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

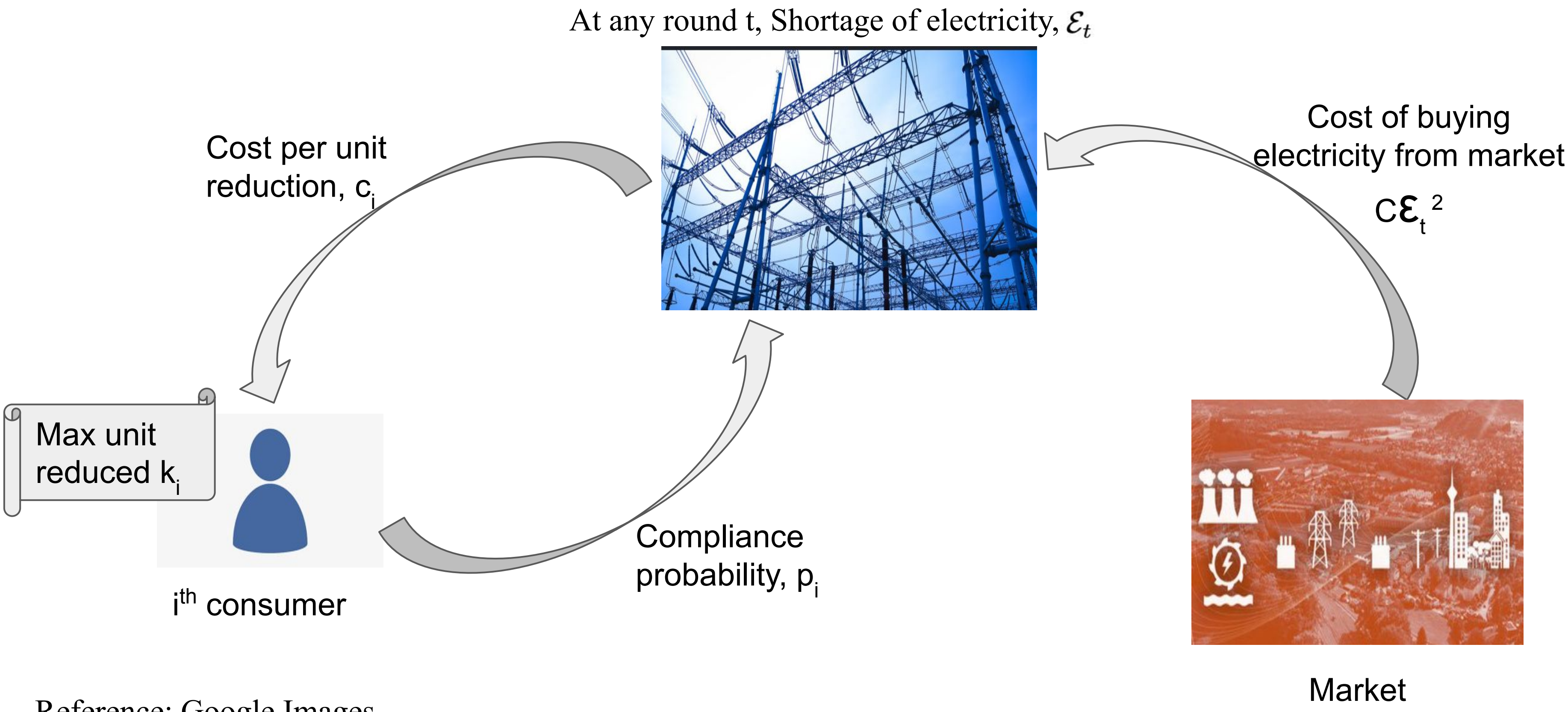
Distributor company needs to buy at that time at market price which will be very high. So it faces losses during peak time.

Reference: Google Images

Does the company have any option other than buying from the market?

Yes *incentivising* the consumers to reduce the electricity consumption.

The Model



Reference: Google Images

Optimization problem

Task: Minimize the expected loss of the distributor company

Minimize:

$$\underbrace{C\left(\sum_{i\in S_t} x_{i,t}p_i - \mathcal{E}_t\right)^2}_{\text{Squared loss from market}} + \underbrace{C\sum_{i\in S_t} x_{i,t}p_i(1-p_i)}_{\text{variance}} + \underbrace{\sum_{i\in S_t} x_{i,t}p_i c_i}_{\text{Incentives to consumers}}$$

Subject to: $0 \leq x_{i,t} \leq k_i$ (Capacity constraint)

Proposed Min-KPDR framework

$$\min_{\mathbf{x}_t} C \sum_{i \in S_t} x_{i,t} p_i (1 - p_i) + \sum_{i \in S_t} x_{i,t} p_i c_i$$

$$\text{s.t.} \sum_{i \in S_t} x_{i,t} p_i \geq \mathcal{E}_t \text{ and } 0 \leq x_{i,t} \leq k_i \; \forall i$$

Assumption: $C \geq c_i \; \forall \; i$

Constant approximation factor to original problem

$$\mathbb{E}L(\tilde{\mathbf{x}}_t) \leq \mathbb{E}L(\mathbf{x}_t^*) + 4C + 1$$

$\tilde{\mathbf{x}}_t$ Allocation vector by solving MinKPDR

$\mathbf{x}_t^*$ Allocation vector by solving optimal algorithm

Unknown Compliance Probabilities

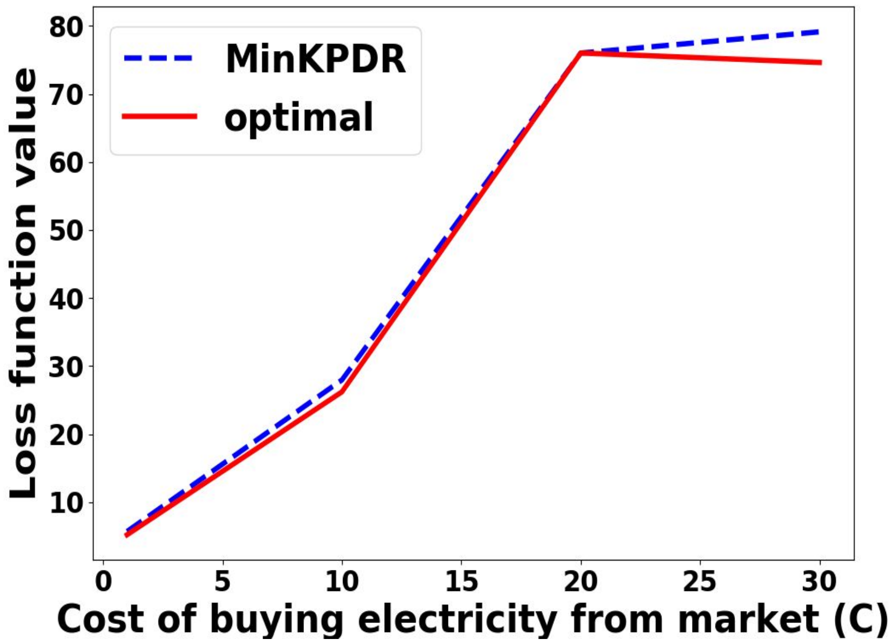
- Problem is formulated to Combinatorial Multiarmed bandit (CMAB) problem
- Why existing CMAB techniques do not work?
  - Non-monotonicity of rewards and time-varying optimal sets
- We propose a novel algorithm Twin-MinKPDR-CB which intelligently uses upper and lower confidence bounds

Theoretical bound on Regret

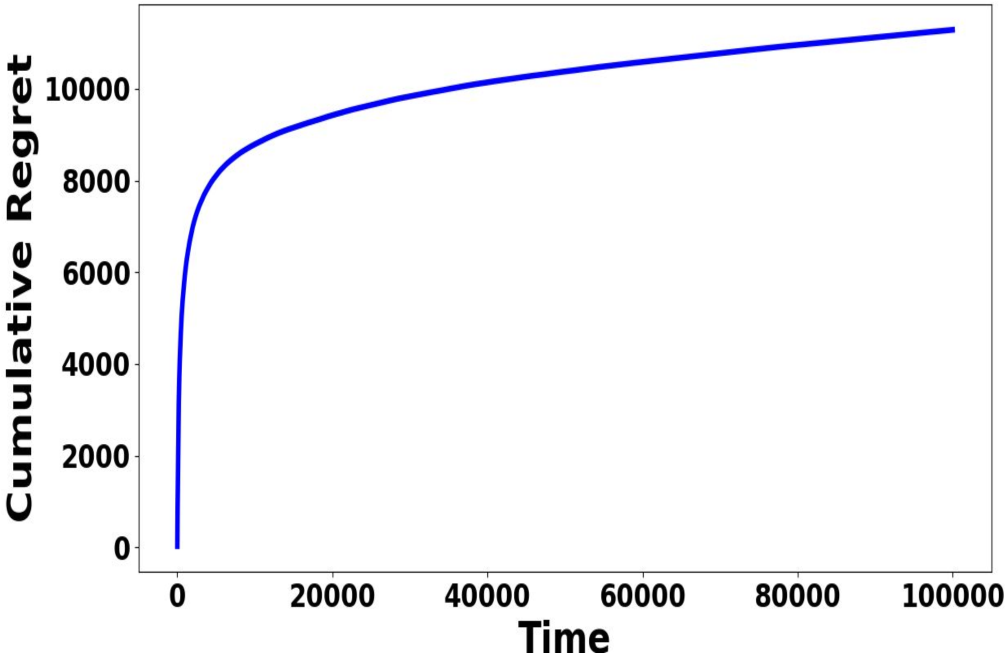
$$\left(\frac{8\ln T}{(f^{-1}(\Delta))^2} + \frac{\pi^2}{3} + 1\right) nC\mathcal{E}^2_{max}$$

Regret is logarithmic in time

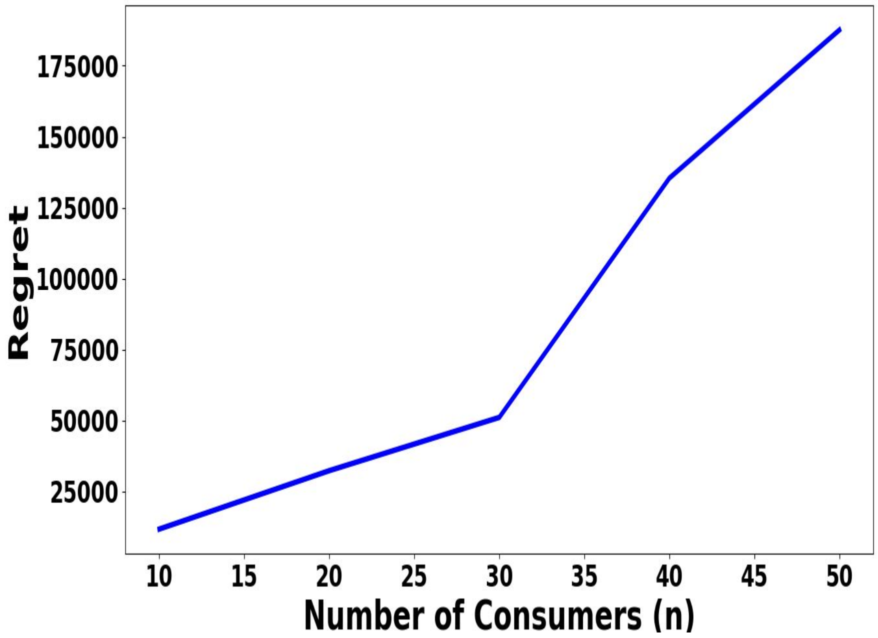
Comparison with respect to optimal algorithm



Regret vs Time



Regret vs number of consumers



Quadratic with number of consumers

Time Efficiency

MINKPDR(Our Algorithm)	GUROBI Optimizer
0.00022	0.00461
0.00053	0.00328
0.00026	0.00321
0.00013	0.00345
0.00022	0.00573
0.00024	0.00291
0.00018	0.00328
0.00018	0.00304
0.00024	0.00399
0.00036	0.00426
0.00022	0.00364
0.00020	0.00414

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!