Enabling Widespread ADR Through Use of a Virtual End-Node (VEN) at the Building Level

Interim Report

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ABSTRACT

Lawrence Berkeley National Laboratory (“LBNL”) planned to create a specification for a standardized building-level VEN (VEN_B) and output application interface, which eliminates the burden of ADR connectivity from the individual end-use loads. Loads need only connect to the VEN_B via its defined communication interface and then receive a standardized signal that indicates when and what type of ADR event is forthcoming or in progress. By equipping the building with a standardized ADR “portal”, manufacturers can deliver systems with embedded connectivity that are ADR-enabled out-of-the-box. End-use systems can then also come preconfigured with ADR control strategies that can be easily enacted once the system pairs with the VEN_B. Because the responsibility of identifying, purchasing and connecting a VEN is removed from the individual end-use system and a standardized building-level portal is provided in its place, customers can more easily participate in ADR programs and at less cost.

1
BACKGROUND AND OBJECTIVES

Project Background

Cost-effective, simple solutions and technologies for use with automated demand response (ADR) are nonexistent for small to medium-sized business (SMB) market. While California energy code tries to regulate newly constructed buildings and some alterations to ensure ADR functionality, the actual technology options available to equip individual end-use loads such as lighting and plug-loads for ADR are sparse. Available options are costly, difficult to obtain, difficult to commission, and poorly documented.

A majority of existing ADR solutions are focused around use of energy or building management systems, which are not often utilized in the SMB sector. As such, SMB loads are rarely leveraged as part of demand side management programs such as ADR. Recent communications with major California utility program providers revealed that less than five commercial customers relied exclusively on lighting load shed as part of their ADR program commitment. In contrast, SMBs consume 81 percent of the electricity spent on lighting in California. The SMB sector represents an enormous reservoir of untapped DR potential, but lack of simple, cost-effective ADR control technology continues to keep these ADR resources locked away.

Currently, as part of ADR programs, utilities broadcast price and event information using the OpenADR 2.0 communication standard, which is based on communication between two types of devices – a virtual top node (VTN) and virtual end node (VEN). The VTN resides with the utility or utility-designated 3rd party, while the VEN is required downstream for any demand-side load participating in an ADR program. While the communication structure has been standardized among California utilities due the consistent use of a VTN operating under the OpenADR protocol as the means to communicate DR program information, end-use loads are left to achieve connectivity to the utility VTN individually, by either purchasing and connecting a VEN directly to their equipment, or by connecting to a BMS, which is then enabled with optional software to serve as the VEN for any connected device.

For lighting and miscellaneous electric loads, the option to purchase and connect a VEN directly can be very challenging, because existing VEN communication methods are limited, typically to communication via Zigbee, ZWave or BACNet. Lighting and miscellaneous load controllers often do not include this communication functionality. Because the application interface on the output side of the VEN is not standardized (VEN to end-use load), manufacturers of end-use equipment such as lighting control systems are reluctant to invest in and provide ADR features for their products. Manufacturers often state that their system can do “demand response” because the system can respond and reduce or turn off loads if a signal is received. The problem is that the method for connecting to the VEN and receiving that DR signal is not defined. Customers and/or solution providers are left to try and procure or create patches that can bridge the end-use system with the VEN, which is costly, time consuming and cumbersome.

Project Objectives

Working with EPRI, CLTC and industry partners, LBNL planned to create a specification for a standardized building-level VEN (VEN_B) and output application interface, which eliminates the burden of ADR connectivity from the individual end-use loads. Loads need only connect to the VEN_B via its defined communication interface and then receive a standardized signal that indicates when and what type of ADR event is forthcoming or in progress. By equipping the building with a standardized ADR “portal”, manufacturers can deliver systems with embedded connectivity that are ADR-enabled out-of-the-box. End-use systems can then also come preconfigured with ADR control strategies that can be easily enacted once the system pairs with the VEN_B. Because the responsibility of identifying, purchasing and connecting a VEN is removed from the individual end-use system and a standardized building-level portal is provided in its place, customers can more easily participate in ADR programs and at less cost.

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PROJECT APPROACH & FINDINGS

Grid-interactive efficient buildings (GEBs) with automated demand response will play an integral role in improving and modernizing the grid. Strategic load management via shifting and shedding has the potential for widespread demand mitigation, if implemented at scale. However, most devices and buildings today are not grid responsive. The purpose of this project is to identify technology paths to enable easy automation of demand response in small commercial buildings, with a focus on flexible loads. The scope will initially consider time of use (TOU) rates and may extend to residential devices in certain cases.

In general, electric utilities express their preferences to customers through 'grid signals', which can be either prices or events. Ultimately, individual end-use devices provide flexibility by changing their functional behavior. Nonetheless, some entity needs to translate the grid signal to the device's functional control. As shown in Fig. 1, this translation function can be implemented by some grid entity (e.g. the utility, or aggregator), a local gateway device, an intermediate device[1] (e.g. a thermostat, external controller, or CTA-2045 module), or the device itself. In an ideal future, all end-use devices will be directly price responsive (a few are today). However, in the near term and transition, building gateways and other intermediate devices will be required to exert control over the majority of non-responsive "dumb" devices.

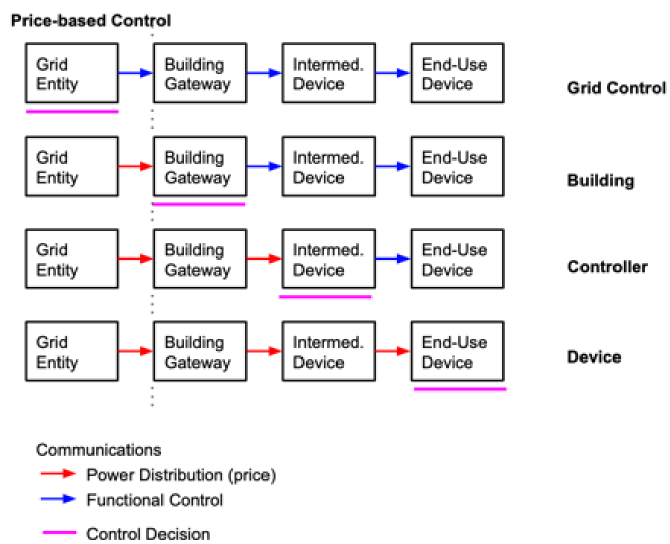
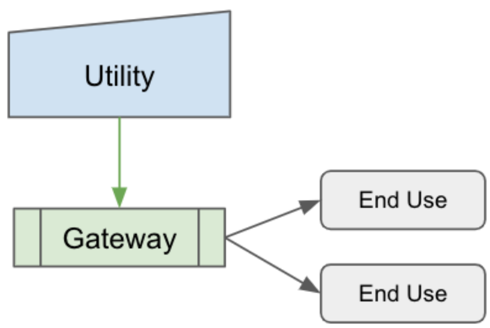


Figure 1. High-level methods for grid-responsive control.

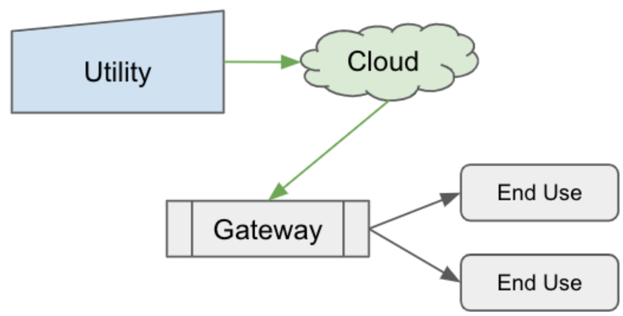
Gateways: A gateway in general is a device that connects two communication domains by doing some protocol translation, usually at the application layer (translation between two Internet Protocol physical layer protocols is usually not considered a gateway function). For this application, the gateway is a special device that communicates with the outside world, relays

[1] Device that passes communication signal, does some form of control to the end-use device, and / or interrupts power.

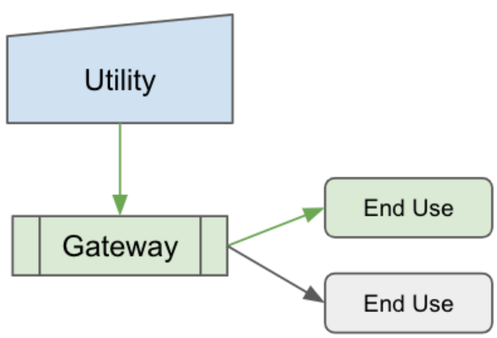
price and control information to end-use devices, and translates price streams into functional commands for devices that are not price responsive. This project aims to show that local gateways are the best way to immediately improve the grid-responsiveness of devices today. Gateways can be designed and certified to accept grid signals, such as OpenADR. As shown in Fig. 2, there are several ways in which gateways can benefit the grid-responsiveness of buildings in the near-term. OpenADR is currently far more cost-efficient to implement and certify at a building central gateway, rather than in each individual device. Gateways also have the added advantage of enabling continued operation during an intermittent outage of the wide area communication, e.g. when an internet connection goes down.



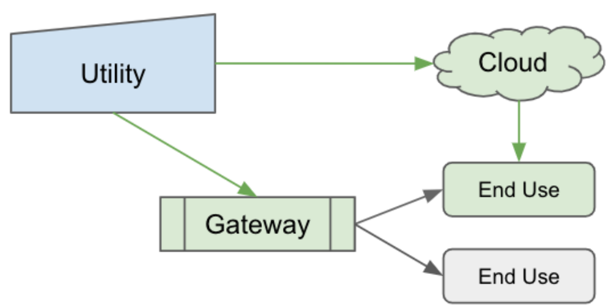
(a) Building gateway is an OpenADR-certified VEN, no end use device is OpenADR capable.



(b) OpenADR certified VEN in the cloud, no end use device is OpenADR capable.



(c) Building gateway is an OpenADR-certified VEN, some devices are OpenADR certified.



(d) Building gateway is an OpenADR-certified VEN, some devices in building have a cloud-based OpenADR VEN.

Figure 2. OpenADR use cases in buildings. Blue: virtual top node (VTN), Green: virtual end node (VEN), Grey: uncertified device.

LBNL already has experience with two potential gateway devices, made by Intwine Connect and Universal Devices. LBNL also identified several others as shown in the table below. Several criteria were considered in the evaluation of the gateways:

- Upstream: Physical layer protocols supported (e.g. Ethernet, Cellular, Wi-Fi).
- Upstream: Application layer protocols supported (e.g.OpenADR, IEEE 2030.5)

- Downstream: Physical layer protocols supported (e.g. Ethernet, Wi-Fi, Zigbee, Z-Wave).
- Downstream: Application layer protocols supported (e.g. OpenADR, IEEE 2030.5, Zigbee)
- Ability for LBNL to add or modify gateway programming, and ease of doing this
- Low cost (e.g. less than $1,000, ideally much less)

LBNL surveyed the market and identified the following twelve devices to consider, as shown in Tables 1 and 2. LBNL has direct experience with the Intwine device and have been in contact with the developer of the Universal Devices product about related research.

Table 1. Basic Gateway Information

Name	Manufacturer	Can receive prices	Programmable	Intended application	Link
ISY 994	Universal Devices	Yes	Yes	commercial	https://www.universal-devices.com/product/isy994-pro-oadr
Connected Gateway	Intwine Connect	Yes	Yes	commercial	https://www.intwineconnect.com/
Smartthing Connect Home Pro	Samsung		Yes	residential	https://www.smartthings.com/products/samsung-connect-home-pro
D-link IoT gateway	D-Link		Probably no	residential	https://www.dlink.com/en/products/dsh-g300-multi-protocol-iot-gateway
Volansys Modular IoT gateway	Volansys		Probably yes	Commercial /Residential	https://volansys.com/modular-iot-gateway/
Dunsun Smart Wireless Gateway	Dunsun		Yes	Commercial /Residential	https://www.dusuniot.com/smart-gateway
DynaGATE	Eurotech		Probably yes?	industrial	https://www.eurotech.com/en/products/iot/multi-service-iot-edge-gateways/dynagate-20-30
Connected Grid Routers	Cisco		Probably yes?	industrial, utility metering	https://www.cisco.com/c/en/us/products/routers/1000-series-connected-grid-routers/index.html
Dell Edge Gateways for IoT	Dell		Yes	industrial	https://www.dell.com/en-us/work/shop/gateways-embedded-computing/sf/edge-gateway
ConnectPort	Digi		Yes	Commercial	https://www.express-inc.com/ProductDetails.asp?ProductCode=X2E-Z3C-

					E1-W
Micro gateway	Rak		Yes	Commercial	https://store.rakwireless.com/products/rak7258-micro-gateway
Gateway	Libelium		Yes?	industrial/commercial	http://www.libelium.com/downloads/new_generation_libelium_product_lines.pdf

Table 2. Gateway physical layer protocols supported

Name	Manufacturer	BLE	Serial	3G/4G	BACnet	Thread	Zigbee	Z-wave
ISY 994	Universal Devices	Yes	Yes	No		No	No	Yes
Connected Gateway	Intwine Connect	Yes	No	Yes		No	Yes	No
Smarthing Connect Home Pro	Samsung	No	No	No	No	Maybe?	Yes	Yes
D-link IoT gateway	D-Link	Yes	No	No	No	Yes	Yes	No
Volansys Modular IoT gateway	Volansys	Yes	Yes	Yes	No	Yes	Yes	Yes
Dunsun Smart Wireless Gateway	Dunsun	Yes	No	Yes	No	No	Yes	Yes
DynaGATE	Eurotech	Yes	Yes	Yes	Yes?	No	No	No
Connected Grid Routers	Cisco	No	Yes	Yes	No	No	No	No
Dell Edge Gateways for IoT	Dell	Yes	Yes	Yes	Yes	No	No	No
ConnectPort	Digi	Yes	Yes	No	No	No	Yes	Yes
Micro gateway	Rak	No	Yes	Yes	No	No	No	No
Gateway	Libelium	Yes	No	Yes	No	Yes	Yes	No

For OpenADR, only the Universal Devices product is certified as supporting OpenADR 2.0b. The Intwine device has OpenADR software written for it by the manufacturer. A research project created an OpenADR VEN for the SmartThings gateway[2]. The rest are not known to support OpenADR

All the gateways support integration with other devices from manufacturers; for example, a consumer can buy a D-link gateway and connect a Philips LED smart bulb. The Cisco and Dell products are oriented to industrial applications; the rest to buildings/IoT. The DynaGate supports RS485 and RS232. The Intwine Connected Gateway exposes communication with devices connected to it through a local web API.

No existing gateway is ideal; however, the Universal Devices gateway best met the project needs, and so LBNL recommends using it for the next phases of the project. The next phase can plan to demonstrate a realistic set of end-use devices connected to its physical layer. If resources permit, there will be a need to add a secondary hub. The SmartThings product is top of the list for this purpose, as it has the widest coverage of integrated devices and a relatively high market share. The Volansys product had the next best set of capabilities. An important feature of Volansys is that it supports Thread. This is important because Project CHIP will likely recommend that the next physical layer should be IEEE 802.15.4 and the next network layer protocol should be IPv6 (because these are strongly supported by Google).

LBNL expected the demonstration to include intermediate devices. Examples of these include:

- A communicating power outlet to power/de-power a device on control of the gateway. A pool pump is an example of this arrangement because it needs to be powered a certain amount of time per day, but with the actual start time(s) flexible.
- A CTA-2045 module. There are two current devices that support this module: a water heater simulator (by A.O. Smith) and an electric vehicle charger (by Siemens).
- A hub device like the Samsung SmartThings.

Ultimately, the gateway will not require any intermediate devices, but will need this flexibility for a (long) transition time. An end-use device can have zero, one, or more intermediates, with one likely being the most common in the near term.

This architecture for grid coordination also applies to central electricity storage (a battery), or to dispatchable generation, but flexible end-use loads are core focus for this project. There is no expectation to include stand-alone storage or generation.

End-Use Devices

The relevant end-use categories are shown in the table below. Load shifting capability is rated based on the ease of shifting without disruption to the occupants. Shedding priority is scaled from low to critical, where low-priority loads are shed first, and critical loads must always be powered. Loads may also have a discrete on/off state-based operation, or can operate at any point on a continuous curve of output vs power consumption. Continuous curves are more amenable to price-based control. It is also assumed that all large motor loads in the future will use variable-speed drives with near-continuous (but variable) operation.

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[2] OpenADR and the Internet of Things: https://www.qualitylogic.com/2016/03/02/openadr-and-the-internet-of-things/

End-Use Category	Sub-category	Load-Shift Score	Operating Curve	Shedding Priority
Lighting		Medium	Continuous	Medium
Electronics	Personal	Hard	Discrete	Medium
	Mobile Charging	Hard	Discrete	Medium
	Network	Hard	Discrete	Critical
	Server	Hard	Discrete	Critical
HVAC	Space Heating	Medium	Continuous	Medium
	Space Cooling	Medium	Continuous	Low
	Ventilation	Medium	Continuous	Low
Water	Water Heating	Easy	Continuous	Low
	Water Cooling	Easy	Continuous	Low
	Circulation Pump	Medium	Continuous	Low
	Sump Pump	Hard	Continuous	Critical
	Well Pump	Easy	Continuous	Critical
Refrigeration		Easy	Continuous	Critical
Transportation	Fast Charging	Hard	Discrete	Medium
	Slow Charging	Easy	Continuous	Low
Appliances	Seldom-use	Hard	Discrete	Low
	Frequent-use	Hard	Discrete	Low
Security, Life, Safety		Hard	Discrete	Critical
Unclassified MELs		Hard	Discrete	Medium

Devices for the demonstration will be selected based on end-use category and protocol. No single gateway implements every relevant protocol, and sub-gateways or hubs will likely be required. As shown in the table below, protocols such as Z-Wave and Insteon are only relevant to a small handful of end-use categories. Most of the larger smart appliances communicate via Wi-Fi, and frequently require intermediate controllers for connectivity.

End-Use Category	Sub-category	Manufacturer	Product	Protocol	Nature of Control
Lighting	Bulb	Zipato	Bulb 2	Z-Wave	on/off, level
Lighting	Switch	GE	In-Wall Smart Dimmer	Z-Wave	on/off, level
Lighting	Switch	Insteon	Dimmer Switch - 600W	Insteon	on/off, level
Lighting	Switch	Insteon	Dimmer Keypad (6-Button)	Insteon	on/off, level
Lighting	Outlet	Insteon	Dimmer Outlet	Insteon	on/off, level
Electronics	Personal	Raspberry Pi	DVFS	Wi-Fi	on/off
HVAC	Thermostat	Honeywell	Thermostat	Z-Wave	setpoint
HVAC	Thermostat	Insteon	Wired Thermostat	Insteon	setpoint
HVAC	Air Conditioner	Midea	Smartcool AC Portable Air Conditioner	Wi-Fi	setpoint
HVAC	Air Conditioner	GE	GE AEC08LY Smart Window Air Conditioner	Wi-Fi	setpoint
HVAC	Space Heater	Crane USA	Smart Ceramic Tower Heater	Wi-Fi	level
HVAC	Space Heater	Mill	AB-H1500WF	Wi-Fi	level
HVAC	Cooling Fan	Cavera	52 in. Indoor Matte Nickel Ceiling Fan	Wi-Fi	level
HVAC	Cooling Fan	Insteon	Ceiling Fan and Light Controller	Insteon	level
HVAC	Ventilation	Tamarack	Smart TC1000-T Sunroom Ventilation Fan	Wi-Fi	level
HVAC	Ventilation	Vents	Micra 100 ERV	Wi-Fi	level
Water	Recirculation Pump	Smart Recirculation Control	Smart Recirculation Pump Control	Wi-Fi	setpoint
Water	Well Pump	Goulds Water Technology	AqWiFi	Wi-Fi	monitor

Water	Well Pump	Sam Controllers	Water Well Pump Controllers	Wi-Fi	monitor
Water	Sump Pump	Burcam Pumps	300500ZSP	Wi-Fi	setpoint
Water	Heating	Shifted Energy	Tempo Controller with Grid Maestro	Cellular	setpoint
Water	Heating	Aquanta	Aquanta	Wi-Fi	setpoint
Water	Heating	Rheem	Performance Platinum Hybrid Smart Electric Water Heater	Wi-Fi	setpoint
Refrigeration	Refrigerator	LG	22.5 Cu. Ft. French InstaView Door-in-Door Counter-Depth Smart Wi-Fi Refrigerator	Wi-Fi	setpoint
Refrigeration	Refrigerator	Kenmore	4675043 Smart French Door Bottom-Mount Refrigerator, 24 cu. ft	Wi-Fi	setpoint
Transportation	Slow charging	Siemens	Versicharge SG	Wi-Fi (over CTA 2045)	level
Appliances	Washer/Dryer	LG	2.8 cu. ft. Compact Smart All-in-One Front Load Washer and Electric Ventless Dryer	Wi-Fi	on/off, level
Appliances	Washer/Dryer	Whirlpool	2.8 cu. ft. Smart All-In-One Washer & Dryer	Wi-Fi	on/off, level
Unclassified MELs	Blinds	Somfy	Z-Wave Digital Motor Interface	Z-Wave	on/off
Unclassified MELs	Air Purifier	Xiaomi	Mi Air Purifier Pro	Wi-Fi	level
Unclassified MELs	Humidifier	SwitchBot	Smart Humidifier	Wi-Fi	level

Unclassified MELs	Motion Detector	Ecolink	Motion Detector	Z-Wave Plus	monitor
Unclassified MELs	Motion Detector	Insteon	Motion Sensor II	Insteon	monitor
Unclassified MELs	Outlet	Eaton	TR Receptacle	Z-Wave	on/off
Unclassified MELs	Switch	Insteon	On/Off DIN Rail Module	Insteon	on/off

Criteria were developed to help us select devices and models to include in future demonstration. Devices should be:

- Already integrated with gateway device by the gateway manufacturer, device manufacturer, or someone else
- Able to accept prices directly
- Contribute to a wide range of end uses for demonstration
- Easy to host at LBNL and to transport (e.g. appliances with water/drain hookups are problematic)
- Not too expensive
- Have a significant amount of shiftable load for small commercial customers; and
- Use innovative control mechanisms.

Other criteria may be applied as the project progresses in the future.

3
NEXT STEPS

The next steps are to finalize a gateway and select end-use devices for the demonstration. The gateway selection will be influenced by the desired behaviors, and the end-use device selection will be motivated by the selected gateway. Once the necessary modifications are finalized, the selected new project team can deliver a report describing the design of the gateway software and messaging architecture.

4 BIBLIOGRAPHY

Below is a list of recent publications that discuss OpenADR VENs and communications for commercial and small commercial buildings. These reports provide an overview of the challenges that formed the need for the SCE-EPRI-LBNL VEN project.

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