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Department of Computer and Information Sciences

How much for your temperature? HVAC Power Conservation through Reverse Auctions and Machine Learning

Dr. Simone Silvestri

Associate Professor and Director of Graduate Studies Department of Computer Science
University of Kentucky

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Abstract: Cyber-Physical-Human Systems (CPHSs) are systems often meant to interact directly and/or indirectly with humans. In this talk, we focus on Residential Energy Management Systems (REMSs), realized through the paradigm of the Internet of Things (IoT), as an example of CPHS. We consider the problem of peak loads resulting from extreme outside temperatures that simultaneously trigger Heating Ventilation Air Conditioning (HVAC) systems. Such peaks severely stress the power system, often resulting in prolonged outages and exorbitant energy bills, as recently experienced in California and Texas. We introduce a comprehensive approach to perform residential HVAC power conservation by exploiting REMS technologies such as smart meters and smart thermostats. Differently from previous solutions, our approach models realistic user behavior and HVAC dynamics of individual homes. Specifically, we formulate a novel reverse auction-based problem, called POwer Conservation Optimization (POCO). The goal is to perform power conservation by motivating users to temporarily adjust their HVAC thermostat settings in exchange for financial rewards. We prove that POCO ensures truthfulness and individual rationality of the auction mechanism, although it is an NP-hard problem. Therefore, we propose an efficient heuristic, called Greedy Ranking AllocatioN (GRAN), which we prove ensures the same formal properties, while incurring only a polynomial complexity. To predict power savings resulting from an HVAC thermostat adjustments, we propose a novel machine learning-based technique called Power Saving Prediction (PSP). In addition, we conduct an online survey to study the willingness to adopt the proposed system and to model realistic user behavior. Survey results show willingness of adoption above 79% and a highly heterogeneous and non-linear user behavior. We perform extensive experiments using highfidelity simulator EnergyPlus. Results show that PSP outperforms a state-of-the-art solution obtaining 85% predictions within a 5% error margin. Furthermore, GRAN achieves near-optimal performance, outperforming a recent state-of-the-art approach obtaining results between 58% and 68% closer to the optimum.

Bio: Simone Silvestri is currently an Associate Professor and Director of Graduate Studies in the Department of Computer Science of the University of Kentucky. Before joining UK, Dr. Silvestri worked as a Post-Doctoral Research Associate in the Department of Computer Science and Engineering at Pennsylvania State University. He received his Ph.D. in Computer Science in 2010 from the Department of Computer Science of the Sapienza University of Rome, Italy. Dr. Silvestri's research interests are in Cyber-Physical-Human Systems, Internet of Things, Smart Grids, Terrestrial and Aerial Mobile Networks, and Network Management. His research is funded by several national and international agencies such as NIFA, NATO and the NSF, and he received the NSF CAREER award in 2020. He published more than 70 papers in international journals and conferences including IEEE Transactions on Mobile Computing, IEEE Transactions on Smart Grids, ACM Transactions on Sensor Networks, IEEE INFOCOM, and IEEE ICDCS. He served in the Organizing and Technical Program Committee of several international conferences, including IEEE INFOCOM, IEEE ICNP, IEEE SECON and IEEE GLOBECOM.