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Managing Uncertainty in Future Smart Grid: An Online-Algorithmic Approach towards Robust and Efficient Decisions

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Abstract:

How to respond to uncertainty is one of the primary challenges facing future power systems, which must operate under significant uncertainty both in the renewable supply (wind/solar) and in the demand patterns. Such uncertainty is often revealed sequentially in time, and thus the decision at each instant must be adjusted based on the information that has already been revealed, and yet be prepared for the remaining uncertainty towards the future. Further, the nature of the power systems often dictates that robust performance guarantees must be ensured even at the worst-case uncertainty, e.g., the energy supply must always meet the demand, and otherwise the entire power grid may fall apart. Thus, there is a pressing need to develop sequential decision algorithms that can achieve robust worst-case performance against future uncertainty. In this talk, we argue that competitive online algorithms could be a useful framework for solving this type of sequential decision problems in future smart grid. In the typical CS literature, an optimal competitive online algorithm, which achieves the smallest possible worst-case competitive ratio compared to the offline solution, can be found even when there is absolutely no prior information about the future input. However, in power systems, such competitive results could be quite pessimistic because it does not exploit any partial (yet inaccurate) future information that may be available. Instead, in this work our goal is to develop computationally-efficient online algorithms that are both robust (in terms of worst-case guarantees), and efficient (in terms of exploiting any partial future information that becomes available).

We present one such study in the context of EV (Electric Vehicle) charging. Consider an aggregator that manages a large number of EVs together with its background load, using both its own renewable supply and the energy procured from the grid. The goal of the aggregator is to minimize its peak procurement from the grid, subject to the constraint that each EV has to be fully charged before its deadline. Here, uncertainty arises in both the future EV demand and the renewable supply, although the aggregator can often predict them with some levels of certainty. The question is then how to best utilize such partial and imprecise forecast information to achieve robust and efficient outcomes. We first propose a 2-level increasing precision model (2-IPM), to capture the uncertainty in both day-ahead and hour-ahead forecasts. We then develop a powerful computational approach that can find the optimal competitive ratio under 2-IPM over any online algorithms, and develop new algorithms that can achieve the optimal competitive ratio.

Further, note that a common dilemma for online algorithm design is that online algorithms with good competitive ratios may exhibit poor average-case performance. We then propose a new “Algorithm Robustification” procedure that can convert an online algorithm with reasonable average-case performance to one with both the optimal competitive ratio and good average-case performance.

Biosketch:

Xiaojun Lin received his B.S. from Zhongshan University, Guangzhou, China, in 1994, and his M.S. and Ph.D. degrees from Purdue University, West Lafayette, Indiana, in 2000 and 2005, respectively. He is currently an Associate Professor of Electrical and Computer Engineering at Purdue University.

Dr. Lin's research interests are in the analysis, control and optimization of large and complex communication networks and cyber-physical systems. He received the IEEE INFOCOM 2008 best paper award and 2005 best paper of the year award from Journal of Communications and Networks. His paper was also one of two runner-up papers for the best-paper award at IEEE INFOCOM 2005. He received the NSF CAREER award in 2007. He is currently serving as an Area Editor for (Elsevier) Computer Networks journal and an Associate Editor for IEEE/ACM Transactions on Networking, and has served as a Guest Editor for (Elsevier) Ad Hoc Networks journal.