Moving from Standards Development to Field Implementation: A Case Study of a Regional Demonstration Project

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Abstract

The on-going DOE-funded Regional Smart Grid Demonstration Projects were asked to contribute to the advancement of Smart Grid interoperability standards. One of the questions that remains unanswered is: How does this intent translate into actual adoption of standards-based products within vendor and utility systems? For the Pacific Northwest (PNW) Regional Demonstration Project[1], a Work Group took on answering this question.

Including the interoperability standards objectives as part of the Project scope and planning is one thing; actually creating the process, methods and culture to implement the objectives is quite another challenge. This paper discusses the approach taken by the Regional Project to organize the assessment of applicable NIST Smart Grid standards; recommending them to the project design team; gaining acceptance and adoption of these standards; and lessons learned to date. The Project developed information on the actual plans for interface standards to be used by the utility members in communications between the transactive control signals and the various assets under utility control, and the local inputs required to the transactive nodes. The patterns of standardization provide an instructive snapshot of the current state of standards awareness and adoption within a subset of regional utilities.

As the industry moves from standards development to standards-based products, the challenges of shifting the culture to embrace standards becomes a major enabler of or impediment to adoption. The lessons learned in the PNW Regional Smart Grid Demonstration Project can help executives and managers committed to standards understand the challenges and better plan and execute their goals.

1. INTRODUCTION

The Pacific Northwest (PNW) Regional Project [1] includes a key objective:

> *"Advance standards for 'interoperability' (the smooth, seamless integration of all elements of the electric system) and cyber security approaches."*

The PNW Regional Project Narrative [2] submitted to DOE included a primary goal:

> *"Contribute to the development of standards and transactive control methodologies for a secure, scalable, interoperable smart grid for regulated and non-regulated utility environments across the nation…*
>
> *"Interoperability will be addressed at the points of interface between the systems and will draw from and contribute to the current NIST smart grid interoperability standards activities. These contributions will include participation in defining real-time pricing signal standards and further definition of transactive control."*

Further, the Interoperability and Cyber Security Plan [3] included a major goal as follows:

> ***"****The overarching goal of the DOE Regional demonstration projects with respect to interoperability standards is to use and/or provide meaningful and specific feedback to NIST and standards organizations regarding standards as they apply to the demonstration projects… The specific technology in the PNW Smart Grid Demonstration Project is the Transactive Control System (TCS), a region-wide electric grid status and value signaling system. This implies creating a knowledge base of existing standards that apply, using them, and in cases where no standards exists or they are inadequate, adapting/merging/modifying them where needed."*

A Project Interoperability Standards Work Group was created to address these project goals and objectives. While the work is continuing over the life of the 5-year project, the work undertaken to date and the results so far are instructive and can inform similar efforts at standards analysis and implementation.

This paper summarizes the process and results to date of the PNW Regional Demonstration Project Interoperability Work Group.

2. INTEROPERABILITY STANDARDS WORKING GROUP

The Project team set up a Standards Working Group headed up by two experts in the NIST Interoperability Standards [4] work and including Project Infrastructure and Utility Partner members. The following charter of the Working Group has governed the Work group efforts:

[1] This material is based upon work supported by the Department of Energy under Award Number DE-OE0000190.

1. Investigate the potential for incorporating appropriate Smart Grid interoperability standards into the PNW Project technology.
2. Create a knowledge base of existing standards that are relevant to PNW Project, starting with the Release Cycle 1 (RC1) Transactive Control Signals [5] and evolving to cover Release Cycles 2 and 3 (RC2 and RC3) functionality[2].
3. Recommend appropriate standards for the PNW Project technology design.
4. In cases where no standards exist or they are inadequate, adapt/merge/modify or help create where needed.
5. Provide feedback to the Standard Setting Organizations where shortcomings are observed and suggest changes based on the Project experience.
6. Assist Project Utility Partners in understanding which standards relate to their demonstration projects and how to make use of them.

The initial scoping for the Work Group included:

1. Standards work based on the layers of the GridWise Architecture Council's GWAC stack[3] [6]:
   a. Emphasis on Semantic Understanding and Syntactic Interoperability Layers of the GWAC Stack (Interoperability Categories 3 and 4).
   b. Comprehend the Business and Organization Layers (Interoperability Categories 5-7) of the GWAC Stack to help with gaps and consistency.
2. Understanding how standards align with project deliverables:
   a. Definition of Transactive Incentive Signal (TIS) and Transactive Feedback Signal (TFS) messages, flows and topologies.
   b. Consideration of algorithms and data used by the Transactive Node (TN) to update the TIS/TFS.
   c. Concern for the management of responsive assets using standardized communications protocols. Mature networking and communications standards, such as HTTPS, SOAP, UDP, etc., are included but assumed to require little modification: this does not preclude Work Group feedback to standards organizations on performance, security, etc. related to networking transport and application layers later in the Project.

The evaluation and use of standards was prioritized based on the schedule for the development of the technology in parallel with the development of each release candidate. To date the Standards Work Group has focused on three distinct technology areas for interoperability standardization:

1. The Transactive Incentive Signal (TIS) and Transactive Feedback Signal (TFS)
2. Output formats from the Transactive Node Toolkit Functions for communication to responsive assets[4], and
3. Formats of local and regional data inputs to the Transactive Node Functions.

The initial approach to the standards challenge for the project was to leverage the NIST recommended standards in the V1.0 Smart Grid Standards Framework and Roadmap [7] and Draft V2.0 [8] as a starting point. The Work Group has to date experimented with three distinct methodologies:

1. For the TIS/TFS analysis, the Work Group performed its own detailed analysis of relevant standards and made a recommendation to the Design team;
2. To investigate the standards that could be output formats for the control of responsive assets, a survey of the utility partners was conducted; and
3. For assessing the potential input standards for data to be used in computing the TIS/TFS signals, a review was conducted of applicable standards with input from several utilities and the Bonneville Power Administration.

2.1. TIS/TFS Standards Review

The TIS/TFS signals are basically location-specific computations and forecasts of the cost of energy at any transactive node in the system in terms of $/kWh or $/mWh. The Work Group research addressed whether standards already existed for communicating such information in a forecast signal that would meet the Project requirements.

The research by the Work Group included:

1. Reviewing the list of standards identified in the NIST Framework and Roadmap V1.0;
2. Expanding the list to include standards being considered for inclusion in the Roadmap;
3. Reviewing relevant SGIP Priority Action Plans (PAPs) [9], especially PAP 3 (price), PAP 4 (scheduling), and PAP 9 (DR, DER, markets);
4. Studying state-of-the-art market signaling specifications from the leading ISO/RTOs such as PJM, ERCOT, and CAISO;
5. Determining if there are areas the Project should borrow from and offer feedback for improvement.

Once specific relevant standards were identified, the team prepared an analysis that included:

- *Supporting Standard Documentation (What documentation the analysis was based upon)* List of

[2] Release Cycle 1 defined the Transactive Incentive and Feedback Signals; Release Cycle 2 defined the Transactive Nodes, inputs and outputs and a Toolkit of functions and algorithms. Release Cycle 3 is an integration cycle but will inform technology from the Project that may be recommended to Standards Setting Organizations.

[3] Interoperability Context-setting Framework, v1.1, is referred to as the GWAC Stack to imply that it is somewhat analogous to the ISO Seven-Layer Communications protocol model.

[4] Those assets deployed by utilities as part of the Demonstration Project that are intended to be controlled in response to the TIS/TFS signal.

standard reference documents with links to web-available documents. Where standards need to be purchased, specific links to purchase web sites are included.

- *Status of the Standard.* Has it been formally adopted? What version is the current one? Is there a formal certification program in operation? Are there products certified or in development? For standards still in development, estimated schedule for completion and availability of vendor products.
- *How is the standard relevant to the PNW Demo Project?* Which aspects of the Project's technology could be satisfied in whole or part using this standard? What benefits would it have over custom-developed solutions?
- *Detailed background.* High level overview of the standard and specific parts most relevant to the Project. What does the standard do? Why this standard versus other standards that address the same interfaces or functionality? If specific parts or components of the standard are most relevant, why?
- *Additional details for design team decisions.* As needed, provide additional details that allow the design team to make a decision on incorporating the standard or portions thereof. Are commercial products or code available? Are commercial test tools and test suites available to support adoption? What changes do the standards imply to initial design concepts and specifications?
- *Summary of observations relevant to the project and recommendations.* What are the specific recommendations to the design team and suggested resources for proceeding to adoption and implementation?

The Work Group then presented the results and recommendations to the Design Team.

2.2. Transactive Node Toolkit Function Output Standards

A key technology aspect of the Project is developing a Toolkit of standardized functions for the computation of the transactive signals and management of the transactive nodes themselves. The standards question concerned whether there were industry standard output formats that would assist facilitation of the development of the transactive nodes and their functions by the Project Utility Partners. It is notable that "outputs" from a node are characterized as control signals or other data communication to a utility's responsive system resources.

The Standards Work Group developed an extensive survey for the Project Utility Partners that covered their expected needs in terms of information outputs from the Transactive Node RC2 Toolkit Algorithms. The survey included a matrix of possible standard information formats that might be used to communicate with each responsive asset class.

Each of the 11 Project Utility Partners was asked to complete the survey during the month of June as best they could. All 11 Partners completed the survey and responded to clarifying questions. This report summarizes their responses and makes recommendations to the design team for the use of specific information output formats from the RC2 Toolkit Algorithms.

The initial questions in the survey were of a general nature aimed at understanding the basic architectural model being planned, as well as the need for specific information format outputs from the Transactive Nodes at the Project Utility Partner level. The Questions included:

1. How are you planning to implement your Transactive Control Node? Using the IBM iCS-based Node (ISO/IEC 18012) and/or the Proxy Node?

   ☐ iCS Node ☐ Proxy Node

2. Will you manage your responsive assets directly from the Transactive Node or use an intermediate asset management or control system?

   ☐ Manage assets directly ☐ Manage assets through a control system

3. How are you planning to convert the information in the Transactive Control Signal to the protocol used to communicate with your responsive assets or the control system for them? [Open-ended responses]
4. How do you plan to communicate information into the Transactive Node algorithms? What format or formats will you use? [Open-ended responses]
5. Would it be useful to include conversions to or from the standard formats you will be using to control your responsive assets in the Transactive Node Toolkit? Please specify which formats would be most useful to you. [Open-ended responses]
6. Would it be useful to include conversions to or from the standard formats you will be using for inputs to your algorithms in the Transactive Node Toolkit? Please specify which formats would be most useful to you.

These were followed by specific sections for each class of the Project's Responsive Assets. Each of these sections listed potentially relevant standards and asked for additional information or non-listed standards to be included.

2.3. Transactive Node Toolkit Function Input Standards

Complementary to the output standards aspect of the Project is the potential use of standardized inputs to the Toolkit Functions for the computation of the TIS/TFS signals themselves. The standards question concerned whether there were industry standard formats that would facilitate the development of the transactive nodes by the Project Utility Partners.

The Work Group started with a catalog of potential data inputs that had been identified in the original Project Requirements Document: "inputs" to a node are characterized as local data of interest for the node's computations and TFS forecasting. These included such data inputs as:

- Forecasted Wind
- Hydro Schedule
- Price of Fuel
- Regional Load Forecasts
- Power Market Indices
- Generation Schedule

- Transmission Topology
- Solar Availability
- Solar Forecast
- Generation Outage Schedule
- DER Forecast
- Current Weather
- Forecasted Weather
- Power Tariffs
- Historical Load Data

The team next developed a matrix of possible standards for each of the inputs. The matrix included a combination of NIST Roadmap identified standards and those in use by regional utilities and BPA.

Finally, the team interviewed experts on each of the inputs and standards from BPA and several of the Project Utility Partners to understand which of the standards were in use and would make most sense to recommend for the Toolkit.

The results of both the Input and Output standards research and recommendations were presented at a Project Team face-to-face meeting in September, 2011.

3. RESULTS AND RECOMMENDATIONS

While the primary focus of this paper is on the process and lessons learned, a quick review of the results to date will inform the discussion.

3.1. TIS/TFS Standards Recommendations and Results

The Standards Work Group developed a final target list of relevant standards after several iterations of analysis and investigation. The final RC1 list included:

Requirement/ Interface	Standard	Status
TIS/TFS Fields Syntax, Semantics	eMIX V1.0	Recommended to design
TIS/TFS Fields Syntax, Semantics	SEP 2.0	Review again for RC2 Toolkit
TIS/TFS Fields Syntax, Semantics	ISO 18012	Included already in TIS/TFS design
TIS/TFS Fields Syntax, Semantics	ISO/IEC 15067-3	Included already in TIS/TFS design
TIS/TFS Fields Syntax, Semantics	ISO/IEC 15045	Companion to 18012
TIS/TFW Fields Syntax, Semantics	IEC 61850	Still researching Part -4-720 DR integration from load end. Possible RC 2
TIS/TFW Fields Syntax, Semantics	CIM, 61970	Recommended to design
Identification of universal object ID Node description	CIM with 61850 identifiers.	Recommended to design for topology of nodes
TIS interval Start Time	WS-Calendar	Recommended to design
Utility standards	P2030	Still in research

The investigators were assigned, to the extent possible, based on relevant expertise in the specific standards.

The next step was to independently evaluate each identified standard and develop a report and recommendation. The team used the model developed early on to document the results of each investigation. The results of the investigations for RC1 are documented in reports included in the minutes and on the Project SharePoint [10].

The Standards Work Group recommended the adoption of the emerging OASIS WS-CAL V1.0 for defining timing intervals of the TIS/TFS forecasts and IEC CIM (IEC 61968/70) for basic communications formats in the Project. ISO 18012 (based on IBM's internet Control System technology) along with ISO/IEC 15067-3 and ISO/IEC 15045 for transactive node technology was included in the original Project proposal and plan and was adopted early on in the Project.

Only the ISO 18012 has been adopted based on its inclusion as an integral part of the transactive node design from the outset of the Project. WS-CAL was rejected because of its excessive overhead in implementation, and CIM was rejected due to its inherent complexity requiring investment in training and skills deemed unavailable to the Project.

3.2. Transactive Node Toolkit Function Output Standards Recommendations and Results

Based on a survey of Subprojects conducted in May-July of 2011, Subprojects plan to use the standards summarized in the Table below:

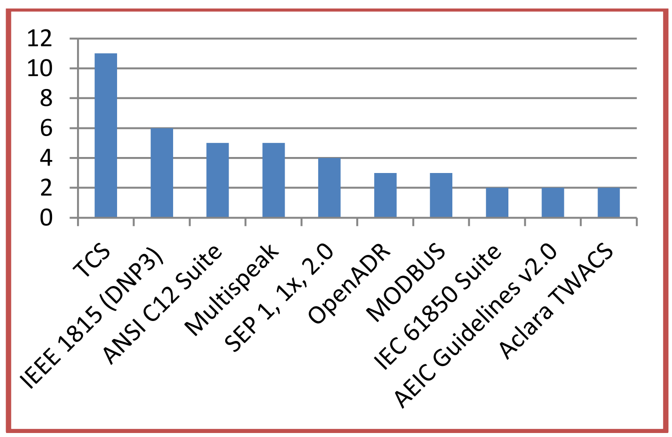

Figure 1: Communications Standards for Responsive Assets

Based on the above summary, the key standards to consider in developing the RC2 Toolkit output are IEEE 1815 (DNP), Multispeak, SEP, OpenADR and MODBUS. Details of the study questions and Subproject data format plans are in the balance of this report.

In terms of conversions from the TIS signal format to another format relevant to the control of responsive assets, two utilities thought it might be helpful; two did not see the value and the others were not sure or did not respond specifically. The survey was conducted before definitive information on the RC2 Toolkit and final TIS/TFS signal definitions was available to the Subprojects, making it difficult to come to firm conclusions.

Due to the variety and uniqueness of assets, control systems, vendors and architectures, the Work Group did not see a specific recommendation it could make to the design team other than to output information from the TN Toolkit functions in a standardized XML format. Each Subproject is importing the TIS signal and any TN processed data into its own set of algorithms which will be converted to appropriate control signals for its unique responsive assets.

3.3. Transactive Node Toolkit Function Input Standards Recommendations and Results

The work on the Input and Output standards was scheduled to be completed before major design decisions were made relative to input and output formats.

Based on discussion with participants, the following standards were considered in detail:

- ICCP (Inter-Control Center Protocol) TASE.2 IEC
- OPC (OLE for Process Control, bridge for Component Object Model)
- EIDE (Energy Information Data Exchange)
- METAR (aviation routine weather report)
- Multispeak (proposed IEC 61968-14 mapping)
- ISO 19115 (GIS meta-data)

The information below is based on further research and discussions the Work Group completed with various Project Partners:

- ICCP
    - Requires investment
    - Client-server package required
    - Real-time standards, requires additional historian for data capture
- OPC Data Access
    - Requires investment
    - Client-server package required
    - Industry de facto standard, but few participants plan to use
- EIDE
    - Technology standard (WECC) for information transfer
    - XML Based, considered easier to implement
- METAR
    - Flat file, XML compatible, many sources for the data
- GIS 19115
    - No evidence to include as a GIS standard for all participants

The team concluded that the two most useful standards for the Project are EIDE and METAR and presented these recommendations, along with a brief overview and references, to the Project Design Team for further study.

4. LESSONS LEARNED

Undertaking the development and execution of a process for introducing evolving standards into a utility development project has proven to be both challenging and very instructive. The results of this process are just starting to become apparent as the Design team works with the recommendations. To date, there are some useful observations about the process that can inform continuing Standards efforts in the PNW Demonstration project as well as in other organizations attempting to implement standards while designing a new system.

1. *Standards start with functional requirements.* The PNW Regional Demonstration Project started with a Requirements process that addressed interoperability standards in some respects:

    a. The design of the Transactive Control signals was specified to be XML standard compliant.

    b. Identified a UTC time standard for time representation.

    c. Identified that interoperability standards were a requirement in general and specifically identified that standard calendaring and scheduling were requirements. Further, the functional requirements identified three specific standards (OASIS WS-Cal, CalConnect (IETF iCal) and ISO 20022) to be considered in the design of the Transactive Control system.

    d. A specific requirement identified CIM as a potential data structure and topology methodology.

    Other than calendaring, CIM and a general requirement to use standards where applicable, the Project functional requirements did not specify interoperability standards. This is standard technology development process. While specifying standards may or may not be part of functional requirements, it is important to send a message to designers that standards are an important issue. Setting the priority to be paid to standards is an important early step in a project.

    The recommendation on this issue is:

    > *Functional requirements need to be explicit on the importance of standards. Where circumstances make a specific standard a requirement, it needs to be explicit in the functional requirements. Otherwise, requiring consideration of standards during the design phase is an important message to send to a team.*

2. *Standards research needs to be done in parallel with actual design and made available in time to affect the design decisions*. Otherwise, the costs in time and effort to implement a standard into a started design may derail the standards effort. The experience so far is that adopting a standard after initial design work has started threatens the project schedule and the investment already made in a non-standard design. This experience reinforces the advisability of making standards an explicit priority early in the project.

3. *Designers need to be involved with standards investigations and need support for adoption*. This is a common-sense management lesson. Those responsible for implementation invariably are more supportive if they have been involved in the implementation strategy decisions, in this case which standard(s) to adopt for each feature or function of the Transactive Control system.

4. *Schedule time and resources for standards evaluation and adoption*. One of the Project's observations was the discovery that once design work has progressed to code development, the project team had increased resistance to any additional requirements or re-writes to incorporate a standard not already planned. If standards are intended to be a key element in the design it is wise to build time and resources into the schedule to accommodate the effort required.

5. *Have team members with knowledge of and involvement in relevant standard groups.* The particular Work Group that assembled for the PNW Regional Demonstration Project was fortunate to have a number of people with a great deal of interoperability standards expertise. This made it relatively easy to understand and evaluate the standards investigated. This also makes it easier to get in touch with the SSO responsible for the standard to get the latest versions and insights into progress on future releases.

6. *Set up a clear evaluation process with clear criteria for selecting and implementing a standard*. This is one thing that was not considered for RC1, but rather the Project operated on subjective and "instinctive" criteria and some discussions about what would make the most sense. Reliance was placed on the judgment of the individual team members who were evaluating a particular standard. While an explicit set of evaluation criteria and associated rating system were not developed, a priority list for standards consideration was created. This acted as a pseudo set of criteria. In hindsight, an explicit set would have been more useful.

The Standards Work Group used the above lessons learned from RC1 in the next phase of standards evaluations. The result was a clear recommendation made early enough in the release cycle to be adopted by the Design team.[5]

[5] As of the writing of this paper the two Input standards had been recommended and are under detailed review by the Lead Architect.

5. FUTURE INTEROPERABILITY STANDARDS TASKS

A number of tasks still remain on the PNW Interoperability Standards Work Group agenda. These include:

- Collecting data from the Utility Partners to support cost/benefit analysis for the various Smart Grid demonstrations included in the Project. This is a key aspect of the Project. The Standards team was asked to assist in identifying the optimum data format standards to use for these purposes.
- Standards recommendations to utility partners. The process of surveying the utility partners suggested a need for a guide to interoperability standards for the Project.
- Interval Schema to OASIS. The Design Team rejected WS-CAL as the standard for forecast intervals and developed a specific XML schema. Since the standardization of forecast intervals is nascent, the Project plans to submit the schema for intervals to an appropriate SSO for possible adoption as a national and international standard.
- National Standards process input for TIS/TFS and other new technologies. Transactive control is a radically new concept for energy market management that does not have any implemented standards. Some work has started to identify potential standards setting organizations that would be interested in developing national standards based on the Project core technology for transactive control.
- Smart Grid Interoperability Maturity Model Trial. The PNW Project intends to be an early adopter of the GridWise Architecture Council's developing Smart Grid Interoperability Maturity Model [11].

6. REFERENCES

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[3] "Pacific Northwest Smart Grid Demonstration Project Interoperability and CyberSecurity Plan", PNW-SGDP-TD-001 Revision 3, March 2011, Battelle memorial Institute, Columbus, OH

[4] Ron Ambrosio, IBM research, former Chair of the GridWise Architecture Council, Chair of the SGIP Smart Grid Architecture Committee. James Mater, member of the SGIP Test and Certification Committee; recognized for contributions to the GridWise Architecture Council mission.

[5] See for instance Melton "Transactive energy system control from concept to application", Grid-Interop Proceedings, 2010.

[6] GridWise Architecture Council, "Interoperability Context-setting Framework, v1.1," March 2008. Accessed February 2010 at http://www.gridwiseac.org/pdfs/interopframework_v1_1.pdf

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[8] National Institute of Standards and Technology, "NIST Framework and Roadmap for Smart Grid Interoperability Standards, DRAFT Release V2.0 Tables 4-1 (3-21-2011) and 4-2 (3-29-2011).

[9] Smart Grid Interoperability Panel Priority Action Plans: see http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PriorityActionPlans descriptions and latest information.

[10] Battelle Northwest maintains a Project SharePoint site that collects and organizes all Project documentation and planning.

[11] GridWise Architecture Council, "Smart Grid Interoperability Maturity Model". See, for instance, J Mater and R Drummond, "A Smart Grid Interoperability Maturity Model Rating System *Predicting "Plug and Play" Integration Probability"*, Grid-Interop 2009, http://www.gridwiseac.org/pdfs/forum_papers09/mater.pdf.

7. BIOGRAPHY

James Mater founded and has held several executive positions at QualityLogic Inc. from June 1994 to present. He is currently Co-Founder and Director working on QualityLogic's Smart Grid strategy, including work with GWAC, the Pacific Northwest Smart Grid Demonstration Project, and giving papers and presentations on interoperability. From 2001 to October, 2008, James oversaw the company as President and CEO. From 1994 to 1999 he founded and built Revision Labs which was merged with Genoa Technologies in 1999 to become QualityLogic. Prior to QualityLogic, James held Product Management roles at Tektronix, Floating Point Systems, Sidereal and Solar Division of International Harvester. He is a graduate of Reed College and Wharton School, University of Pennsylvania.

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Bora Akyol holds M.Sc. and Ph.D. degrees from Stanford University in Electrical Engineering in the area of Wireless Networking. Before joining Battelle, he was a technical leader at Cisco Systems in San Jose. His work at Cisco includes service blades for the Catalyst 6500 series switches, 1250 and 1140 series 802.11n access points, IKE and IPSEC protocols, as well as the next generation identity-based networking products. Bora has published 2 IETF RFCs, holds over 10 patents in the areas of wireless and Ethernet networks, congestion control and software engineering, and has been active in both IETF and IEEE. He is a veteran of three start-ups in SF Bay Area. At Battelle, Bora is performing research and development in the areas of network security, information sharing protocols and Smart Grid. He is the cyber security lead for the Pacific Northwest Smart Grid Demonstration project.