Negotiated Learning for Multiscale Decision-Making in Smart Grid Agents

Abstract:

Striving to reduce the environmental impact of our growing energy demand creates tough new challenges in how we generate and use electricity. We need to develop Smart Grid systems in which distributed sustainable energy resources are fully integrated and energy consumption is efficient. Customers, i.e., consumers and distributed producers, require agent technology that automates much of their decision-making to become active participants in the Smart Grid. This thesis proposal addresses models and learning algorithms for such autonomous agents in an environment where customers operate in modern retail power markets and thus have a choice of intermediary brokers with whom they can contract to buy or sell power. In this setting, customers face a learning and multiscale decision-making problem — they must manage contracts with one or more brokers and simultaneously, on a finer timescale, manage their consumption or production levels under existing contracts. On a contextual scale, they can optimize their isolated self-interest or consider their shared goals with other agents.

We advance the idea that a Learning Utility Management Agent (LUMA), or a network of such agents, deployed on behalf of a Smart Grid customer can autonomously address that customer’s multiscale decision-making responsibilities. We study three relationships, from a LUMA to: (i) the associated customer delegate and capacity originators, (ii) the brokers, and (iii) other customers or their agents. These relationships are semi-cooperative as the degree of expected cooperation can change dynamically with the evolving state of the world. Suitable game-theoretic and multiagent reinforcement learning algorithms pose severe computational challenges. Thus, we intend to exploit the multiagent structure of the problem to control the degree of partial observability. Since a large portion of relevant hidden information is visible to the other agents in the environment, we propose methods for Negotiated Learning, whereby a LUMA can offer incentives to the other agents to obtain information that sufficiently reduces its own uncertainty while trading off the cost of offering those incentives.

We have already accomplished several steps towards the thesis goal. Specifically, we have: (i) developed a learning algorithm that classifies the physical layouts of networked mobile agents to employ class-specific multiagent control policies; (ii) analyzed the risk of price volatility in real wholesale power markets; (iii) contributed to the creation of Power TAC, an extensive open-source Smart Grid simulation platform; (iv) studied the role of intermediary brokers as a risk aggregation mechanism and introduced a novel MDP formulation of an autonomous broker agent’s goal; (v) studied empirical equilibria with multiple learning broker agents; (vi) developed a hierarchical Bayesian model for long-range timeseries simulation; (vii) introduced a model for a customer utility optimization agent that addresses the multiscale decisions that need to be made by customers using an adaptive capacity shifting algorithm.

We propose to extend our work by introducing Negotiable Decision Processes (NDP) as a formal representation where partial observability is negotiable amongst certain classes of agents. We intend to then develop Negotiated Learning techniques, which leverage the variability of hidden information for efficient multiagent learning. We can then formulate a Learning Utility Management Agent (LUMA) as an NDP and use Negotiated Learning techniques within a prototype LUMA strategy. We propose to evaluate the work on real data as available, and on an agent-based Smart Grid simulation platform like Power TAC, with the intent to substantiate the value of autonomous learning customer agents in the Smart Grid by measuring their contribution towards the financial and energy efficiency goals of customers.

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