Uncertain FlexOffers: a scalable, uncertainty-aware model for energy flexibility

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Problem description

There are four main issues regarding flexibility models:

- They are often hard-coded for specific devices.
- Exact models scale badly with respect to many devices or long time horizons.
- Approximate models may lose too much flexibility.
- Flexibility for long time horizons carries uncertainty, which is usually neglected.

FlexOffers

The baseline for our work are **FlexOffers**. They are objects that represent flexibility as sets of constraints, which are generated and executed by an agent at prosumer level, and aggregated/optimized at aggregator level.

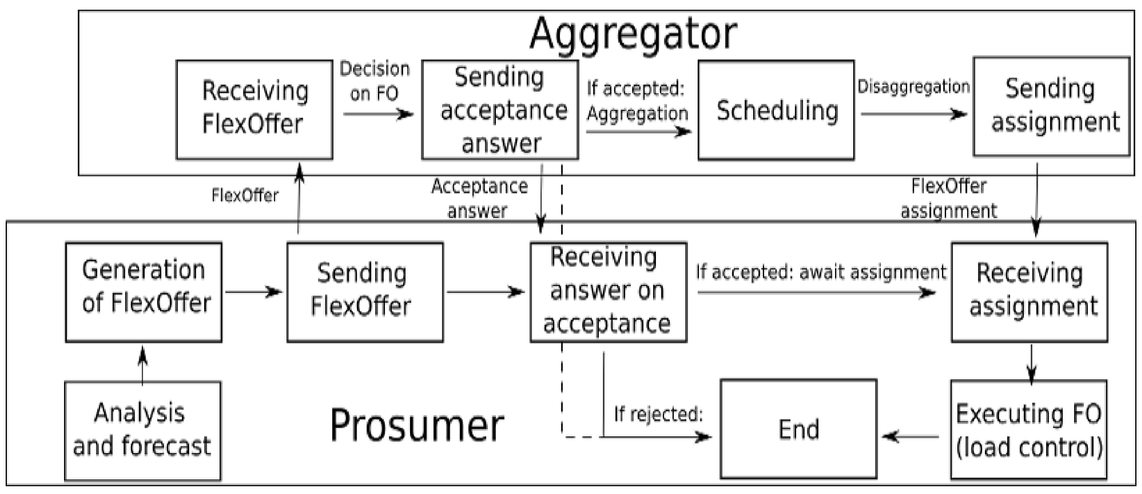

Fig. 1: FlexOffers life-cycle

Types of FlexOffers

FlexOffers are objects representing flexibility as a set of constraints over the values for consumable energy in the next time units. There are three main types of FlexOffers, depending on the constraints used:

- Standard FlexOffers. (Slice constraints)

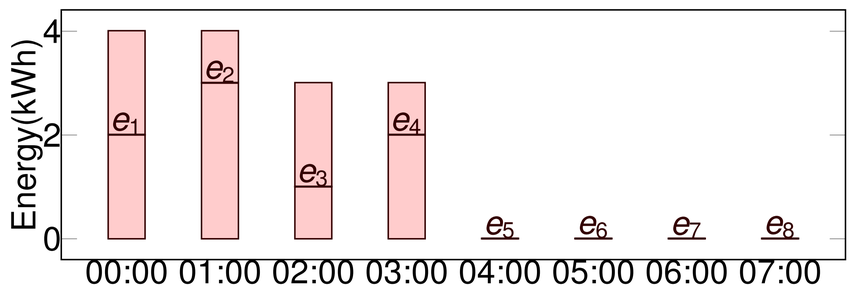

Fig. 2: A Standard FlexOffer.

- Total Energy Constraint FlexOffers. (Total energy constraints)

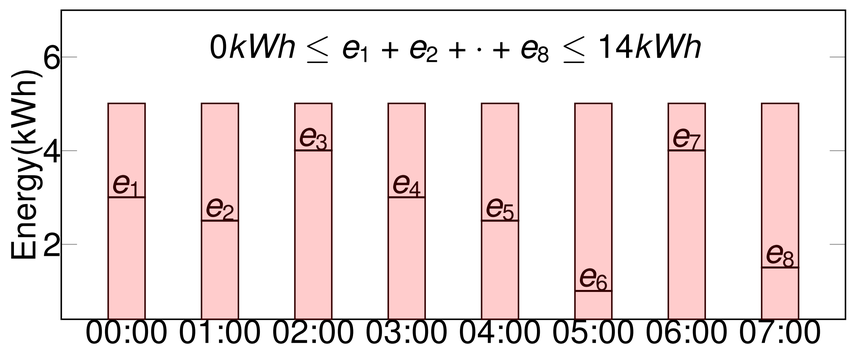

Fig. 3: A Total Energy Constraint FlexOffer.

- Dependency FlexOffers. (Dependency energy constraints)

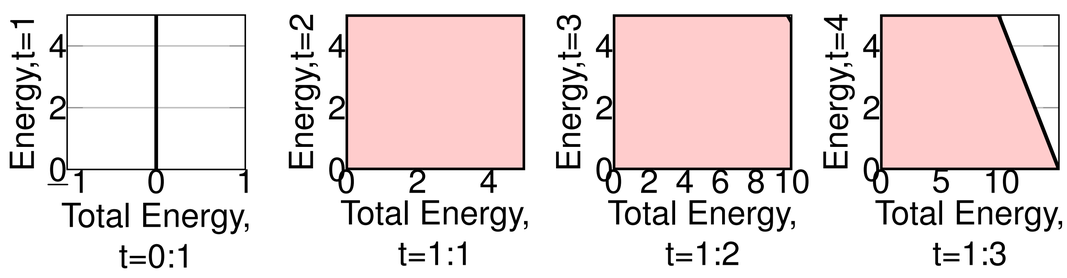

Fig. 4: A Dependency FlexOffer.

The above examples refer to a *Tesla Powerwall* battery.

Uncertainty Types

We identified three main types of uncertainty. Consider the example of charging an electric vehicle (EV) overnight:

- **Existence uncertainty** is the uncertainty for the EV to be plugged in that night.
- **Time uncertainty** is the uncertainty on the time for the EV to start charging.
- **Amount uncertainty** is the uncertainty on the amount of energy that can be given to the EV at any time.

Uncertain FlexOffers

Our proposed model are **Uncertain FlexOffers** (UFOs). They are realized in two steps:

- Modeling uncertainty over the device status at each time t.
- Calculating the probability for energy values to be feasible.

An UFO is a set of functions $\{f_1, \ldots, f_T\}$ describing, for each possible energy value at each time, the probability of being feasible. UFOs can be visualized by choosing a probability threshold P_0: at every time t, the energy values having probability at least P_0 of being feasible can be described by intervals.

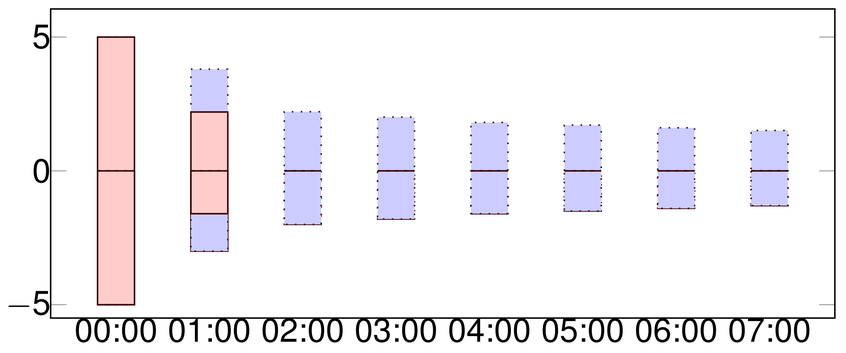

Fig. 5: Visualization of an UFO, $P_0 = 1$ (pink) and $P_0 = 0.8$ (blue).

Preliminary Results

Experiments:

- Charging and discharging a battery, exploiting flexibility for making profits by buying energy at low price, and selling it at high price.
- Doing the same by aggregating multiple batteries, with a 30 minutes time limit for aggregation.

Results:

- UFOs capture all the flexibility if the battery can only charge or discharge, and 88.4% of it for high imbalance prices, against 77.4% from dependency FlexOffers.
- UFOs perform optimization in 0.802 seconds for a 24 hours time horizon, against the 5.6 hours needed for an exact approach, which is infeasible in practice.
- It is possible to aggregate 3000 batteries for a time horizon of 24 hours, and 750 batteries for 96 hours. Exact models fail for more than 21 hours, or 330 batteries.

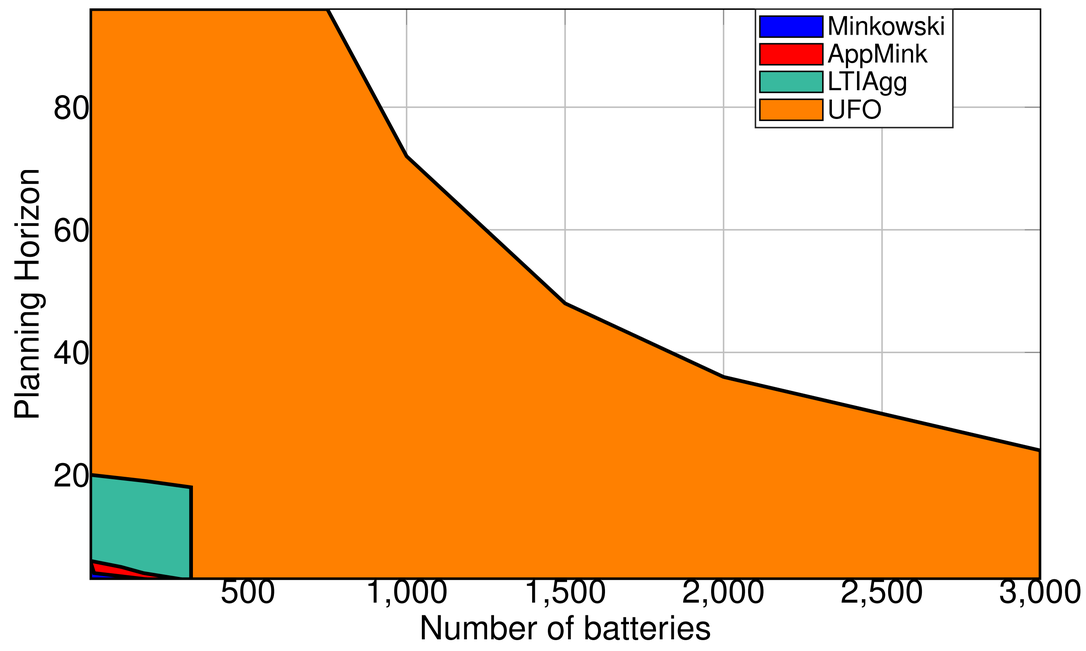

Fig. 6: Results for aggregation feasibility.

Acknowledgements

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