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Stochastic Resource Auctions in Smart-Grid Networks

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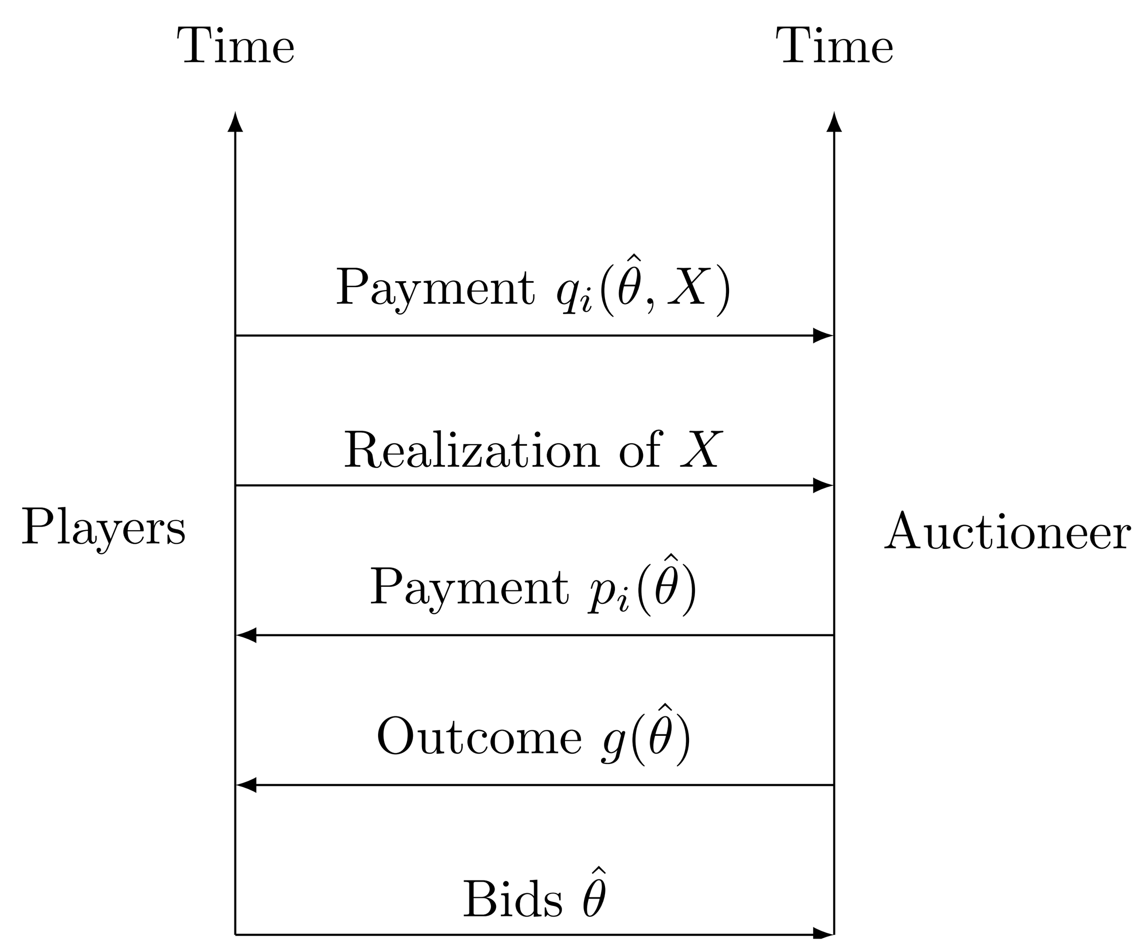
Motivation

- California requires one-third of the state's electricity to come from renewable energy by 2020
- Challenges of renewable energy: variability and unpredictability
- How the electric power economy operates
- Auctions for stochastic resources have not been studied
- Goal: elicit the generation distributions so as to achieve efficiency

Model

- Renewable energy generators: $i = 1, \dots, N$
- Tomorrow's generation: X_i with CDF $F_i(\cdot) \equiv \theta_i$ (type)
- Stochastic resource auction



- Goal: contract with the one with the highest expected generation

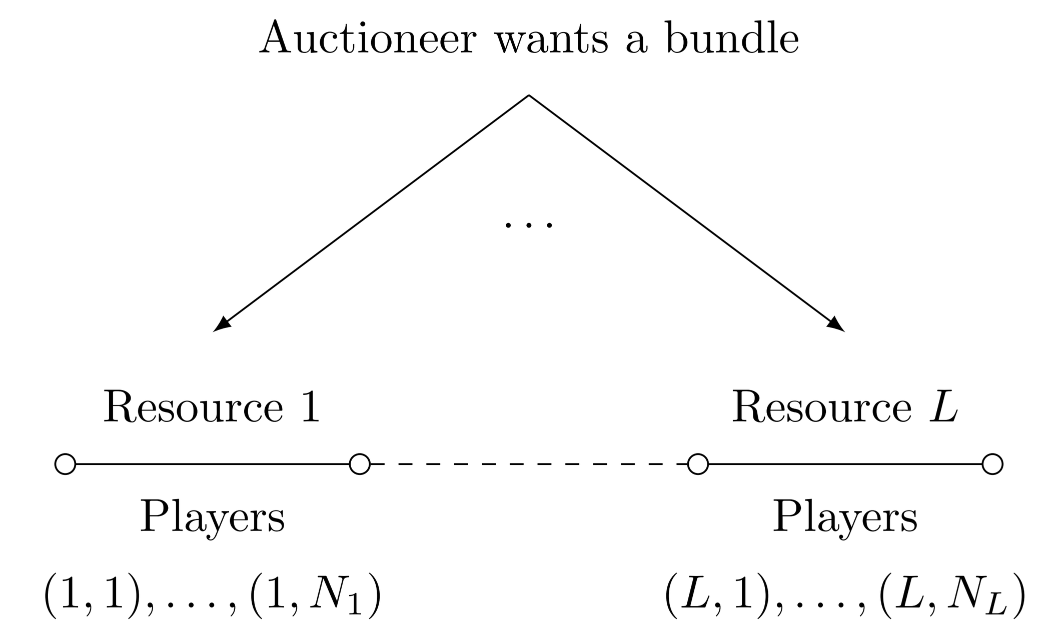
$$i' \in \arg\max_i \mathbb{E}[X_i]$$

Two Basic Mechanisms

- Same rule to determine the winner
  - winner $i' \in \arg\max_i \int x \, d\hat{F}_i(x)$
  - marginal loser $i'' \in \arg\max_{i \neq i'} \int x \, d\hat{F}_i(x)$
- Stochastic VCG mechanism
  - ex ante payment $-p_{i'} = \int x \, d\hat{F}_{i''}(x)$
  - ex post payment $-q_{i'} = X_{i'}$
  - winner's payoff $U_{i'} = X_{i'} - \int x \, d\hat{F}_{i''}(x)$
- Stochastic shortfall penalty mechanism
  - ex ante payment $p_{i'} = 1$
  - ex post payment $q_{i'} = \lambda(1 - X_{i'})$
  - penalty price $\lambda = 1/[1 - \int x \, d\hat{F}_{i''}(x)]$
  - winner's payoff $U_{i'} = 1 - \lambda(1 - X_{i'})$
- Both are incentive compatible
- Quasi-duality between the mechanisms
- Revenue comparison: SVCG $\geq$ SSP

Generalizations

- General objective function: $i' \in \arg\max_i \mathbb{E}[h(X_i)]$
- Bundled auction



- Multiple winners

Generation Assignment Auction

- Generators assume risk and compete for assignment y
- Generator's cost function

$$c_i(y_i) := \mathbb{E}[\lambda(y_i - X_i)^+]$$

- Aggregator's cost function

$$c(y) := \mathbb{E}[\lambda(Z - y)^+]$$

- Social welfare optimization

$$\underset{y_1,\dots,y_N,y}{\text{minimize}} \quad \sum_i c_i(y_i) + c(y)$$
$$\text{subject to } y = \sum_i y_i, \; 0 \leq y_i \leq 1, \; \forall i$$

- VCG mechanism for parametric $c_i(\cdot)$
  - allocation rule

$$\underset{y_1,\dots,y_N,y}{\text{minimize}} \quad \sum_i \tilde{c}_i(y_i) + c(y)$$
$$\text{subject to } y = \sum_i y_i, \; 0 \leq y_i \leq 1, \; \forall i$$

  - payment scheme

$$w_i = \sum_{j \neq i} [\tilde{c}_j(y_j^{-i}) - \tilde{c}_j(y_j)] + c(y^{-i}) - c(y)$$

- i-VCG mechanism for non-parametric $c_i(\cdot)$
  - $b_i = (\beta_i, d_i)$, ask price and maximum quantity offered
  - allocation rule

$$\underset{y_1,\dots,y_N,y}{\text{minimize}} \quad \sum_i \beta_i y_i + c(y)$$
$$\text{subject to } y = \sum_i y_i, \; 0 \leq y_i \leq d_i, \; \forall i$$

  - payment scheme

$$w_i = \sum_{j \neq i} \beta_j (y_j^{-i} - y_j) + c(y^{-i}) - c(y)$$

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