Wireless Energy Charging Policy for Mobile Nodes

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Motivation

- Constrained energy and energy management issues of mobile nodes
- Wireless energy charging: A perpetual type of energy source for mobile nodes
- Wireless energy as a commodity: Price fluctuation
- A (rational) mobile node decision the right time, right place to charge / not to charge

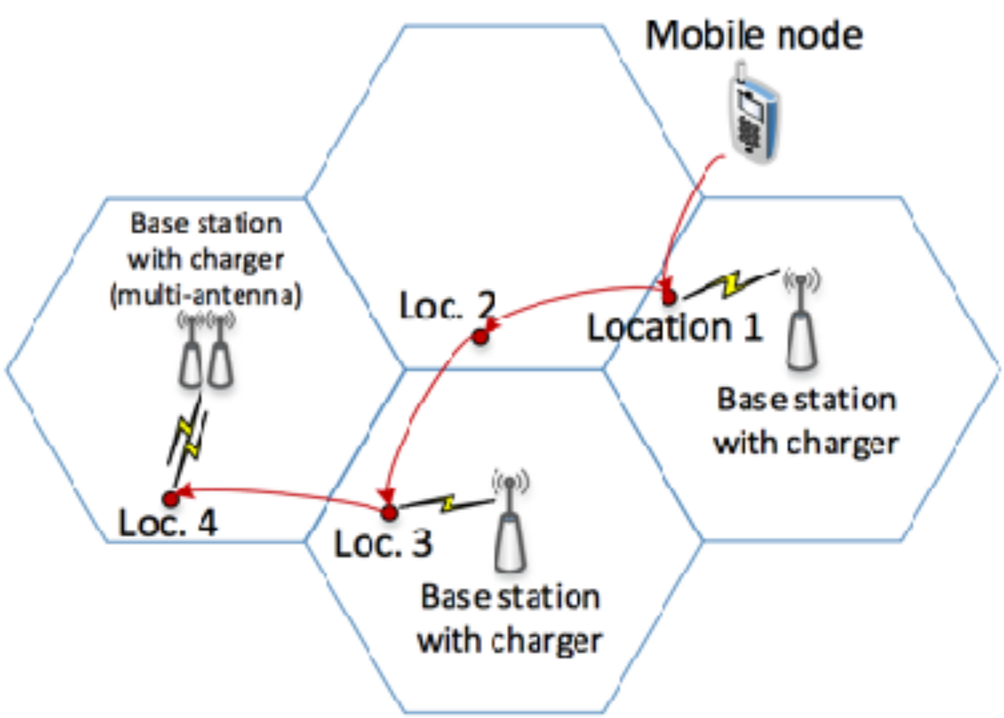
Objectives

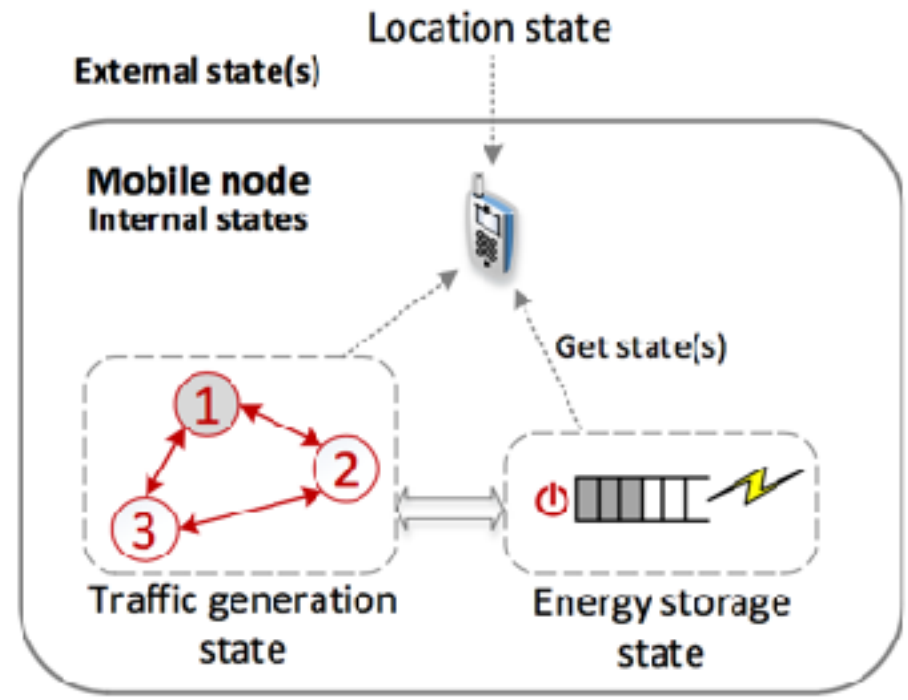
- We initiate a general system model to describe the wireless energy charging system for mobile nodes
- A Markov decision process (MDP) is formulated to minimize a mobile node's cost of energy charging
  - Considering:
    - Energy level of mobile node
    - Current traffic being processed
    - Mobility

System description

- System contains two major components:
  - Mobile node
  - Cellular base stations
    - BSs with wireless energy charging facilities, or
    - BSs for communication only

System description





External states

Internal states

Wireless energy transmitter

Wireless energy harvester

System description

- Stochastic parameters in the system (system states):
  - The location of mobile node, and the nature of wireless energy source (e.g., BS) of the current location
  - The current traffic load of mobile node
  - The current energy level of mobile node
- … Called system states

Optimization model formulation

- To analyze the cost minimization of the relay in the long run, we formulated an MDP problem
  - **Input**: Mobile node's system states, system state transitions (i.e., the prob. of state changing), cost (reward) function(s), actions
  - **Output**: A policy (strategy) - the mobile node's best action in response of any current system state
  - Objective: Maximize/minimize overall expected reward/cost

Optimization model formulation

- The formulated MDP includes system states:
  - State set of mobile node's mobility (in terms of locations):

$$\mathcal{L} \in \mathbb{L} = \{1, 2, \cdots, L\}$$

  - Set of traffic state: $\mathcal{W} \in \mathbb{W} = \{1, 2, \cdots, A\}$
  - Energy storage of mobile node:

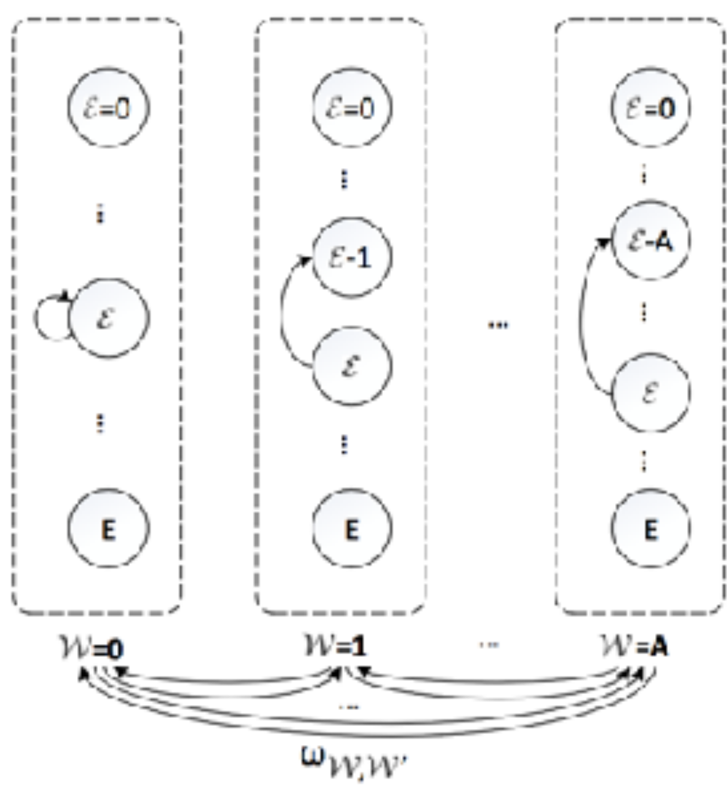
$$\mathcal{E} \in \mathbb{G} = \{1, 2, \cdots, E\}$$

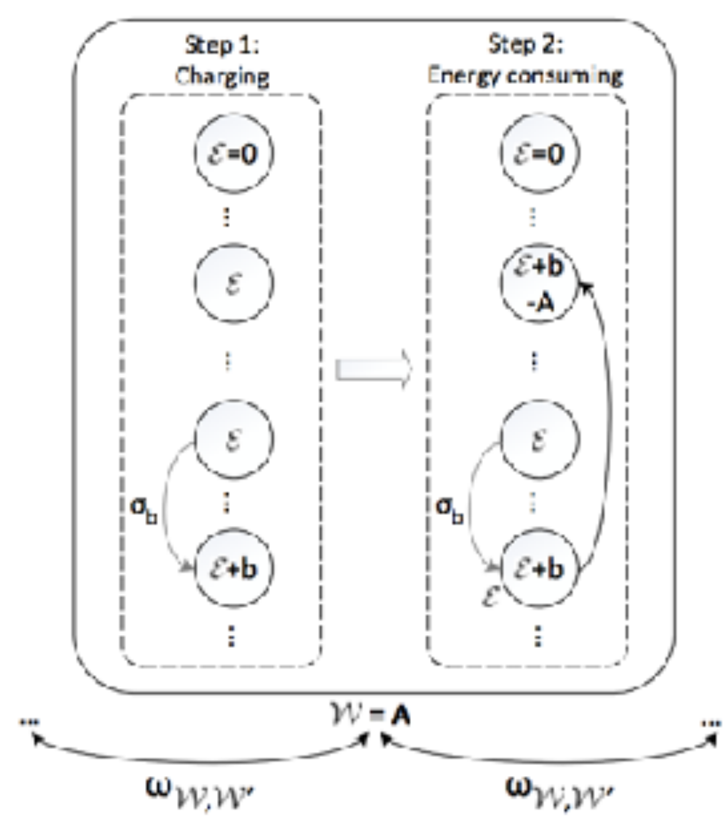
- The formulated MDP includes actions:

$$\mathcal{A} \in \mathbb{A} = \{0, 1\}$$

Optimization model formulation

- The formulated MDP includes state transitions
    - M(arkov)DP, the states change as controlled Markov chains





Solving the MDP optimization model

- Bellman equation is employed

$$V(\mathcal{S}) = \max_{\pi(\mathcal{A}|\mathcal{S})} H(\mathcal{S}|\mathcal{A})$$

$$\phi^*(\mathcal{A}|\mathcal{S}) = \arg\max_{\pi(\mathcal{A}|\mathcal{S})} H(\mathcal{S}|\mathcal{A})$$

$$\boxed{H(\mathcal{S}|\mathcal{A}) = F(\mathcal{S}|\mathcal{A}) + \gamma \sum_{\mathcal{S}'} P(\mathcal{S}, \mathcal{S}'|\mathcal{A}) V(\mathcal{S}')}$$

  - Optimally choose actions to different current states
  - To maximize/minimize the reward/cost
  - When objective function achieved, optimal actions achieved

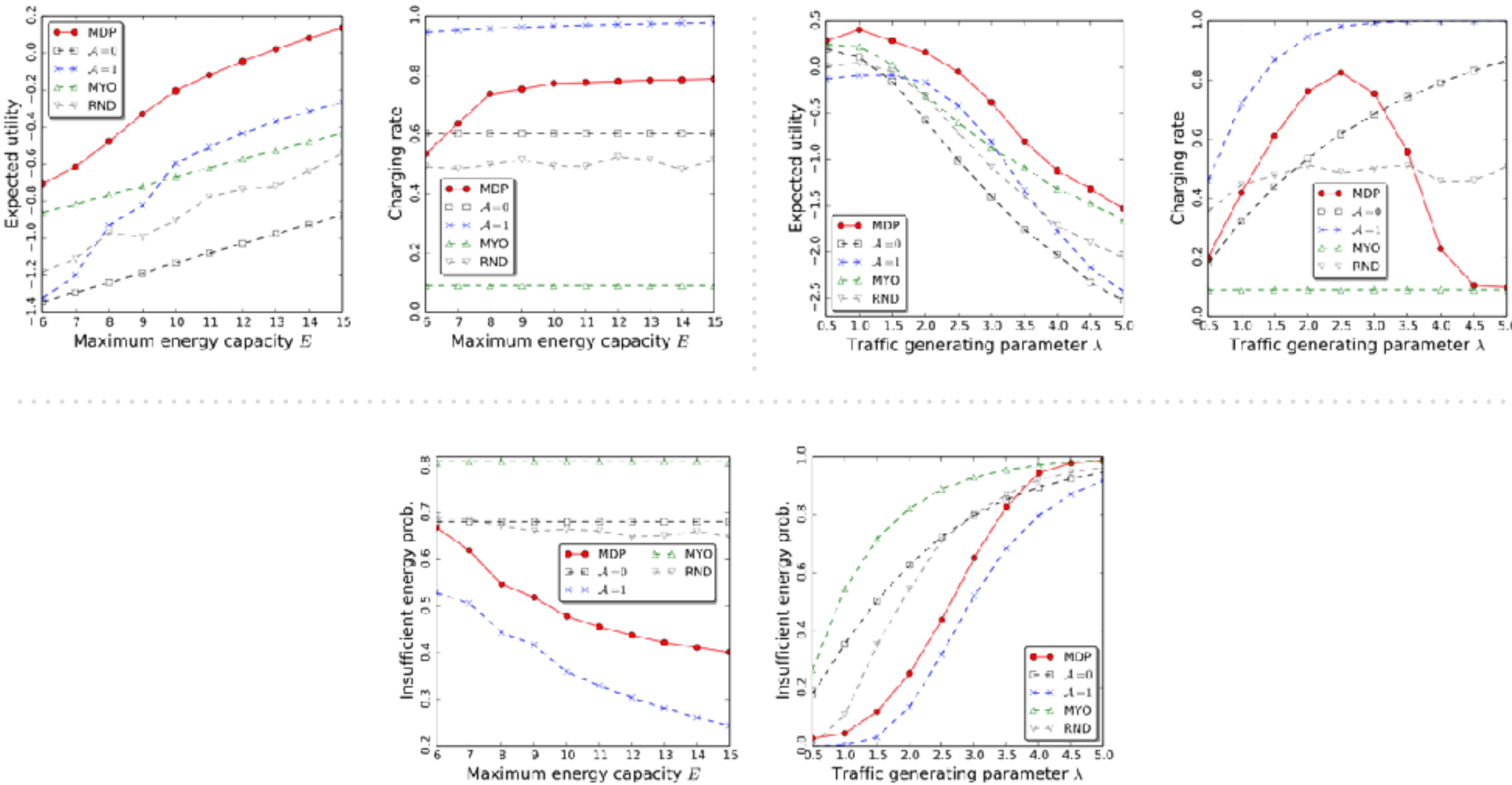
Numerical results

- System parameters, we set:
    - The mobile node moves among 11 locations, with prob. of mobility known in advance (how?)
    - Energy storage of the node is 10
    - 5 types of different traffics generated in the node

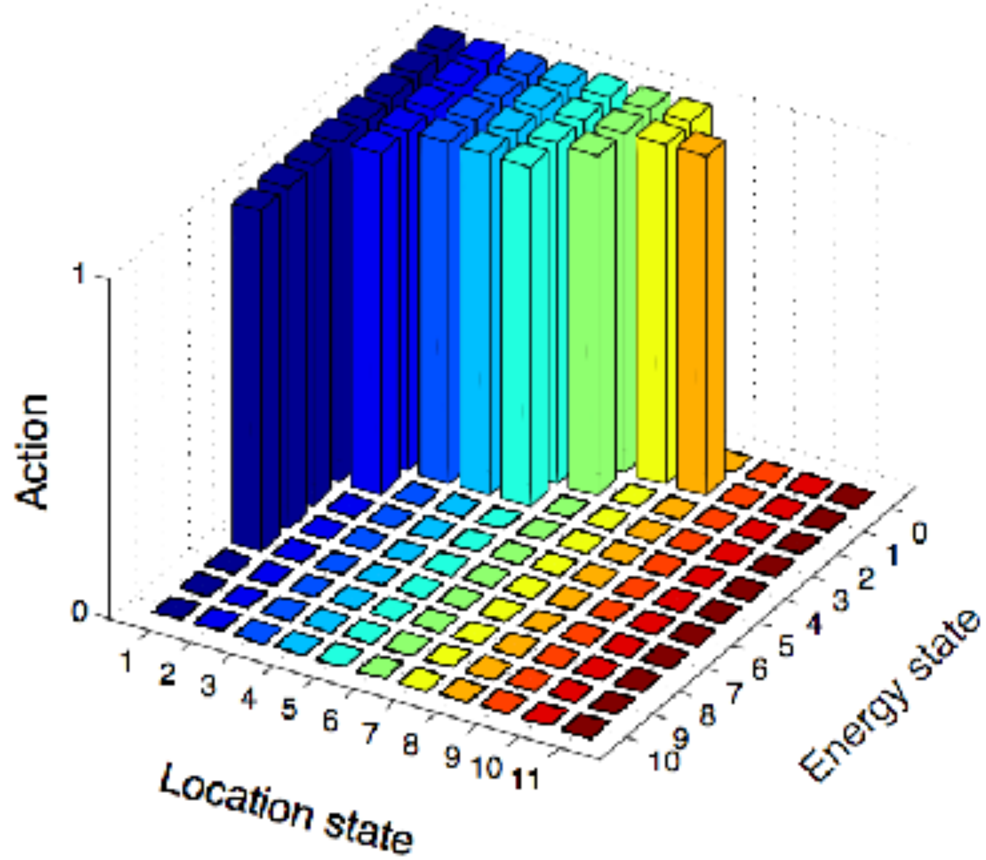
Numerical results

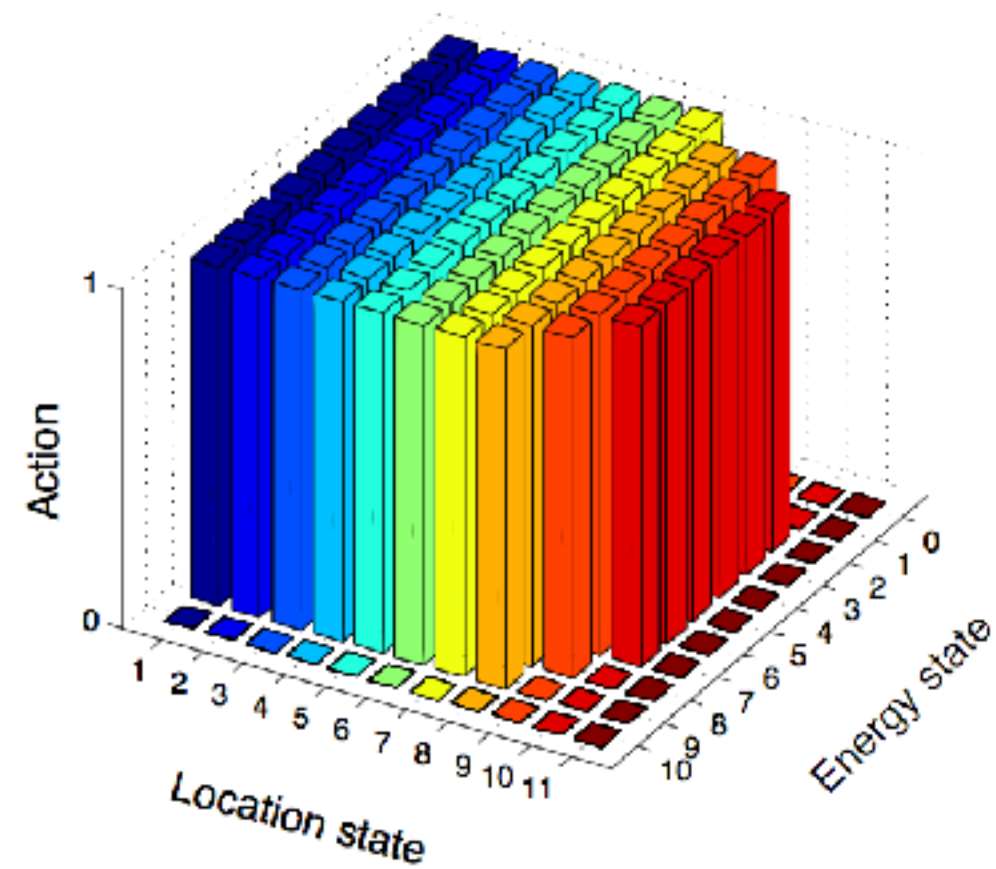
- Performance criteria
  - Expected Utility: The solved optimal policy is supposed to maximize the mobile node's expected utility when the system operates forever.
  - Charging ratio: Denoting the ratio of charing actions to all the actions ever taken in the long run
  - Insufficient energy prob. / Avg. node energy level

Numerical results



Numerical results





Thanks!
Q&A

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