Free Market Choice for Appliance Physical Layer Communications

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Executive Summary

1. The home energy management market is at an early development stage. Existing technologies are being integrated into innovative new energy management applications, while new technologies are being specifically developed to address this market. The dataset regarding consumer behavior and responses to these new applications is miniscule. While beliefs on how consumers will respond over time continue to be postulated, no one is certain which approach(es) to home energy management will prevail—from a business model, user interface, device, or communications standpoint.

   Accordingly, we believe that it is premature to choose any particular home energy management technologies now, particularly in the area of communication. As an analogy, consider how the use of the Internet developed as technology evolved. Internet access is available via many different MAC/PHY technologies, each of which is appropriate for some applications. Smart Grid-specific technologies will continue to evolve to serve specific markets. To encourage innovation, physical communications standards should not be mandated, certainly not at too early a stage in the market development process.

2. Some stakeholders support the architecture of embedding communication protocols in appliance. However, selecting a short list of communication transports to be embedded in appliances at this early stage is fraught with unintended risks to consumers. Such risks may include obsolescence and the possibility of unauthorized, remote access to appliances via the embedded communications capability. Industry should focus on developing secure messaging models to ensure standardized messaging delivery in a secure fashion, *regardless* of communications transport.

3. To address the risks identified in #2 the H2G group will develop high level requirements for a modular appliance socket interface (like USB, PCI, etc.) (the "Socket Interface"). The Socket Interface must define the physical characteristics and a data transfer protocol sufficient to ensure interoperability and extensibility. These requirements should be passed to NIST and the SGIPGB so they may create a PAP to define the detailed physical, logical, and testing the specifications.

   The objective of the Socket Interface is to provide original equipment manufacturers (OEMs) with an alternative architecture for enabling innovation. This architecture reduces the risk of obsolescence and relieves the appliance manufacturer of the responsibility of designing and warranting a secure HAN (home area network) method. The responsibility instead shifts to the energy service provider who has an ongoing relationship with the customer and who gains the benefits from energy control. Additionally, this architecture allows customers, subsequent to the appliance purchase, to insert a communications module that supports a communications method consistent with a service provider's infrastructure, or consistent with the customer's existing home-energy management system.

   This Socket Interface approach follows proven, best engineering practices to introduce nascent communication technology into existing products. Well-defined socket interfaces have proven to be the most durable interface available in consumer goods. Not embedding a specific HAN protocol directly inside the appliance also gives the consumer ultimate control over access and security. The customer always has the option to remove an inadequate or malfunctioning communication device. This architecture also allows the customer, or their service provider, to replace the existing communications option with a more advanced, or feature-rich option at any time.

Introduction

The Energy Independence and Security Act (EISA) of 2007 directed NIST to assess and coordinate the development of interoperability standards that would be required for the realization of electric Smart Grid. NIST is working with many agencies such as DOE, FERC, and NARUC to fulfill this mandate. (Please see the Smart Grid overview at www.nist.gov/smartgrid.)

In residences, Smart Grid communications for energy management between networked appliances and devices is facilitated both by wireless and wired communications protocols that comprise home area networks (HANs). Today, no single HAN protocol dominates the market, or is sufficiently mature enough to be called pervasive. Even widely used technologies like Wi-Fi are only one of multiple wireless options that are available to consumers.

Until sufficient real-world market data exists, it is impossible to forecast accurately which protocols will be cost-effective options for HAN applications beyond Internet access, such as demand response (DR). Also, the industry and regulators must gain extensive field experience about the performance of wireless communications in a wide variety of home construction environments. Furthermore, many networking solutions exist, including Ethernet on twisted-pair wiring, powerline carrier communications, phoneline, coaxial cable, and numerous flavors of wireless. Although many new homes now include wired infrastructure to enable easier deployment of data networks, all these wired technologies combined are a fraction of the installed base of Wi-Fi. The significant economic advantages of the Socket Interface approach are detailed in the section titled: Economic Consequences.

Some well-organized stakeholders are proposing to choose a "preferred" protocol for both wired and wireless networking. This paper presents technical, market, and economic arguments why such a choice of HAN technologies at this early stage would likely be a serious, shortsighted mistake. Instead, we offer specific recommendations to NIST for adopting an alternative approach.

Technical Issues with Selecting a Physical Layer Protocol

What are the Real Requirements for Communications Protocols?

Limitations of Advanced Metering Infrastructure (AMI)

AMI networks have been proposed for demand response. However, the following issues may challenge an AMI network:

- When large quantities of customers participate in DR using synchronized rate designs like time of use (TOU) and critical peak pricing (CPP), the rebound in demand when high-price periods end may create load problems.[1]
- If short duration (e.g., five-minute) real time prices are the solution, the combination of limited available bandwidth today, asymmetric loading, and long latency of AMI networks may not be appropriate to convey[2] real time price signals to one billion[3] home appliances.
- Latency and signaling requirements for ancillary services may stress AMI networks.[4]
- Network requirements for sending phasor information that keeps millions of roof top solar units on-line during grid transients may not align with AMI networks.

Clearly we need flexibility in communication protocols to enable the more demanding grid applications anticipated.

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[1] The rebound problem from large direct load control programs is well known empirically with many credible references published by EPRI and IEEE. A method to alleviate the problem, such as randomizing restart after a curtailment event, was described by Burke and Auslander, *Modular and Extensible Systemic Simulation of Demand Response Networks* at the Conference on Power Systems in Winnipeg October 2008. http://billstron.com/documents/SystemicControlModel_cigreCanada.pdf.
There are no large implementations of CPP in the US; consequently there is no experience with CPP rebound. In many technology-enabled pilots, CPP has the effect of causing a significant curtailment as in direct load control. However unlike direct load control programs where the utility can control the rebound through the techniques described above, utilities are at the mercy of appropriate rebound control strategies implemented by third parties.

[2] The author has direct personal experience with the operation of more than one radio-based AMI systems installed at Portland General Electric. AMI systems were not designed to send recurring commands or messages to a significant percentage of the communication nodes over a short period, or even hourly. There is enough bandwidth however, to achieve this type of messaging with group broadcast techniques. However these group broadcast techniques may expose undesirable security problems. Even if the broadcasts are secure, frequent repetitive messaging will likely interfere with robust collection of meter data.

[3] One billion appliances assume a future state with most significant appliances receiving control or price signals. This is based on growth from 110 million households in 2010 with an average of five loads appropriate for control. Refrigerators, freezers, window air-conditioning units, dehumidifiers, dishwashers, water heaters, electric dryers, electric space heating, central air-conditioning , pool pumps, electric spas, and others such appliances could be cost effective demand response control points

[4] Certain appliances such as electric water heaters are ideal for providing ancillary services or absorbing unexpected production from wind generation plants. Frequency regulation signals can changes as often as every minute and as described above the AMI networks are not design to send messages every minute. Even a broadcast of such a command every minute will compromise system performance for meter reading. Thus frequency regulation must be implemented for autonomous, local control. However, the control algorithms could be driven by settings that can be updated via the AMI network, and the performance of the appliance under these algorithms could be collected daily. But use cases to modify control algorithms and to collect performances metrics have not been developed.

Are Current Utility Requirements Realistic?

Some industry stakeholders have recently commented that certain use cases requiring feedback from appliances may not be accurate or realistic. Specifically, Google has recommended relying upon meter data for statistical analysis rather than state information from appliances, such as customer override of a control signal. The Google approach[5] is to consider home energy consumption from a macro level, through the use of meter data. There is a real risk that appliance manufacturers and home energy-management system providers will take the OpenHAN requirements and expend unnecessary time and money implementing use cases that don't have proven value when they could be starting with a much simpler set of uses cases and commands.

The importance of the recommended Socket Interface approach is that the initial specification could define a short list of messages with desired, but optional, behavior when the appliance receives them. For example a message that represents "price is higher than average" could be associated with the desired behavior of "cut back average power level or defer operation." The communication module has responsibility to translate the current and any future complex use cases to the relevant command set available at the appliance. Under this approach there is no need to second guess whether the OpenHAN requirements are correct or incorrect. The communication module plugged in by the consumer will implement OpenHAN requirements.

If the early attempts reveal flaws, then the requirements are easily repaired. In the worst case, the consumer will be sent a new communication module but the appliance will be as reliable and functional as the day it was purchased. Some appliances may be able to accept the more complex use cases directly without translation, but the benefit of starting simple is that a basic command set could be implemented sooner. This has large economic benefits. Appliance OEMs don't have to wait for the complex use cases to be vetted by the utility industry. Also there is no risk of incorrectly embedding the interpretation of the more complex use case in the appliance firmware.

A question to be answered is whether the breadth and depth of current use cases burden appliance OEMs with too much cost for communication. For this reason, we think it is premature to mandate full-stack communications and transport protocols for appliance interfaces. Instead, we should start with the essential and basic requirements, and let market experience guide revisions and protocol extensions. Starting with a simple but extensible Socket Interface will ensure an innovative, cost-competitive market delivering benefits for consumers, utilities, and regulators.

The approach described above to eliminate complexity for OEMs is consistent with the reasoning provided by AHAM (Association of Home Appliance Manufacturers) at an April 2010 meeting sponsored by EPRI where AHAM suggested the use of an embedded "light" communication protocol. The AHAM model moves most of the security

[5] The Google approach is stated in comments regarding the development of OpenHAN 2.0 on March 30, 2010.

problems and translation of OpenHAN messaging to a hub or gateway in the home but external to the appliance. If this light communication protocol follows an open protocol common to all OEMs, it would help minimize obsolescence. However, there is still the risk that the selected physical link may not operate in some home, multifamily, or farm settings. If the appliances OEMs do not converge on a single open protocol from the appliance to the hub, obsolesce of the appliance communications protocol is certainly an issue.

Beyond the Smart Grid and Energy Management: the Inter-connected Home

Energy Management is only a subset of home communication applications. Home entertainment systems, such as video gaming systems, TVs, set-top boxes, computer systems, and smart appliances will be interconnected to enable services we cannot even imagine today. These use cases are not yet well understood. In order to enable this capability, a communication protocol embedded in smart appliances needs to be flexible in order to adapt to the marketplace by offering solutions customers can afford and understand.

Firmware Upgrade Limitations with Embedded Communications

Appliance firmware upgrades in the field must be considered for those devices that participate in DR. However, this is a challenge for appliances because some communication systems to the home may be one-way or relatively slow. Also, the additional cost and complexity for appliance makers may be difficult to justify—a truck roll every four or five years adds cost that OEMs, utilities, and consumers will be unwilling to bear. The alternative, for consumers to bring their appliance to a repair center for upgrade is unreasonable. The Socket Interface approach means the repair option for the service provider is to send the customer a new communication module.

Standardized Socket Interface for Communications

One solution to these technical problems might be the Socket Interface that would allow smart appliances to work with a variety of communications devices. Any HAN device would then be customer-installable via a plug-in communication device costing $5 to $10. For example, RS-232, USB, a proposal by EPRI, and U-SNAP are all possible options for a Socket Interface. The EPRI project aims to create an interface specification after soliciting interface requirements from utilities, appliance OEMs, and communication device manufacturers. At this price point, the consumer can readily adopt new communication methods to meet the value propositions of tomorrow—not so with embedded appliance communications designed for the needs of today. Obviously, the Socket Interface would need to be carefully chosen to support anticipated communications requirements.

Communication Solution

There is no optimum single choice of access networks (e.g., xDSL, cable, satellite, fiber, GSM/CDMA, WiMAX) to deliver energy management data and/or control messages to the consumer premises—if there were, utilities would be using it by now.[6] Instead, utilities deploy various methods today, and will continue to do so in the future. One-way VHF and one-way pager actually top the list of the most commonly used communication methods based on the volume of points that have been deployed. Rural utilities have used low speed power line communication techniques for decades to read meters because of the value proposition. Recently, some utilities have proposed reaching homes using one network technology for access, then continuing into the home with other networks such as LonWorks, BACNet, ZigBee, IEEE P1901, or ITU G.hn.

The key motivator for choosing a utility access network is low cost and reliability. One-way, FM/RDS is another method gaining traction in some areas of California and Canada because it meets the needs of simple implementation, low cost, and reliability.

Basic two-way communications enhances reliability by acknowledging the transmitted packet. A notable example of an acknowledged protocol for DR has been deployed by Florida Power & Light (FPL) Company to more than a million points. The technology chosen was *Two-Way Automatic Communications System* (TWACS® from Aclara). Non-communicating meters are used in this particular program. The return communications channel acknowledges the receipt of a utility control signal for appliance operation, allowing FPL to verify that the control signal has reached the controlled point. Ironically, with AMI, the interval data can be used to validate load response; consequently, communications to the appliance with a response from the application rather than just an acknowledgement is not needed to validate that the direct load control signal has reached the premises. Under time-varying pricing, customers will be responsible (as in any other retail market) for observing and responding to price signals.

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[6] For the advantages of different physical layer protocols see the references.

ITU-T, G.995.1 (02/01) Overview of digital subscriber line (DSL) Recommendations [ITU-T standards are called "recommendations." ITU, the International Telecommunications Union, is part of the United Nations.]

"Design Review of Satellite Telemetry based on CCSDS standards and Proposed Hardware Implementation of CanSat," by Waqas Afzal and Adnan Mahmood, *Proceedings of the International MultiConference of Engineers and Computer Scientists* 2008 Volume II IMECS 2008, 19-21 March, 2008, Hong Kong.

"Residential Fiber Optic Subscriber Loops: Information Pipeline or Technology Pipedream?" by B. Mullinix, *IEEE Journal on Selected Areas in Communications*, December 1986.

"Digital cellular telecommunications system (Phase 2+); Specification of the Subscriber Identity Module - Mobile Equipment (SIM - ME) interface, (GSM 11.11)," ETSI (European Telecommunications Standards Institute).

TIA-95-B (October 2004), *Mobile Station-Base-Base Station Compatibility Standard for Wideband Spread Spectrum Cellular Systems* [CDMA].

IEEE Standard 802.16-2001, *IEEE Standard for Local and metropolitan area networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems* [WiMAX].

IEEE Std 802.16e-2005 *Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems - Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands.*

In the present heterogeneous utility environment, no single protocol is likely to be best for a specific home and application. Of greater concern with 2-way DR programs is the fact that the industry, comprised of utilities, appliance makers, and DR providers, has had experience with only a few thousand homes. Customers in these carefully managed pilots based had strong support for the new two-way communication technologies being tested. Under the circumstances, our proposition is that simply not enough evidence of market experience exists to pick protocol winners.

Obsolescence

Typically, home appliances can be expected to last twenty years or more; significant changes occur in the communications industry in such a timeframe. For example, twenty years ago home PC ownership was 19%, with almost none connected to the Internet. As technology evolved, so too have network protocols, with some becoming obsolete in as few as five years. While the Internet launched packet switching on wired networks, it evolved to embrace a wide range of physical media, such as radio, fiber optics, coaxial cable, and twisted pair wires. The Internet incorporates myriad networking technologies including Ethernet, Wi-Fi, cellular, WiMAX, powerline carrier, and more. Each solution was developed in order to meet the constraints of the operating environment and the needs of the applications.

A similar type of environment is envisioned for the Smart Grid, one that will require a range of flexible connectivity options. Thus, based on current limited evidence, it would be too risky a proposition to propose HAN communication standards based on the existing suite of protocols, some of which could very well be obsolete in five years or less.

Best Engineering Practices

The communication modularity in personal computers (PC), now a household commodity, provides an excellent example for the Smart Grid industry. The life of a PC is typically only three to five years, and yet, manufacturers were so concerned about obsolescence and lack of interoperability that they developed modular standardized physical interfaces—enabling them to adapt and support newer communications technologies. These interfaces were based on socket architectures for service offerings such as wireless connectivity to hedge against obsolescence risks. Example of such sockets included the serial port, the ISA slot, the PCI slot, and the PCMCIA socket (which accommodated plug-in Ethernet and Wi-Fi modules, storage, and other technologies). By the mid 1990s, PC manufacturers had enough experience to add Ethernet directly to the PC motherboard, However, since Ethernet was a relatively new technology, it was added via the PCI socket in accordance with best engineering practices. This engineering practice was valid and wise because the initial network interface cards were not always interoperable. The customer could easily correct the network problem by buying a relatively inexpensive new card rather replace the PC or living without network functionality.

This example demonstrates that embedded communication technologies are best considered only after 1) a standard has been accepted by the market, and 2) shortcomings found in a sufficiently large (e.g., the first 10 million) number of units have been resolved, and 3) best design practices are understood by most manufacturers.

Appliance Makers not Motivated to Collaborate on a Communications Protocol

Currently, the largest appliance OEMs do not have the motivation to collaborate on a common communications protocol. Rather, these OEMs prefer to maintain a proprietary machine-local protocol used for inter-module communications within a single appliance and not open the possibility of interoperable communication with their competitors. These local protocols could easily communicate with a small transceiver embedded in the appliance for communication with the Smart Grid. However, with the diversity of proprietary protocols used, this transceiver module would also be proprietary and specific to the appliance manufacturer. Without evidence of a significant market advantage of providing a smart-grid appliance, the OEMs are not willing to move towards a common local protocol to interface with a smart-grid transceiver. Considerable value would be gained by adopting a best-practices approach through research, field trials, and learning from market failures and successes.

Market Issues with Selecting a Physical Layer Protocol

Customer Experience with Two-Way Control Protocols for Demand Response

As mentioned above, customer experience with communication embedded in appliances is practically non-existent; thus, we don't have convincing answers to the following questions:

- What are the market acceptance barriers to two-way communication technologies (versus one-way communication technologies)? How much DR market opportunity will be lost if those customers who prefer to participate only anonymously under a one-way signaling process opt out? (Market tests have revealed some consumer resistance to two-way communications, particularly due to privacy concerns.)
- Will manufacturers and customers prefer energy management embedded in existing network electronics, such as cable/DSL modems, VoIP answering machines, Internet connected TVs, and home media centers? Communication technologies embedded in these relatively short life span devices will change over the life of these appliances—to the consumer's detriment or benefit?
- What business entity is suited to provide service for in-home energy management: store staffs (e.g., Geek Squad), HVAC technicians, utilities themselves, or new Internet-based businesses? Won't these entities have preferences for the communications method to reach the appliances?

Unintended Market Outcomes

If appliance manufacturers embed "standardized" communications protocols into their appliances, and with all the attendant business risks highlighted above, we may inadvertently stifle innovative appliance design. For example, the cost of embedding communications could instead be utilized towards more creative design of "DR-ready" appliances with sophisticated operational flexibility that can be invoked when necessary.

Embedding communication protocols in appliances may impose security and obsolescence risks on the appliance OEM, the customer, or both, but likely not upon the utility that holds the value proposition for smart appliances in the first place.

Risks of Selecting a Physical Layer Protocol

Selecting Specific Protocols Now Imposes Unnecessary Risk

Recommending a small list of protocols now creates the following risks:

- The wrong protocols are picked based on politics and/or incomplete market experience.
- Once selected, the pressure to deliver smart appliances with these protocols could short-change complete and thorough development leading to:
  - Permanent security threats in home appliances, or costly fixes.
  - Appliances with use cases based on immature communication protocols that will quickly become obsolete.
  - Appliances that could be capable of much greater operational flexibility in the future might be short-changed by unintentional limitations of the embedded protocols and associated information models.
- Cessation of innovation in alternative communication methods.
- Privacy concerns are of paramount importance to customers. Two-way communication protocols that send information from inside the home to third parties could be deemed an unconstitutional invasion of privacy on the basis that customers must sacrifice privacy in order to lower their electric bills.[7]
- Hacker conferences (e.g., Black Hat) are featuring the ability to modify firmware in immature protocols to create worms that could take advantage of the two-way feature and infect nearby "wireless" devices, which in turn infect more devices within their reach. This is a good reason not to eschew one-way technologies or to limit the consumer options such as upgrading existing communication devices.

[7] See legal precedents described by Lisovich and Wicker, *Privacy Concerns in Upcoming Residential and Commercial Demand Response Systems*, IEEE Proceedings on Power Systems, Vol.1 No.1 March 2008

Economic Consequences from Selecting Physical Layer "Winners"

Interoperability is a challenge even with proven protocols. In the Pacific Northwest GridWise Demonstration Project, collection of data from the demand response nodes was a problem.[8] Cable and DSL Internet services were sufficiently different that only one of them could be used. The lessons learned from this project resulted in a published paper for the 2007 Grid-Interop conference on the definition and advantages of the Socket Interface approach.[9] This paper documents that implementing a standardized appliance socket creates a present value of benefit greater than $50 billion. The critical assumption to capturing this wealth is that the socket should be universally added to all appropriate appliances over a five-year development period. Once a socket has been added to a product line, all appliances produced in that line would be sold as demand response-ready. Because of the long life of appliances, adding the socket captures what would otherwise be a lost opportunity when a late-adopter customer is finally sold on the idea and adds a communications device 10 years later.

In 2009 Portland General Electric did additional analysis with the model built for the 2007 paper cited above. The analysis demonstrated that even a one-year delay in developing the standardized socket would reduce the present value benefits by $6 billion dollars. They submitted a summary of these results to encourage an effort to fill the gap caused by the lack of a standard appliance interface.[10]

The large economic consequence of delay explains why the Socket Interface approach should be an option in addition to the embedded communication approach. The embedded approach will likely be either slower or riskier than the Socket Interface approach. The embedded approach may delay the integration of demand programs into appliances with a significant cost to society in wasted energy expenditures.

If embedding communications is adopted quickly, the risk of unintended and negative outcomes increases significantly as described in previous sections. The correction of a security flaw, for example, would cause the appliance OEMs significant economic harm either to repair the firmware (if this were even possible) or damage to the brand equity. There is a significant cost to manage a knowledge base of vendor-specific protocols to provide for interoperability at a router or gateway to support the DR applications of a service provider.

With embedded communications consumers are likely to bear a significant cost to be early adopters. While this is not certain until this architecture is rolled out, experience with

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[8] See page 5.9, *Pacific Northwest GridWise Test Bed Demonstration Projects Part II Grid Friendly Appliance Project*, October 2007, Hammerstrom, Principal Investigator. http://gridwise.pnl.gov/docs/gfa_project_final_report_pnnl17079.pdf

[9] Eustis, Horst, and Hammerstrom, *Appliance Interface for Grid Responses*, October 2007, http://www.gridwiseac.org/pdfs/forum_papers/103_106_paper_final.pdf

[10] Portland General Electric comments on the Draft Interoperability Standards Release 1.0 filed November 9, 2009.

consumer risk is common with other new platform launches in the consumer goods space. Consider consumers that bought Betamax video tape recorders. This is a type of embedded communications that was quickly made obsolete by VHS adoption. The same problem occurred with early purchasers of HD-DVD players that competed with BluRay high definition disk players. Another example is the security breaches possible with early versions of Outlook. Consumers lost the privacy of their personal contact information. How do we know that appliances with early versions of communication protocols won't get exploited? What cost will the industry suffer if we get a visible security problem with early appliances?

Best business practice demonstrates that success in new endeavors is enhanced when the business parties focus on their core competencies. For DR, this means that:

- The utility role will be limited to sending basic and reliable communication signals.
- The appliance OEM role will be limited to modifying appliance controls to accept basic signals and re-engineering user interface to be receptive to energy management options.
- Communication OEMs will have a role to innovate communications methods to bridge signals between the utility and the appliance.

Deviating from a proven and successful market paradigm, or worse, imposing a barrier to this model is likely to introduce unnecessary costs to the consumer.

For good reasons, appliance OEMs and utilities both practice conservative, risk-averse design principles. To maximize economic benefits, the architecture of the DR infrastructure should allow business entities with experience in communications and information technology to play an active role in innovation. A facilitation of this principle would be a Socket Interface on the appliance, rather than limiting utilities in the communication options they might choose to invoke in reaching an appliance.

Recommendations to NIST on Facilitating HAN Communication Standards

1. Until the evolving DR use cases have been practiced in millions of households, businesses, and varying climates, vendors and utilities should have the option to implement a wide variety of wired, wireless, and power line carrier technologies. Utilities should test these technologies for acceptance in a variety of markets that cater to different needs and customer preferences.
2. The H2G DEWG should define high level requirements for a Socket Interface. The H2G DEWG may then recommend to NIST and the SGIPGB that these requirements be used as the basis for creating a PAP to propose the detailed physical, logical, and testing specifications for a Socket Interface. This socket Interface specification would offer appliance OEMs an alternative to embedding a specific protocol. The H2G DEWG would review

the PAP developments for practicality in a variety of home environments or may recommend field evaluation.

3. Allow utilities and third-party developers of energy management services time to determine what kinds of programs are successful in the marketplace, and allow consumers the time to acclimatize to new energy programs (possibly many years).
4. Avoid embedding short-lived communications technologies in long-lived appliances without a plan to accommodate upgrades. Most communications products (e.g., home routers and cable/DSL modems) have a maximum of five to seven-year lifecycles, whereas appliances have life spans two to three times as long.
5. Focus on the energy services interface (also called the residential gateway or customer services interface) between the energy management service provider (outside the house) and the home network (inside the house).
6. Leave the communication system architecture open to investigation. One should not assume that a meter will serve as the communication gateway to a residence, nor should one assume that a HAN is required for DR purposes, as opposed to a wide-area communication signal direct to end devices.
7. As part of a future PAP process, solicit the inputs of a diverse cross-section of the appliance industry, including manufacturers of white goods (large kitchen and laundry appliances), consumer electronics, and small appliances that consume significant energy (such as portable heaters, fans, window air conditioners, and de-humidifiers).
8. Educate the appliance and consumer electronics industry about the value of a Socket Interface to a home network for energy management and other services. Urge product designers to include such Socket Interfaces in future product and application designs.
9. Support consumer freedom to mix and match appliances, water-heaters, entertainment devices, and networking gear from multiple vendors.
10. Allow options for demand response both with, and without, in-home energy management systems. Let the free market determine value of these DR options.

In summary, no single HAN protocol choice can cover all applications, nor does choosing a single HAN technology reflect market developments in the home systems industry. Choosing a limited set of preferred solution(s) now for wired or wireless technologies has a number of risks and might stifle innovation among appliance and their suppliers, while limiting consumer choice. The consequences are potentially higher prices for white goods due to a lack of market-driven efficiencies. Today, certain interest groups are urging NIST, FERC, and the Executive Office to make a decision with significant impact on U.S. consumers—despite the fact that a *de minimis* knowledge base exists on how consumers will utilize smart appliances.

As a useful analogy, we can see the benefits of market development and choice in mobile devices. If the federal government had mandated a standard mobile operating system four years ago, consumers would not have benefited from the introduction of the Apple iPhone, which has led to a healthy and competitive marketplace, one that has prompted worldwide innovation by Google, Microsoft, Palm, and others.

If establishing a limited set of wireless and/or wired protocols for home area networks is a desired architecture, there should be a demonstration that puts each solution through a rigorous interoperability compliance and testing regimen to prove its suitability for Smart Grid applications. This competition would be similar to the evaluation currently undertaken by the Society of Automotive Engineers to determine the most appropriate solution for communications between an electric vehicle and its charging equipment.

Market-driven economies are very efficient. The creation of a Socket Interface suitable for appliances offers an alternative architecture that allows a path for innovation and market validation similar to that demonstrated with personal computers. The lack of a standardized socket represents a clear gap in existing standards. However, this standard will not occur without focus and discipline that can be achieved through the PAP process. Once a standard is created, the market will eventually decide the best solutions and architectures.