Energy Efficient Scheduling on Smart Grid

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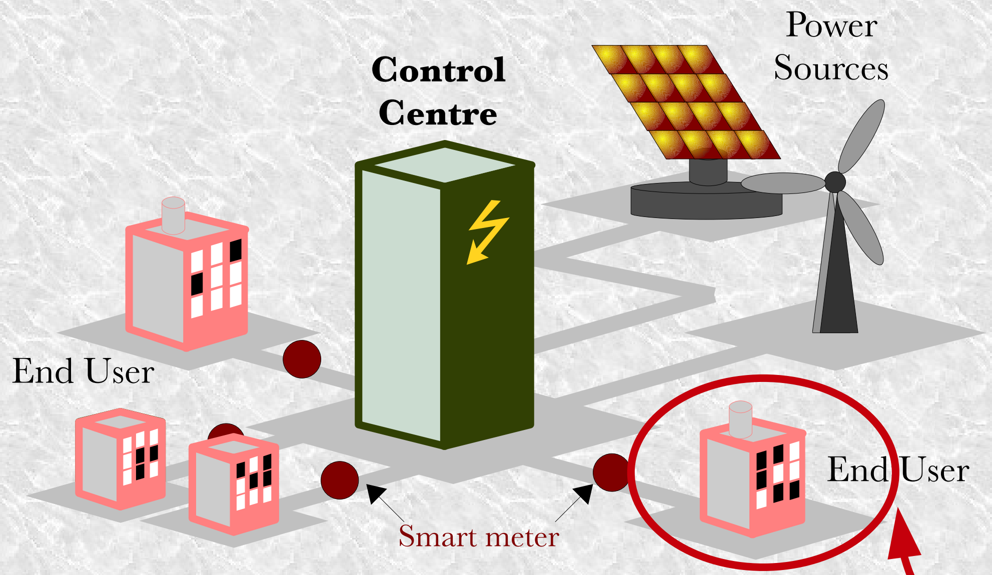
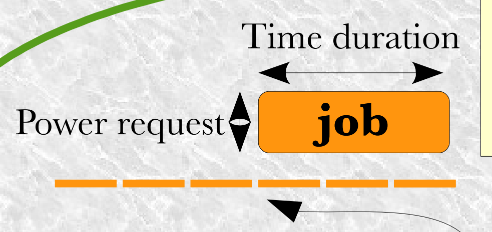
Introduction

We study an offline scheduling problem arising in demand response management in smart grid. Consumers send in power requests with several flexible time interval during which their requests can be served. For example, a consumer may request the dishwasher to operate for one hour during the periods 8am to 1pm or 3pm to 5pm. The grid controller, upon receiving power requests, schedules each request within the specified duration. The electricity cost is measured by a convex function of the load at each time. The objective of the problem is to schedule all requests with the minimum total electricity cost. As a first attempt, we consider a special case in which the power requirement and the duration a request needs service are both unit-size. For this problem, we present a polynomial time offline algorithm that gives an optimal solution.



Smart Grid

- The smart grid uses information and communication technologies in an automated fashion to improve the efficiency and reliability of production and distribution of electricity. By sensing and measurement devices the control centre can gather information such as the behavior of power sources and end users. And the centre can act on the information and make the usage of electricity more efficient and reliable.
- One of the weakness of the smart grid system is, peak demand hours happen only for a short duration, yet makes existing electrical grid less efficient. For Example, in the US power grid, 10% of all generation assets and 25% of distribution infrastructure are Required for less than 400 hours per year, roughly 5% of the time.
- **Demand response management** attempts to overcome this problem by shifting users' demand to off-peak hours in order to reduce peak load.



We use rectangles to represent the jobs

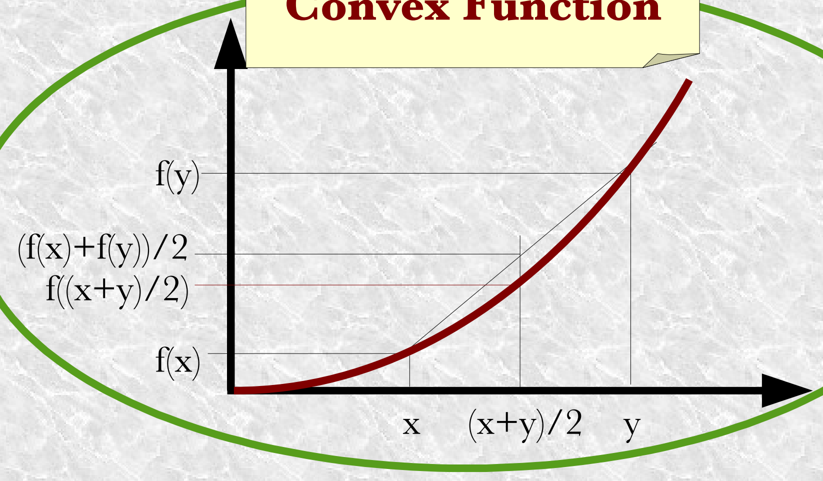
Our Aim

Our aim is to help the end user to finish all jobs with minimum electricity cost in time. User can request the jobs they want to do with corresponding time interval during which the job can be served. Each job also has its power requirement and time duration, which depend on the job type (for instance, a dishwashing request or an air-conditioning request.) Our scheduler will assign an appropriate execution time for each job according to the requests.

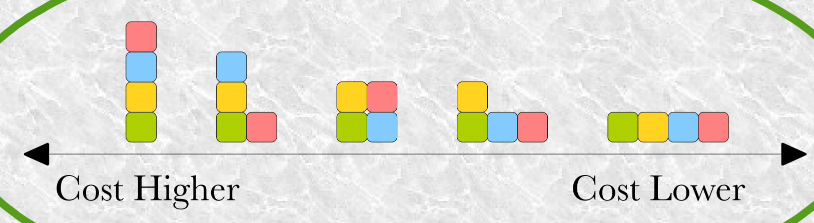
Scheduling Problem

- We assume that time is divided into unit integral timeslots. Each job request can be executed only at certain feasible timeslots.
- At each timeslot the load is the total power requirement at that timeslot. The energy cost at each timeslot is a convex function of the load. The objective is to find an assignment of all jobs to feasible timeslots such that the total cost of all timeslots is minimized.
- This scheduling problem is NP-hard. We consider a special case in which requests have unit power requirement and unit time duration.

Convex Function



Because of the convexity, the jobs should be put as even as possible. (However, we are constrained by the feasible timeslots.)

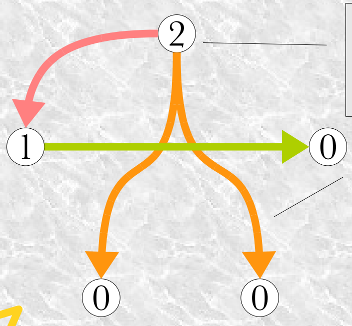


Feasible Graph Algorithm

Consider the jobs one by one:
Step 1: Assign the job to its feasible timeslot t with lowest load
Step 2: Update the feasible graph
Step 3: If there is a legal-path start from t, shift the jobs along the path (if there are more than one legal-path, break ties arbitrarily.

Feasible graph

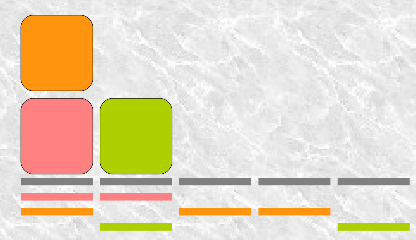
Feasible graph is a directed multi-graph. Each timeslot is represented by a vertex.



The number inside the vertex denotes the load of the vertex.

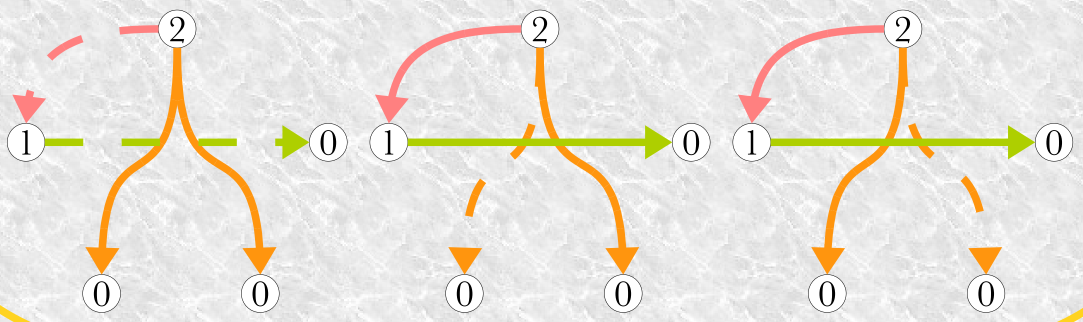
If job Ji is assigned to timeslot r, then for each other feasible timeslot w we add a directed arc from r to w with Ji as its label. (Here we use color to represent the label. Each job is represented by a unique color.)

This graph is actually the corresponding job assignment:

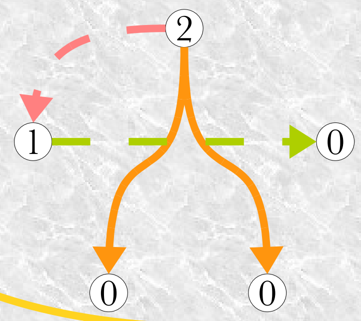


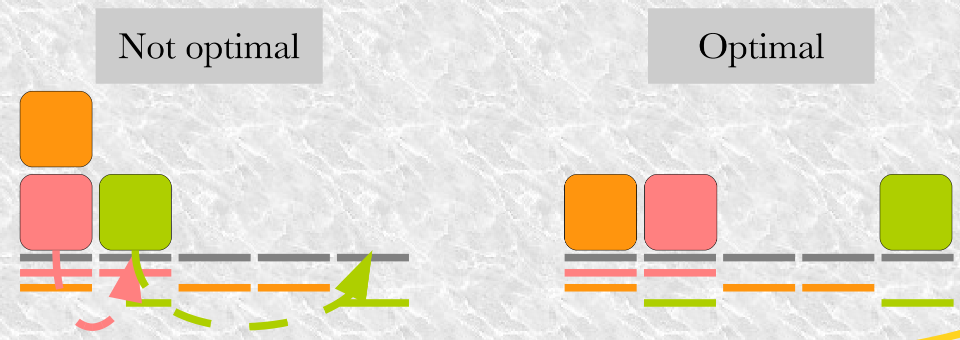
Legal-path

If there are a sequence of shifts of job from timeslot to timeslot, by which the cost could be reduced, the shifts would form a path in the feasible graph. Moreover, the load of the starting point in the path would be two more than the load of the ending point. We call such kind of path a legal-path.
In this assignment, there are three legal-paths which can reduce the cost (marked by dotted lines.)



If there is a legal-path in the feasible graph G, the corresponding job assignment is not optimal. We can make the assignment legal by shifting along arbitrary one legal-path according to the jobs labeled on the edges.





Conclusion

We can find the optimal schedule in polynomial time if all jobs have uniform power requirement and uniform time duration.

References

Mihai Burcea, Wing-Kai Hon, Hsiang-Hsuan Liu, Prudence W. H. Wong, David K. Y. Yau: Scheduling for Electricity Cost in Smart Grid. COCOA 2013:306-317