Semantic Information Integration and Processing for Demand Response Optimization

Qunzhi Zhou, Sreedhar Natarajan, Yogesh Simmhan and Viktor Prasanna

University of Southern California, Los Angeles, CA

Demand response optimization (DR) deals with curtailing power consumption when peak demand on the power grid is observed. In recent years, the power grid is under rapid modernization to a Smart Grid by integrating digital and information technologies. DR can make use of real-time monitoring of power use activities provided by the Smart Grid and of indirect influencers of consumption to improve traditional demand prediction and curtailment. These information sources for DR are diverse, and come from smart meters that report near real-time power usage, intelligent building sensors that measure and control facilities, and even weather forecasts from online services.

In order for DR programs to take advantage of the large data influx, meaningful information integration and processing models are required. In this poster, we propose a solution to this problem using a combination of Semantic Web technology and Complex Event Processing (CEP), as part of a *software architecture for demand-response optimization*. We apply this architecture to the USC Campus Microgrid, which is a testbed for the Los Angeles Smart Grid Demonstration Project.

1.   Semantic Information Integration for a Smart Grid Information Repository

Large scale information systems require information from heterogeneous sources to be integrated into a single repository. This hides the protocol and format diversity, and allows uniform access by external applications. As a novel challenge, the Smart Grid applications require dynamic data to be integrated. The dynamism comes from the varied sources, each of which has different access methods and format specifications. For instance weather forecast can be gathered from a web service every hour while smart meter readings may need to be updated every minute from real-time steams. In addition, traditional information integration systems use structured data but fail to leverage contextual information which is essential for inter-disciplinary domains.

Semantic Web allows complex relationships between concepts in multiple domains to be established and enables easy querying over complex data. We have developed an *ontology* to support the Smart Grid Project by combining and extending existing standards, and use this as the schema for our *Semantic Information Repository*. The repository stores integrated information about meter readings, weather forecast, building information, and classroom schedules. These provide a rich feature set for building demand prediction models.

Information integration into this repository is realized through an *agent based pipeline architecture*. Each agent adds one layer of abstraction at a time and localizes its scope of operation. For instance, the *Transport Agent* deals with access protocols used to access the information source such as HTTP, FTP, etc., the *Parser Agent* deals with how the information is extracted from different formats, and the *Semantic Agent* annotation the data with semantics. The agents are modular and we are working towards distributing them across a loosely coupled cluster of machines for scalability.

2.   Complex Event Processing for Dynamic Demand Response Optimization

Existing DR programs are typically based on static planning that either use *time of use* power pricing or *load curtailment schedules* at pre-determined peak hours. Smart Grids allow *dynamic pricing in real-time*. This broadcasts pricing signals to all consumers but the outcome is unpredictable. These static DR models are insufficient as power use activities become more dynamic in a Smart Grid. We are investigating the use of information patterns from different sources to describe dynamic situations that help us intelligently perform DR. These transient patterns can be used to locate outliers missed by coarse grained models and allow opportunistic curtailment.

We propose to apply Complex Event Processing (CEP) for dynamic DR. CEP deals with detecting situations represented as event patterns from a collection of data streams with real time events. CEP has been successfully applied in many application domains ranging from supply chain management to financial services. The requirement of timely response to electricity use activities in dynamic DR makes CEP an attractive solution. We abstract incoming data from the information integration pipeline as a logical stream of events. We have developed a semantic CEP engine that uses consists of several models such as semantic annotation, filtering and matching modules. The engine performs continuous pattern queries over events and domain ontologies to correlate power grid events for detecting peak load occurrences and load curtailment opportunities. This makes it easier to identify events that impact DR with low latency, and take subsequent action in real time. Since our event data conforms to a formal semantics, domain experts will be able to encode their knowledge of meaningful event patterns and define responses to events using declarative languages.