Optimal Real-time Pricing Algorithm for Smart Grid having Multiple energy providers: Utility Maximization Approach

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Summary
We consider a smart grid environment that allows two-way communication among smart meters. We propose a real-time pricing algorithm for the future smart grid having multiple sources (both renewable and non-renewable) with variable production and pricing constraints. First, we analytically model the subscribers’ preferences and their energy consumption patterns in the form of carefully selected utility functions based on concepts from microeconomics. Second, we propose a distributed algorithm which automatically manages the interactions among the consumer and the energy providers. The algorithm finds the optimal energy consumption level for each subscriber to maximize the aggregate utility of all subscribers in the system. The algorithm also finds the optimal energy production level of all the energy providers to have the minimal cost of production satisfying the demand of all consumers. Finally, we show that some desirable consumption and production patterns can be encouraged by the proposed real-time pricing interactions.

INTRODUCTION
The dependency of almost all parts of industry and different aspects of our life on electrical energy makes the massive infrastructure a strategic entity. There is increased need to develop new methods for demand side management (DSM). We focus on the real-time interactions among subscribers and the energy providers and introduce a real-time pricing algorithm for the future smart grid.

SYSTEM MODEL

DISTRIBUTED ALGORITHM
If the energy provider would be able to charge the users at the optimal rate and each individual user tries to maximize its own welfare function, it will be guaranteed by strong duality that the total power consumption will not exceed capacity.

Fig 2. Interaction between energy providers and subscribers in the system

The distributed algorithms of each subscribers and energy providers are summarized in algorithm 1 and algorithm 2, respectively. The initialization in both the cases is random. Then the loop continues.

Algorithm 1: Executed by each subscriber $i \in N$.
1. Initialization.
2. repeat
3. receive the new value of $\lambda^i$ from energy provider.
4. Update the consumption value $x^i_\pi(N) \pi$ by solving (17).
5. Communicate the updated $x^i_\pi(N) \pi$ to energy provider.
6. end

Algorithm 2: Executed by the energy provider.
1. Initialization.
2. repeat
3. if $t \in T$
4. Compute the new value of $\lambda^i$ using (20).
5. Broadcast the new value of $\lambda^i$ to all the subscribers.
6. else
7. Update the capacity value $\lambda^i(N)$ by solving (18).
8. Receive $x^i_\pi(N) \pi$ from all the subscribers $i \in N$.
9. Update the total load $\sum_{i \in N} x^i_\pi(N) \pi$ accordingly.
10. end

PERFORMANCE EVALUATION

In our simulation model we assume N=10 subscribers and M=2 energy providers. The entire time cycle is divided into 24 time slots representing the 24 of the day. The minimum and maximum power requirements vary in each slot.

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