HUMBOLDT-UNIVERSITÄT ZU BERLIN

NUS National University of Singapore

HU-NUS Programme
REPORT

1. Title of Joint Project / Workshop: (please indicate)
Event-Driven Methods for Demand Response in Electric Grids

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3. HU Berlin Principal Investigator, University/Institution, Department and Faculty:
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4. Project Start and End Date:
1 November 2017 to 31 October 2018

5. Summary of Activities, Results and Achievement of the Project / Workshop:

Summary of Activities

1. A workstation has been set up at NUS to develop and execute load forecasting techniques, consumer demand models, and power system simulation tools.
2. Workshop at HU Berlin: The NUS PI presented at HU Berlin in November 2017. Discussions were held to exchange basic concepts of the two teams' research, and set up specific collaborative research goals for this project.
3. Workshop at NUS: The HU Berlin PI presented his research at NUS in September 2018. Informal brainstorming sessions were held to develop new research ideas, as well as to work on our conference paper on adaptive event stream monitoring for dynamic decision-making for demand response.
4. A consumer behaviour model was developed to develop simulations of residential event-based demand response in a smart grid.
5. An event stream monitoring implementation of demand response was simulated, and the developed ideas were compiled as a conference paper. This is planned to be extended in the near future as an impactful journal article.

Summary of technical contributions

The traditional approaches for implementing event-based Demand Response (DR) have been static, and do not involve feedback to the consumers regardless of their performance during the DR event. This may however lead to an incomplete system-wide response, thereby forcing the utility to employ direct load control to achieve the required response, or buy additional generation reserve from the spot market. To mitigate this inefficiency, we propose closing the loop through an incentive control for residential DR participants enabled using event stream monitoring. By realizing the latter in an adaptive and distributed manner, we reduce the data communication and computation overhead involved in the decision making process. Using simple assumptions, we demonstrate that methods for event stream processing could be used to ensure that the scheduled DR is achieved completely. Therefore, the proposed implementation allows for scalable, effective, privacy-preserving, and robust implementation of incentive-based residential DR that ensures full overall compliance of the flexible resources to the DR task.

<u>Consumer behavioural model for event-based demand response</u>
In event-based DR implementations, as the name suggests, the response from the consumer is triggered by an explicit signal from the utility that specifies the time of the event, the energy reduction requested, and the incentive for the same response. This consumer behaviour is simulated using a probabilistic decision-making model, wherein the various decisions made by the consumer, viz., whether to participate or not, and if yes, the extent of participation, are considered.

Event stream monitoring for demand response implementation in a smart grid

The implementation of event-based DR, especially in the residential sector, has traditionally been open-loop, as illustrated in Fig. 1. The utility generates a DR request that is communicated to the DR participants. Based on an expected response from these consumers, the utility schedules other resources such as conventional or distributed generation or storage to achieve the appropriate reserve levels. In this scenario, no further communication or feedback is sent to the consumer during the actual DR event period. The success of the DR event, and the conformance of the consumers is only assessed in retrospect, after the fact, for billing purposes.

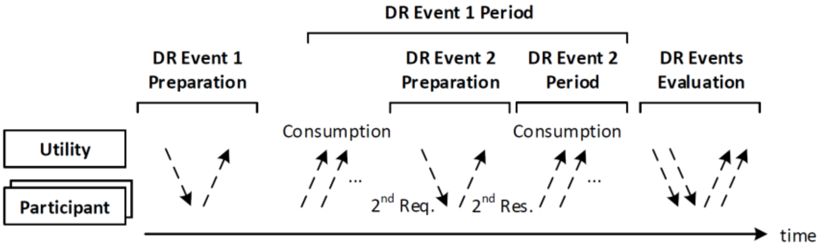

Fig. 1. The traditional approach to event-based DR.

This static approach has drawbacks because it lacks flexibility: first, in terms of the granularity at which trade-offs (offers to consumers vs. coping with increased energy consumption) are managed. There is only one DR request issued for the whole network, which is moreover before the time frame in which the savings shall materialize. Second, there is no flexibility or means for the utility to manage resources if the overall system-wide response falls short of the expected value, forcing it to turn to other resources such as the DLC flexibility provided by the commercial and industrial sector. Clearly, this is not economically optimal due to the under-utilization of the residential demand flexibility.

We therefore argue for a dynamic approach to control incentives in an event-based DR implementation, as outlined in Fig. 2. This has at its core, a feedback loop from the utility to the consumer that enables the utility to announce new incentives-a second DR event-to a subset of the participants within the time frame of the first DR event as it unfolds. Our approach to dynamic decision making for demand response exploits concepts of event stream processing. Events denote `occurrences of interest', which may represent low-level measurements (e.g., the current energy at a smart meter) as well as high-level observations (e.g., for a set of smart meters, the accumulated energy is larger than expected).

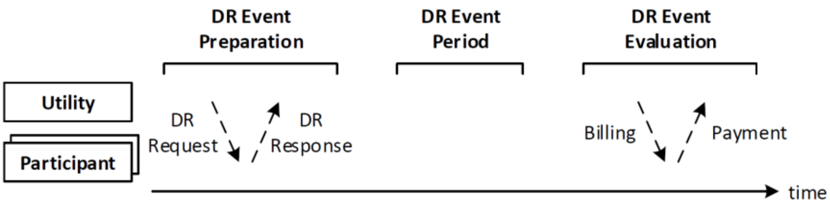

Fig. 2. Proposed approach to event-bsed DR including a feedback loop.

This decision-making approach meets the following requirements:

1. *Distributed processing:* the computation underlying decision making needs to be distributed to achieve scalability to large-scale networks, to ensure consumer privacy, and to avoid a single-point of failure, thereby achieving fault tolerance in decision making.
2. *Traceable processing:* the decision making is explicit, and not hidden in black0box models in order to enable manual monitoring.

3. *Online processing:* to enable dynamic decision making, data on the behaviour of consumers needs to be processed immediately, with low latency.

To realize dynamic DR that is based on a continuous assessment of the residents' energy consumption, we rely on event stream monitoring as illustrated in Fig. 3. That is, following the topology of a network, all DR participants are divided into groups to enable decentralized prediction of their compliance while a DR event unfolds. The compliance predictions on the group level are then used for compliance prediction at the global level by the utility. Based thereon, decisions on additional DR events are taken. Reflecting on the requirements for dynamic DR, the group-based approach to monitoring means that the approach is inherently distributed.

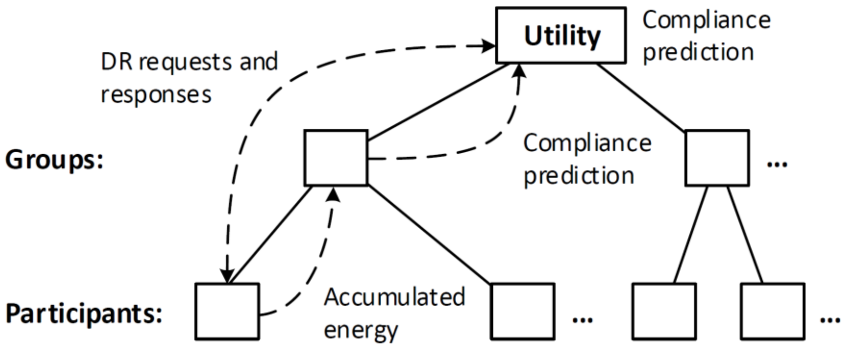

Fig. 3. Infrastructure for dynamic DR based on event strea monitoring.

Using a simple threshold-based event compliance detection, we implement the developed decision making model for a case study. The resultant load profiles are shown in Fig. 4. Analysis of these curves shows that sending a second message results in increased system-wide energy reduction during the event-duration, which is the main objective of this work.

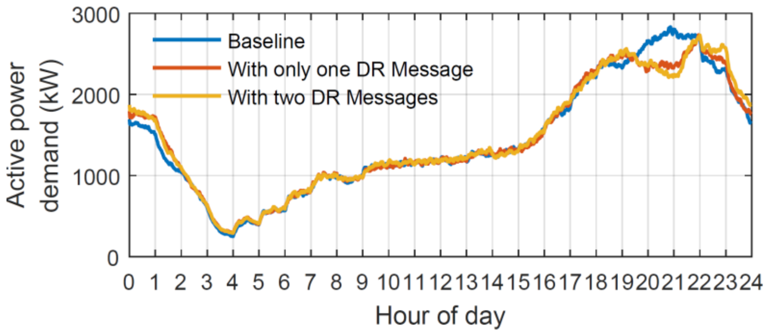

Fig. 4. System profiles using the developed DR model.

We further analyse the monitoring cost, which is comprised of the communication and computation costs. Overall, the adaptive distributed event-stream processing architecture proposed here results in a smaller overhead to the power utility.

Publications from this research collaboration

We published a manuscript, entitled "Dynamic Decision making for Demand Response through Adaptive Event Stream Monitoring," at IEEE Power and Energy Society General Meeting Conference. This was held at Atlanta, USA in August 2019. This paper details a technique for increasing the demand response compliance of residential consumers in a system, which in turn will help the power utility in maximizing the use of the residential demand flexibility to alleviate the uncertainty in renewable and other generation sources.