GridWise Architecture Council / NIST
Home-to-Grid Domain Expert Working Group

Requirements

prepared by

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Foreword

On December 5, 2008 the United States National Institute of Standards and Technology (NIST) Home-to-Grid (H2G) Domain Experts Working Group (DEWG) appointed a subcommittee to write this Requirements report. The members of this subcommittee were:

- Dr. Kenneth Wacks, chair of the Requirements Subcommittee; co-chair of the H2G DEWG; member of the GridWise Architecture Council
- Ron Ambrosio, IBM, chair of the GridWise Architecture Council
- David Bergman, NIST
- Erich Gunther, EnerNex, member of the GridWise Architecture Council
- Michel Kohanim, Universal Devices

An interim report authored by Dr. Wacks and reviewed by the subcommittee was posted on the H2G TWiki (a web collaboration tool) on January 21, 2009 for review by the H2G DEWG. The H2G DEWG members were asked to submit comments and proposed changes by March 20, 2009.

A total of 36 comments were received from four organizations and posted on the H2G TWiki. Dr. Wacks studied each comment, inserted proposed resolutions for each, and edited this requirements document. All comments were either accepted as proposed, accommodated in part, or noted with an explanation. No comments were rejected. The subcommittee reviewed all changes prior to posting this current report.

1 Introduction

The GridWise Architecture Council (appointed by the United States Department of Energy) and the U.S. National Institute of Standards and Technology (NIST) have formed Domain Experts Working Groups (DEWGs) to develop a report for the U.S. Congress about the state of standards for electric smart grids. The Home-to-Grid DEWG (H2G DEWG) is investigating communications between utilities and home devices to facilitate demand response programs that implement energy management. The federal Energy Independence and Security Act of 2007 mandates improved reliability and security of the electric grid with the goal of building a "smart grid." Among the recommendations are planning for the deployment of demand response systems. The need for demand response stems from:

- Electric supply limitations
- Public resistance to building large generating plants
- Concerns for environmental pollution including greenhouse gases
- Opposition to siting transmission lines
- The anticipated demands for electricity by electric vehicles
- The introduction of distributed generators
- The fluctuation in output with time and weather from distributed generation sources such as wind and solar panels

This document is intended to assist NIST in assessing standards available for implementing demand response. Since demand response systems extend beyond the meter into customer premises, those impacted by demand response technology choices include utilities, third-party suppliers of demand response services, home network developers, and appliance manufacturers. NIST created the H2G DEWG in recognition of these diverse constituencies to seek their inputs as NIST advises Congress and the Administration on recommendations and mandates for demand response systems. An example of a third-party demand response service provider is an aggregator serving a large building or neighborhood. The roles of the utility and the aggregator are shown in Figure 1. The components for demand response management in the home, including the residential gateway, energy management controller, and home area network devices, are defined in this report.

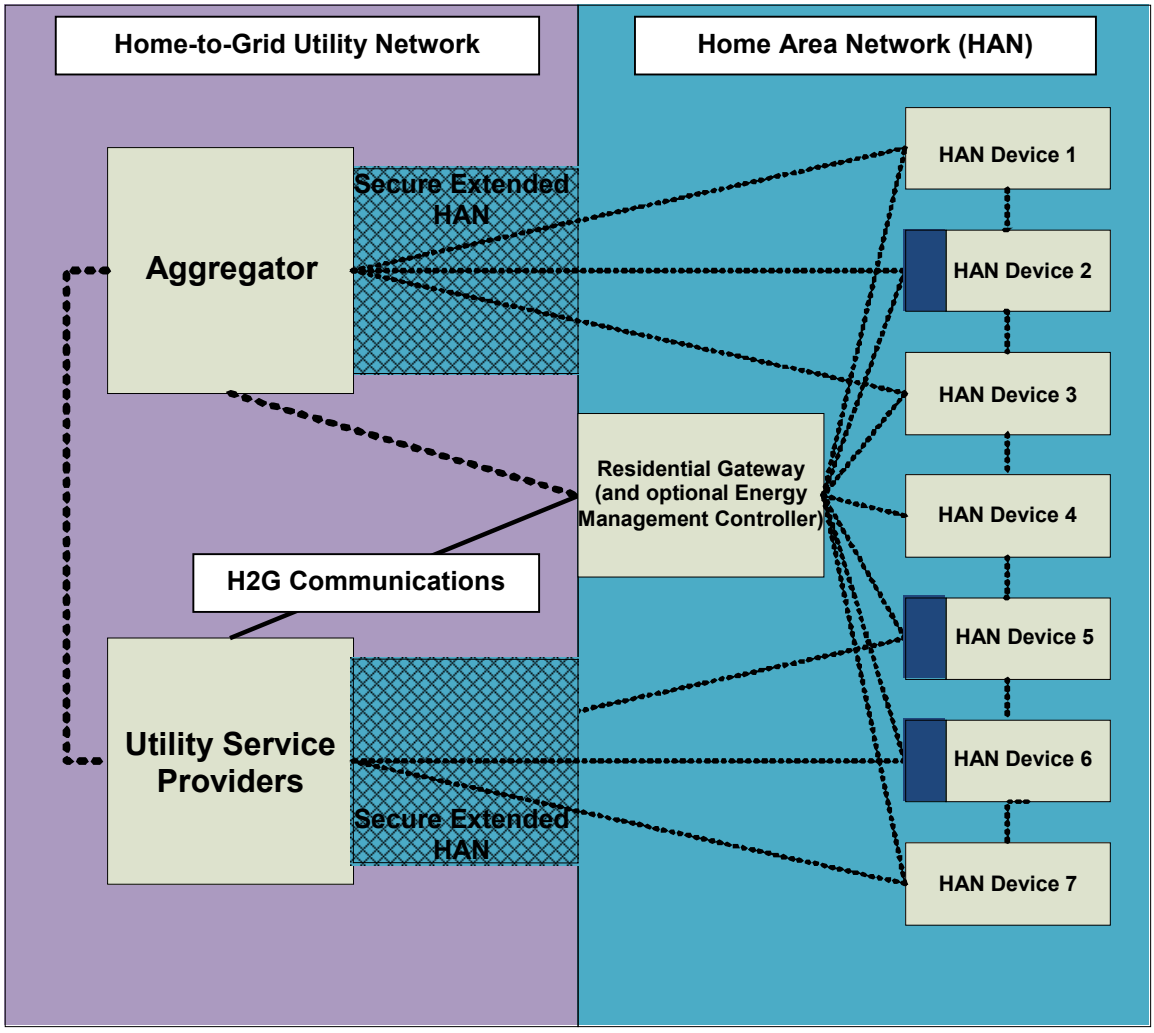

Figure 1 – Demand Response System
(Drawing courtesy of PNNL)

The H2G DEWG named a Requirements Subcommittee to specify requirements for residential demand response systems. NIST asked the Requirements Subcommittee to start with material derived from "UtilityAMI 2008 Home Area Network System Requirements" published by the UCA® International Users Group. The UtilityAMI requirements are summarized in Annex A of this report.

The requirements defined in this report facilitate the implementation of demand response. Therefore, this report begins with an overview of demand response techniques. This overview is based on a published ISO/IEC[1] Technical Report, ISO/IEC 15067-3 "Model of

[1] ISO = International Organization for Standardization
IEC = International Electrotechnical Commission
ISO/IEC = Designation of international standards related to information technology

an energy management system for the Home Electronic System."[2] As explained in the overview, there are various methods for implementing demand response. The choices will vary by utility to achieve the load shape that aligns with supply limitations, transmission and distribution capabilities, regulatory constraints, and business considerations. Also, as the market develops for energy management products, consumer electronics companies may offer products that combine load management for demand response with energy conservation.

An important factor for the success of demand response is the development of appropriate gateways, controllers, and Home Area Network (HAN) devices. Utilities can specify what they would like in such products, but must also motivate manufacturers to design and market them. Utilities deal with many suppliers of industrial and business products, but most have not cultivated relationships in the consumer product industries. The annual market for consumer electronics is almost $200 billion[3] and for home appliances is about $25 billion[4]. Both markets include hundred of manufacturers that produce thousands of new products each year. Thus, there are many options for negotiating product specifications adapted for energy management provided there is motivation from public policy and from utilities.

These requirements for communications protocol specifications are intended to assist in selecting protocols. These requirements do not apply to NIST, but rather to standards developing organizations (SDOs) that have issued protocols or may create new protocols for demand response. PNNL (Pacific Northwest National Laboratory) recommends that the priority communications protocol should be the link between utility service providers and the residential gateway, as shown in Figure 1 with the label "H2G Communications."

The missions of ISO and the IEC are to foster international trade and commerce.

As a member of the World Trade Organization (WTO), the United States has agreed to use international standards unless it writes "higher standards if there is scientific justification." [per WTO agreement]

[2] ISO/IEC standards may be purchased from the American National Standards Institute at http://webstore.ansi.org.

[3] Market size per Consumer Electronics Association (www.ce.org).

[4] Market size per Hoovers, a D&B Company (www.hoovers.com).

2 Terminology

The following terminology is included to establish a common understanding about key elements attached to a home area network in a demand response system intended for residential customers. Some of the components for a residential demand response system are located within homes. Thus, a "smart grid" extends to end-devices located inside homes. This report does not address the issues of who owns and maintains equipment located beyond the meter.

2.1 Energy Management Controller

Definition: A set of functions that manage energy consumption as an agent for the customer.

Physically, these functions may be embedded in a residential gateway, in an appliance, or in a stand-alone device. As explained in Section 3.5, the operation of an Energy Management Controller may be influenced by customer choices.

2.2 HAN Devices

Definition: A device located in the home that can be connected to a home network.

The device may be a home appliance, consumer electronics device, sensor, actuator, user interface, or controller. Examples of such devices typically involved with energy management include thermostats, HVAC (heating, ventilation, and air-conditioning) equipment, displays, and major appliances (called "white goods" by the appliance industry). The home network may be wired or wireless. For real-time energy management applications, the home network is linked to a utility network, possibly via a residential gateway.

Appliances that function as HAN Devices are sometimes called "smart appliances." Smart appliances can communicate via the HAN with other appliances, with a HAN controller, or with the utility, depending on the application. The term "smart appliance" as applied to demand response may encompass a range of products such as a thermostat, heating and air-conditioning equipment, kitchen appliances, and other devices that consume significant power.

Smart appliances might respond to rate data or control signals from the utility in one of the following ways:

- Shedding load in a limited number of levels (for example, four or five possible power consumption levels) all under direct control of the appliance.
- Responding to commands from an optional Energy Management Controller that is interpreting or managing data from the utility.
- Presenting the consumer with information that would encourage the consumer to delay use at that time.

The customer will always have the option to override these actions and resort to full power usage or different energy modes.

2.3 Residential Gateway

Definition: A communications function that interconnects two networks operating with different communications protocols.

The two protocols may differ by media type, digital data encoding, timing, and message sets. The purpose of the gateway is to translate and deliver messages from one network to the other.

For utility applications, this gateway is sometimes called a Utility Gateway. The functions of a utility gateway may be embedded in a stand-alone device, in a utility meter, or in a device in the home such as an appliance. Multiple gateways may be located in a house for the delivery of various services such as demand response, entertainment, Internet, and telephony. The general architecture of a residential gateway is specified in the following international standard: ISO/IEC 15045-1, "A Residential gateway model for Home Electronic System." According to this standard, the responsibilities of the gateway include protocol translation and provisions for ensuring the privacy, safety, and security of consumers.

UtilityAMI specifies the utility-related functions of a utility gateway using the term "Energy Services Interface." The Energy Services Interface specification focuses on security of messages communicated between the utility and HAN Devices involved with energy management.

3 Demand Response (DR)

3.1 Demand Response introduction

Electricity consumption patterns have peaks daily and seasonally. During weather extremes of heat and cold the demand for electricity rises sharply. To meet these occasional peak demands, some utilities need to keep relatively expensive generators running or must build new plants.

U.S. utilities are required to maintain the supply of electricity sufficient to meet any demand. However, this is becoming less practical because of the cost of new electricity plants, public resistance to new plants, and government rules controlling environmental pollution. The pressure for plants to meet peak demands could be reduced if customers evened out their power consumption so the peaks are flattened. Utilities have developed specific programs to influence the customer demand for power in order to align with the available supply. Such utility programs are called *demand-side management* (DSM).

The objective of DSM is to reduce peak demands for electricity by about 5% up to 100 hours per year, according to a December 2005 report of the Demand Response and Advanced Metering Coalition (DRAM)[5]. The Electric Power Research Institute estimated in 2001 that "… a 2.5% reduction in electricity demand statewide could reduce wholesale spot prices in California by as much as 24%; a 10% reduction in demand might slash wholesale price spikes by half."[6]

3.2 What is Demand Response (DR)

Programs for energy management initially focused on providing incentives for using less electricity with more efficient appliances. Some programs offer rebates for switching from tungsten to compact fluorescent lamps, for adding building insulation, and for purchasing energy efficient appliances.

Utilities have developed more deterministic methods for influencing the demand through DSM. Since DSM programs may not involve explicit management by the utility, the term *demand response* (DR) is being widely used in the industry. DR uses incentive-based and indirect methods for controlling how much electricity is consumed during a specified time interval by water heaters, air-conditioners, and industrial equipment. The more innovative methods of load control depend on market forces for exerting control by varying the price of electricity.

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[5] Demand Response and Advanced Metering Coalition (DRAM), comments filed in Docket AD06-2, December 19, 2005, 5. Reported in FERC, *Assessment of Demand Response and Advanced Metering Staff Report*, Docket AD06-2-000, August 2006.

[6] Taylor Moore, "Energizing Customer Demand Response in California," *EPRI Journal*, Summer 2001, p. 8.

DR offers effective methods of DSM, but is currently applied only to about 8% of all U.S. customers, according to a FERC (Federal Energy Regulatory Commission) survey reported in December 2008[7].

3.3 Demand Response methods

Demand Response includes programs and technologies to modify customer demand for energy directly by remote control of customer appliances (called *Direct Load Control*) or indirectly through pricing incentives or event notifications.

Some large industrial customers volunteer for lower electric rates in exchange for deliberate service interruption. When the utilities are facing a supply limitation, perhaps on a hot summer day, they order these volunteers to reduce or to curtail some energy consuming equipment. The analogous program for residential customers is Direct Load Control, where the operation of selected devices like air-conditioners and water heaters is interrupted. In a typical version of Direct Load Control the utility sends a signal via the power line or radio to a switch that limits the run time of air-conditioners to 0-15 minutes each half-hour for up to six hours each day. Water heaters are generally turned off entirely for 2-6 hours.

Direct Load Control requires prior arrangements with customers for permission and equipment installation. Many customers in the U.S. are offered rebates of up to $10 a month for participating in Direct Load Control. Of the 5% of U.S. customer under load control, most are participating in Direct Control.

3.4 Demand Response via electricity pricing

An indirect method of Load Control is based on electric rates that vary over time or a notice to customers of a pending event, such as a partial supply interruption, requiring consumption reductions. Time-varying pricing evolved from time-of-use (TOU) pricing where the utility establishes a peak and off-peak price. Initially the ratio of on-to-off peak pricing was chosen high enough to motivate customers to defer heavy power-consuming appliance usage to the off-peak times. For this technique, called *Local Load Control*, to be effective the customer must:

- Remember the time period for off-peak pricing of power.
- Know which appliances consume relatively large amounts of energy.
- Not be significantly inconvenienced by deferring appliance operation to off-peak times.

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[7] "FERC Report Marks Significant Progress in Demand Response, Advanced Metering," News Release from FERC, R-08-70, December 29, 2008.

Much more effective DR is possible by exploiting microprocessor-based intelligence at the customer premises. *Distributed Load Control* combines local and direct load control with much increased flexibility and customer control. The utility has the opportunity to change prices when a peak demand is expected. Eventually, utility policy makers would like to adjust prices according to the wholesale market price of electricity to reflect actual utility costs. Smart appliances respond with minimal user involvement or inconvenience.

The following scenario is an example of how a user might interact with an integrated Distributed Load Control system:

> It is 4 PM and the user is about to run the dishwasher. The following options appear on the appliance display panel:
>
> 1. *Wash dishes now.*
> 2. *Delay wash by 3 hours and save 25¢*
> 3. *Delay wash by 6 hours and save 50¢*

The user makes a simple decision based on criteria that are understandable: "Do I need the dishes cleaned in the next three hours (perhaps for a dinner party at 7 PM), or can I wait and save some money?" This makes buying energy as simple as shopping at a retail store.

3.5 Implementing effective demand response

As noted, demand response systems may range from direct control of selected appliances to distributed control with pricing and event data. It is possible to implement distributed load control by sending utility prices and event notifications directly to smart appliances. This is called "prices to devices." Such appliances would need to be programmed to understand the price or event messages and to respond accordingly with reduced consumption where appropriate.

The introduction of an Energy Management Controller (EMC) adds functionality to distributed load control by enabling the allocation of limited energy (or a limited budget for energy) among appliances according to consumer preferences. Figure 2 shows a feasible Distributed Load Control residential implementation. The utility sends pricing data electronically to all houses in real-time over a network such as the Internet. This pricing signal enters the house through the Utility Gateway, a version of a residential gateway. This gateway interconnects a public network using telephone, cable TV, power lines, or radio with a home network. The gateway may be a separate device, as shown in Figure 2, or could be integrated with other gateways, controllers, or even inside an electric meter.

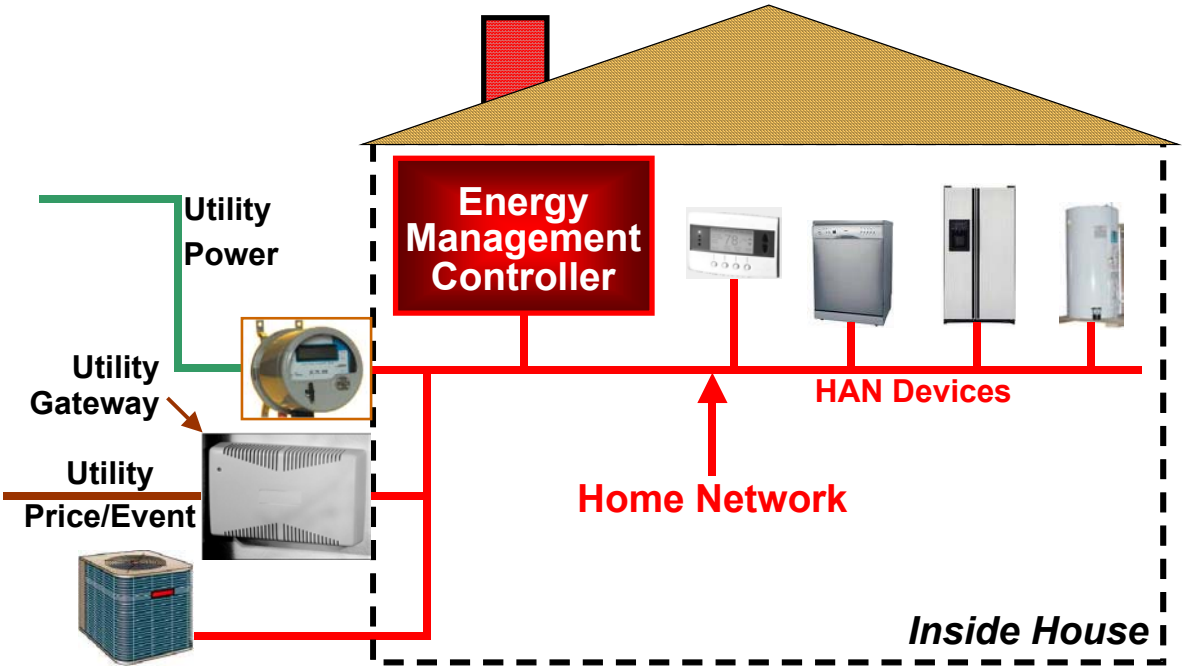

Figure 2 – Distributed Load Control System
(Drawing courtesy of Kenneth Wacks)
(Utility Gateway courtesy of GridPlex, Inc.)

The element in this system responsible for regulating energy consumption is the Energy Management Controller (EMC). As noted in the Terminology section of this report, the EMC may be a discrete physical device or the EMC functions may embedded in the gateway, in an appliance, or in a controller providing a diversity of home services.

The EMC performs specialized computing functions by receiving the electricity rate data from the residential gateway and applying sophisticated software algorithms to determine which appliances to operate and when. The functions of the EMC are illustrated in Figure 3.

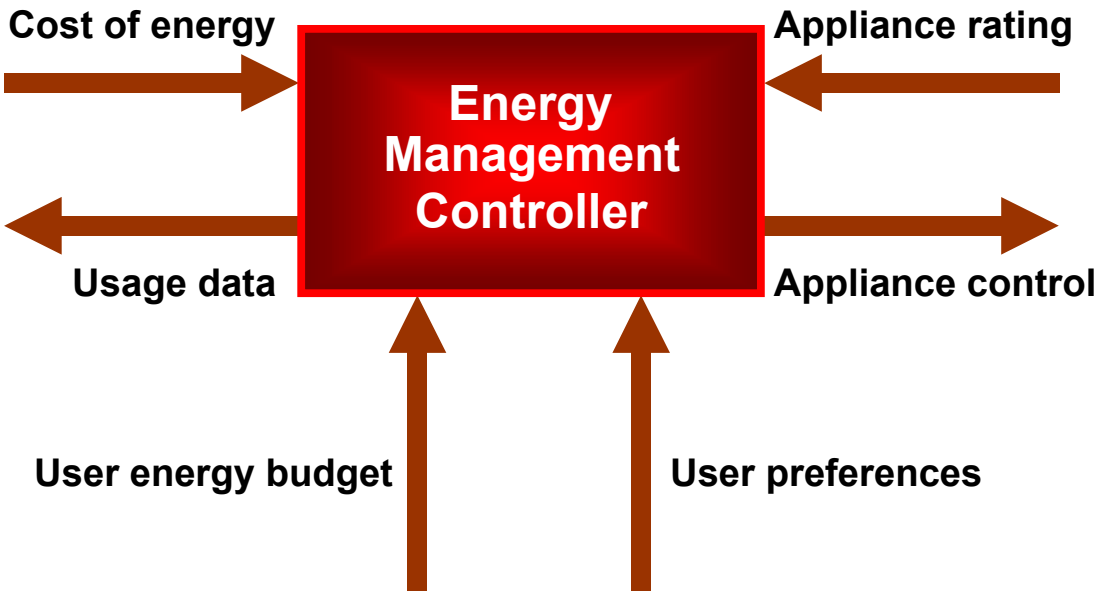

Figure 3 – Energy Management Controller
(Drawing courtesy of Kenneth Wacks)

The EMC is programmed to determine how and when to operate appliances based on the cost of energy, the energy requirements of the appliances, and user inputs. The user might specify a monthly energy budget (for example, $100 per month) and preferences (shower at 8 AM, air conditioning at 6 PM, pool at 8 PM, etc.). The customer should always be able to override decisions of the EMC. After processing these data, the controller issues signals that are distributed over a home network to the relevant appliances. Smart appliances that can operate in energy conserving modes can improve the effectiveness of a Distributed Load Control system. The EMC acts an intelligent agent for the customer.

Communications between the utility and the Energy Management Controller consists of the two data flows shown on the left side of Figure 3. The cost of energy data are sent by the utility or a demand response service provider using a secure link that ensures the data originated from the utility or the service provider. This level of security entails authentication to confirm that the data is from the real source and has not been altered during transmission. It is not necessary to encrypt such data since it is public. However, the customer usage data should be encrypted so that if intercepted, a potential burglar could not determine customer daily activities and occupancy. Also, the customer and the utility need to agree on how frequently usage data are collected. The more frequently the usage data are sent, the more detailed a record of household activities and preferences can be accumulated, thereby impacting customer privacy.

4 Assumptions

The following assumptions help organize and explain the choice of H2G requirements.

1. The Energy Management Controller makes local decisions about energy consumption based on customer preferences, customer budget, appliance energy and operational requirements, energy costs, and energy events (such as a temporary supply limitation). This is called "distributed load control."

2. Utilities or third-party service suppliers may optionally contract with customers to manage energy consumption remotely by controlling HAN Device energy consumption. Control may be exercised by remote operation of selected appliances (direct load control) or via pricing and event data coupled with intelligent appliances or an intelligent agent in the house. The intelligent agent (Energy Management Controller) may be omitted for direct load control or may have limited functionality.

3. The utility or an intermediary (third-party) energy management service provider is responsible for sending data about energy costs and energy events, or for sending control signals for direct load control.

4. The only required data sent to the utility are aggregated energy consumption data for billing. The customer decides how often consumption data are sent to the utility based on the tariffs offered by the utility and the tariff chosen by the customer. The data sent may be disaggregated for specific appliances (such as HVAC) depending on the tariff chosen.

5. The Energy Management Controller and associated appliances, some of which may include network connections ("smart appliances" or "HAN Devices"), may be furnished by the utility or by third parties, or may be purchased from retailers by consumers.

5 General requirements

These requirements are generic and have been extracted from the UtilityAMI requirements. Additional requirements specific to the DR solution chosen by UtilityAMI can be found in Annex A.

1. The Energy Management Controller shall accept data from the utility. Such data shall include price data and event data. Such data may include control signals if the customer chooses direct load control for some or for all loads. For direct control these control signals may bypass an Energy Management Controller and be sent between the residential gateway and the HAN Device or directly from the utility network to the HAN Device.

2. Utilities, manufacturers of Energy Management Controllers, and makers of appliances under direct load control shall agree on a communications protocol that includes acknowledgement of packet transmission for data integrity, verification of data validity (data sent from a legitimate source), and execution (or execution failure) of a specified

command. This minimum requirement for acknowledgement confirms that the packet was received without detectable error.

3. All message protocol definitions for messages exchanged between from the utility or demand response service provider and equipment in the house shall be based on published standards to ensure inclusive manufacturer participation and to allow manufacturers to achieve maximum interoperability. This standard protocol shall be implemented in any residential gateway or in any smart appliance that is connected directly to the utility network. This requirement does not apply to smart appliances operating on a home network where a gateway is interposed between the utility network and the home network.

4. The HAN network implementing demand response shall be based on a communications protocol that sends acknowledged data packets and acknowledged messages (composed of one or more data packets). A packet shall be acknowledged if is contains no detectable errors using error detection and correction mechanisms such as checksums, cyclical redundancy checks (CRCs), or more complex methods. A retransmission mechanism to recover damaged packets shall be provided. When applicable, the routing options should be optimized and diversity in pathways shall be provided for media subject to fluctuation (such as a radio link).

5. In all cases, the Smart Appliance shall retain control of the appliance. The Smart Appliance shall always allow the consumer the option to override a power reduction command, if the consumer so desires.

6. The Energy Management Controller shall delay restoration of operational state (after a power failure) based on a pre-configured time (e.g., random number). Smart appliances may optionally be programmed for delayed restoration without an Energy Management Controller.

7. The Energy Management Controller shall include a power cycle function to reboot the device.

8. The Energy Management Controller shall provide a user reset input, which returns the device to its pre-installation state by a simple user operation, such as pushing a button.

6 Requirements based on features chosen by consumer

The following optional features may be needed in HAN Devices or in an Energy Management Controller depending on the type of tariff the customer chooses and flexibility desired. Manufacturers and retailers may offer HAN Devices and Energy Management Controllers with various capabilities at a variety of price points and levels of potential energy savings. (This is similar to the choices offered by consumer electronics manufacturers.)

1. Respond to request to cycle operational state (i.e., duty cycle).

2. Respond to request to limit operational mode based on thresholds, set-points or triggers (e.g., price points). This can support "prices to devices" if no Energy Management Controller is present.

3. Respond to requests for variable output (e.g., load limiting, energy savings mode).

4. Measure instantaneous demand (e.g., W).

5. Measure accumulated consumption (e.g., Wh).

6. Measure accumulated production (e.g., Wh) for locally generated power.

7. Measure consumption per interval (e.g., Wh, BTU, CCF, HCF).

8. Measure production per interval (e.g., Wh) for locally generated power.

9. Store interval measurements (e.g., 30 days of interval reads).

10. Allow interval configuration (e.g., 15 Minutes).

11. Monitor energy state (e.g., state of charge), where applicable (e.g., for home devices with storage capability).

12. Measure capacity (e.g., W, Volt-Amps), where applicable (e.g., for home devices with storage capability).

13. Monitor the device state (e.g., operational, stand-by, maintenance).

14. Monitor the operational mode (e.g., charging, discharging).

15. Measure power quality (e.g., frequency, neutral voltage, harmonic content).

16. Monitor environmental state (e.g., temperature, motion, wind).

17. Monitor the operational mode of connected home devices (e.g., duty cycle).

18. Monitor environmental impact (e.g., CO_2).

19. Provide visual indicators that indicate operational state (e.g., commissioned, event status, device state). The indicator data may be sent to display devices or terminals elsewhere in the house or made available for remote viewing, perhaps on a cell phone.

20. Provide non-visual sensory feedback (e.g., motion, vibration, audible).

21. Provide a sight and hearing impaired interface.

22. Provide a user configurable display.

23. Accept user configurations.

24. Accept user preferences (e.g., Celsius/Fahrenheit, color, language).

25. Provide alarm notifications (e.g., price threshold, event messages, internal device alarms).

26. Display application-specific information (e.g., cost, consumption, environmental impact).

27. Accept application-specific configurations (e.g., pre-configured periods (e.g., hour, day, week), configurable periods (e.g., interval length, Time-of-Use (TOU) period), variable periods (e.g., Critical Peak Price period).

28. For battery-powered devices, provide a battery life indicator.

7 Payment options

Options for an Energy Management Controller that provides local payment facilities, like prepay or bill-paying options.

1. Display application-specific information (e.g., payment credit, remaining account credit).

2. Accept payment data from the consumer.

8 Requirements for customer education application

Options for an application in an Energy Management Controller or in a HAN Device that provides consumption and cost details. These values are intended to provide customer education and guidance for effective energy conservation. They are not necessarily accurate enough for revenue billing. The set of parameters defined here enables a range of educational products. Thus, the product manufacturer can choose subsets appropriate for a target market depending on age or anticipated skill set.

1. The application shall calculate a HAN Device energy cost of accumulated energy consumption as monetary value (e.g., $/kWh * accumulated kWhrs = $).

2. The application shall calculate a HAN Device energy cost of instantaneous power consumption as a monetary value per time interval, (e.g., $/Wh * instantaneous W= $/hr).

3. The application shall calculate a HAN Device cost for Hourly Energy rates.

4. The application shall calculate a HAN Device energy cost for rate tiers/energy blocks.

5. The application shall calculate a HAN Device energy cost for Time-of-Use (TOU) energy rates.

6. The application shall calculate a HAN Device cost for Critical Peak Pricing (CPP).

7. The application shall calculate a HAN Device cost for Peak Time Rebate (PTR).

8. The application shall calculate a HAN Device cost for capacity billing rates.

9. The application shall calculate costs for other billing determinants (e.g., monthly Consumer charges, taxes & franchise fee, surcharges, discounts, ratcheted demand, bond charges).

10. The application shall accept aggregated consumption and rate information from user-configurable sources (e.g., Energy Management Controller, residential gateway, AMI System, and/or human-machine interface).

11. The application shall calculate and forecast a HAN Device consumption based on user defined parameters (e.g., estimated kWh/month).

12. The application shall calculate and forecast a HAN Device production based on user-defined parameters (e.g., estimated kWh/month).

13. The application shall forecast a HAN Device estimated cost calculation based on user-defined parameters (e.g., monthly consumption at current rate/usage).

14. The application shall calculate a HAN Device consumption based on user-defined parameters (e.g., historical reporting).

15. The application shall calculate a HAN Device production based on user-defined parameters (e.g., historical reporting).

16. The application shall calculate and/or predict a HAN Device environmental impact based on user-defined parameters (e.g., historical carbon footprint, forecasted carbon credits earned).

17. The application shall supply a method for local billing resolution (e.g., orphaned billing charge, consumption debits/credits).

18. The application shall calculate and suggest methods to optimize energy consumption and cost based on user-defined parameters (e.g., programmable communicating thermostat thresholds, lighting settings, pool pump cycling).

19. The application shall calculate a HAN Device relative efficiency (e.g., comparison can be based on historical data, baseline at install, manufacturer's parameters, industry/governmental standards, other devices, other premises).

20. The application shall calculate available load for demand reduction based on user-defined parameters (e.g., percentage of load available for various response scenarios).

21. The application shall calculate user-defined thresholds for consumption, production, and cost (e.g., if aggregated consumption reaches a certain level, an alert is generated).

9 Requirements for Direct Load Control

Options for HAN Devices that may be chosen by the consumer for participation in direct control offered by the utility or by a third-party supplier.

1. Respond to requests to cease operational state (e.g., open contact).
2. Respond to requests to resume operational state (e.g., close contact).
3. Acknowledge receipt of control signal.
4. Acknowledge execution of control request.
5. Acknowledge execution failure of request (i.e., exceptions).
6. Capability to signal any consumer-initiated overrides, at consumer's option.
7. Respond to request to cease operation state at a specific time.
8. Respond to request to resume operation state at a specific time.
9. HAN Devices under direct load control shall accept and display data source configurations from the Residential Gateway or from other HAN Devices.
10. The Residential Gateway shall store a list of available, commissioned HAN Devices in the premise and make that list available to the utility upon request if required in the direct load control agreement between the utility and the customer.
11. The Residential Gateway shall provide a configurable HAN filtering function that filters based on allowable message types.
12. The Residential Gateway shall provide a configurable HAN filtering function that filters messages based on structural integrity of the message.
13. The Residential Gateway shall provide a configurable HAN filtering function that filters based on allowable message rates.
14. The Residential Gateway shall protect a HAN Device from malicious code (e.g., buffer overflow protection, limit executable code exposure).
15. The Residential Gateway shall provide non-repudiation mechanisms for devices and users.
16. The Residential Gateway shall provide a mechanism for source identification of data (e.g., HAN Device and utility data).
17. HAN Device shall supply accurate time keeping and counter functions.

18. HAN Device shall not act on expired signals (e.g., message validity duration or sequence).

19. HAN Device shall accept network time synchronization from the Residential Gateway.

20. HAN Device shall display on packaging utility compatibility guidance to verify that a HAN Device is compatible with a particular DR direct load control system.

21. The following are recommended for all direct control devices (they are required by UtilityAMI). The choice to implement may depend on device costs, market conditions, and negotiations between manufacturers and utilities.

    a) HAN Device Manufacturer shall include installation documentation that includes instructions for installation (e.g., placement), commissioning, and registration, including any external dependencies.

    b) HAN Device Manufacturer shall include a HAN Device user's manual in the Device packaging.

    c) HAN Device Manufacturer shall include Manufacturer contact information in the Device packaging.

    d) HAN Device Manufacturer shall supply technical support services (e.g., help desk, web site).

    e) HAN Device shall have a selfcheck (i.e., initialization) function that notifies the Installer that the HAN Device is functioning properly.

    f) Residential gateway shall have a configurable ability to log all utility to gateway system communications.

    g) When the HAN Device is rebooted, HAN device shall reset to the configured (i.e., post-installation commissioning and registration) state and shall reestablish communication with the Energy Services Interface.

    h) HAN Device shall have a user operable testing function that is equivalent to the self-testing function.

    i) HAN Device shall supply a maintenance port for field diagnostics.

    j) HAN Device shall simulate utility events for diagnostic purposes.

    k) HAN Device shall supply network management functions for diagnostic purposes.

    l) For battery-powered devices, HAN Device shall communicate low-battery state to the utility system.

    m) HAN Device Manufacturer shall supply and support a flaw remediation process.

n) HAN Device shall support a communications feedback mechanism (i.e., ping).

10 Network configuration and management

1. The HAN shall include methods for assigning network addresses to attached devices such as a Residential Gateway, Energy Management Controller, and HAN Devices.

2. The HAN shall include methods for newly attached devices to associate with energy management applications offered by an in-home Energy Management Controller (distributed control) or by the utility via a Residential Gateway (direct control). Association includes product identification and product capabilities for participating in energy management applications. This process is called commissioning.

3. HAN Devices shall acknowledge successful commissioning requests (i.e., provide acknowledgement to the requesting HAN Device).

4. The Energy Management Controller (distributed control) or the Residential Gateway (direct control) shall have the ability to accept or reject HAN Device requests.

5. HAN Device shall acknowledge successful commissioning requests (i.e., provide acknowledgement to the requesting HAN Device).

6. HAN Device shall provide notification to the Installer of the commissioning status. Status conveyed shall be either: successful/unsuccessful.

7. The Energy Management Controller (distributed control) or the Residential Gateway (direct control) shall maintain an updated list of commissioned (i.e., connected) HAN Devices.

8. The Energy Management Controller (distributed control) or the Residential Gateway (direct control) shall have the ability to remove HAN Devices from participating in DR.

9. After loss of power, HAN Device shall return to post configuration state (i.e., shall persist communication and registration configurations).

10. When a HAN Device is triggered (e.g. Power-on, button), HAN Device shall provide the Energy Management Controller (distributed control) or the Residential Gateway (direct control) with device-specific information to identify the device functions subject to remote management. Such data might include device address and device type.

11. The Energy Management Controller (distributed control) or the Residential Gateway (direct control) shall have the ability to accept or reject a HAN Device request based on device type.

12. The Energy Management Controller (distributed control) or the Residential Gateway (direct control) shall have the ability to query the status of HAN Devices.

11 Network security

1. Control signals, consumption data, and on-line billing exchanged shall be protected using tools comparable to Internet commerce including authorization, authentication, and encryption, as appropriate.

2. Communications between the Residential Gateway and the utility should be designed to prevent attacks such as replay, masquerading, delay, spoofing, sequence change, and deletion attacks. This is especially important for direct load control where the utility or third-party service provider controls home appliances remotely. Annex A contains specific security requirements chosen by UtilityAMI.

3. When HAN devices are connected to a HAN network, they are configured to exchange messages with an Energy Management Controller or with a service outside the house for direct load control or "prices-to-devices." Security is required for communications between the utility or third-party demand response service provider and the residential gateway. If no residential gateway is present and is not embedded is a HAN Device, security requirements are extended via the HAN to appliances under load control.

4. The first line of defense for security is the Residential Gateway. As noted in the section of this report describing the gateway, the ISO/IEC 15045-1, "A Residential gateway model for Home Electronic System" international standard includes specifications for security. The following are additional relevant international standards:

    a) ISO/IEC 24767-1, "Information technology – Home network security – Part 1: Security requirements"

    b) ISO/IEC 24767-2 Ed.1.0, "Information technology – Home network security - Part 2: Internal security services – Secure communication protocol for middleware (SCPM)"

    c) ISO/IEC 14762, "Information technology – Functional safety requirements for Home Electronic Systems (HES)"

Annex A - UtilityAMI HAN System Requirements

UtilityAMI OpenHAN Task Force

Extracted from Version 1.04 of August 19, 2008

A.1 Categories of requirements

The name of each requirement category is listed with the number of requirements in parentheses.

- Application Control requirements (13)
- Application Measure (15)
- Application Human-Machine Interface (16)
- Application Process (20)
- Communication Commissioning (13)
- Communication Control (10)
- Security Access (13)
- Security Integrity (16)
- Security Account (9)
- Security Registration (13)
- Performance (14)
- Operations, Maintenance, and Logistics; Manufacturing and Distribution (12)
- Operations, Maintenance, and Logistics; Installation (4)
- Operations, Maintenance, and Logistics; Manage and Maintain (10)

A.2 List of OpenAMI Requirements

A.2.1 Application Control requirements (13)

1. HAN Device shall accept control signals from the Utility.
2. HAN Device shall respond to requests to cease operational state (e.g., open contact).

3. HAN Device shall respond to requests to resume operational state (e.g., close contact).
4. HAN Device shall acknowledge receipt of control signal.
5. HAN Device shall acknowledge execution of control request.
6. HAN Device shall acknowledge execution failure of request (i.e., exceptions).
7. HAN Device shall signal any consumer-initiated overrides.
8. HAN Device shall respond to request to cease operation state at a specific time.
9. HAN Device shall respond to request to resume operation state at a specific time.
10. HAN Device shall delay restoration of operational state based on a pre-configured time (e.g., random number).
11. HAN Device shall respond to request to cycle operational state (i.e., duty cycle).
12. HAN Device shall respond to request to limit operational mode based on thresholds, set-points or triggers (e.g., price points).
13. HAN Device shall respond to requests for variable output (e.g., load limiting, energy savings mode)

A.2.2 Application Measure (15)

1. HAN Device shall measure instantaneous demand (e.g., W).
2. HAN Device shall measure accumulated consumption (e.g., Wh).
3. HAN Device shall measure accumulated production (e.g., Wh).
4. HAN Device shall measure consumption per interval (e.g., Wh, BTU, CCF, HCF).
5. HAN Device shall measure production per interval (e.g., Wh).
6. HAN Device shall store interval measurements (e.g., 30 days of interval reads).
7. HAN Device shall allow interval configuration (e.g., 15 Minutes).
8. HAN Device shall monitor energy state (e.g., state of charge), where applicable (e.g., for HAN Devices with storage capability).
9. HAN Device shall measure available capacity (e.g., W, Volt-Amps), where applicable (e.g., for HAN Devices with storage capability).
10. HAN Device shall monitor the device state (e.g., operational, stand-by, maintenance).

11. HAN Device shall monitor the operational mode (e.g., charging, discharging).

12. HAN Device shall measure power quality (e.g., frequency, neutral voltage, harmonic content).

13. HAN Device shall monitor environmental state (e.g., temperature, motion, wind).

14. HAN Device shall monitor the operational mode of other devices (e.g., duty cycle).

15. HAN Device shall monitor environmental impact (e.g., CO2).

A.2.3 Application Human-Machine Interface (16)

1. HAN Device shall provide visual indicators that indicate operational state (e.g., commissioned, registered, event status, device state).

2. HAN Device shall provide a power cycle input, which reboots the device.

3. HAN Device shall provide a user reset input, which returns the device to its pre-installation state (e.g., button).

4. HAN Device shall provide an alphanumeric display that indicates operational state (e.g., LCD screen).

5. HAN Device shall provide nonvisual sensory feedback (e.g., motion, vibration, audible).

6. HAN Device shall provide a sight and hearing impaired interface. NA

7. HAN Device shall provide a user configurable display.

8. HAN Device shall accept user configurations.

9. HAN Device shall accept user preferences (e.g., Celsius/Fahrenheit, color, language).

10. HAN Device shall provide alarm notifications (e.g., price threshold, event messages, internal device alarms).

11. HAN Device shall accept Utility data source configurations (e.g., Energy Services Interface, other HAN Devices).

12. HAN Device shall display Utility data source configurations (e.g., Energy Services Interface, other HAN Devices).

13. HAN Device shall display application-specific information (e.g., cost, consumption, environmental impact, payment credit, remaining account credit).

14. HAN Device shall accept application-specific configurations (e.g., preconfigured periods (e.g., hour, day, week), configurable periods (e.g., interval length, TOU period), variable periods (e.g., Critical Peak Price period).

15. For battery-powered devices, HAN Device shall provide a battery life indicator.

16. HAN Device shall accept payment data from the consumer.

A.2.4 Application Process (20)

1. The application shall calculate a HAN Device's energy cost of accumulated energy consumption as monetary value (e.g., $/kWh * accumulated kWhrs = $).

2. The application shall calculate a HAN Device's energy cost of instantaneous power consumption as a monetary value per time interval, (e.g., $/Wh * instantaneous W= $/hr).

3. The application shall calculate a HAN Device's cost for Hourly Energy rates.

4. The application shall calculate a HAN Device's energy cost for rate tiers/energy blocks.

5. The application shall calculate a HAN Device's energy cost for Time-of-Use (TOU) energy rates.

6. The application shall calculate a HAN Device's cost for Critical Peak Pricing (CPP).

7. The application shall calculate a HAN Device's cost for capacity billing rates.

8. The application shall calculate costs for other billing determinants (e.g., monthly Consumer charges, taxes & franchise fee, surcharges, discounts, ratcheted demand, bond charges).

9. The application shall accept aggregated consumption and rate information from user-configurable sources (e.g., Energy Services Interface, AMI System, and/or HMI).

10. The application shall calculate and forecast a HAN Device's consumption based on user defined parameters (e.g., estimated kWh/month).

11. The application shall calculate and forecast a HAN Device's production based on user-defined parameters (e.g., estimated kWh/month).

12. The application shall forecast a HAN Device's estimated cost calculation based on user-defined parameters (e.g., monthly consumption at current rate/usage).

13. The application shall calculate a HAN Device's consumption based on user-defined parameters (e.g., historical reporting).

14. The application shall calculate a HAN Device's production based on user-defined parameters (e.g., historical reporting).

15. The application shall calculate and/or predict a HAN Device's environmental impact based on user-defined parameters (e.g., historical carbon footprint, forecasted carbon credits earned).

16. The application shall supply a method for local billing resolution (e.g., orphaned billing charge, consumption debits/credits).

17. The application shall calculate and suggest methods to optimize energy consumption and cost based on user-defined parameters (e.g., PCT thresholds, lighting settings, pool pump cycling).

18. The application shall calculate a HAN Device's relative efficiency (e.g., comparison can be based on historical data, baseline at install, manufacturer's parameters, industry/governmental standards, other devices, other premises).

19. The application shall calculate available load for demand reduction based on user-defined parameters (e.g., percentage of load available for various response scenarios).

20. The application shall calculate user-defined thresholds for consumption, production, and cost (e.g., if aggregated consumption reaches a certain level, an alert is generated).

A.2.5 Communication Commissioning (13)

1. HAN Device shall accept network configuration data which allows for private Utility networking (e.g., private address/ID)

2. HAN Device shall accept commissioning configuration data by the manufacturer (e.g., link key).

3. HAN Device shall accept commissioning configuration from the Installer.

4. When Energy Services Interface is triggered (e.g., Allow Join Command), HAN Device location-specific/ contact-specific data shall be provided to other HAN Devices in the premise.

5. When a HAN Device is triggered (e.g. Power-on, button), HAN Device shall provide the Energy Services Interface with device specific information including device ID and device type.

6. When a HAN Device is triggered (e.g. power on, button), HAN Device shall provide the Energy Services Interface with device specific Utility information, including network ID, gateway ID, and Utility ID, if pre-configured with Utility information.

7. Energy Services Interface shall have the ability to accept or reject the request based on device type.

8. Energy Services Interface shall have the ability to accept or reject device requests based on Utility specific information (e.g., network ID, gateway/ Utility ID)

9. HAN Device shall acknowledge successful commissioning requests (i.e., provide acknowledgement to the requesting HAN Device).

10. When a HAN Device is communicating with the Energy Services Interface, HAN Device shall indicate link connectivity.

11. HAN Device shall provide notification to the Installer of the commissioning status. Status conveyed shall be either: successful/unsuccessful.

12. Energy Services Interface shall maintain an updated list of commissioned (i.e., connected) HAN Devices.

13. Energy Services Interface shall have the ability to remove HAN Devices from the Utility HAN.

A.2.6 Communication Control (10)

1. HAN Device shall accept network organization messages from the Energy Services Interface (e.g., gateway location, routing table, address).

2. HAN Device shall accept network organization messages from peer devices (e.g., hidden node).

3. HAN Device shall use the most reliable path to the Energy Services Interface (e.g., based on signal strength/quality).

4. HAN Device shall only use Utility designated routes.

5. HAN Device shall have the ability to automatically adapt to communications interference through detection and analysis of environmental conditions (e.g., channel hopping, channel avoidance, signal-to-noise ratio).

6. HAN Device shall include a data integrity mechanism for all communications (e.g., checksum)

7. Energy Services Interface shall have the ability to activate and deactivate its HAN communication.

8. HAN Device shall communicate its availability (i.e., `heartbeat') to the Energy Services Interface at least once per day.

9. HAN Device shall have a configurable availability communication (i.e., heartbeat) frequency to the Energy Services Interface.

10. Energy Services Interface shall store a list of available, commissioned HAN Devices in the premise and make that list available to the AMI System upon request.

A.2.7 Security Access (13)

1. Energy Services Interface shall provide access control (i.e., logical segmentation) to Utility applications, data, and services (e.g., control data, consumer specific consumption data).

2. HAN Device shall control access to persistent Utility HAN data (data at rest).

3. HAN Device shall control access to transmitted Utility HAN data (data in transit).

4. HAN Device shall provide protection of Utility HAN data while being processed (data in processing) (e.g., trusted processor).

5. HAN Device shall control access to data in accordance with a configurable Utility security policy (e.g., users, applications, devices, data access-read/write).

6. Energy Services Interface shall provide mechanisms to enforce a policy based on least privilege (i.e., explicit authorization).

7. Energy Services Interface shall have the ability to enforce policy periods (time constraints) for security policy elements (e.g., maintenance/firmware window).

8. HAN Device shall provide methods to query and report access control data settings.

9. HAN Device shall provide access control methods which prevent known attacks, including replay, man-in-the-middle, delay, spoofing, sequence change, and deletion attacks.

10. HAN Device shall implement mechanisms to prevent unintended disclosure of source/originator data to unauthorized principals.

11. HAN Device shall implement controls that limit access to audit information.

12. HAN Device shall support confidentiality and access controls that employ cryptographic operations (e.g., digital signatures).

13. HAN Device shall support confidentiality and access controls that employ cryptographic keys (e.g., encryption authentication, or digital signatures).

A.2.8 Security Integrity (16)

1. HAN Device shall protect the integrity of the HAN system (e.g., shall not adversely impact the operations of the HAN system by introducing malicious or unintended activity).

2. Energy Services Interface shall provide a configurable HAN filtering function that filters based on allowable message types.

3. Energy Services Interface shall provide a configurable HAN filtering function that filters messages based on structural integrity of the message.

4. Energy Services Interface shall provide a configurable HAN filtering function that filters based on allowable message rates.

5. HAN Device shall detect unauthorized modification of security-related data during storage

6. HAN Device shall detect unauthorized modification of data during network transit (e.g., check sums and hashes).

7. HAN Device shall detect unauthorized modification of data attributes (e.g., modification to a message type).

8. HAN Device shall attempt to correct unauthorized modification of data attributes (e.g., NAK, resend)

9. HAN Device shall only accept data from an authorized, trusted source (e.g., Energy Services Interface, certified EMS).

10. HAN Device shall protect the HAN from malicious code (e.g., buffer overflow protection, limit executable code exposure).

11. HAN Device shall separate security critical functionality and data from non-security critical system data.

12. HAN Device shall validate the source of HAN security policy.

13. HAN Device shall detect unauthorized modification of HAN security policy.

14. HAN Device shall detect unauthorized modification of audit data.

15. HAN Device shall validate the integrity of all software updates, including source, structure, and version.

16. HAN Device shall use tamper resistant hardware (e.g., epoxy, TPM).

A.2.9 Security Account (9)

1. HAN Device shall alert the Energy Services Interface of all detected, security-related activities, including access control, authentication, and integrity violations.

2. HAN Device shall audit and store all security-related activities, including access control violations, authentication activities, etc.

3. HAN Device shall provide, at a minimum, the following information for all detected security events: date and time of the event, type of event, device/user identity.

4. HAN Device shall provide the AMI System access to audit data.

5. Energy Services Interface shall provide non-repudiation mechanisms for devices and users.

6. Energy Services Interface shall provide a mechanism for source identification of data (e.g., HAN and AMI System data).

7. Energy Services Interface shall provide the capability to audit both system and user operations as defined by the HAN security policy.

8. HAN Device shall provide the ability to perform searches, sorts, and filters of audit data based on date and time, type and/or user identity.

9. HAN Device shall provide the capability to identify mandatory and configurable audit elements (In this context, mandatory refers to audit elements which are always enabled and configurable refers to audit elements which can be enabled or disabled at the discretion of the Consumer or Utility).

A.2.10 Security Registration (13)

1. HAN Device shall support mutual authentication.

2. HAN Device shall authenticate the source of all control signals.

3. HAN Device shall provide a mechanism that allows for multiple and configurable authentication materials (e.g., device ID, device type, key, serial key, Utility ID, and device configuration).

4. HAN Device shall be configured with Utility-approved or Utility provided authentication materials (e.g., certificate, key).

5. HAN Device shall not send authentication materials over the network in an insecure fashion (e.g., do not transmit passwords or keys in the clear).

6. HAN Device shall be compatible with a Utility-defined registration process.

7. HAN Device shall provide a means to update (i.e., change, reconstitute, rollover) authentication materials.

8. Energy Services Interface shall allow registration revocation for connected HAN Devices.

9. Energy Services Interface shall support a configurable registration and expiration period (e.g., registration timeout, registration persistence).

10. HAN Device shall use security services (i.e., cryptographic services) which are either FIPS approved or NIST-recommended.

11. HAN Device shall support a registration method that employs cryptographic operations (e.g., digital signatures).

12. Energy Services Interface shall provide an authentication mechanism which proxies for the AMI System (e.g., negotiates on behalf of the Utility).

13. HAN Device shall provide notification to the Installer of the registration status. Status conveyed shall be either: registered/not registered.

A.2.11 Performance (14)

1. HAN Device shall supply functionality that maintains communications availability to the Energy Services Interface.

2. HAN Device shall supply functionality that maintains application availability to the AMI System (e.g., software/hardware application watchdog).

3. After loss of power, HAN Device shall return to its post configuration state (i.e., shall persist communication and registration configurations).

4. HAN Device shall supply adequate computational performance (i.e., Device shall not hamper overall operational state of the HAN)

5. HAN Device shall supply adequate communications performance (e.g., bandwidth and throughput).

6. HAN Device shall supply accurate time keeping and counter functions.

7. HAN Device shall not act on expired signals (e.g., message validity duration or sequence).

8. HAN Device shall provide configurable communications such that the system is scalable (e.g., heartbeat and request frequency).

9. For battery-powered HAN Devices, HAN Device shall function for a minimum of 1 year without requiring replacement of the battery.

10. HAN Device shall supply a field programmable software upgrade function (i.e., firmware upgrade).

11. HAN Device shall supply a remote software upgrade function (i.e., firmware upgrade).

12. HAN Device shall meet the quality, interoperability, and testing (i.e., certification) requirements of its respective technology platform body.

13. HAN Device shall accept network time synchronization from the Energy Services Interface.

14. Energy Services Interface shall accept time synchronization from a Utility-approved source.

A.2.12 Operations, Maintenance, and Logistics; Manufacturing and Distribution (12)

1. Prior to installation (e.g., factory, depot), HAN Device shall support placement of commissioning data (e.g., pre-placed device credentials).

2. Prior to installation (e.g., factory, depot), a HAN Device shall support placement of registration data (e.g., pre-placed registration credentials).

3. HAN device shall support preplaced methods or materials that support commissioning and registration by multiple Utilities (does not imply simultaneous Utility registration).

4. HAN Device shall support preplacement of application-specific configurations (e.g., cost, consumption, environmental impact, configurable time/rate intervals).

5. HAN Device shall have and display appropriate certification (e.g., electrical, safety, and communications requirements) on its packaging or body.

6. HAN Device shall have and display appropriate commissioning and registration information on its packaging and body (e.g., serial number, registration code).

7. HAN Device shall display Utility compatibility guidance to verify that a HAN Device is compatible with a particular AMI system on its packaging.

8. HAN Device shall display its HAN network technology compatibility on its outside packaging and body.

9. HAN Device shall display UtilityAMI compliance on its packaging.

10. HAN Device shall display Enhanced UtilityAMI compliance on its packaging.

11. The HAN device shall display, on its packaging, any secondary device requirements (e.g., required EMS, bridge device).

12. HAN Device shall be manufactured to support multiple distribution channels (e.g., retail, direct Utility).

A.2.13 Operations, Maintenance, and Logistics; Installation (4)

1. HAN Device Manufacturer shall include installation documentation that includes instructions for installation (e.g., placement), commissioning, and registration, including any external dependencies.

2. HAN Device Manufacturer shall include a HAN Device user's manual in the Device packaging.

3. HAN Device Manufacturer shall include Manufacturer contact information in the Device packaging.

4. HAN Device Manufacturer shall supply technical support services (e.g., help desk, web site).

A.2.14 Operations, Maintenance, and Logistics; Manage and Maintain (10)

1. HAN Device shall have a selfcheck (i.e., initialization) function that notifies the Installer that the HAN Device is functioning properly.

2. Energy Services Interface shall have a configurable ability to log all AMI System-to-HAN System communications.

3. When the HAN Device is rebooted, HAN device shall reset to its configured (i.e., post-installation commissioning and registration) state and shall reestablish communication with the Energy Services Interface.

4. HAN Device shall have a user operable testing function that is equivalent to the self-testing function.

5. HAN Device shall supply a maintenance port for field diagnostics.

6. HAN Device shall simulate Utility events for diagnostic purposes.

7. HAN Device shall supply network management functions for diagnostic purposes.

8. For battery-powered devices, HAN Device shall communicate low battery state to the AMI System.

9. HAN Device Manufacturer shall supply and support a flaw remediation process.

10. HAN Device shall support a communications feedback mechanism (i.e., ping).