods
- Informative
 - UML model – used to generate XSD

Stacks

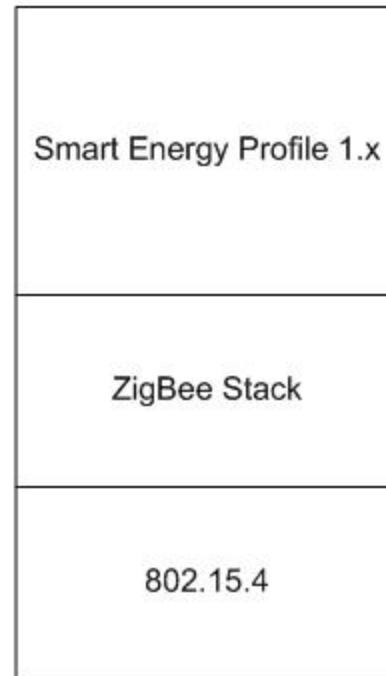
OSI Reference Model



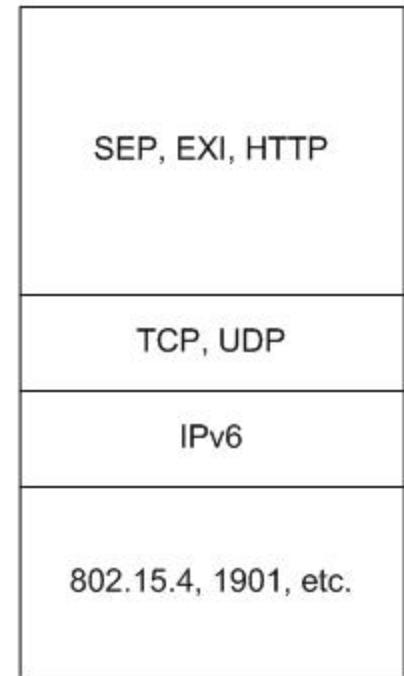
Internet Model



ZigBee SEP 1.x



SEP 2.0



Also:

- Service Discovery
- Security

Name Resolution

- xmDNS – Multicast DNS
- Familiar to many via Apple Bonjour (mDNS)
- Enables DNS names without the need for a centralized DNS server
- Used in conjunction with DNS-SD (next slide) to provide device and service discovery
- mDNS: RFC 6762
- xmDNS: draft-lynn-homenet-site-mdns-01

Device and Service Discovery

- DNS-SD, used in conjunction with xmDNS
- IEEE 2030.5 types and sub-types
- Essentially just DNS TXT records
- “All smartenergy devices”
- “All smartenergy Pricing function set servers”
- Returns various information such as path
- Can also query for a specific device’s information
- Allows flexibility in addresses

Application Transport Protocol

- HTTP/1.1 – the web protocol we all know and love
- Used to interface with **resources** in a **RESTful** manner
 - GET
 - PUT
 - POST
 - DELETE
- IEEE 2030.5 devices are essentially extremely lightweight little web servers and clients

* For more on REST, I recommend "RESTful Web Services"

(<http://shop.oreilly.com/product/9780596529260.do>)

While not focused on embedded devices, it provides an excellent overview of REST and resource-oriented architectures

Security

- Application security: TLS 1.2
- May also have link layer security
- Think “https”
- Have agreed on a specific ECC ciphersuite for interoperability (ECDHE – NIST Suite B)
- All devices have certificates (some may be self-signed)

Payload Encoding

- Message format of HTTP resources
- Two mandatory for servers
 - XML
 - EXI
- Clients may use either (or both)
- Enables rapid development of specifications and technology (machine-generated code from schema and WADL)
- Easily extended for new applications / messages / objects in the future

Semantic Model

- A profile of the IEC CIM (61968)
- The “what”
- UML -> Schema -> Resources
- Resources are then exposed via RESTful model

Model Details

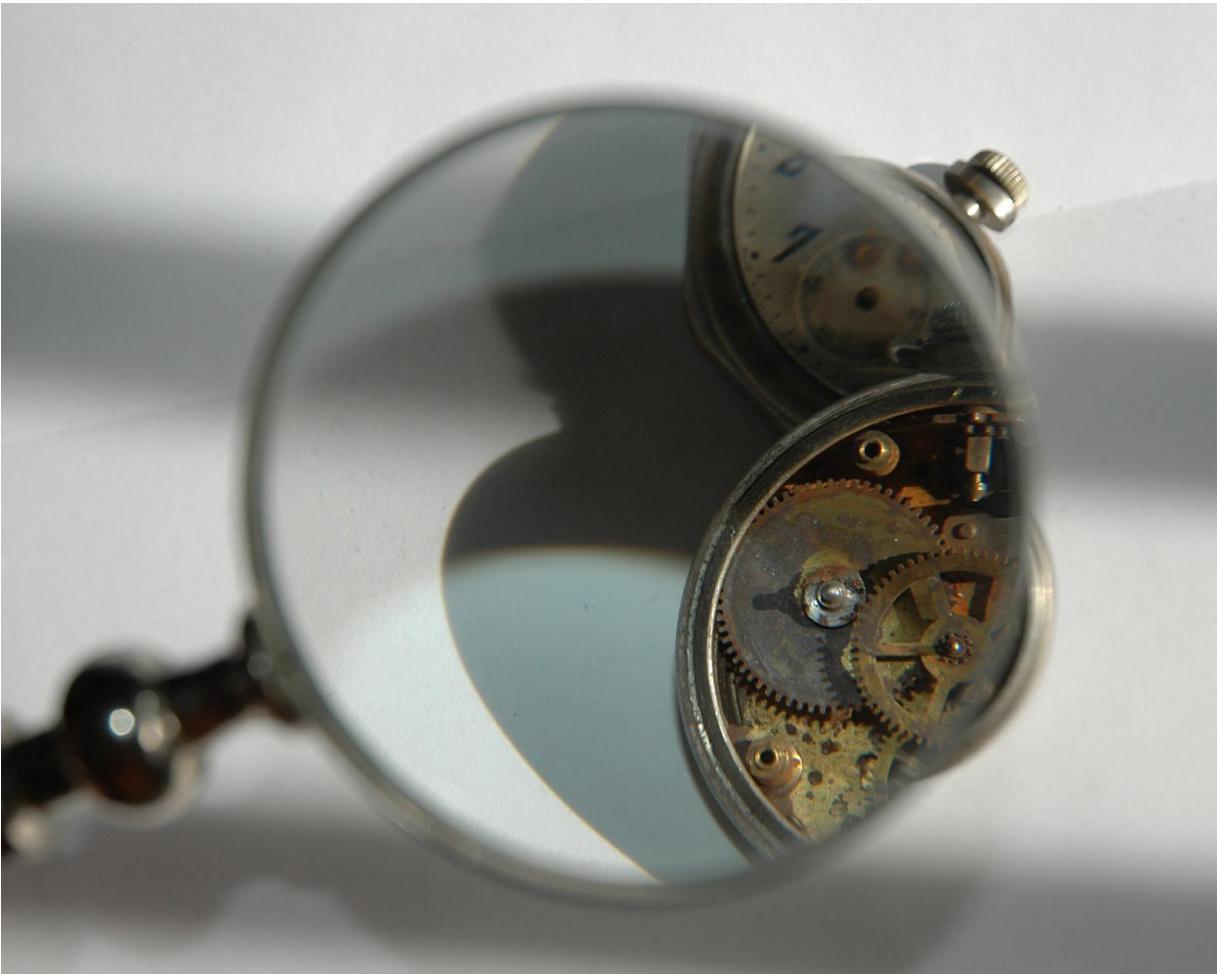


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Short-form Device Identifier (SF DI)

- A 36-bit identifier of a device generated using a SHA-256 operation over the device's entire DER-encoded certificate
- Not confidential
- Not used to derive keying material
- Displayed as 11 decimal digits with an additional sum-of-digits checksum (e.g., 167-261-211-391)
- May be printed on packaging

SelfDevice and EndDevice

- SelfDevice: a mechanism for a device to publish information about itself locally (version numbers, configuration, capabilities, etc.)
- EndDevice: if a device does not wish to serve its own SelfDevice, it may post it on an EndDevice server
 - Also allows for registration information and verification (via SFDI and PIN)
 - Devices may search for EndDevice servers using SFDI

Function Set Assignments

- Mechanism for a server to assign client(s) to specific instances of function sets and servers
- Live on server
- Individual clients may have assignments on multiple servers
- May also simply have “public” function sets

Generic Construct: Lists

- Many resources are organized into lists (Price events, Demand Response events, various programs, etc.)
- Lists contain attributes:
 - “all” – total number of items in the list
 - “results” – number of items returned
- Lists also support filters / paging
 - “s” – **starting** ordinal position
 - “a” – items **after** a given date/time
 - “l” – **limits** the number of items returned

Example: [https://\[server\]/list?s=4&l=5](https://[server]/list?s=4&l=5)

Returns no more than 5 items, starting with the 5th item (0 is the 1st item)

mRIDs

- “Master Resource Identifier”
- Many objects contain an mRID (any object derived from IdentifiedObject)
- A globally unique identifier
- For example, allows a demand response event to be uniquely identified, should it be received through multiple channels

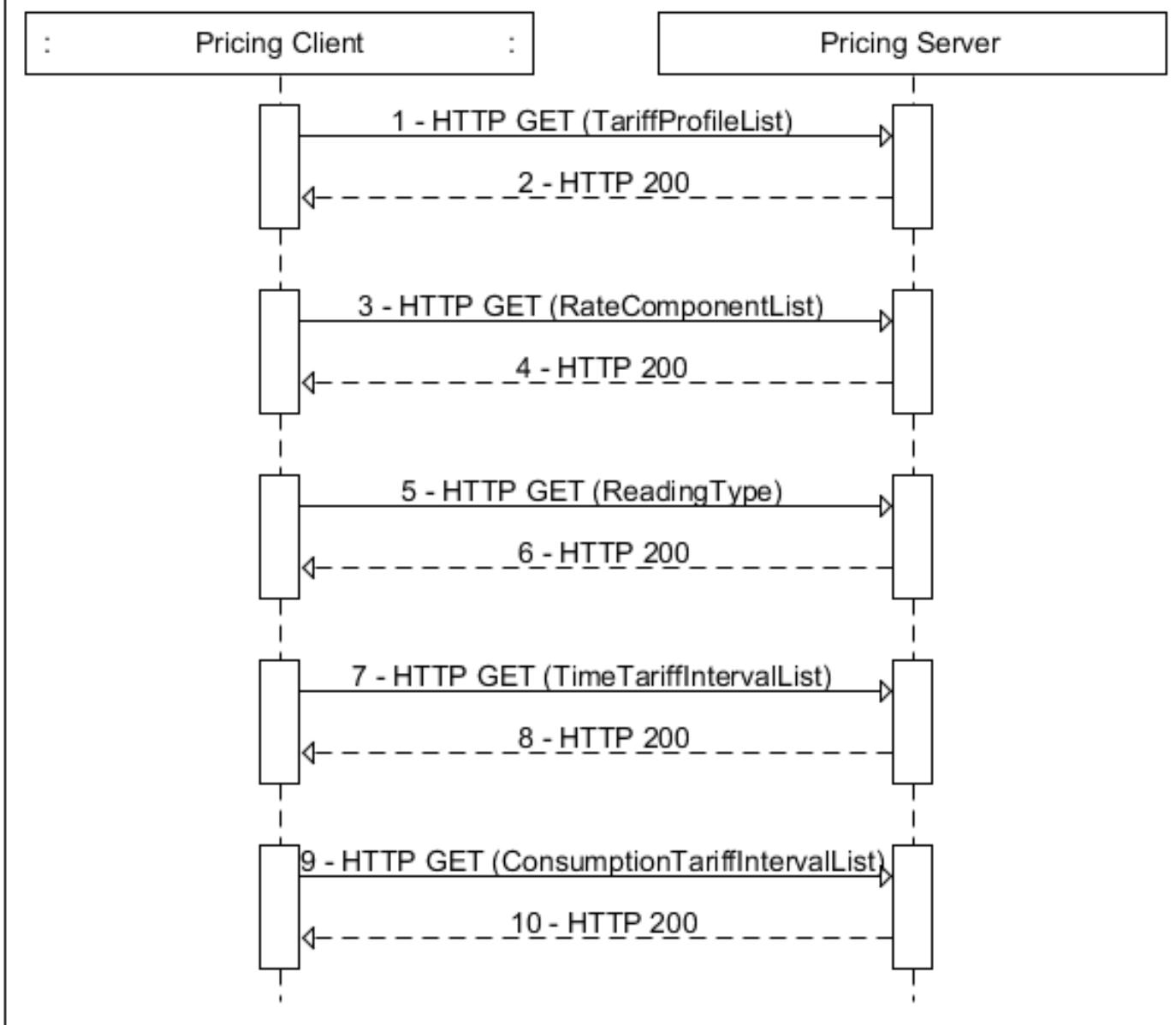
Subscription / Notification

- A RESTful mechanism to support “pub/sub” behavior
- Allows a device to subscribe to certain resources (those marked “subscribable”) and receive notifications when those resources change
- Supports thresholds
- Requires both client and server to implement HTTP server

An Example: Finding Price Server

- Ignoring Registration and FunctionSetAssignments for the moment
 - 1. Client (e.g., display) joins HAN (link layer)
 - 2. Client issues xmDNS/DNS-SD query with type=smartenergy and subtype=tp
 - 3. Appropriate server(s) respond with various information including path:
path=/tp (only an example URI, could be different)

Pricing: TOU



An Example: Obtaining Current Price (the first time)

1. Client requests `https://[server]/tp`
2. Server responds with a list of TariffProfile objects:

```
<TariffProfileList href="/tp" all="1" results="1" xmlns="http://zigbee.org/sep">

  <TariffProfile href="/tp/1">

    <mRID>799794f4620b17e00000e566</mRID>

    <description>Standard Rate</description>

    <currency>840</currency>

    <pricePowerOfTenMultiplier>-6</pricePowerOfTenMultiplier>

    <primacy>0</primacy>

    <rateCode>FLAT</rateCode>

    <RateComponentListLink all="1" href="/tp/1/rc"/>

    <serviceCategoryKind>0</serviceCategoryKind>

  </TariffProfile>

</TariffProfileList>
```

An Example: Obtaining Current Price (continued)

3. Client requests `https://[server]/tp/1/rc`
4. Server responds with a list of RateComponent objects:

```
<RateComponentList href="/tp/1/rc" all="1" results="1" xmlns="http://zigbee.org/sep">

  <RateComponent href="/tp/1/rc/1">

    <mRID>fc000b07143d24fc0000e566</mRID>

    <description>Standard Rate</description>

    <ActiveTimeTariffIntervalListLink all="1" href="/tp/1/rc/1/acttti" />

    <ReadingTypeLink href="/rt/1" />

    <roleFlags>1</roleFlags>

    <TimeTariffIntervalListLink all="5" href="/tp/1/rc/3/tti" />

  </RateComponent>

</RateComponentList>
```

An Example: Obtaining Current Price (continued)

5. Client requests `https://[server]/rt/1`
6. Server responds with a `ReadingType` object:

```
<ReadingType href="/rt/1" xmlns="http://zigbee.org/sep">  
    <accumulationBehavior>9</accumulationBehavior>  
    <commodity>1</commodity>  
    <dataQualifier>12</dataQualifier>  
    <flowDirection>1</flowDirection>  
    <kind>37</kind>  
    <numberOfConsumptionBlocks>1</numberOfConsumptionBlocks>  
    <numberOfTouTiers>1</numberOfTouTiers>  
    <phase>0</phase>  
    <powerOfTenMultiplier>3</powerOfTenMultiplier>  
    <uom>72</uom>  
</ReadingType>
```

An Example: Obtaining Current Price (continued)

7. Client requests `https://[server]/tp/1/rc/1/acttti`
8. Server responds with a list of TimeTariffInterval objects:

```
<TimeTariffIntervalList href="/tp/1/rc/1/acttti" all="1" results="1"
subscribable="1" xmlns="http://zigbee.org/sep">

  <TimeTariffInterval href="/tp/1/rc/1/tti/0">

    <mRID>ef06fa23dc0a0f650000e566</mRID>

    <description>Standard Rate</description>

    <creationTime>1357430400</creationTime>

    <EventStatus>

      <currentStatus>1</currentStatus>

      <dateTime>1357516800</dateTime>

      <potentiallySuperseded>false</potentiallySuperseded>

    </EventStatus>
  
```

(Continued on next slide)

An Example: Obtaining Current Price (continued)

```
<interval>
    <duration>28800</duration>
    <start>1357516800</start>
</interval>
<randomizeDuration>300</randomizeDuration>
<randomizeStart>300</randomizeStart>
<ConsumptionTariffIntervalListLink href="/tp/1/rc/1/tti/0/cti"
all="1" />
<touTier>1</touTier>
</TimeTariffInterval>
</TimeTariffIntervalList>
```

An Example: Obtaining Current Price (continued)

9. Client requests `https://[server]/tp/1/rc/1/tti/0/cti`
10. Server responds with a list of ConsumptionTariffInterval objects:

```
<ConsumptionTariffIntervalList href="/tp/1/rc/1/tti/0/cti" all="1" results="1"
xmlns="http://zigbee.org/sep">

  <ConsumptionTariffInterval href="/tp/1/rc/1/tti/0/cti/0">

    <consumptionBlock>1</consumptionBlock>

    <price>113000</price>

    <startValue>0</startValue>

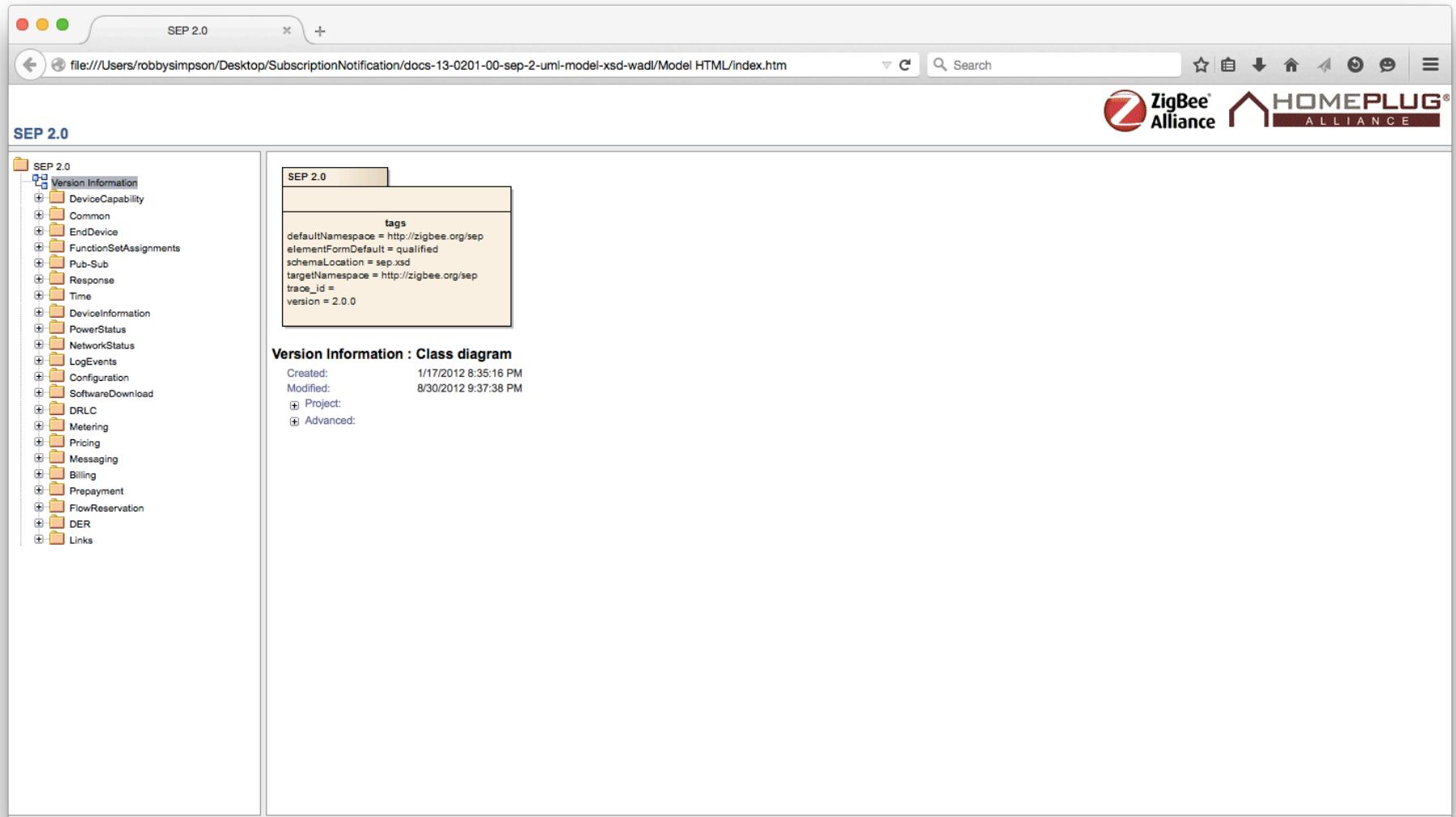
  </ConsumptionTariffInterval>

</ConsumptionTariffIntervalList>
```

An Example: Obtaining Current Price (after the First Time)

- After the first time, clients need only perform steps 7 – 10 to obtain an updated price, as the results of steps 1 – 6 are not likely to change often
- IEEE 2030.5 gives guidance on when steps 1 – 6 may need to be repeated
- Clients can intelligently understand how often price may change
- Clients can subscribe to price to be alerted of changes
- Clients can query the overall list of TimeTariffIntervals to understand future prices

Let's Open the Model and Look Around!



Contact Information

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