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. Therefore, it is premature to choose a communication technology now. 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 be developed serving various markets. Innovation should be encouraged by not mandating a physical communications standard at too early a stage in the deployment process.
2. Selecting a short list of wireless protocols 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.
3. To address the risks identified in #2, we recommend that the NIST H2G DEWG investigate the specifications for a USB-like socket interface on appliances. Original equipment manufacturers (OEMs) can then choose to utilize such a socket interface to insert modules supporting a variety of

protocols instead of having to embed a specific protocol directly inside the appliance. This approach follows proven, best engineering practices to introduce nascent communication methods to an existing product.

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, we need extensive field experience about the performance of wireless communications in a wide variety of home construction environments. Furthermore, many wired networking solutions exist, including Ethernet on twisted-pair wiring, powerline carrier communications, phoneline, and coaxial cable. Although many new homes now include wired data networks, all these wired technologies combined are a fraction of the installed base of Wi-Fi.

Certain interests are intensely lobbying NIST 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 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), there is a risk that the rebound in demand when high-price periods end may create problems.
- 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 real time price signals to one billion home appliances.
- The latency and signaling requirements for ancillary services may stress AMI networks.
- 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.

Are the Current Utility Requirements Even Realistic?

Google recently commented, with strong supporting logic, that some of the use cases requiring feedback from appliances are untenable. Google recommending relying upon meter data for statistical analysis rather than state information from appliances, such as customer override of a control signal. Are we putting burdensome and potentially costly requirements on the appliance OEMs with too many use-cases initially? We think it is premature to mandate a full-stack communications protocol for appliance interfaces. Instead, we should start with the essential and basic requirements, and let market experience guide revisions and protocol extensions.

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

Energy Management is only a subset of what home communication can do. 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

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.

Standardized Socket for Communication Interface

One solution to these technical problems might be the incorporation of a modular, standard socket that would allow smart appliances to work with a variety of communications devices. A new communications protocol would then be customer-installable via a plug-in communication device costing $5 to $10. (For example, RS-232, USB, and a proposal by the U-SNAP alliance are all possible options for a universal hardware interface.

EPRI has a project that aims to create an interface specification after soliciting interface requirements form utilities, appliance OEMs, and communication device manufacturers.) 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 requirements.

Communication Solution

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 various 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. 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 program. The return communications channel acknowledges 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 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.

In the present heterogeneous utility environment, no single protocol is likely to be best for a specific home and application. Of greater concern 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 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. The Internet began using packet-switching networks and evolved to cover a large number of physical mediums, such as fiber optics, coaxial cable, twisted pair, and many wireless protocols. The Internet incorporates myriad networking technologies including Ethernet, Wi-Fi, cellular, WiMAX, powerline, 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. PCs last 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 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 have sufficient communications engineering experience to design interoperable applications (with other vendor's products). It is unrealistic to expect these appliance makers to create a design quickly and to implement successful interoperable appliances with embedded communications. There is considerable value in 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 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 extensibility. However, smaller appliance makers likely will not have this capability.

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 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 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 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.

[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

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 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 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 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 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. The NIST H2G DEWG should investigate the specifications for a standardized, USB-like socket interface that appliances OEMs can choose to adopt instead of embedding a specific protocol. If technical issues need to be

330 investigated in depth, the H2G DEWG may recommend the creation of a
331 PAP to assess the alternatives.

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

339 4. Allow utilities and third-party developers of energy management services time
340 to determine what kinds of programs are successful in the marketplace, and
341 allow consumers the time to acclimatize to new energy programs (possibly
342 many years).

343 5. Avoid embedding short-lived communications technologies in long-lived
344 appliances without a plan to accommodate upgrades; most communications
345 products (e.g., home routers, cable/DSL modems) have maximum five to
346 seven year lifecycles, whereas appliances have life spans two to three times as
347 long.

348 6. Focus on the energy services interface (also called the residential gateway or
349 customer services interface) between the energy management service provider
350 (outside the house) and the home network (inside the house).

351 7. Leave the interface on individual home appliances open to investigation, field
352 trials, and market testing. NIST could provide a forum to compare results,
353 encourage cooperation, and eventually focus on a limited set of choices.
354 Currently, it is too soon to mandate one appliance interface because we do not
355 know what works in the widest set of environments and cost-sensitive
356 appliances.

357 8. Leave the communication system architecture open to investigation. One
358 should not assume that a meter will serve as the communication gateway to a
359 residence, nor should one assume that a HAN is required for DR purposes, as
360 opposed to a wide-area communication signal direct to end devices.

361 9. Solicit the inputs of a diverse cross-section of the appliance industry, including
362 manufacturers of white goods (large kitchen and laundry appliances),
363 consumer electronics, and small appliances that consume significant energy
364 (such as portable heaters, fans, window air conditioners, and de-humidifiers).
365 Specifically, we recommend that NIST facilitate large-scale participation and
366 contributions in various domain expert working groups (DEWG) and priority
367 action plans (PAP) that NIST manages as part of the Smart Grid program.

10. 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.
11. Defend consumer freedom to mix and match appliances, water-heaters, entertainment devices, and networking gear from multiple vendors.
12. 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 preferred solution(s) now for wired or wireless technologies will stifle innovation among 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 on U.S. consumers—despite the fact that no knowledge base exists on how consumers will utilize smart appliances. No single HAN protocol 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 that 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 communications 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 now. Allowing any mechanism other than the market to decide is not only ill advised, it is anti-competitive.