Zero: **E**fficient **R**esource **O**ptimization

Introduction

Electric energy is the most consumed form of energy in the modern world. Almost all the appliances that are used on a daily basis require electricity to function. This also means that the society’s electricity consumption is rapidly increasing because of the growing population and rising economic conditions in developing countries. Hence, it is of paramount importance to optimize energy generation and consumption for both producers and consumers respectively. In addition to this, carbon emissions from energy generation using fossil fuels has contributed towards climate change. Therefore, efficient energy utilization while also reducing dependency on fossil fuel generated is the need of the hour. Several measures have been taken in this light from energy producers. In order to incentivize efficient electricity usage, utility companies have come up with a variable rate. Under this plan, the marginal price of the electricity rises during the peak power usage and reduces during off peak usage. However, it has been shown that this does little to actually address the issue. One reason for this might be that the consumers are required to study these plans and schedule their appliances accordingly which is cumbersome. Hence, there is a need for a smart-home solution which can schedule various appliances with deferrable work load depending on the variable rate plan which in turn reduces the dependency on the fossil fuel generated electric energy (energy during peak power usage is mostly generated from the fossil fuel based generators).

In order to address these challenges, we designed a smart-home solution aptly titled **Zero** is an intelligent smart-home solution which automates scheduling of appliances using an efficient electricity usage policy model by taking into account variable rate plan which also has a benefit of reducing the dependency on fossil fuel-based energy generators. In addition to this, it also allows the user to type in the preferences such as savings in electricity cost or low carbon footprint or a balance between the two.

System Architecture

The system architecture of ZERO is shown in Figure 1. The scheduling algorithm is implemented on the Raspberry Pi which acts as the central controller. The controller wirelessly controls several WEMO smart switches plugged to the power outlets which are in turn connected to the appliances which represent deferrable loads. The controller has a user interface where the homeowners can provide their preferences such as usage duration window of each appliance, operating duration of the appliances, low electricity vs. low carbon footprint or a combination of both. The algorithm uses the dataset containing locational marginal price (variable rate plan) and carbon intensity percentage of the energy source. Initially the owner enter the preferences. Based on that the optimization algorithm running on the controller comes up with a schedule for all the appliances in the home. After this, the controller comes executes the policy using a python daemon which controls the smart switches.

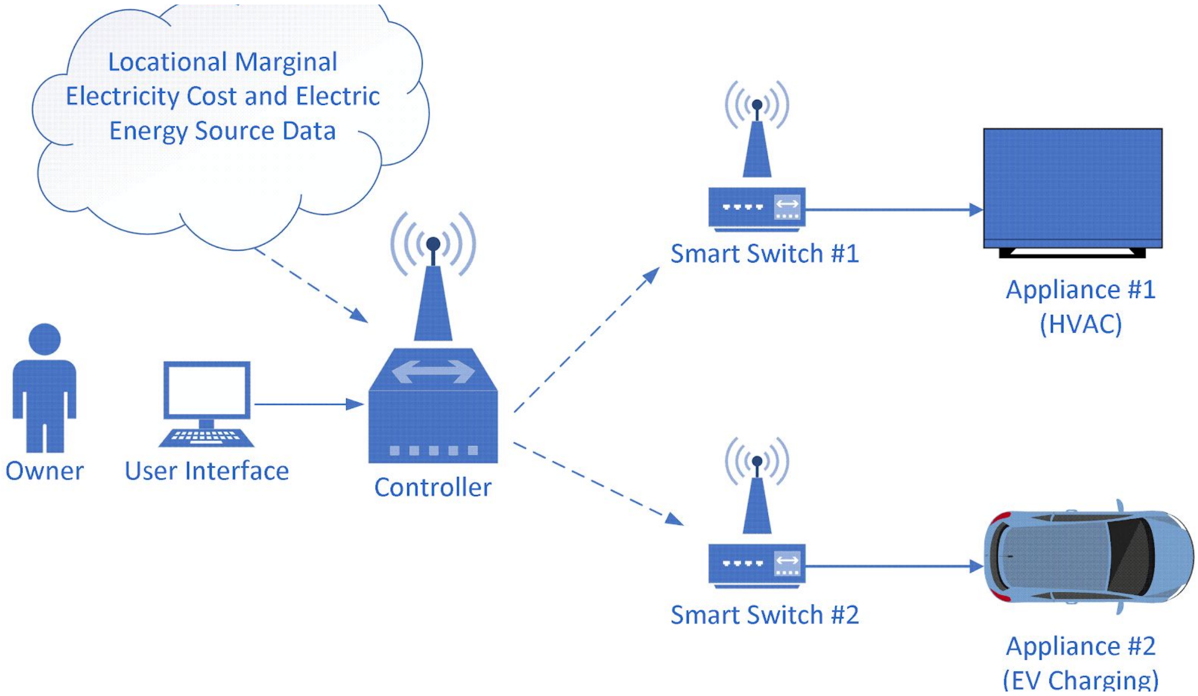

Figure 1: System Architecture of ZERO

Dataset

The ISO New England web service (https://webservices.iso-ne.com/docs/v1.1/) provides a comprehensive hourly data of locational marginal cost and generated fuel mix from different sources contributing to the electricity being delivered. The sources of electric energy that were considered were Coal, Nuclear, solar, wind etc(to be finalized). As an alternative to the fuel mix data, we can consider using co2 emission data (https://api.electricitymap.org/).

Discussion

ZERO is successful in scheduling the appliances according to the requirements. However, while we optimized an individual's energy utilization, we faced secondary effects due to democratic aggregation. Since the user preferences, on an average will be same across large number of houses, the system schedules the appliances of the homes simultaneously during off peak periods creating secondary peaks in power usage. This might in turn prompt the utility companies to increase the prices during those periods thus undoing the optimizations suggested by ZERO (see figure 2).

We consider several possible solutions for this issue. One naive approach is to introduce small gaussian perturbations in each electricity rate tables passed to individual system. This leads to policies that are more spread out. Few advanced techniques to tackle this issue could be i) computing noisy priors by splitting covariance matrix to mimic uniform distribution, and ii) assuming a multivariate gaussian distribution and learning a diagonal covariance matrix using variational autoencoders or similar variational learning methods.

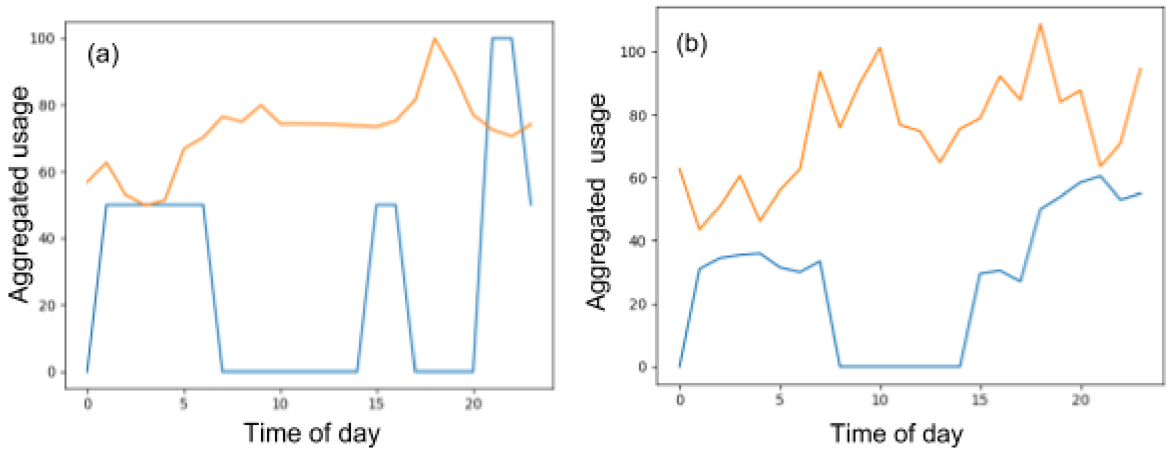

Figure 2(a): Effect of large amount of users adopting the same optimization algorithm. The 'dips' in the energy rates(orange plot) form sharp peaks in the cases of workload distribution(blue plot); Figure 2(b): Toward demographic aggregation. Adding unit variance noise to energy rates leads to a more spread-out usage distribution.

As mentioned earlier, the controller controls the smart switches wirelessly using the WIFI. Configuring the smart switches to achieve this was challenging. The switches couldn't be configured to work with the public WIFI. A router was used to create a private network to configure the switches.

Another challenging aspect was to come up with a schedule for HVAC appliances. The policy is to schedule the HVAC appliances during the off peak periods when the owner is not at home. Evaluating the savings of the proposed policy obtained for typical applications with deferrable load (EV, heating/cooling) is non-trivial and involve calculations based on thermodynamic concepts.

Results and Conclusion

The estimated savings were 20% for charging an electric car using the proposed model which is considerable given that it is high load. Also, we estimated 20% - 25% savings for HVAC appliances of a living room in an average sized house in U.S. The system successfully scheduled the appliances according to the requirement. As part of the future work, secondary effects will be more closely considered when optimizing for the cost. Also, a more robust evaluation scheme will be considered.