Optimizing Prosumer Policies in Periodic Double Auctions Inspired by Equilibrium Analysis

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I. Motivation

- The Periodic Double Auction is made up of Suppliers and Consumers.
- Objective is to find policies for the consumers to **minimize the cost**.
- Application of PDA is that it models a Day Ahead Electricity Market.
- Hence, the developed policies can be used in the Market.
- Day Ahead Electricity Market has two components: Suppliers and Cosumers.

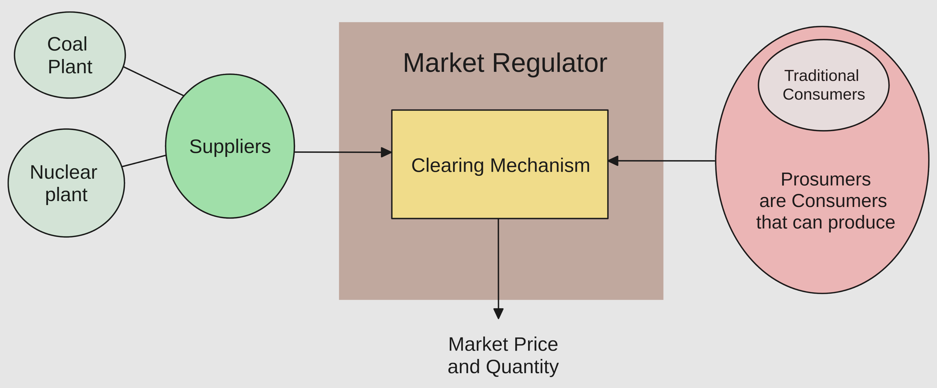

Figure 1: Day Ahead Electricity Market

- When Consumers are allowed to sell small quantities, they are called as **Prosumers**.

II. Introduction

- **Double Auction** is where the Suppliers and Prosumers are strategic.
- A Market Regulator matches the Asks placed by supplier with the Bids placed by the Prosumers.
- Both Asks and Bids are the pair of price and quantity.

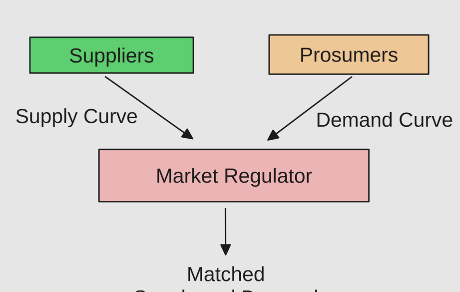

Figure 1: Double Auction

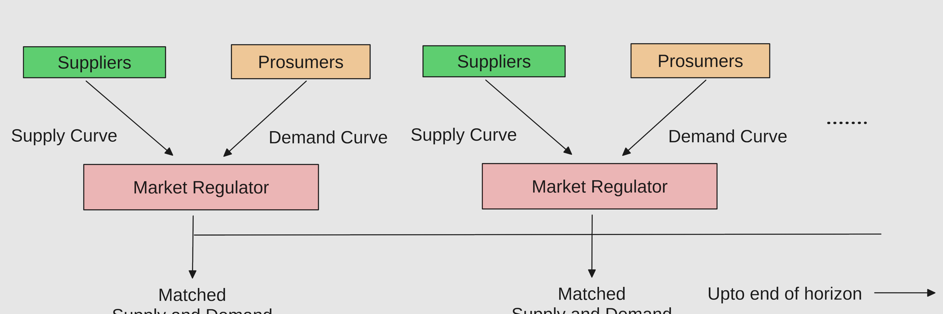

Figure 2: Periodic Double Auction

- The Periodic Double Auction is the sequence of Double Auctions and it has a finite horizon.

III. Problem Statement and Solution Approach

- The goal is to find **policies** for the **Prosumers** to minimize the **procurement cost**.

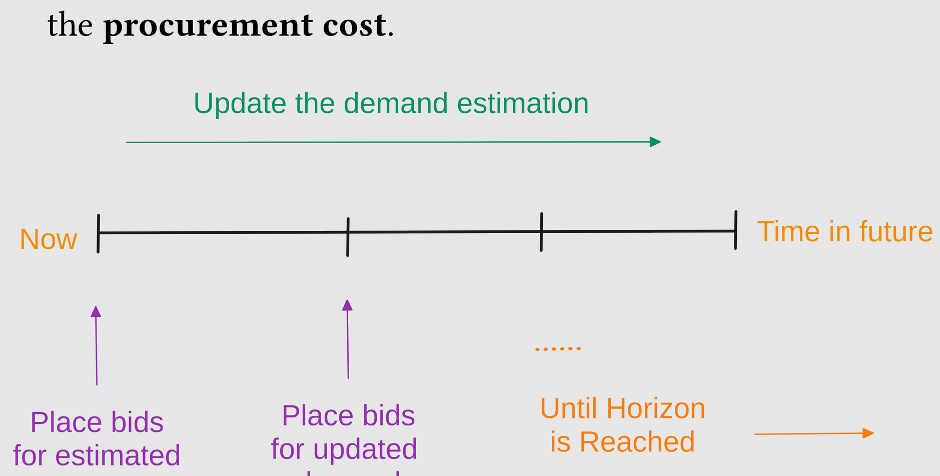

Figure 3: Prosumer's Objective

- A **Solution Approach** is as follows.
- The PDA is modeled as a **Markov game**.
- A **Nash equilibrium** (NE) is formulated in an ideal setting.
- Based on the NE analysis, an algorithm for the policy is developed.

IV. Markov Game Formulation

- The PDA is modeled as a Markov game $\langle N, S, A, P, C, H \rangle$.
- N is the number of Prosumers in the auction,
- A is the Joint Action Space,
- S is the State Space comprising of Supply and Demand,
- P is the transition kernel,
- C is the cost function, which outputs the product of cleared price and cleared quantity as the cost given the state,
- H is number of Horizon.

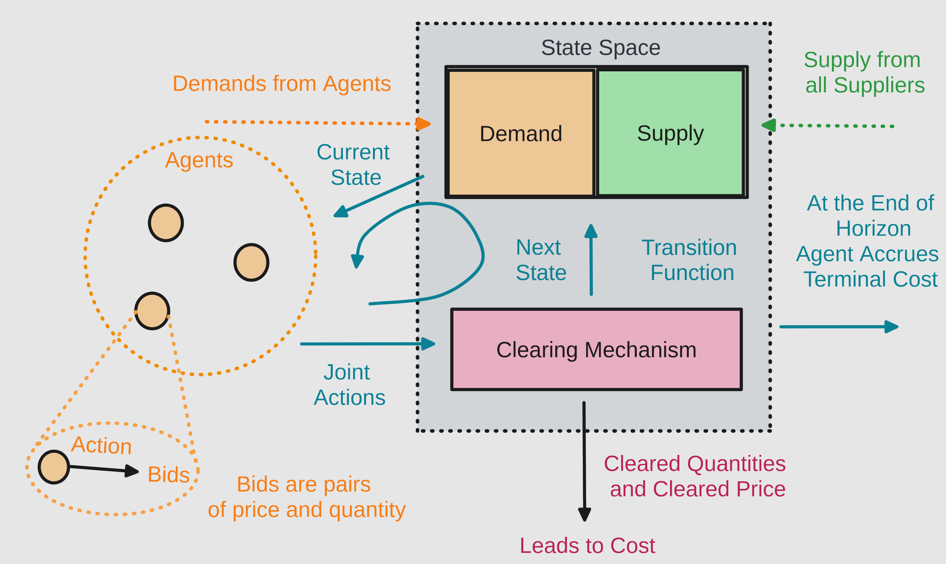

Figure 4: Markov Game Formulation

- The procurement cost is the **sum of costs** in each of the rounds until the end of Horizon.
- Starting from a state $s \in S$, the procurement cost is denoted as $V(s)$.
- $V(s)$ is also called as the Value function.

V. Insights from Nash Equilibrium Analysis

- NE is a joint policy $a \in A$, in which no agent can unilaterally deviate from the alloted action.
- A Nash Equilibrium was proposed for the Markov Game and **the insights from the Nash equilibrium are as follows**.
- If there are enough rounds for players, then they would want to utilize the rounds.
- If the rounds are not enough, then the players would bid at maximum possible price to avoid paying very high price outside the auction.
- The policy suggests the players with higher requirement have more leverage.

VI. Algorithm

- Nash Equilirium inspired algorithm is proposed in this work.
- Nash Equilibrium Analysis is mainly used in estimating the bid price in each of the rounds.

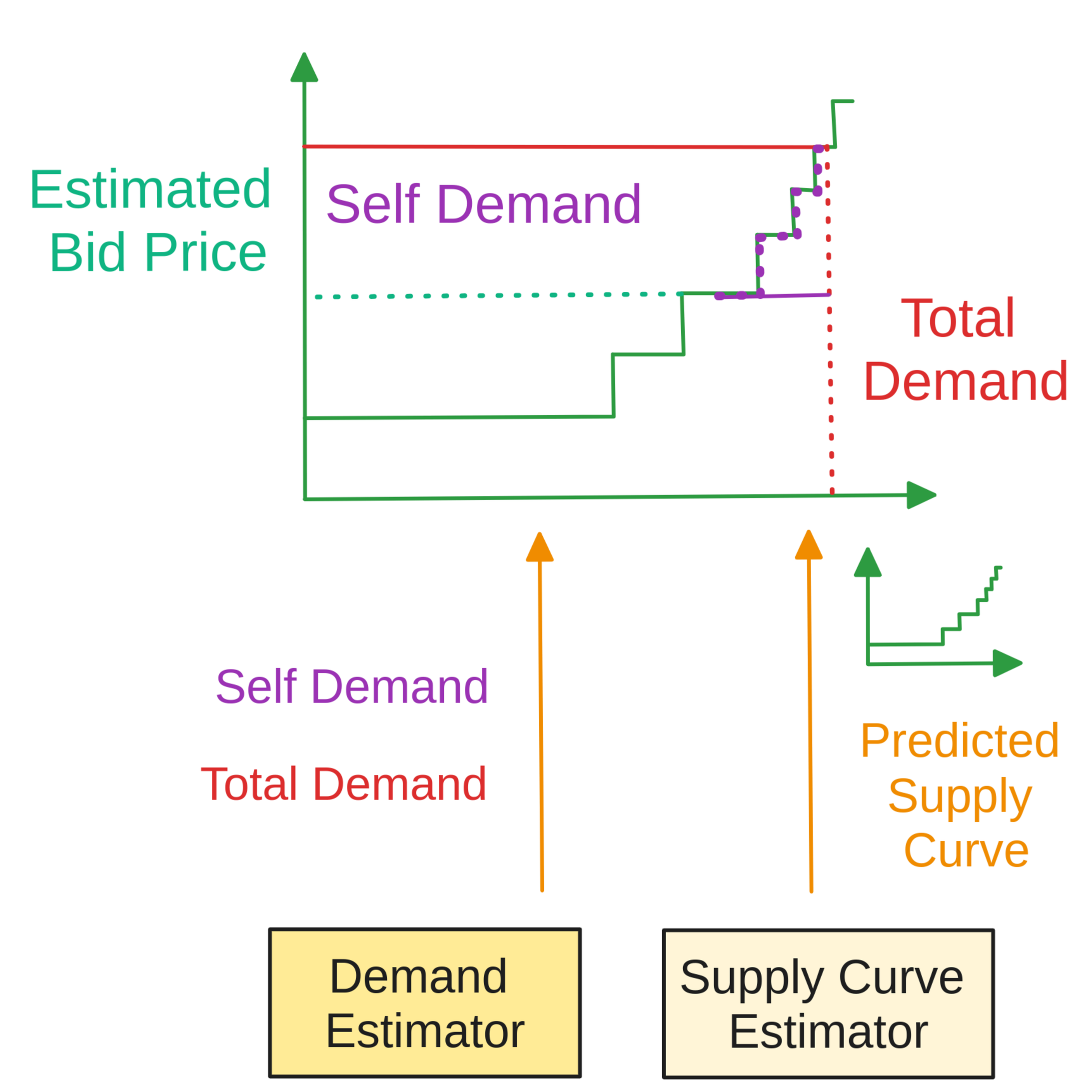

Figure 5: The Function which Estimates the Bid Price

- Nash Equilibrium Analysis is done in a Perfect Information setting, where one needs to know the full state information.
- As the Nash Equilibrium is a function of state, one needs to know the demands of all players and the supply curve.
- To circumvent the above problems, following techniques are used.
- The estimates of supply curve, self demand and total demand are used.
- In Equilibrium analysis, it was found that most often one's bid price depends on the remaining number of opportunities and total demand.
- Hence, an assumption is made such that other players would always bid at highest price.

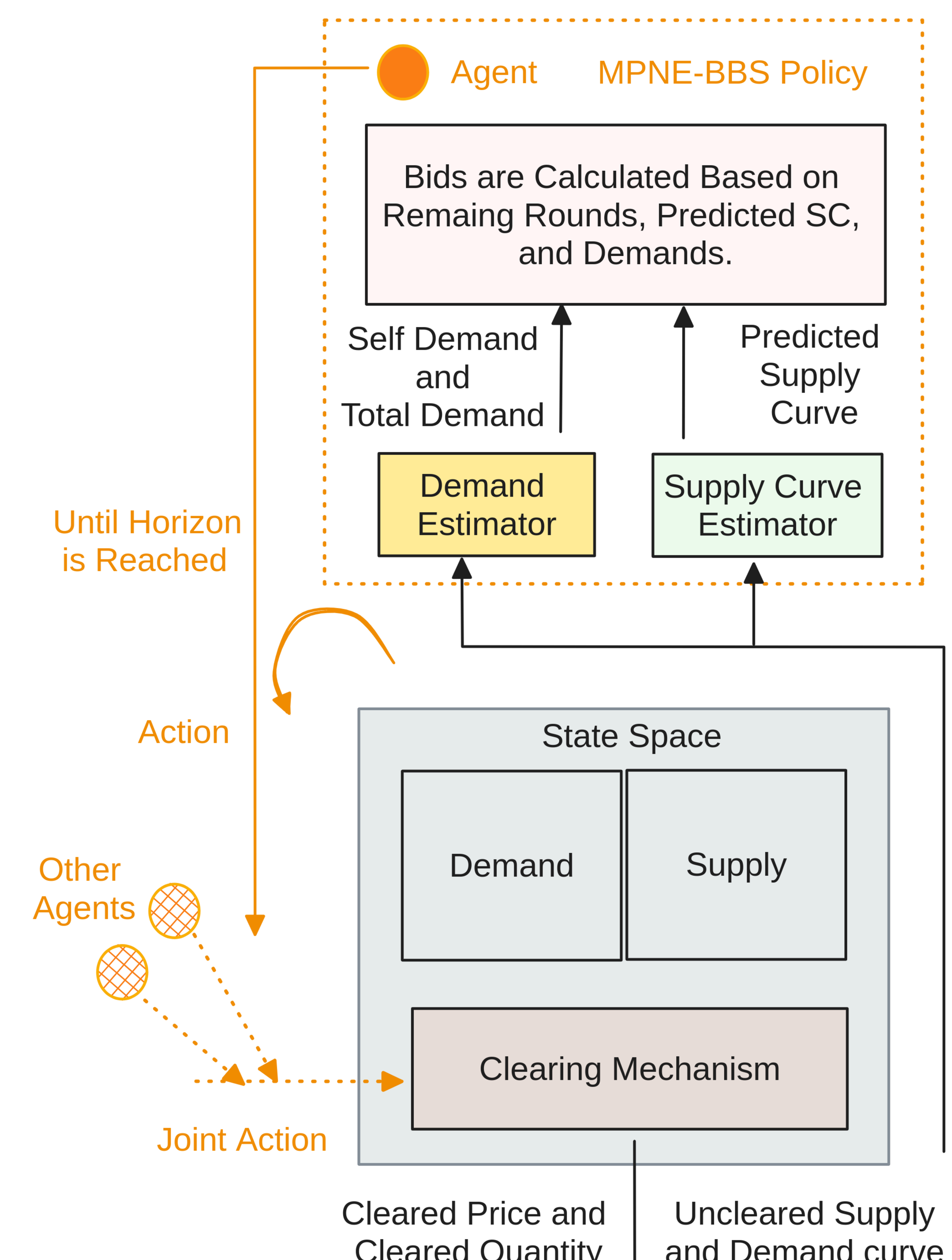

Figure 6: MPNE-BBS Algorithm

VII. Results

- The MPNE-BBS Policy is played against 7 Players including the state-of-the-art policies.

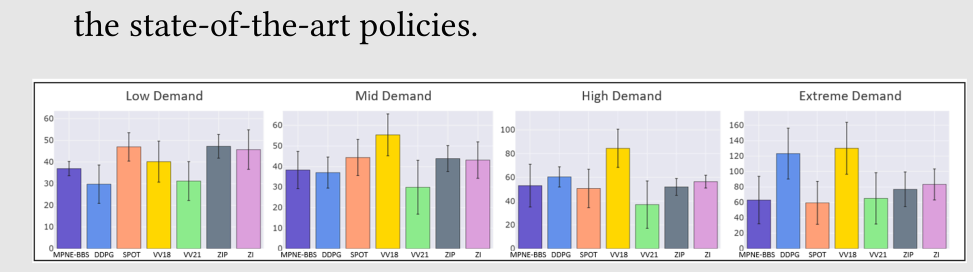

Figure 7: Wholesale Cost Comparison in 7-Player Games

VIII. Conclusion and Future work

- A Nash Equilibrium for a PDA modeled as Markov game is devised.
- This Equilibrium helps in explaining the policy of the players in different scenarios.
- Devised an algorithm based on the Nash Equilibrium Analysis, results show that it works well in practice.
- In future, the goal is to find reasons to why in some cases, the policy is second best.
- In future work, aim is to extend the analysis to partial observable setting and see how it can help in devising algorithms.

For More Details:-