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Allocation of computing tasks in distributed MEC servers co-powered by renewable sources and the power grid

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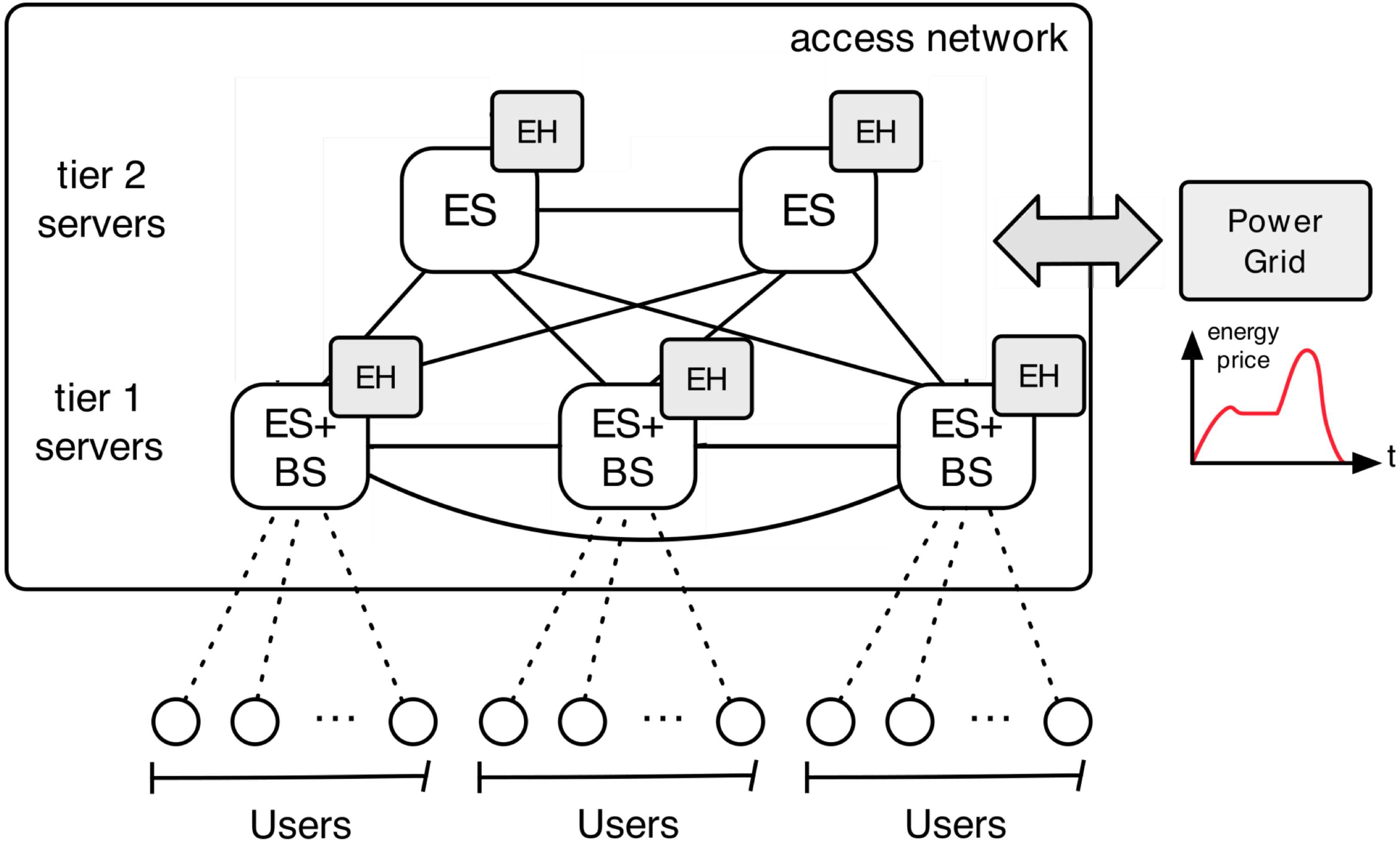
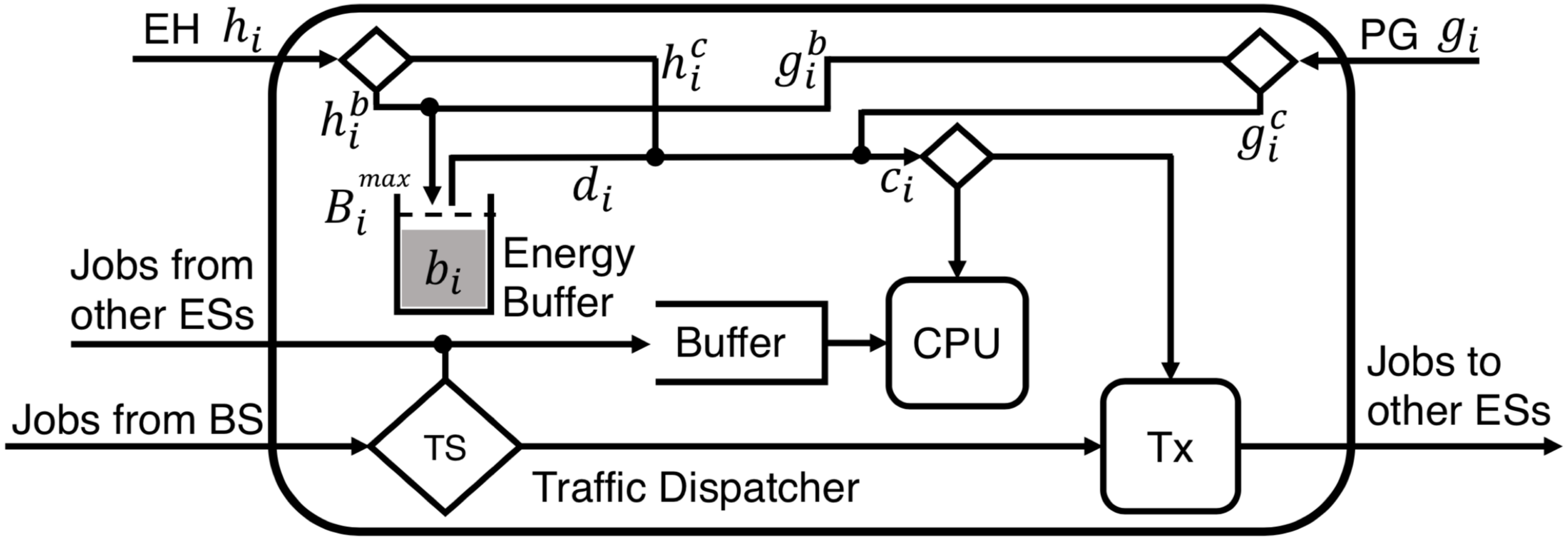
Scenario

Radio Access Network

- MEC architecture
  - Tier-1 servers
    - Co-located with BSs
  - Tier-2 servers
- Servers have to process users' jobs, that must be dispatched among the servers
- Time is slotted



Scenario: Edge Server



- Processing unit
- Communication unit
- Energy harvesting (e.g., photovoltaics)
- Energy purchase from power grid
- Energy storage (e.g., battery)

Objective

Objective: minimize the monetary cost incurred by the servers in the energy purchases from the power grid, while executing the offloaded jobs.

Proposal: online algorithm that

- dispatches the job flows among the servers
- decides when to buy energy
- manages the batteries

Accounting for the fact that users jobs' flows, energy harvested and grid energy price are variable over time and unknown a priori.

Optimization problem

$$\underset{\substack{g_i^b(k),\, g_i^c(k),\, h_i^b(k),\\ h_i^c(k),\, d_i(k),\, r_{ij}(k),\\ i\in\mathcal{M},\, j\in\mathcal{M}\setminus\{i\},\, 0\le k\le T}}{\text{minimize}} \quad \sum_{k=1}^{T} p(k) \sum_{i\in\mathcal{M}} g_i(k)$$

T = # of time slots
$\mathcal{M}$ = set of servers
$p(k)$ = energy price
$g_i(k)$ = purchased energy

subject to:

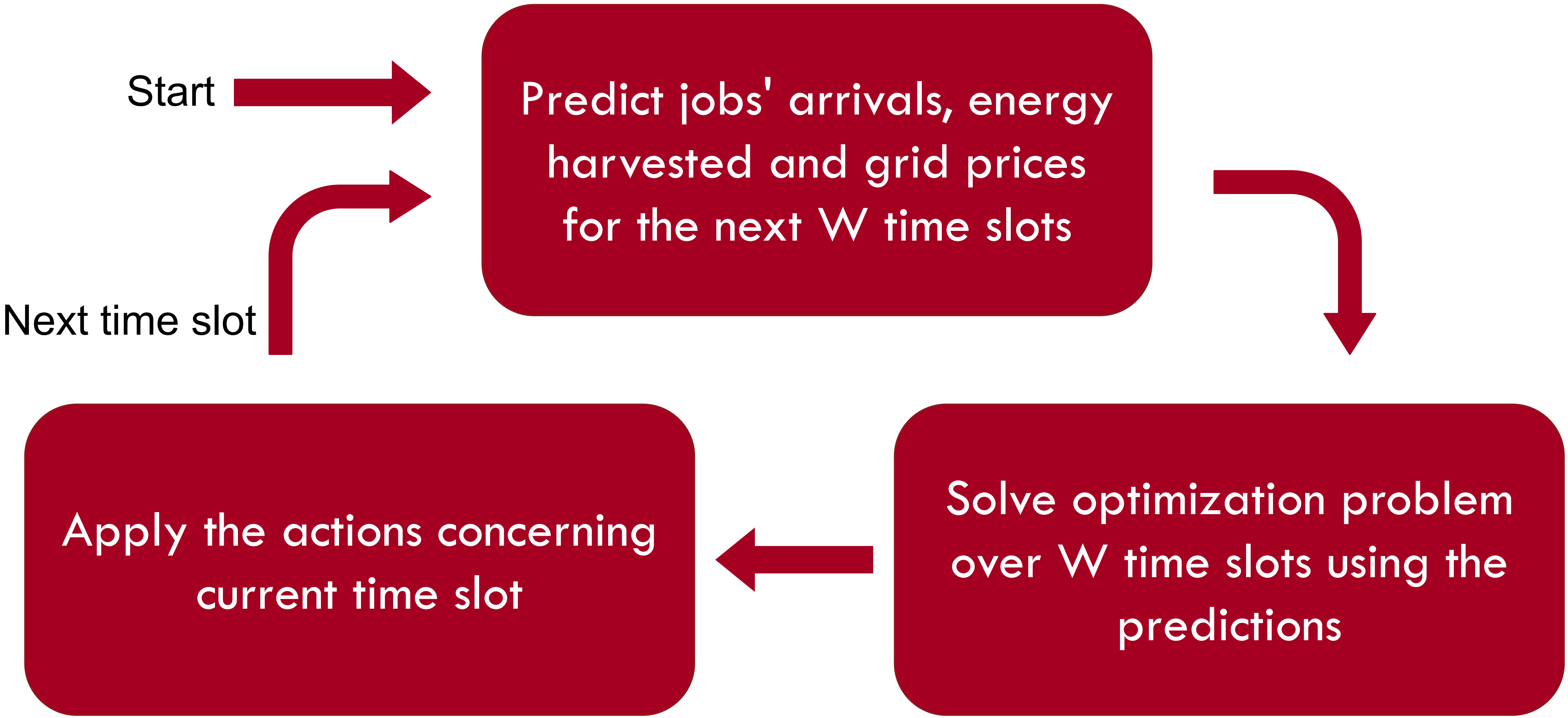
Linear relations between energy consumption and job processing
Linear relations between energy consumption and communications
Battery levels evolution
Job flow conservation
Maximum harvested energy
Maximum battery drained
Maximum battery capacity
Non-negativity of variables

Predictions

How to deal with uncertainty?

- Grid energy price: available one day ahead ("one day ahead Market")
- Jobs' arrivals: average load profiles of each BS are used as job flow predictions
- Energy harvested: Long Shot-Term Memory (LSTM) neural networks are used as predictor for future harvested energy availability
  - 1 hidden layer consisting of 40 neurons
  - Trained for 80 epochs over 4 years of harvested energy measurements
  - Outputs the forecasts for W time slots, by using the most recent L=24 samples

Online algorithm

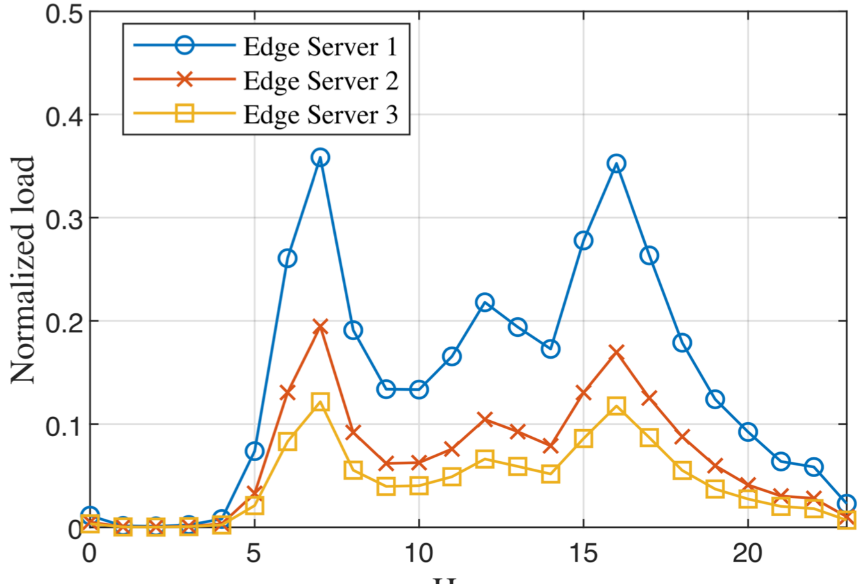


Simulations

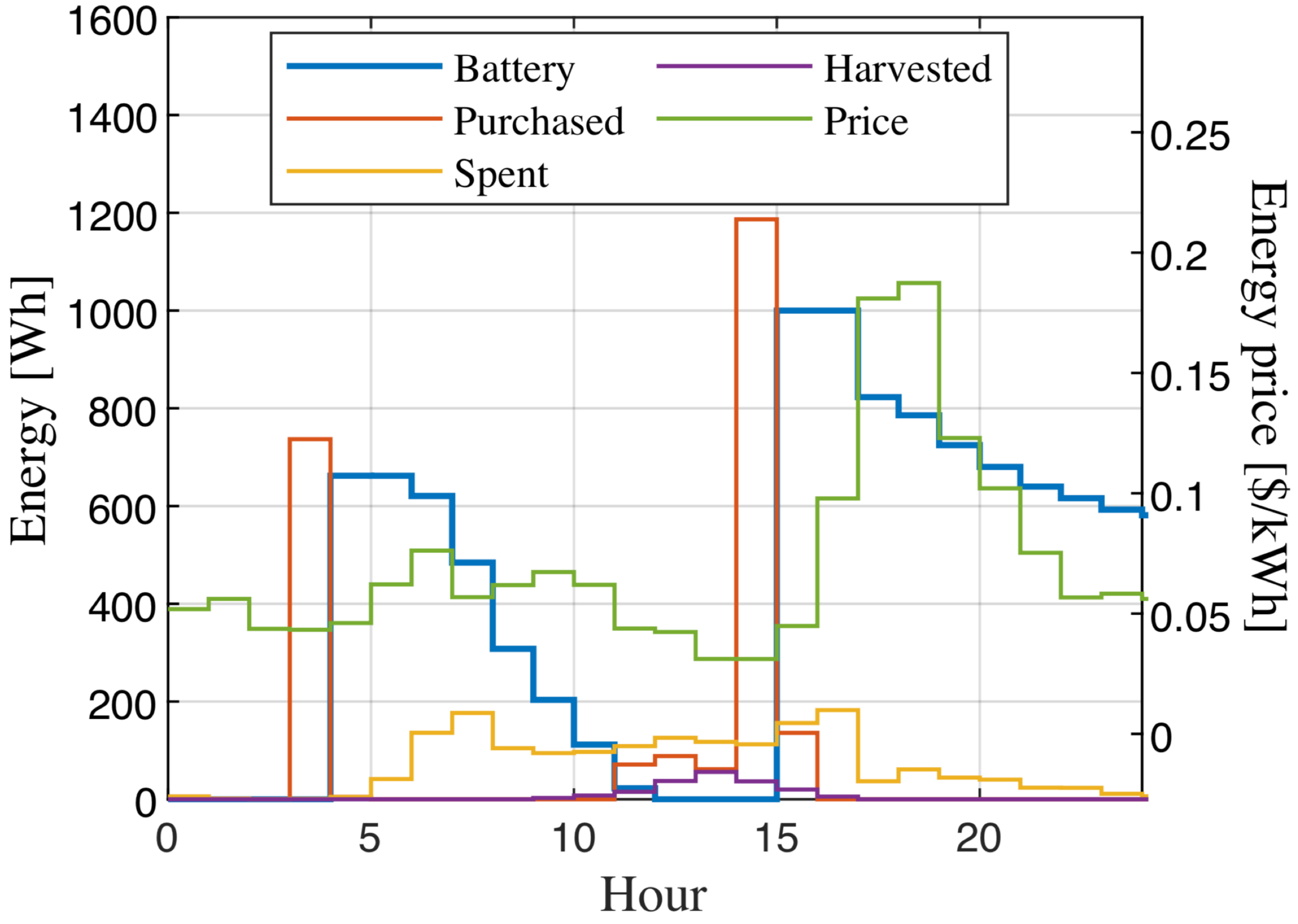
- T = 360h; time step = 1h; 3 tier-1 servers; 2 tier-2 servers

Inputs:

- Energy harvested: real traces available on the SolarStat tool
- Grid energy price: from US National Grid database
- Job flows: synthetic time series generated with SUMO



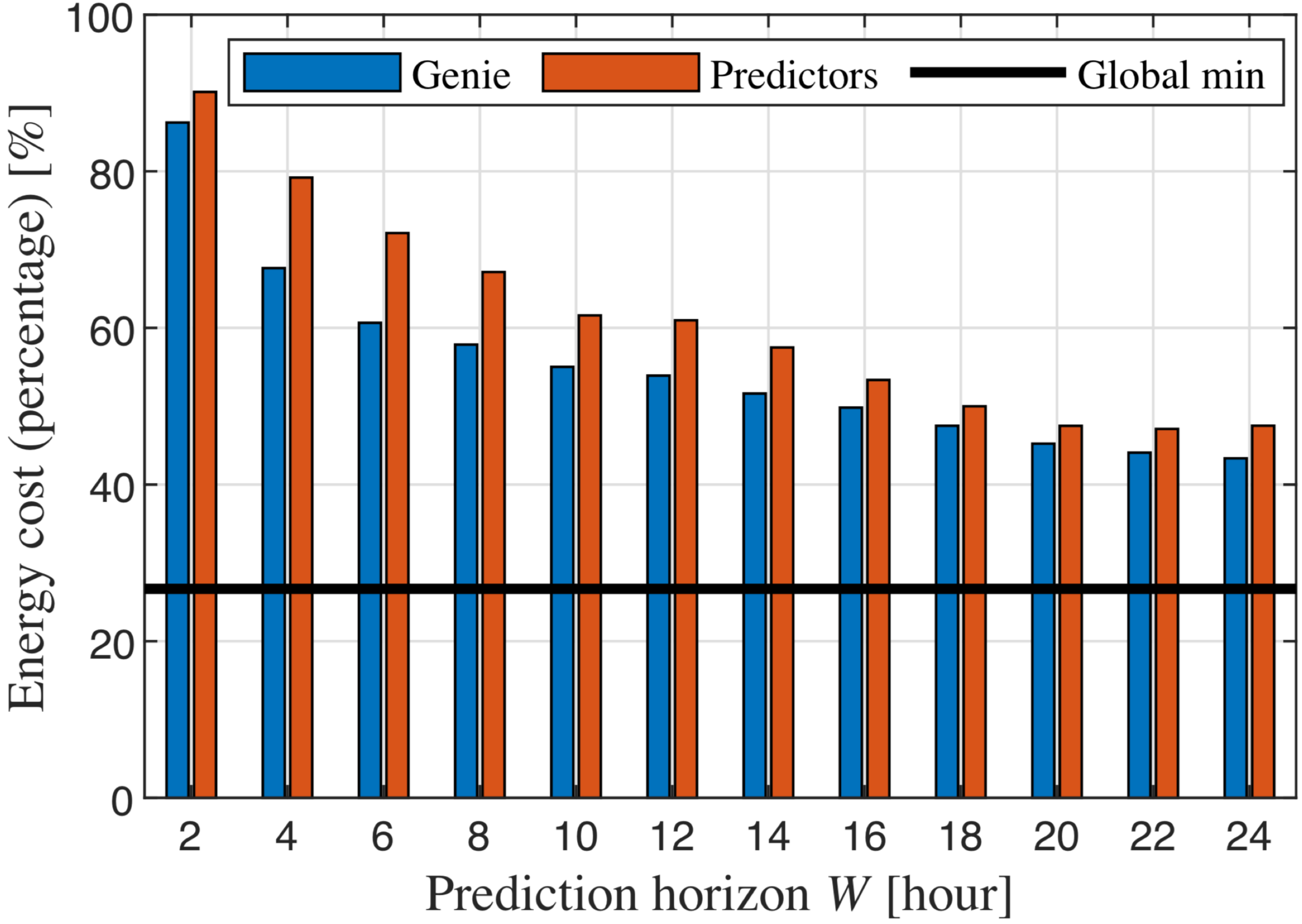
Results



Plot shows the energy price and the state evolution of server 1 (in tier 1) obtained using W = 24 hours.

The ES purchases energy from the power grid on energy price's local minima.

Results



Plot shows the energy cost achieved by Genie predictors and our Predictors, while varying the length of the prediction horizon W (results in percentage with respect to the energy cost incurred with W = 1).

With our Predictors, setting W = 4 hours allows reducing the energy expenses by 20%. With W = 18 hours, the energy cost is halved.

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