Free Market Choice for Appliance Physical Layer Communications

prepared by

Conrad Eustis, Portland General Electric

edited by

Mike Coop, heyCoop, LLC
Michel Kohanim, Universal Devices
Dr. Chellury (Ram) Sastry, Pacific Northwest National Lab
Brian Seal, Electric Power Research Institute
Dr. Kenneth Wacks*, www.kenwacks.com

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* Member, GridWise Architecture Council, U.S. Department of Energy

The Energy Independence and Security Act (EISA) of 2007 directed NIST to assess standards for an electric smart grid to enhance the reliability of electricity in the United States. NIST is working with many agencies such as DOE, FERC, and NARUC to fulfill this mandate. (Please see 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). Similarly, many wired networking solutions exist, including Ethernet on twisted-pair wiring, powerline carrier communications, phoneline, and coaxial cable. All these wired technologies combined are a fraction of the installed base of Wi-Fi, although much new home construction now includes wired data networks.

Certain interests are lobbying heavily for NIST to choose a “preferred” solution for both wired and wireless networking. This paper presents technical, market, and economic arguments that show such a choice of HAN technologies at this time would be a serious, short-sighted mistake. Instead, we offer specific recommendations to NIST for adopting an alternative approach.

Technical Issues with Selecting a Physical Layer Protocol

Communication Solution

First and foremost, there is no optimum single choice of access networks (telephone, cable TV, cell phone, etc.) to deliver energy management data and/or control messages to the consumer premises—if there were, utilities would be using it by now. Instead, utilities deploy numerous methods today. 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, or HomePlug.

The key motivator for choosing a utility access network is low cost and reliability. FM/RDS is another one-way method that is gaining traction in some areas of California and Canada because it meets the criteria for low cost and reliability. The most notable use of a two-way communications technology for DR is by Florida Power & Light (FPL) Company, which has connected more than a million points using Two-Way Automatic Communications System (TWACS from Aclara). The return communications channel is used to acknowledge the receipt of a utility control signal for appliance operation. This feature allows FPL to verify that the control signal has reached the controlled point. Ironically, with an advanced metering infrastructure (AMI), two-way communications to customer loads would no longer be a necessity because either:

1. The meter communications can be used to verify load reduction, or
2. Looking into the future, customers will be responsible (as in any other retail market) for acting on price signals.

In the present heterogeneous utility environment, no single protocol is likely to be best for a specific home and application.

Even more disturbing is the fact that the industry, comprised of utilities, appliance makers, and DR providers, has had experience with residential premises on the order of just a few thousand. These customers opted into boutique pilots based on more robust two-way communication technologies. Under the circumstances, our proposition is that there simply is not enough evidence of market experience to pick 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 has evolved, so too have network protocols, with some becoming obsolete in as few as five years. For example, we have had plain old telephone service (POTS), digital subscriber line (DSL), satellite, WiMAX, Wi-Fi, cable, fiber optic services (such as FiOS), and major mobile carriers offering wireless connectivity. 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

Even with ubiquitous appliances such as the personal computer (PC) that last only 3 to 5 years, competent manufactures were so concerned about obsolescence and non-interoperability that they developed standardized physical interfaces to enable modularity and to protect themselves and the consumer. 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 year 2000, PC manufacturers had enough experience to determine that Wi-Fi capabilities could be built into the PC itself. However, the dependence on sockets was a wise decision because LAN cards then were not interoperable.

The moral of the story gathered through this PC experience has been that embedded communication technologies should be 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.

Do Appliance Makers Have Communications Design Experience?

Currently, there is no evidence to suggest that the largest appliance OEMs (original equipment manufacturers) have sufficient communications engineering experience to design interoperable applications (with other vendor's products). One cannot expect that appliance OEMs can forego the evolution of learning and adopting the best practices approach, and jump immediately to the design and implementation of successful interoperable appliances with embedded communication.

What are the Real Requirements for Communications Protocols?

When large quantities of customers participate in DR using synchronizing rate designs like time of use (TOU) and critical peak pricing (CPP), there is a risk that the rebound load when the high-price period ends may create problems. Furthermore, if short duration (e.g., five-minute) real time prices are the solution, will the combination of limited available bandwidth today , asymmetric loading, and long latency AMI networks be appropriate to convey real time price signals to one billion home appliances? What about latency and signaling requirements for ancillary services? What are the right network requirements and energy management uses cases to send phasor information that keeps millions of roof top solar units on-line during grid transients? Clearly we need flexibility in communication protocols to enable the more demanding grid applications of the future.

A solution that could be considered for adapting appliances participating in DR is field upgrading of firmware. 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. The alternative for consumers to bring their appliance to a repair center for upgrade is unreasonable.

One solution to these technical problems might be the incorporation of a modular standard socket that would allow appliances to work with a variety of communications devices. A new communications protocol would then be inserted into these smart appliances via a plug-in communication device costing $5 to $10. (This is the approach that is being promoted by the Utility Smart Network Access Port (U-SNAP) alliance). At this price point, the consumer can readily adopt new communication methods to meet value propositions of tomorrow—not so with embedded appliance communications designed for the needs of today. Obviously, the port technology would need to be carefully chosen to support anticipated communications needs.

Market Issues with Selecting a Physical Layer Protocol

Customer Experience with Two-Way Control Protocols for Demand Response

As mentioned above, customer experience with modern two-way 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 invasive 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? Won't communication technologies in these short-lived devices change over the life of these appliances?
- What business entity is suited to provide service for in-home energy management: store staffs (e.g., Geek Squad), HVAC technicians, utilities themselves, new Internet-based businesses? Won't these entities have preferences for the communications method to reach the appliances?

Unintended Market Outcomes

The author and editors acknowledge that some large appliance OEMs, particularly those with billions of dollars in revenue, have extensive, highly-skilled staffs who are reasonably-well positioned to absorb the development risk of embedding communication protocols into their appliances, fixing security bugs, and designing their appliances with forward extensibility. However, smaller appliance makers likely will not have this luxury.

By mandating appliance manufacturers to embed "standardized" communications protocols into their appliances with all the attendant business risks highlighted above, we may also 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 pose security and obsolescence risks upon either 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 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 are capable of much greater operational flexibility than could possibly be invoked through these communication 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.[1]
- Hacker conferences (e.g., Black Hat) are featuring the ability to modify firmware in immature protocols to create worms that, using the two-way feature, 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.

Economic Consequences from Selecting Physical Layer "Winners"

- The probability of substantial negative economic consequences of prematurely selecting a winning technology is quite high given the immature state of the market and nearly total absence of material experience with two-way communication protocols.
- With communication protocols embedded prematurely, smart appliance consumers bear a high risk of unexpectedly buying a capability that is prematurely obsolete, or worse, for becoming a victim of cyber crimes.
- Best business practices demonstrate that success in new endeavors is enhanced when the business parties remain within 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 the appliance controls and user interface to be receptive.
    - Communication OEMs will have a role to innovate communications methods to bridge signals between the utility and the appliance.

  Deviating from such a proven 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-adverse design principles. To maximize economic benefits the architecture of the DR

[1] 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

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 standardized communication 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, encourage implementation of a wide variety of wired, wireless, and power line carrier technologies to encourage markets that cater to different needs and acceptance levels.

2. Gather extensive field experience in a variety of homes with various building materials, infrastructures, and climates, rather than declaring a winning technology or choosing a standard. If a solution presents itself head and shoulders above the competition, NIST could consider a recommendation. However, NIST should keep in mind that innovation occurs in leapfrog phases, and that any winner NIST declares now (at a peak) may fall out of favor in as little as 12 to 24 months (in a valley).

3. Allow utilities time to determine what kinds of programs are successful in the marketplace and 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, cable/DSL modems) have maximum 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 interface on individual home appliances open to investigation, field trials, and market testing. NIST could provide a forum to compare results, encourage cooperation, and eventually focus on a limited set of choices. Currently, it is too soon to mandate one appliance interface because we do not know what works in the widest set of environments and cost-sensitive appliances.

7. 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.

8. 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). Specifically, we recommend that NIST facilitate large-scale participation and contributions in various domain expert working groups (DEWG) and priority action plans (PAP) that NIST manages as part of the Smart Grid program.

9. Educate the appliance and consumer electronics industry about the value of an interface to a home network for energy management and other services. Urge product designers to include such interfaces in future product and application designs.

10. Defend consumer freedom to mix and match appliances, water-heaters, entertainment devices, and networking gear from multiple vendors.

11. Allow for options both with and without in-home energy management systems, and let the free market decide on their value.

In summary, choosing a solution now for wired or wireless technologies will stifle innovation by American appliance and vehicle manufacturers 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 to U.S. consumers – despite the fact that no knowledge base exists on how consumers will utilize smart appliances. No single technology choice can cover all applications.

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 which has prompted worldwide innovation by Google, Microsoft, Palm, and others.

If the Executive Office and NIST feel compelled to choose a "preferred" solution for wireless or wired home area network communications, they should announce a competition to put 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 communication between an electric vehicle and its charging equipment.

Market-driven economies are very efficient. The market should decide the winner over a period of time, not an ill-informed pronouncement of a so-called "preferred" solution at a given moment in time. Allowing any mechanism other than the market to decide is not only ill advised, it is anti-competitive.