

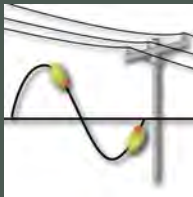
Communication Modularity

A Practical Approach to Enabling Residential Demand Response

May 2011



An EPRI White Paper



Situation Analysis

An important part of the smart grid vision is enabling communication-connectedness with residential devices so that they can be informed of grid conditions, including energy price, critical peaks, and other curtailment events. Informed devices may respond by reducing consumption or delaying their operation until another time, according to the preferences and settings of owners. Communication to intelligent devices, rather than cutting their power off with a remotely managed switch, provides more flexibility for consumers and allows manufacturers to innovate, discovering creative ways to maximize energy savings while minimizing user inconvenience.

Many different communication architectures and technologies are presently being used and several new ones are being considered for integration of residential loads. Grid information may reach the home through diverse means (e.g. AMI system, cellular, FM radio, Internet, paging, power-line carrier, etc), each being optimal under different utility circumstances. At the home, these signals may be received directly by individual end devices, or may end at the meter or an energy management console that passes information along to local devices using a secondary communication system. Another possibility, particularly in the near term, is that consumers may prefer to stay on a flat rate and not to receive or respond to utility signals at all. These consumers would not require any demand response (DR) communication and may not be willing to pay more for products that have such capability.

The natural difficulty in providing products to serve such a diverse market is compounded by the fact that the end products may serve for 20, 30, or even 40 years whereas communication technologies are evolving much faster. In addition, consumers may relocate from one utility service territory to another, taking their products with them.

A practical way to address this problem is through the definition of a standard modular interface (such as illustrated in Figure 1) that enables products to be compatible with any demand response system through plug-in communication modules. If standardized and broadly adopted, this kind of socket interface would enable utilities to freely choose and evolve their communication systems, while



Figure 1 – Modular Communication Interface Concept

maintaining compatibility with all end devices. Similarly, consumers would be free to select and employ the kinds of systems they prefer, or none at all, without having unnecessary or undesired costs passed their way.

Design through Broad Collaboration

Two years ago, EPRI began a research project to study this concept in depth. The project was designed to bring together end device manufacturers, communication system providers, and utilities in balanced representation. The group was provided with a blank slate, and the challenge to identify the characteristics and capabilities that a modular interface must have in order to satisfy the interests of each stakeholder group and to equally support the wide range of systems and devices from the simple to the complex. Participation

Table of Contents

Situation Analysis.....	2
Design through Broad Collaboration	2
Coordination with Other Industry Activities.....	3
Successful Prototyping and Interoperability Testing.....	3
Ongoing Design Refinement	5
Pathway to a Universal Open Standard	6
EPRI Perspective	6

This white paper was prepared by Chuck Thomas and Brian Seal of the Electric Power Research Institute (EPRI).

was open, free of charge, and free of commitment. Over the course of the project, participation grew to over 150 individuals representing 65+ companies.

The work began with use-case identification, from which requirements were derived. A design was then produced by the project participants based on these requirements. The design is both simple and easily extended, and is supportive of the pass-through of existing standard protocols including IP, OpenADR, and Smart Energy Profile. It guarantees that basic demand responsiveness may always be supported, even if the communication system or the end device is only capable of a few basic of commands, but allows the use of more complex methods whenever both the communication module and the end device are capable.

The simple communication messaging supports direct load control, time of use, critical peak pricing, peak time rebates, all kinds of block rates, real time pricing, and a range of ancillary services. The functionality of the removable modules may be tailored by utilities or other load managing entities to provide support for the unique business drivers of a given region or service territory, and yet without impacting the end-device.

Coordination with Other Industry Activities

Throughout the project, coordination with related industry activity was carried out through presentations, interviews, and cross-participation in working meetings. Applicable bodies of work were studied by the project participants and beneficial elements were incorporated into the work. The final design was influenced by elements from the ClimateTalk Alliance, the Zigbee Smart Energy Profile, Cambridge Consultants' Universal Metering Interface, AS-4755, the MODBUS protocol, and the Serial Line Internet Protocol (SLIP).

The most significant point of coordination was with the USNAP Alliance, where a liaison agreement was put in place that allowed open information sharing between the two groups. The EPRI project and the USNAP Alliance were formed at about the same time, completely independent of one another, but with the same basic vision of a single universal standard for modular communication. The similarity of visions has made the exchange of information and design ideas beneficial to both groups over the course of the project.

Successful Prototyping and Interoperability Testing

At the end of 2010, EPRI project participants concluded that the socket interface design was complete enough to prototype and test, and believed that the best way to identify gaps and ambiguities in the specification was through interoperability testing of devices independently produced. A series of workshops were envisioned, and the first was hosted in May 2011 by Southern Company at Alabama Power's Technology Applications Center in Calera, AL.

Several providers of both end devices and communication systems for demand response voluntarily produced prototypes for this event, including those identified in Figure 2. Several additional companies



Figure 2 – First Interoperability Workshop Participants: Alabama Power, A.O. Smith, ClimateTalk, ClipperCreek, Comverge, e-Radio, EDC, Emerson, Landis+Gyr, Pentair, Portland General Electric, Rheem, Sensus, Southern Company

have prototypes in-process which will be added in the testing in the next phase.

The workshop was a multi-day technical event designed to provide each participant with an opportunity to test their device for compatibility with each of the other products and systems represented. Figure 3 illustrates the range of product and communication system types that were involved in the testing.

As indicated, modules from a total of seven different communication systems were involved in the testing, representing a diverse set of technologies and architectures. To receive these modules were seven types of end devices, allowing a large number of combinations (communication system + end device) to be evaluated.

By the close of the workshop, every product was tested and every combination worked successfully. Both the vendor participants and the utilities who witnessed the testing were impressed by the demonstration of a single consumer product responding cor-

rectly to DR messages delivered through a diverse set of systems. Likewise, much discussion was stimulated by the sight of a single communication module being compatible with a broad cross-section of end devices.

Demonstrated Architectural Flexibility

A modular communication interface enables a wide range of communication architectures. Less technical consumers may prefer not to own or manage a local network and may prefer instead that utility information be received directly by their end-devices through a wide-area communication system such as FM radio, pager, PLC, or other utility AMI. Others may prefer to own and manage a local network, possibly involving a central point of management, coordinated onsite preference settings, and multiple communication technologies. In the latter case, the utility communication system may end at a gateway device or energy management console that represents and manages multiple downstream devices. Discussion regarding utility systems that accommodate

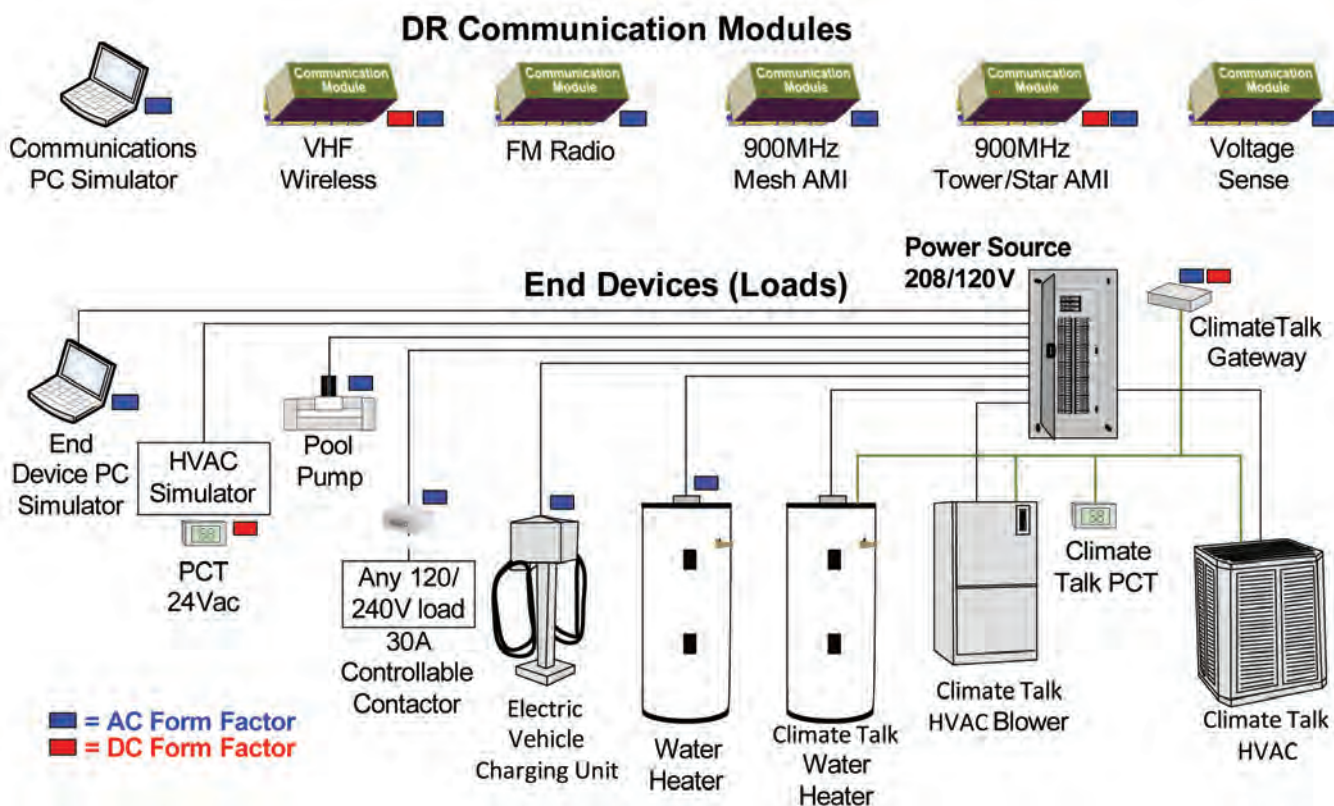


Figure 3 – Each Communication System Tested with Each End Device

architectural diversity and customer system flexibility has been introduced in previous EPRI works.¹

One implementation of this concept was demonstrated during the workshop through the provision of a ClimateTalk gateway and ClimateTalk products from a group of participants. As illustrated in Figure 4, the gateway device was equipped with the socket, allowing it to accept any of the communication modules and thereby to receive the information necessary for demand response. The gateway device then managed the array of downstream devices on the ClimateTalk network using the ClimateTalk protocol. Through this arrangement, the utility systems were able to affect the behavior of all the downstream devices with no system changes. In other words, the same set of communication modules that plugged into the range of end-devices represented in the workshop, also plugged into the ClimateTalk gateway and worked, without modification.

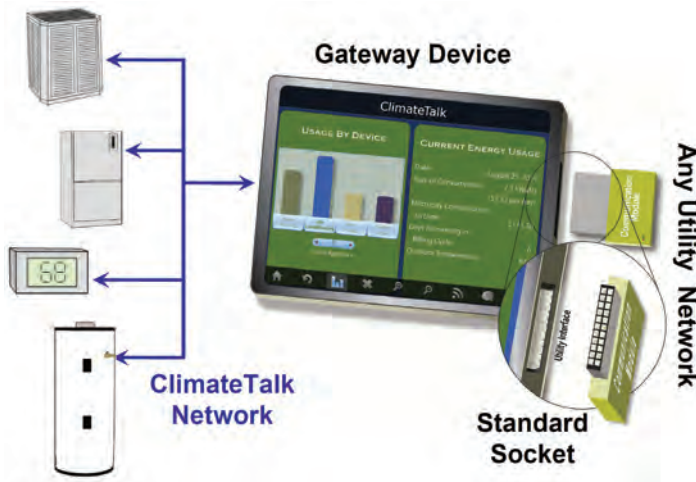


Figure 4 – Gateway Managing Downstream Devices

Demonstrated Dynamic Grid Support

In the typical use of the modular communication interface, the load management messages that are provided to the end-device originate at the utility or other load controlling entity and are transmitted to the end-device through a communication system. An additional possibility also exists, as illustrated in Figure 5.

An AC form factor for the modular interface includes 120/240 line voltage on the connector. This enables power-line carrier communication modules and avoids the necessity of a regulating DC power

¹ http://my.epri.com/portal/server.pt?Abstract_id=00000000001020432

² http://gridwise.pnnl.gov/docs/gfa_project_final_report_pnnl17079.pdf

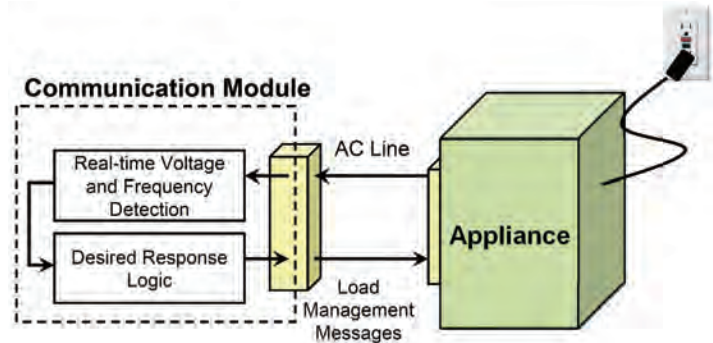


Figure 5 – Local Detection of Grid Disturbances

supply in certain end-devices. In addition, it allows a communication module to directly monitor power quality events such as voltage dips, swells, or frequency deviations; and to take immediate local action to support the grid. Upon detection of an event, the module could instantly generate responsive load management messages to the end-device. The ability for end devices to provide this kind of dynamic grid stabilization was the subject of the Grid Friendly Appliance project at PNNL.² The use of a communication module to provide this functionality adds the flexibility of tailoring the appropriate response to the particular voltage and frequency characteristics of the local system.

To demonstrate this capability, a “Voltage Sense Module” was created for the interoperability workshop. This module did not actually receive any communication from an outside source. Instead, it monitored the line voltage provided on the AC interface and responded in just a few milliseconds with load curtailment messages whenever the voltage dropped below a threshold.

Ongoing Design Refinement

The process of having many participants independently build products to the interface specification was effective in identifying gaps and ambiguities in the specification. During the interoperability workshop, wherever things didn’t just plug-in and work, careful notes were made as to why and how the specification might have been unclear. These findings have helped to improve the specification in ongoing refinement.

Still, there are many optional capabilities of the specification that have not yet been evaluated because they were not implemented by

any of the participants in the workshop. For a feature to be tested, at least one communication system provider and one end-device provider must choose to employ the same feature. The specification then allows for such devices to recognize this capability in one another, and to then begin using the optional feature. An example of this is some of the pass-through protocols such as Internet Protocol and the applications it may transport such as OpenADR or Smart Energy.

Another area of the specification that deserves attention is the physical layer connectors. Project participants, while willing to prototype products using the current electrical/mechanical specification, generally agree that a more optimized connector may be possible. Some devices, such as clothes washers, dryers, or automobiles, involve significant shock and vibration. Others may involve exposure to moisture or temperature extremes. The EPRI project has not conducted any physical-layer environmental testing, although this is planned for the next phase.

Pathway to a Universal Open Standard

In order to be of significant industry benefit, a modular interface specification must become a universal open standard. If such a standard were created and broadly adopted, an economy of interoperable devices would become increasingly viable. Toward this goal, the NIST Home to Grid Domain Expert Working Group (H2G DEWG) requested in early 2011 that EPRI and the USNAP Alliance merge their respective works into a single specification so that it can be contributed to a de jure Standards Development Organization. Both EPRI and the USNAP Alliance were receptive to the request and have been working to produce a unified specification, drawing the best characteristics from each body of work. The activity has progressed quickly, due to the similarity of the high level goals of the two groups of participants.

The merged work is anticipated to be complete by mid-year, and contributed to the selected SDO shortly thereafter. The companies that have been participating in this research, prototyping and testing have expressed a willingness to remain involved in the standards process. Candidate SDOs have estimated processes in the 9 to 12 month timeframe from receipt of the initial contribution to release of a first version specification.

EPRI is currently launching a Phase 2 project, scheduled to coincide with the steps of the SDO process. This project will be centered on building and testing prototypes to continuously evaluate the specification as it progresses through the SDO process. Continued prototype development by independent sources is necessary to identify gaps and ambiguities in the standard as it is finalized and to guarantee interoperability of products. This Phase 2 project will contribute to the development of a general test harness to provide support for product developers and for device evaluation relative to the standard. In the long term, this test harness may be contributed to a users-group or vendor alliance, such as the USNAP Alliance, that could provide ongoing product testing and certification.

EPRI Perspective

It is EPRI's perspective that the public interest is well served by the definition and broad adoption of a universal standard for communication modularity. Such will allow consumer devices to be grid-ready, without bearing unnecessary upfront cost for communication capability that the consumer may never elect to employ. It will also free consumers who are so inclined to choose the programs and networking technologies that they prefer.

Utility interests are likewise served, in that a standard interface allows the design and evolution of demand response systems as needed, being assured of compatibility with end devices and without risk of obsolescence. It enables a single utility system to be equally supportive of both simple, single-appliance connectivity and advanced in-premise networks, without overextending the utility's system reach into areas where commissioning, management, privacy and security are better left to the consumer.

When considered as a whole, EPRI research in the area of integration with residential devices points to the need for modularity of the communication elements. The wide ranging business needs of utilities, the diversity in circumstances (e.g. energy price, customer density, terrain, availability of existing infrastructure), the uncertainty of consumer preferences, the fast pace of communication technology evolution, and the long service life of residential devices; together present an integration challenge that may only be reasonably met by a modular interface.

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI's members represent more than 90 percent of the electricity generated and delivered in the United States, and international participation extends to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together . . . Shaping the Future of Electricity

EPRI Resources

Chuck Thomas, *Senior Project Engineer, EPRI*
865.218.8031, cthomas@epri.com

Gary Aumaugher, *Senior Project Engineer, EPRI*
865.218.8047, gaumaugher@epri.com

Brian Seal, *Technical Executive, EPRI*
865.218.8181, bseal@epri.com

**Communication Modularity: A Practical Approach to
Enabling Residential Demand Response, Program 170**