4th AIMMS-MOPTA Optimization Modeling Competition

Scheduling in SmartGrids

Energy demands in a home or across multiple homes in a neighborhood are often flexible. Of course, if a customer needs a light on immediately, then they expect to be able to flip a switch and have it turn on right away. However, if a customer needs to run a dishwasher to have clean dishes by the morning, then they may not care when the appliance actually runs; what matters is that it is at least finished before breakfast. One manner in which the costs incurred for flexible demands can be reduced is through the use of data from smart meters. These meters can provide real-time electricity prices to homes. If this information is utilized effectively by customers via an electricity management controller (EMC), then they can reduce their energy costs by shifting their load to off-peak hours when prices have been reduced. These shifts can also potentially benefit utilities by making it easier to keep the grid stable, thus avoiding equipment overload, brownouts, and blackouts. Your team's task is to formulate optimization models for scheduling electricity consumption within a home (and a neighborhood) and create a user-friendly system in AIMMS that solves your models.

1 Problem description

1.1 Base Case

The basic problem is to consider the optimization of the running time of appliances within a single home. Each appliance, when on, may consume a different amount of power. Requests for the use of these appliances occur randomly throughout the day, and the duration that each needs to remain on may also be random. If a certain appliance needs to be turned on immediately once it is requested (e.g., a lamp), then such a device cannot be rescheduled at a later time. However, if there is simply a waiting cost that must be incurred for the time period that a customer has to wait for an appliance to turn on (up until, perhaps, some maximum delay length), then such a device can be scheduled at a later time to reduce cost. Your goal is to formulate an optimization model to find the optimal running time for each appliance. The waiting costs may be attractive in some time periods as the cost of energy varies throughout the day. For the basic problem, these costs are deterministic.

1.2 Capacity Constraints

A potential complicating factor in the scheduling of appliances are capacity constraints for a given time period. For example, these may need to be enforced as the utility may supply only a limited amount of power to a neighborhood, an amount that cannot handle all customers in the neighborhood running all of their appliances at the same time. Thus, only a limited amount of power is available to each household during each time period of the day. The scheduling of a appliance that may be scheduled to run at a later time must account for the fact that sufficient power to run the appliance may not be available later on in the day.

1.3 Neighborhood-level Scheduling

Negative side effects (from the utility's perspective) may result from individual customers all shifting their loads to traditionally "off-peak" hours. Thus, in order to ensure a level load throughout the day, the utility may impose a maximum allowable peak power consumption level for a given neighborhood. Each home may be allowed a guaranteed minimum power level, but for the remaining power, homes may compete for its use. If a home wishes to use more than its minimum power level, then its EMC must communicate with EMCs in the other homes so that, overall, they adhere to the maximum consumption level.

2 Goals

The neighborhood association has hired you to create a tool in AIMMS for the EMC within a home (and the set of EMCs in multiple homes in a neighborhood) to quickly and easily optimize the scheduling of appliances. They also would like to know the benefit of using your optimization tool to schedule the EMC(s). As the people in the neighborhood are new to this type of problem, they would like to see that this tool addresses the three levels of complexity outlined in §1. (These levels are listed in terms of increasing difficulty and the latter two are not required for the competition. Teams that only develop some of the functionality are still encouraged to submit their solution. Teams are also encouraged to address additional or alternative "realistic" factors in the scheduling of appliances beyond those described above.)

The neighborhood association would like to know if you observe any strange, unfair, or other sort of undesirable behavior in the solutions of your models, from the perspective of the households and/or from that of the utility company. If you observe any of such behavior, then they consider it a bonus if you can extend your model to address these issues as well.

You will be given data sets including pertinent information about sets of appliances, but you are also encouraged to construct your own "realistic" data sets that take into account the various costs (listed in this document and otherwise) associated with running appliances and having to wait for their services. Your optimization models should account for user-side preferences as well as utility-side preferences, the latter of which includes level loads throughout the day. If some data is missing, feel free to generate it, but be sure to specify any modeling decisions you make when generating data.

2.1 Software

A full version of the AIMMS modeling platform along with solvers CPLEX, GUROBI, MOSEK, XA, CONOPT, MINOS, SNOPT, LGO, AOA, PATH, and, through COIN-OR, CBC and IPOPT are provided to the teams free of charge. You may use any combination of these to solve your models. We encourage all teams to take advantage of the procedural aspect of the AIMMS modeling system and solve the problems in multiple stages. Please study the documentation about the features and capabilities of these solvers.

If you have any questions about the software please contact mopta@aimms.com.

2.2 Data sets

You are provided with data for the appliances for a collection of homes. This data corresponds to one possible method for modeling the consumption of power via appliances for a given day. Teams are encouraged to manipulate, if necessary, this data for other types of models, such as continuous-time models or those in which the stochasticity of appliance start and running times are modeled in other ways.

Each file includes information for a set of N appliances. A day consists of T time periods. Each appliance, when on, is assumed to consume a consistent amount of power, denoted as p_n kilowatt-hours (kWh). (An appliance is assumed to consume no power when it is off.) If an appliance is off in period t, then the probability that it is requested in period $t+1$ is a_{nt}. Similarly, if an appliance is on in period t, then the probability that it is off in period $t+1$ is b_{nt}. If an appliance is requested during time period t, but its operation gets delayed, then a cost of c_{n1} dollars ($) is incurred for each time period of delay. Ideally, appliance n will only be delayed up to m_n time periods (the "maximum" delay time). However, if appliance n is delayed more than m_n time periods, then the cost of delay increases to $\$c_{n2}$ per time period. The cost of electricity in time period t, in \$/kWh, is given by e_t.

Please see the given data files for more information about the given data.

2.3 More information

You are free to browse and use the scheduling literature for inspiration. Please cite all sources and carefully distinguish your ideas from those obtained in the literature.

3 Deliverables

Your team needs to deliver a solution to the problem described in this case study, including

- implementation of your models in AIMMS, including a user interface, providing the user graphical and textual output;
- solutions of the models for the given data sets, as well as those for your data sets;
- a 10–15 page report that discusses your models, the mathematical background of your techniques, the solutions that you obtained, and further recommendations.

The deadline for submission is May 31, 2012 23:59 EDT. If you have questions about the problem or the competition in general, please contact Frank E. Curtis at inmopta@lehigh.edu.