Mechanism for a Subset Selection of customers for Demand Response in Smart Grids

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Demand Response

Peak load demand  Smart Grids
When consumption increases in peak hours and distributor has no more power to supply, distributor company needs to buy at that time at market price which will be very high. So it faces losses during peak time.
Does the company have any option other than buying from the market?

Yes incentivising the consumers to reduce the electricity consumption.
At any round $t$, Shortage of electricity, $\mathcal{E}_t$

Cost per unit reduction, $c_i$

Max unit reduced $k_i$

$i^{th}$ consumer

Compliance probability, $p_i$

Cost of buying electricity from market $C\mathcal{E}_t^2$

Reference: Google Images
Optimization problem

Task: Minimize the expected loss of the distributor company

Minimize: \[ C \left( \sum_{i \in S_t} x_{i,t} p_i - \mathcal{E}_t \right)^2 + C \sum_{i \in S_t} x_{i,t} p_i (1 - p_i) + \sum_{i \in S_t} x_{i,t} p_i c_i \]

Subject to: \[ 0 \leq x_{i,t} \leq k_i \] (Capacity constraint)
Proposed Min-KPDR framework

\[
\min_{x_t} C \sum_{i \in S_t} x_i, t p_i (1 - p_i) + \sum_{i \in S_t} x_i, t p_i c_i
\]

s.t. \( \sum_{i \in S_t} x_i, t p_i \geq E_t \) and \( 0 \leq x_i, t \leq k_i \ \forall i \)

Assumption: \( C \geq c_i \ \forall \ i \)
Constant approximation factor to original problem

\[ \mathbb{E}L(\tilde{x}_t) \leq \mathbb{E}L(x_t^*) + 4C + 1 \]

\( \tilde{x}_t \) Allocation vector by solving MinKPDR

\( x_t^* \) Allocation vector by solving optimal algorithm
Unknown Compliance Probabilities

- Problem is formulated to Combinatorial Multiarmed bandit (CMAB) problem
- Why existing CMAB techniques do not work?
  - Non-monotonicity of rewards and time-varying optimal sets
- We propose a novel algorithm Twin-MinKPDR-CB which intelligently uses upper and lower confidence bounds
Theoretical bound on Regret

\[
\left( \frac{8 \ln T}{(f^{-1}(\Delta))^2} + \frac{\pi^2}{3} + 1 \right) n C \mathcal{E}^2_{max}
\]

Regret is logarithmic in time
Comparison with respect to optimal algorithm
Regret vs number of consumers

Quadratic with number of consumers
### Time Efficiency

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<th>MINKPDR (Our Algorithm)</th>
<th>GUROBI Optimizer</th>
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MinKPDR performs 20x than the optimal algorithm
Conclusion

● Proposed a novel min-knapsack framework to reduce the peak load consumption
● Proposed Twin-MinKPDR-CB algorithm with regret $O(\log T)$ when compliance probabilities are unknown
● Twin-MinKPDR-CB algorithm works for non-monotone, supermodular reward function
Thankyou!