Architecture Concepts and Technical Issues for an Open, Interoperable Automated Demand Response Infrastructure

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Keywords: Demand response, automation, commercial buildings, architecture

Abstract

This paper presents the technical and architectural issues associated with automating Demand Response (DR) programs. The paper focuses on a description of the Demand Response Automation Server (DRAS), which is the main component used to automate the interactions between the Utilities and their customers for DR programs. Use cases are presented that show the role of the DRAS in automating various aspects of DR programs. This paper also describes the various technical aspects of the DRAS including its interfaces and major modes of operation. This includes how the DRAS supports automating such Utility/Customer interactions as automated DR bidding, automated DR event handling, and finally real-time pricing.

1. INTRODUCTION

Since 2002 the process of automating DR programs has been under investigation by the Demand Response Research Center (DRRC) of Lawrence Berkeley National Laboratories (LBNL) and various Utilities in California. These efforts are described in more detail in [1]. This paper describes the technical aspects of the results of those efforts.

As described in [1] **Fully-Automated Demand Response** does not involve human intervention, but is initiated at a home, building, or facility through receipt of an external communications signal. The receipt of the external signal initiates pre-programmed demand response strategies [2]. The authors refer to this as Auto-DR. One important concept in Auto-DR is that a homeowner or facility manager should be able to "opt out" or "override" a DR event if the event comes at time when the reduction in end-use services is not acceptable.

From the customer side, modifications to the site's electric load shape can be achieved by modifying end-use loads. Examples of demand response strategies include reducing electric loads by dimming or turning off non-critical lights, changing comfort thermostat set points, or turning off non-critical equipment. These demand response activities are triggered by specific actions set by the electricity service provider, such as dynamic pricing or demand bidding. Many electricity customers have suggested that automation will help them institutionalize their demand response. The alternative is manual demand response -- where building staff receives a signal and manually reduces demand. LBNL research has found that many building energy management and controls systems (EMCS) and related lighting and other controls can be pre-programmed to initiate and manage electric demand response.

Following the hot summer of 2006 the California Public Utilities Commission requested the three California Investor Owned Utilities to partner with the DRRC to begin using Auto-DR technologies. As part of that effort a more formal definition of Auto-DR was developed to outline the principles for the automation system design. **Automated Demand Response for commercial and industrial facilities can be defined** as fully automated DR initiated by a signal from a utility or other appropriate entity and provide full-automated connectivity to customer end-use control strategies.

Signaling - The Auto-DR technology should provide continuous, secure, reliable, two-way communication with end-use customers to allow end-use sites to be identified as listening and acknowledging receipt of DR signals.

Industry Standards - Automated DR consists of open, interoperable industry standard control and communications technologies designed to integrate with both common energy management and control systems and other end-use devices that can receive a dry contact relay or similar signals (such as internet based XML).

Timing of Notification - Day ahead and day of signals are provided by Auto-DR technologies to facilitate a diverse set of end-use strategies such as pre-cooling for "day ahead" notification, or near real-time communications to automation "day of" control strategies. Timing of DR automation server communications must consider day ahead events that include weekends and holidays.

A key infrastructure component used to automate DR programs is the so-called Demand Response Automation Server (DRAS). Figure 1 depicts a conceptual overview of Auto-DR and the role that the DRAS plays in the over all infrastructure.

As shown in Figure 1 the DRAS plays a crucial role in automating the interactions between the Utility/ISO and the DR program Participants. The DRAS is designed to generate, manage, and track DR signals between Utilities/ISO's to aggregators and end-use customers and their control systems that perform various shed strategies in response to the DR signals.

Each facility or end-use customer hosts a DRAS Client that is responsible for bridging communications between the DRAS and the automated system (e.g. Energy Management Control Systems) responsible for controlling electricity consumption. It may be a software-based client implemented with an existing sub-system or a dedicated piece of hardware whose responsibility is to proxy communications between the DRAS and the EMCS. The latter is depicted by the CLIR box (Client Logic and Integrated Relay) in Figure 1.

2. USE CASES

The DRAS is designed to support two major classes of Utility/ISO and Participant interactions: DR event notification and automated bid submission. How the DRAS is used in each of these functions is detailed in this section.

2.1. Automated DR Event Notification

Almost all DR programs require Participants to respond to

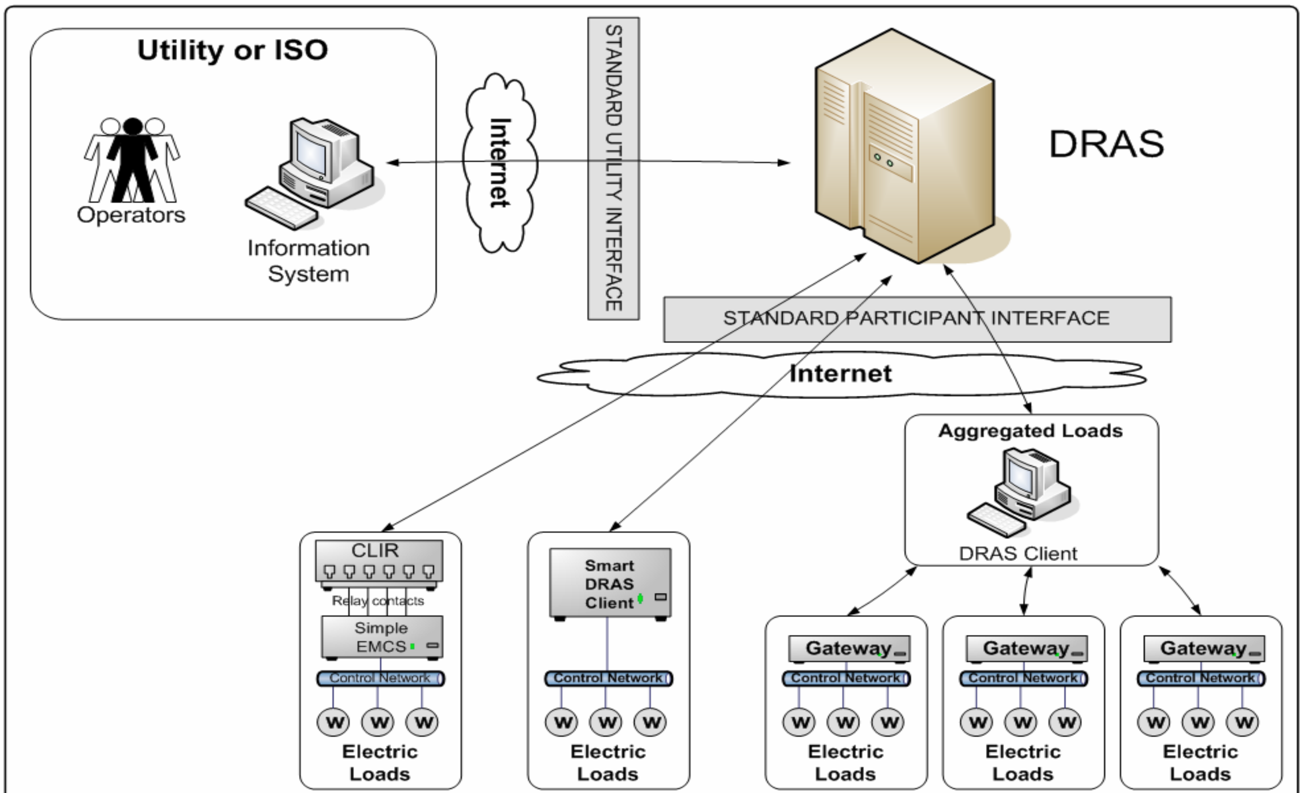

Figure 1. Automated Demand Response

DR events from the Utility/ISO which are normally handled by human operators. The main concept of Auto-DR is to remove the humans from the loop as much as possible and thus automating the actions within the facilities. The DRAS accomplishes this by brokering the communications between the Utility/ISO and the equipment in the facilities. This is depicted in the Automated DR event notification is shown in the use case diagram of Figure 2.

In addition to specific DR events the DRAS is also designed to handle Real Time Pricing (RTP) streams from the Utility and potentially convert these into DR events for the facility to act upon.

Note that a number of ancillary operations are also performed in support of DR Event notifications including configuration, operations and reports. The DRAS also support these activities although they are not described in detail in this paper.

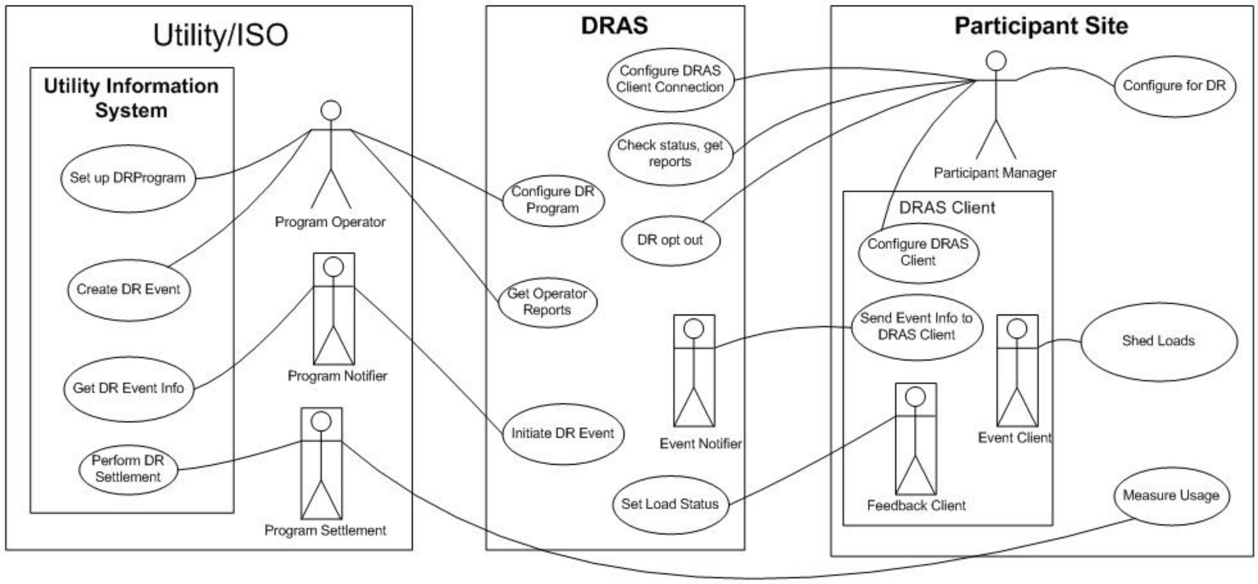

Figure 2. DR Event Notification Use Case

The sequence of operations that take place when a DR event is issued by the Utility/ISO is the following:

1. Utility Program Operator creates DR Event in Utility Information System.
2. Utility Program Notifier gets DR Event information from Utility Information System. (date and time) and initiates DR event in DRAS
3. Event Notifier in DRAS sends event info to all DRAS clients in DR program.
4. DRAS Event Client in Facility sends event info to Client sub-systems resulting in the shedding of loads.
5. DRAS Feedback Client in Facility sets load status in DRAS (e.g. shed status information).
6. Utility Program Settlement measures usage in Client Sites and performs settlement in Utility Information System.

2.2. Automated Bid Submissions

Some DR programs require that Participants submit bids for available shed resources. The Utility/ISO will then either accept or reject those bids and those that are accepted will receive subsequent DR Event notifications to perform the actual sheds. The submission of bids is yet another DR related activity that requires a human in the loop and is thus a candidate for further automation.

Experience has shown that many Participants that participate in these types of DR programs rarely change their bids from one DR Event to another. Thus the DRAS can be used to automate the submission of bids by using the concept of a “standing bid”. Standing bids can be programmed into the DRAS by the Participants and whenever a request for bids is issued by the Utility/ISO the standing bids can be submitted by the DRAS at the appropriate time. Figure 3 shows the use case diagram for automating the submission of standing bids by Participants.

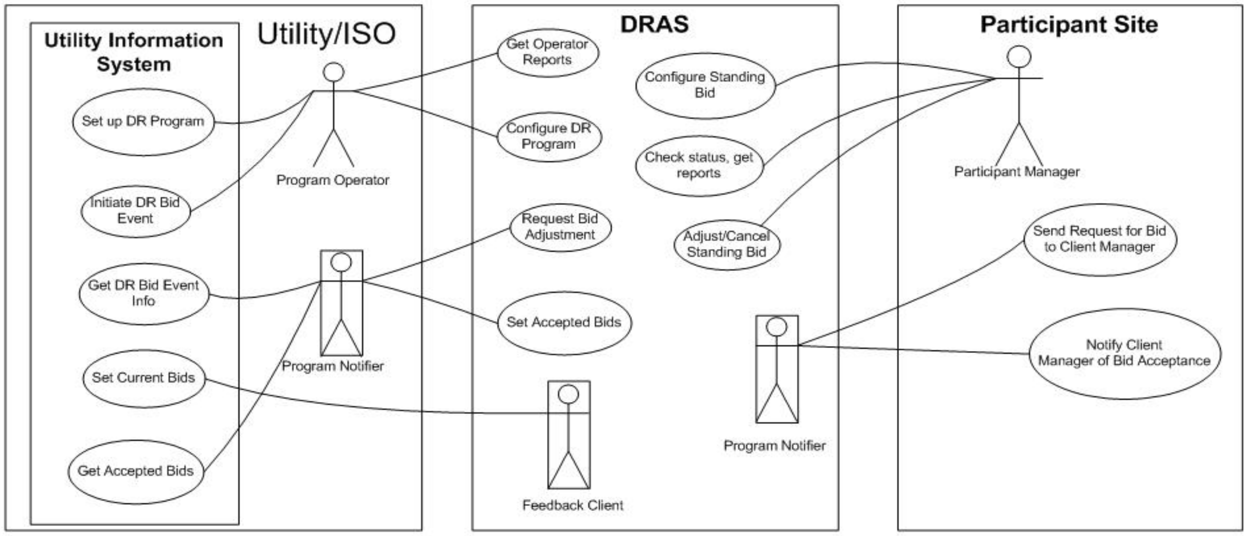

Figure 3. Automated Bidding

The sequence of steps used to perform automated bid submissions are the following:

1. Utility Program Operator initiates Bid Event in Utility Information System.
2. Utility Program Notifier gets bid event information from Utility Information System. (date and time) and initiates a request for Bid adjustment in DRAS (request for bids)
3. DRAS Program Notifier sends request for bid to the Participant Manager
4. Participant Manager Adjusts/Cancels current bid in DRAS (optional).
5. After specified time limit the Bidding Proxy in DRAS sets the current bid in the Utility Information System.
6. Utility Program Notifier gets accepted bids from Utility Information System and sets accepted bids in DRAS
7. DRAS Program Notifier sends the acceptance notification to the Client Manager

3. DRAS OPEN INTERFACE STANDARDIZATION

A standard for the various DRAS interfaces would have the benefits of lowering the effort and cost of implementing Auto-DR programs and thus increase the level and reliability of participation in them.

In 2007 the DRRC began a standardization effort by bringing together a consortium of industry stake holders primarily composed of the major Utilities and ISO in California. In addition other research and standards organizations such as the California Energy Commission (CEC), Electric Power Research Institute (EPRI), Building Automaton Control Network (BACnet), National Institute for Standards and Testing (NIST), and Open Home Automation Network (OpenHAN) are participating in the effort.

The standardization effort is relying heavily upon the lessons learned since 2002 in implementing Auto-DR programs in California. The objective is to have an initial draft of the standard by early 2008 that can form the basis of a DRAS implementation that can be used in the DR programs that will be made available in the summer of 2008. It is anticipated that the standard produced by this industry consortium may eventually be submitted to a standards organization such as IEEE (Institute of Electrical and Electronics Engineers, Inc.) or ASHRAE (American Society of Heating, Refrigeration, and Air conditioning Engineers) to become an official standard.

3.1. DRAS Requirements

The following are some of the general requirements of the DRAS:

1. Communications with the DRAS should use readily available and existing networks such as the internet.
2. The DRAS interfaces should be platform independent and leverage existing standards such as XML and Web Services.

3. The DRAS communications should use a security policy that enables both the authentication and the encryption of the communications with the DRAS.
4. The DRAS should support communications with a variety of control systems that may range from a very simple EMCS to those with sophisticated data processing and programming capabilities.
5. The DRAS should not be dependent on specific control systems within the facilities.
6. DRAS Clients that communicate with the DRAS should easily integrate with existing facility networks and IT infrastructures.
7. The DRAS should support aggregated loads that may be managed by third party aggregators.
8. Reconciliation of DR Event participation is outside the scope of the DRAS. There are a number of methods such as aggregators, AMI, etc. that can and will handle the measurement of sheds for the purposes of the reconciliation of DR programs.

4. ARCHITECTURE

The general architecture for handling automated DR Events is shown in Figure 4. Although not shown, the same architecture also handles the Automated Bidding functions.

The DRAS is intended to interface to two different types of DRAS clients within the Participant's facility. The first is called the "Smart DRAS Client" which is capable of receiving full DR Event information as specified by the Utility. The second is referred to as the "Simple DRAS Client" (CLIR box of Figure 1), which receives a simplified characterization of the DR Event in terms of simple levels such as normal, moderate, and high. The Simple DRAS Client is intended to be used in environments where there is not a sophisticated EMCS that can be easily programmed. In this case the Simple DRAS Client can be nothing more than a gateway with simple relay contacts that interface to an existing EMCS.

Furthermore the interface with the DRAS Client is intended to support both a PUSH and PULL model of interaction. In the PULL model the DRAS Client polls the DRAS for information while in the PUSH model the DRAS asynchronously sends information to the DRAS Client. The PULL model has the benefit of being easier to integrate with existing IT infrastructures because of firewall issues and security certificates. The PUSH model has the benefit of reduced latency and network activity.

As shown in Figure 4 Real Time Pricing (RTP) is depicted as being supported in the DRAS. It is anticipated that in the case of Smart DRAS Clients the RTP information is sent directly to the DRAS Clients when it is received. In the case of Simple DRAS Clients there will be a set of rules configured in the DRAS that converts RTP information to the simple level information that the Simple DRAS Clients require.

Note that the user interface is depicted as being outside the DRAS. It may be that for a particular implementation of the DRAS a web based UI may be part of the DRAS, but the look and feel of the UI to the DRAS is considered outside the scope of the standard.

In Figure 4 the DRAS is depicted as a stand alone component, but it should be understood that the DRAS may be integrated with the Utility/ISO or the Participants information systems.

5. CONCLUSION

The DRAS plays an important role in automating DR programs and has proven its worth over a number of years in both research and actual commercial environments at LBNL and the big three IOU's in California.

Because its functionality has been focused on removing the human from the loop its scope is relative narrow and thus easily integrated with existing infrastructures and operations on both the Utility/ISO and the Participants side of the equation.

With the development of standard interfaces to the DRAS it is hoped that the architecture will become even more widespread and there will be the development of more DRAS clients that will enable a wider range of facilities to leverage the benefits of DR.

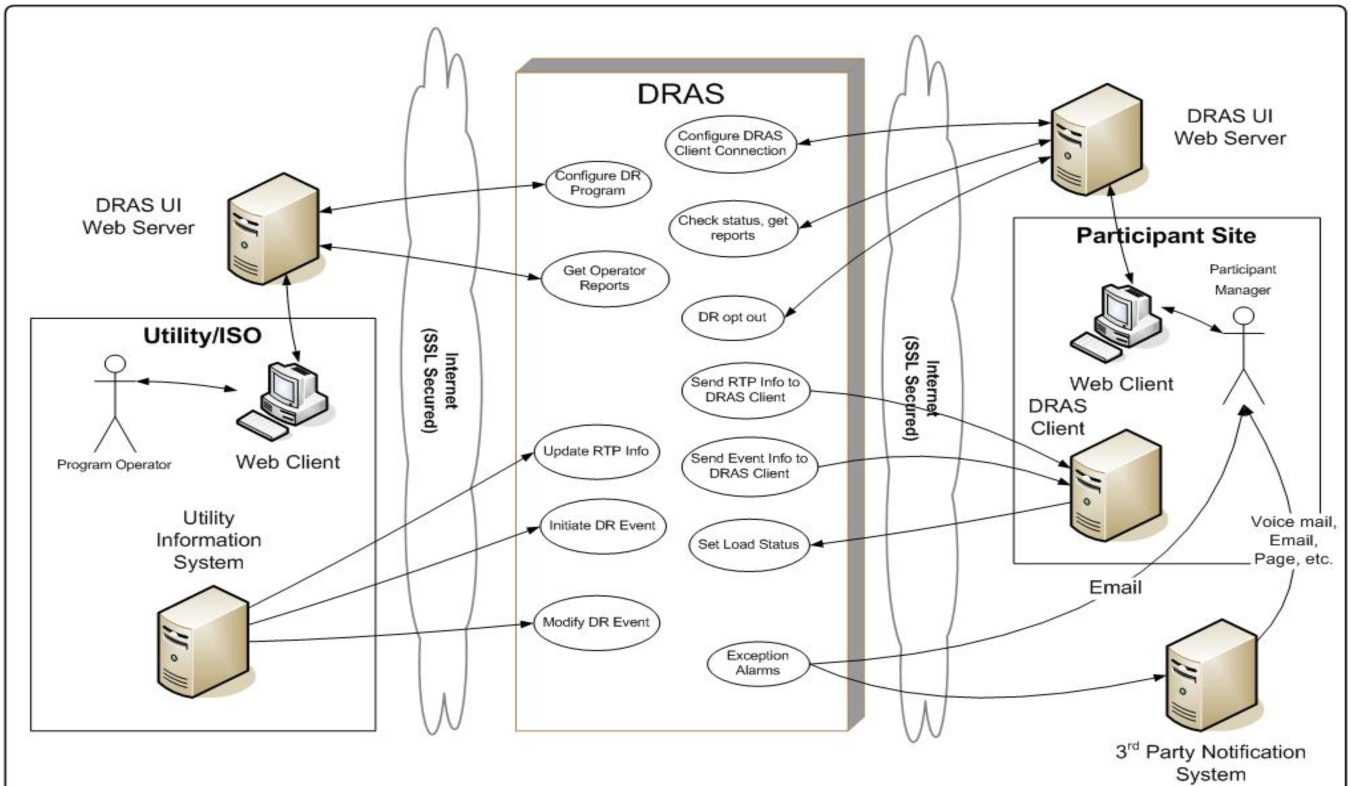

Figure 4. Automated DR Events Architecture

6. ACKNOWLEDGEMENTS

This research was sponsored by the Demand Response Research Center which is funded by the California Energy Commission (Energy Commission), Public Interest Energy Research (PIER) Program, under Work for Others Contract No.500-03-026, Am #1 and by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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Biography

Ed Koch is founder and CTO of Akuacom. Akuacom specializes in enterprise systems for automated energy control and monitoring in commercial and residential buildings, especially as it applies to Demand Response Programs. Prior to that Ed was the founder and CTO of Coactive Networks which specialized in creating solutions for linking distributed control networks used in energy management systems to IP networks and enterprise applications.

Mary Ann Piette is a Staff Scientist at Lawrence Berkeley National Laboratory and the Research Director of the PIER Demand Response Research Center. She has at LBNL since 1983 and has extensive experience evaluating the performance of energy efficiency and demand response in large facilities. The DRRC is a 3-year old Center to plan, manage, conduct and disseminate DR research for the California Energy Commission. Ms. Piette has a BA in Physcial Science and a MS Degree in Mechanical Engineering from UC Berkeley and a Licentiate from the Chalmers University of Technology in Gothenburg, Sweden.