RED-BL: Relocate Energy Demand to Better Locations

Muhammad Saqib Ilyas

Agenda

- Background and motivation
- Problem statement and formulation
- Two case studies – simulation results
- Conclusions and future work

Motivation

- Large scale networks:
  - Enable critical services

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Motivation

- Large scale networks:
  - Enable critical services
  - Consume a lot of energy
- Estimated electricity cost for a 100 MW data center in the US
  - $114 M/year
- Network electricity costs expected to increase
  - Electricity prices are rising globally

Example – Google Search

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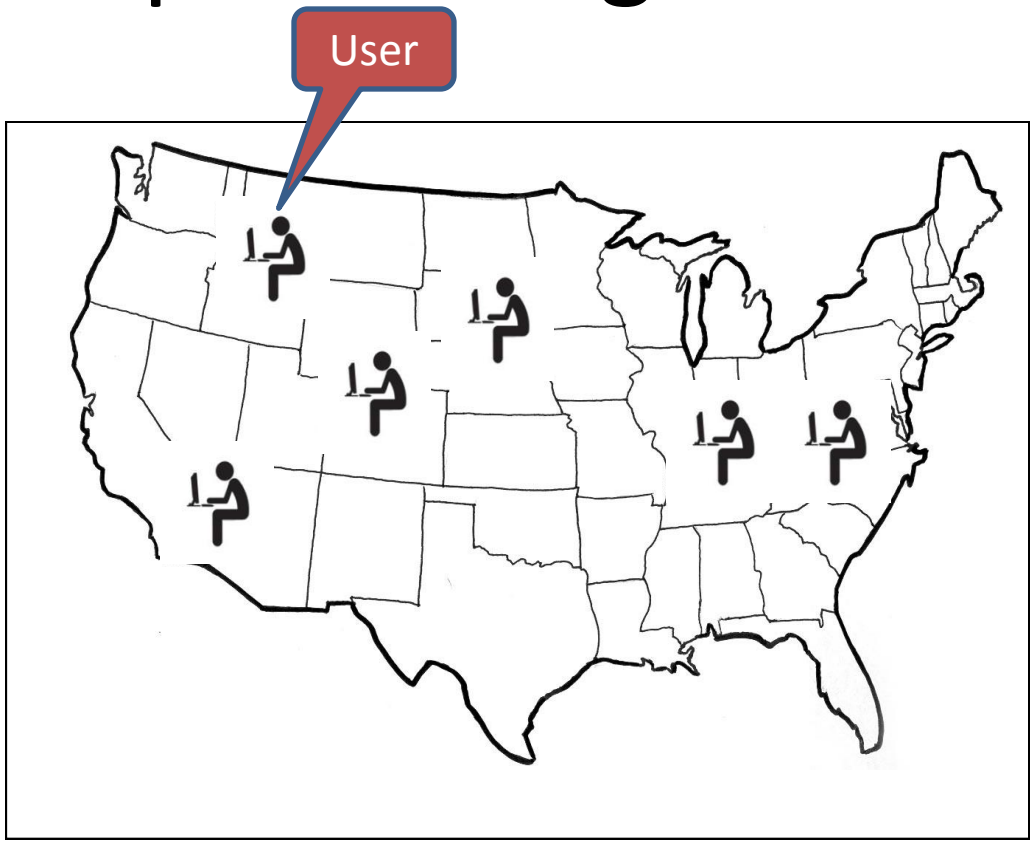

Example – Google Search

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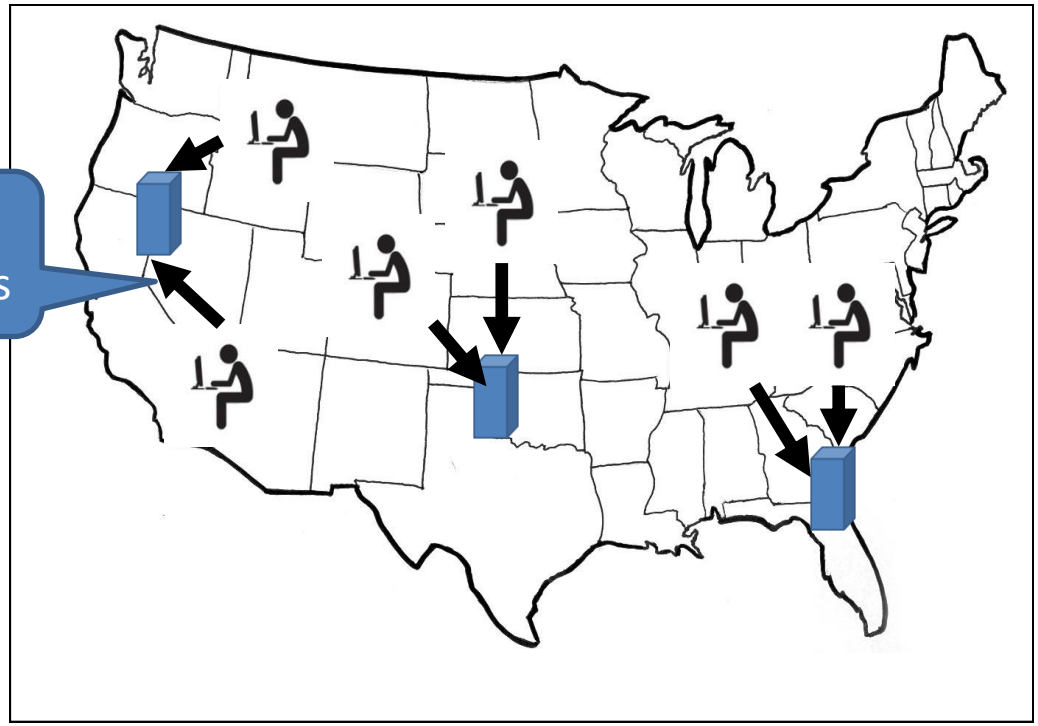
Traffic is distributed amongst data centers



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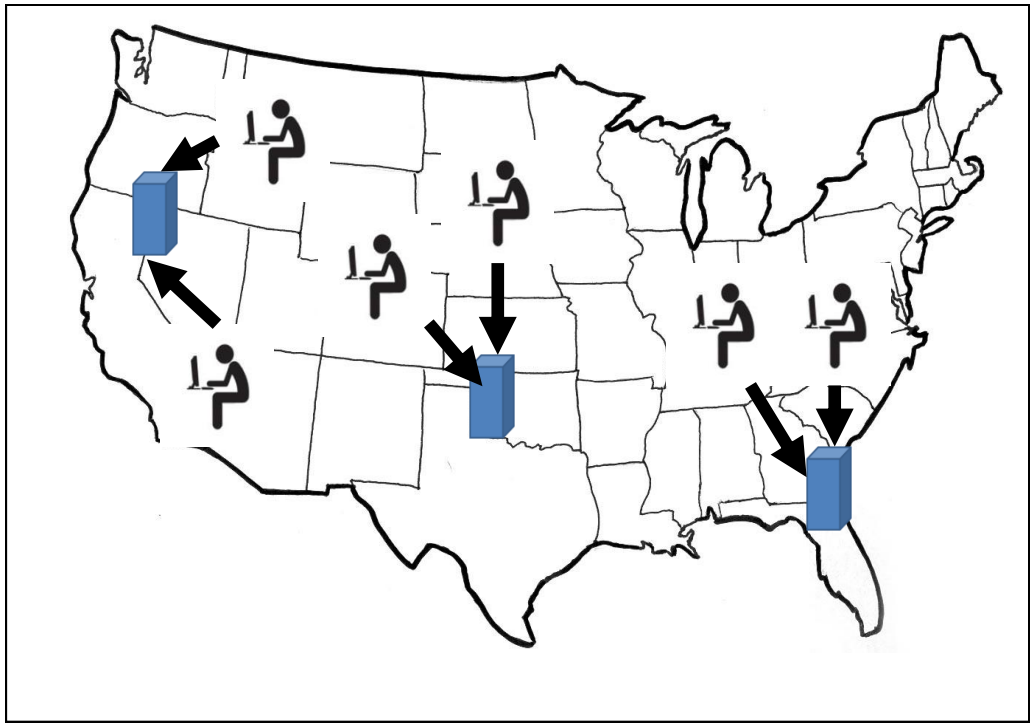

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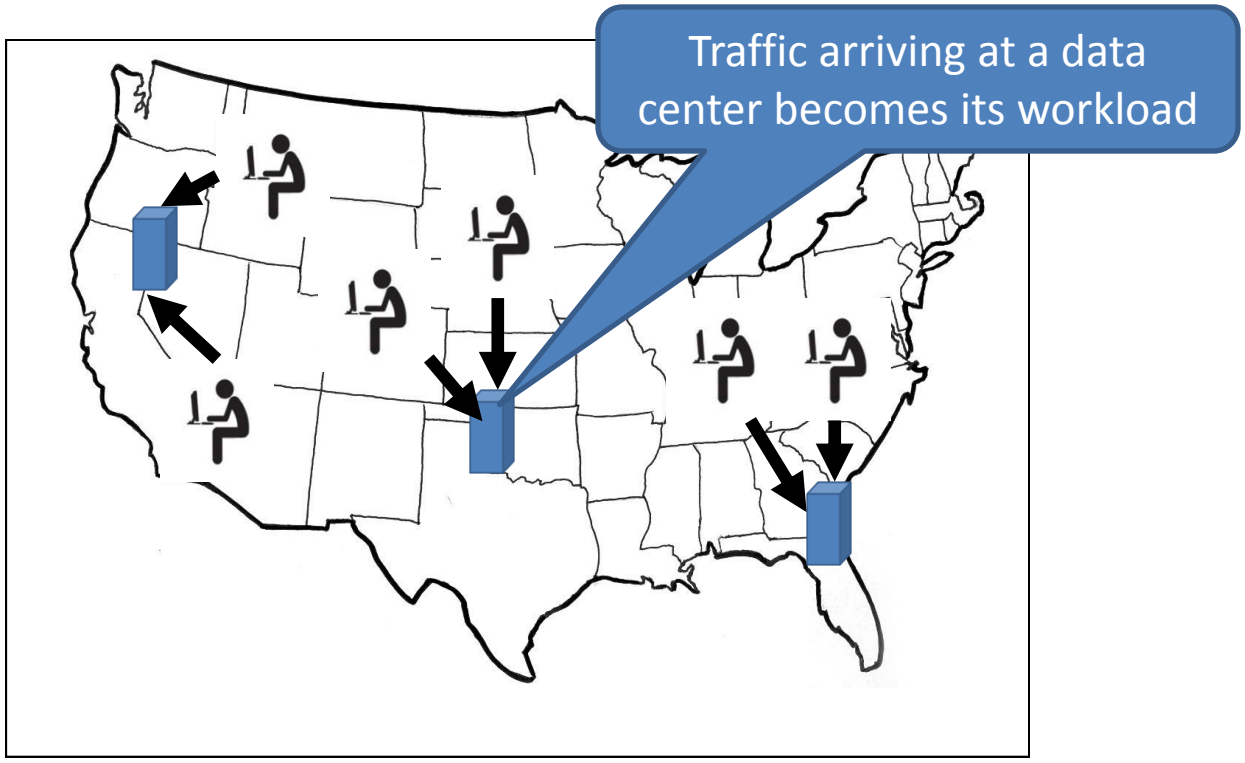

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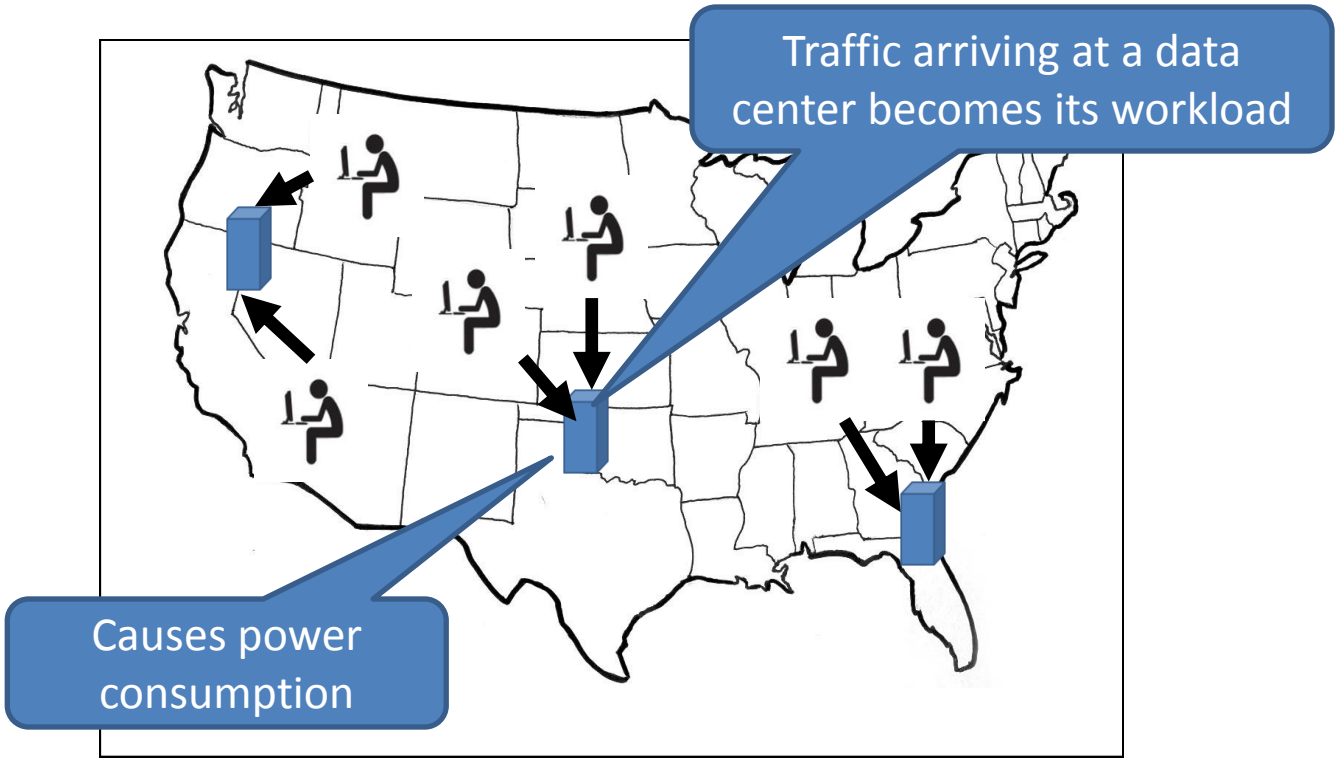
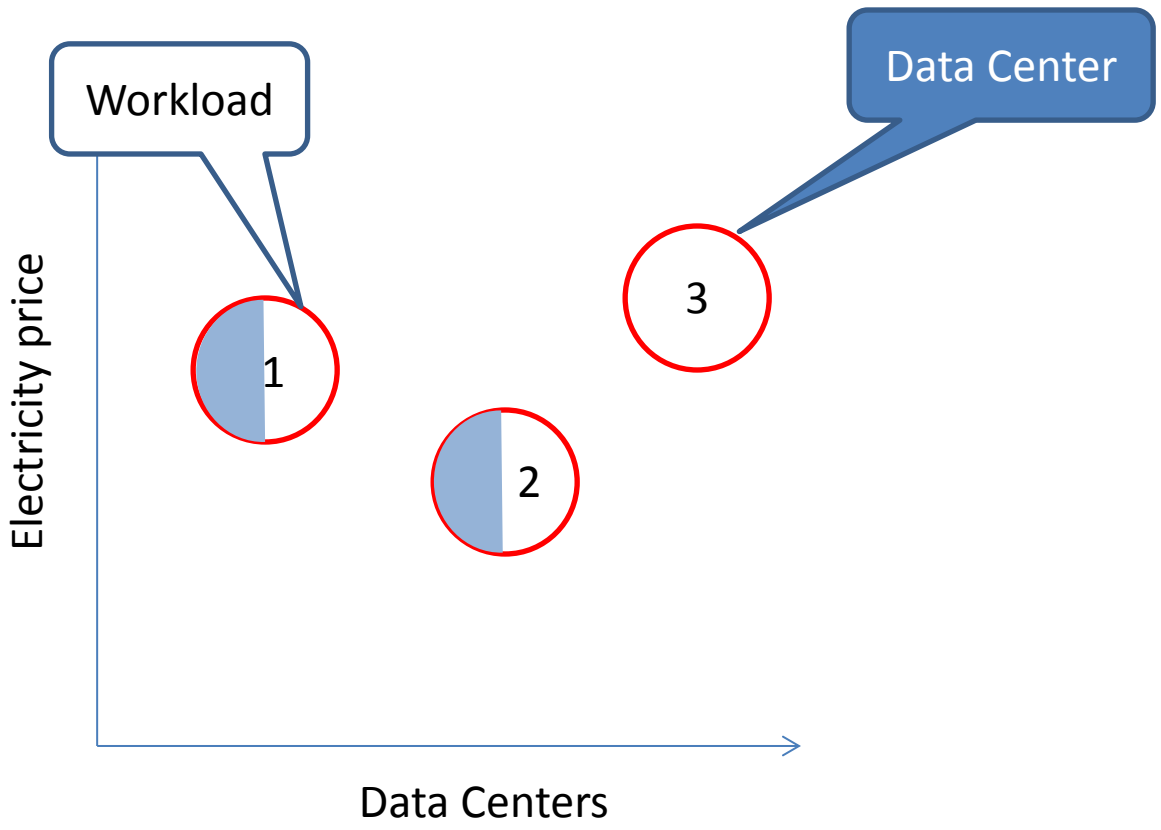


Using Cheaper Electricity



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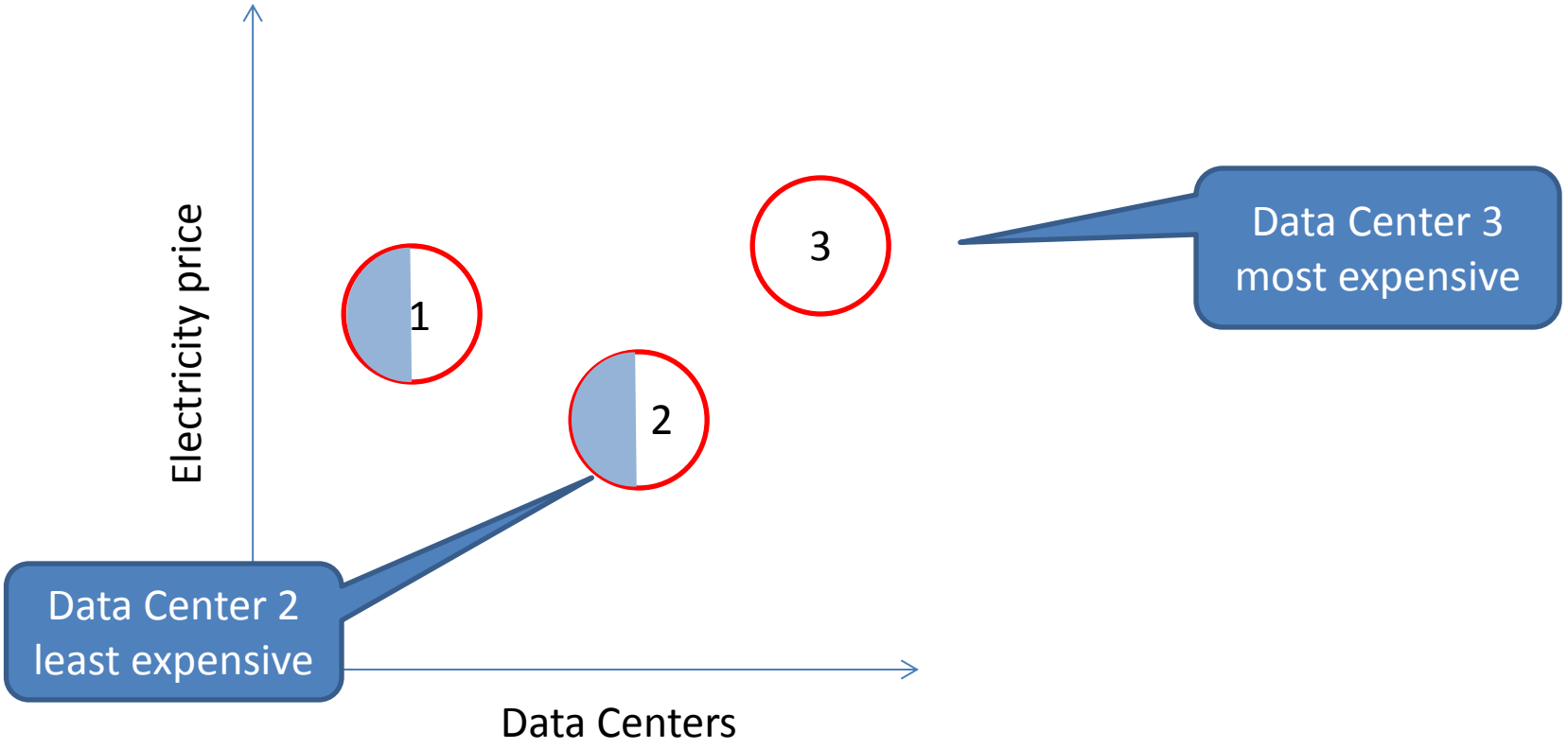

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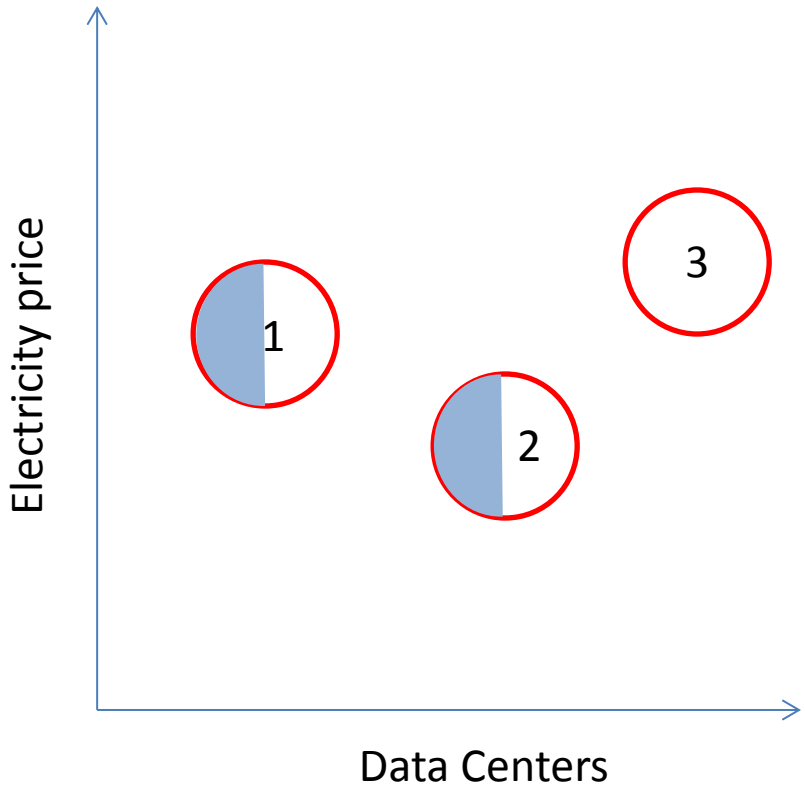

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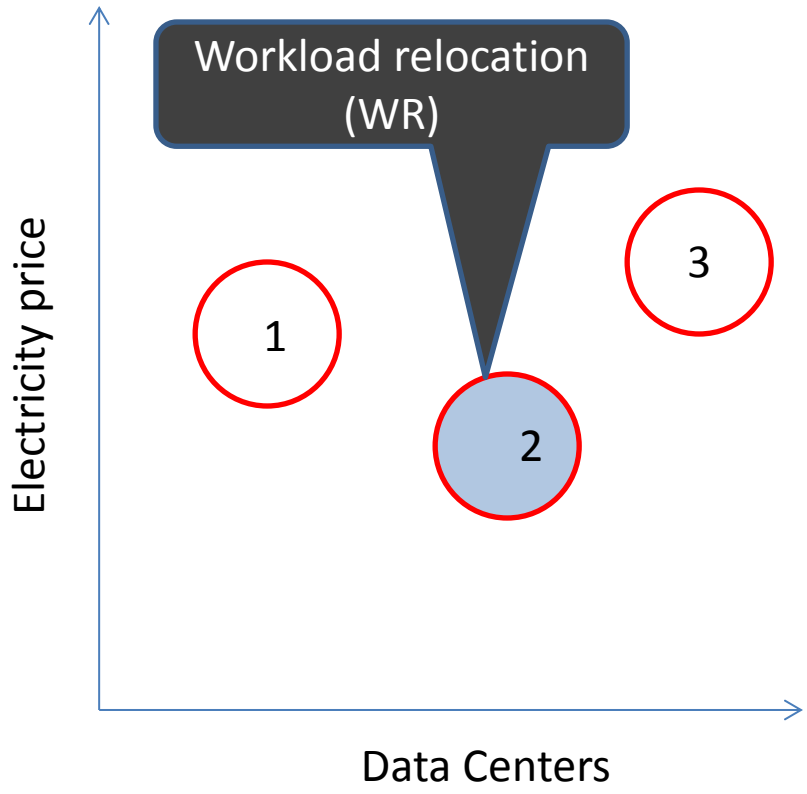

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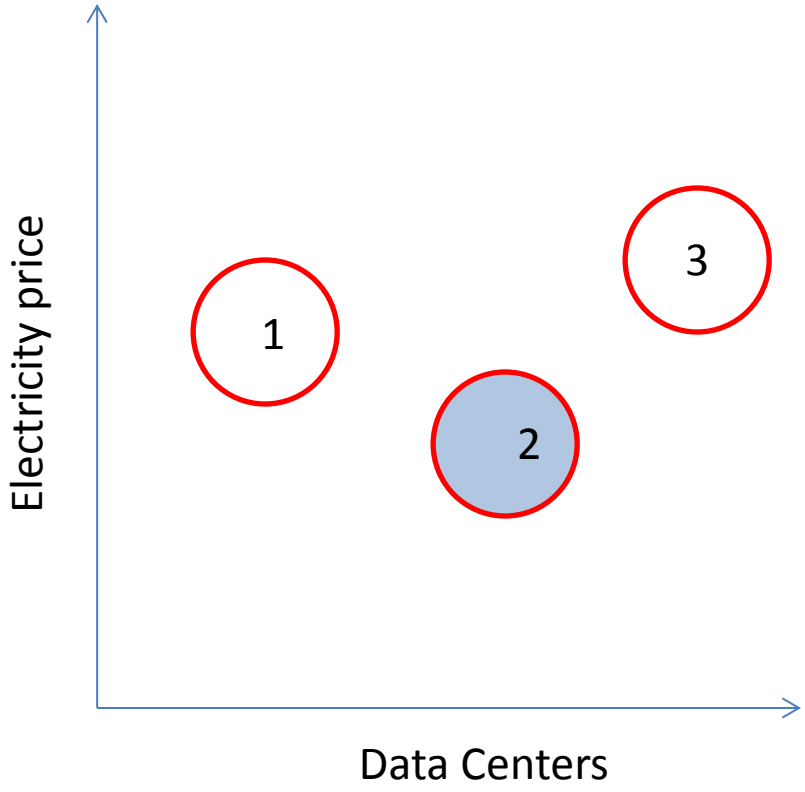
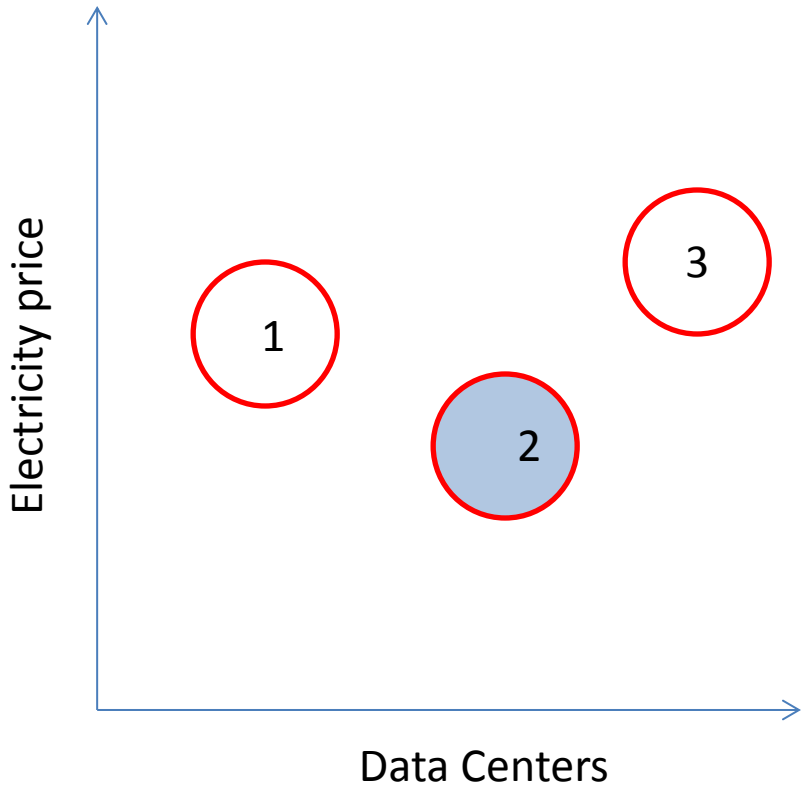


Relocate Energy Demand to Cheaper Locations (RED-CL)

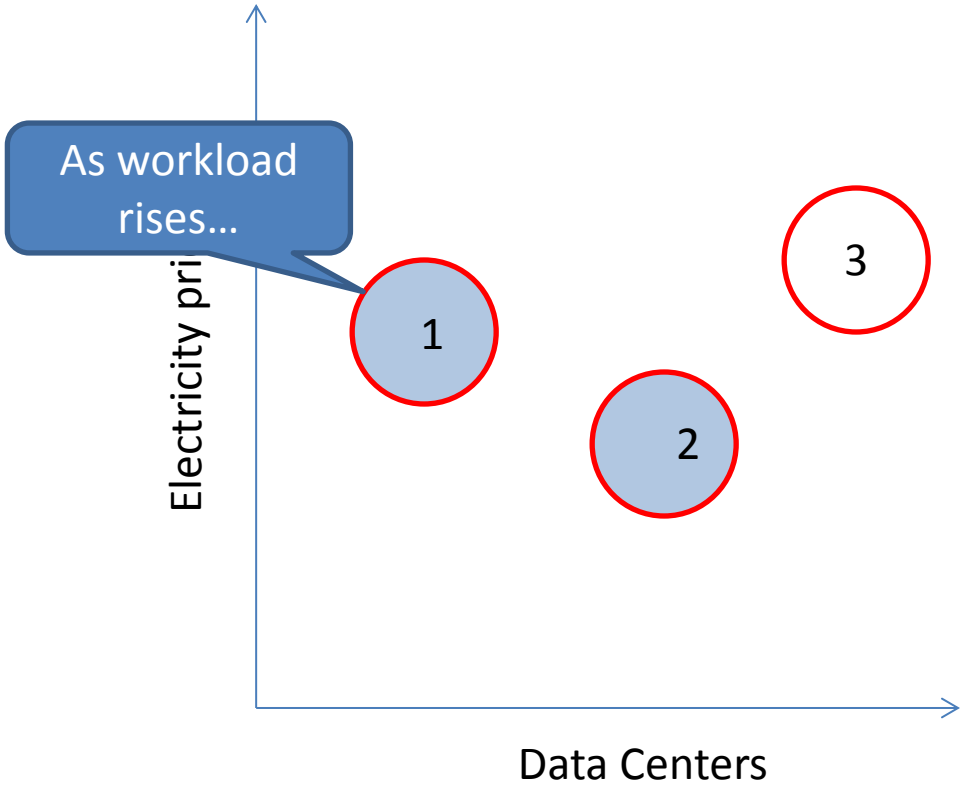
Using Cheaper Electricity



Relocate Energy Demand to Cheaper Locations (RED-CL)

Workload relocation can help reduce electricity cost

Using Cheaper Electricity



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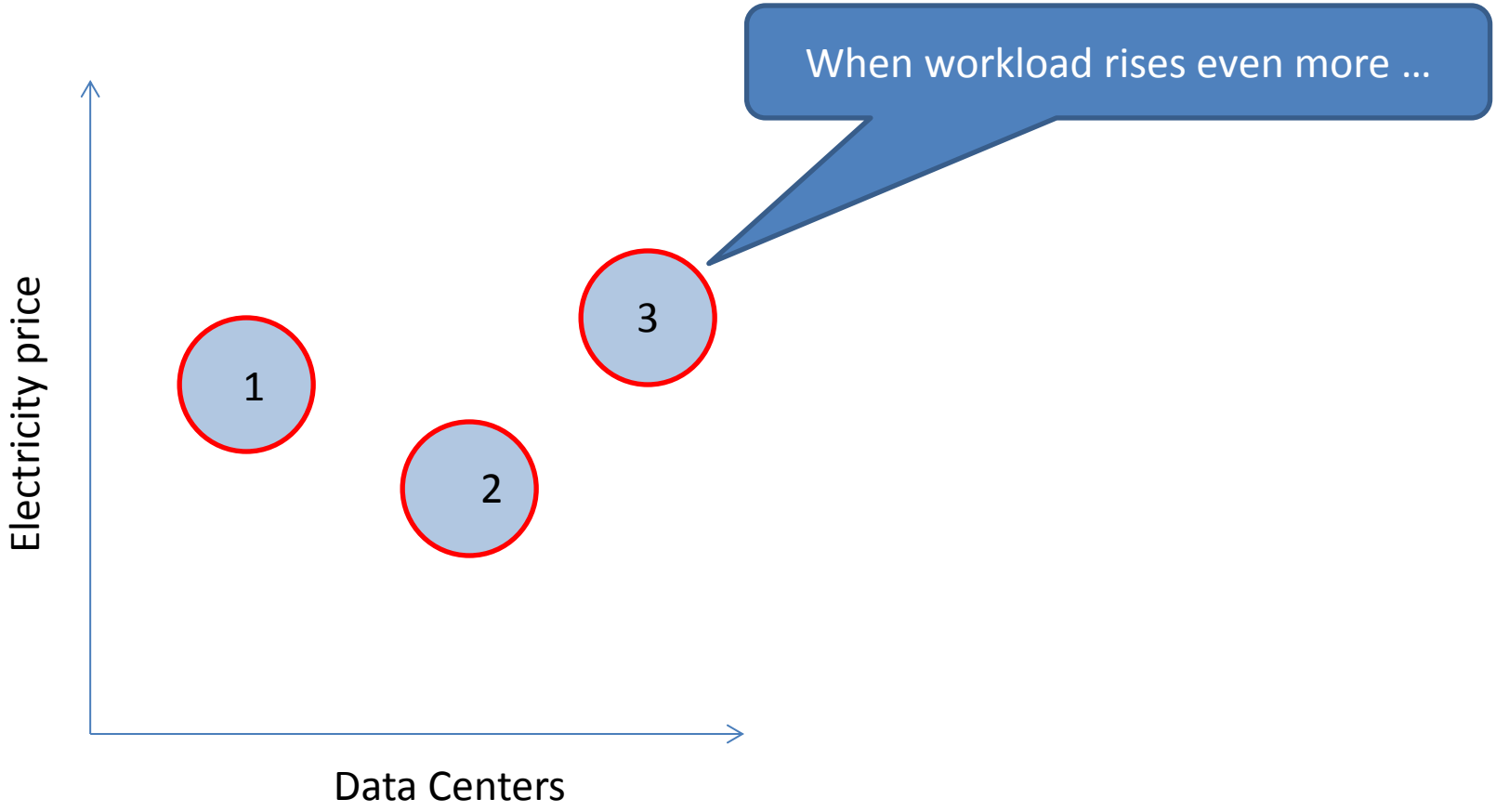

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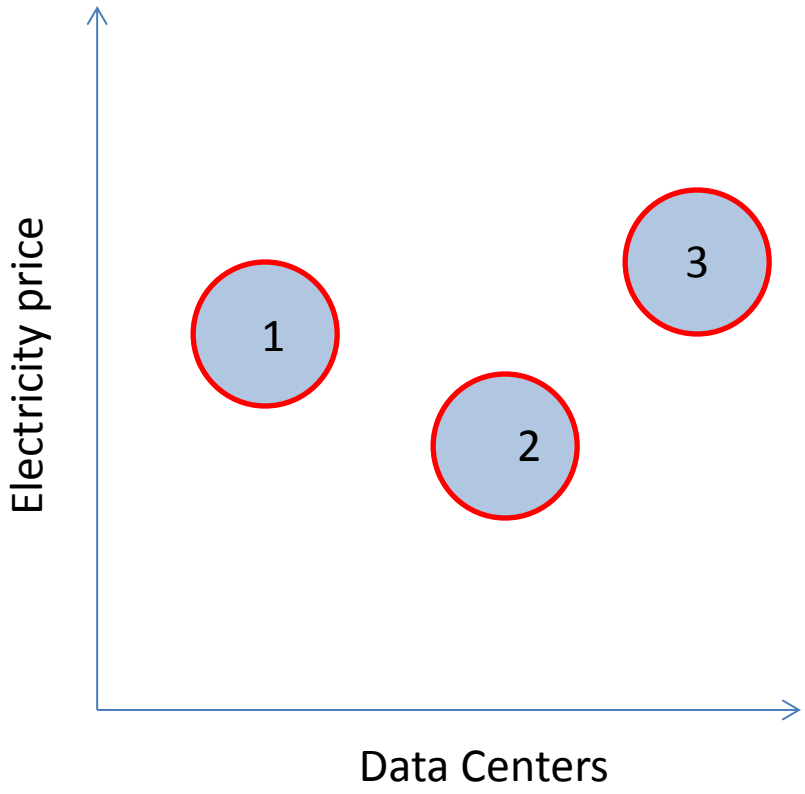

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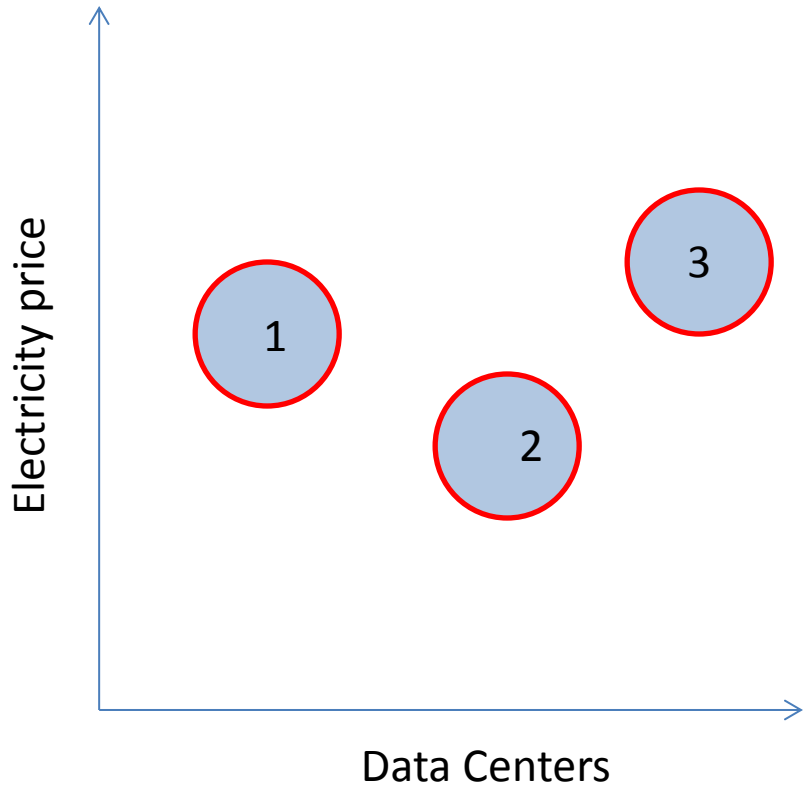

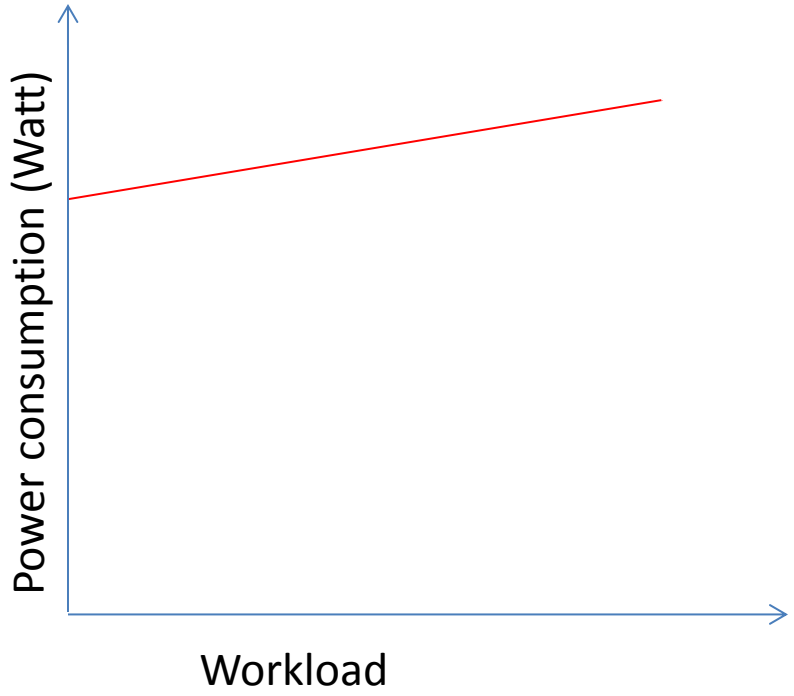

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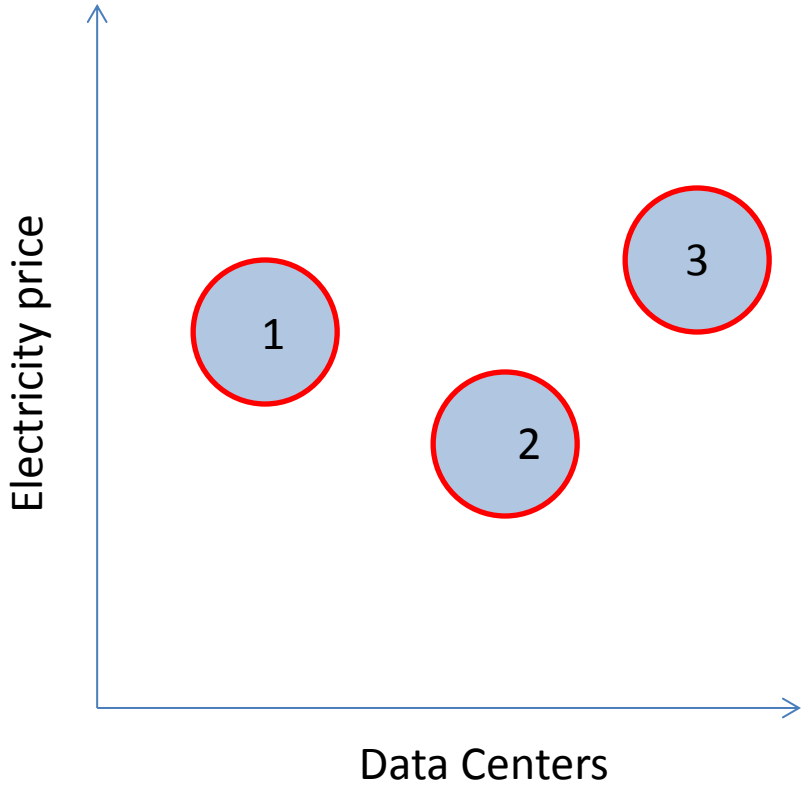

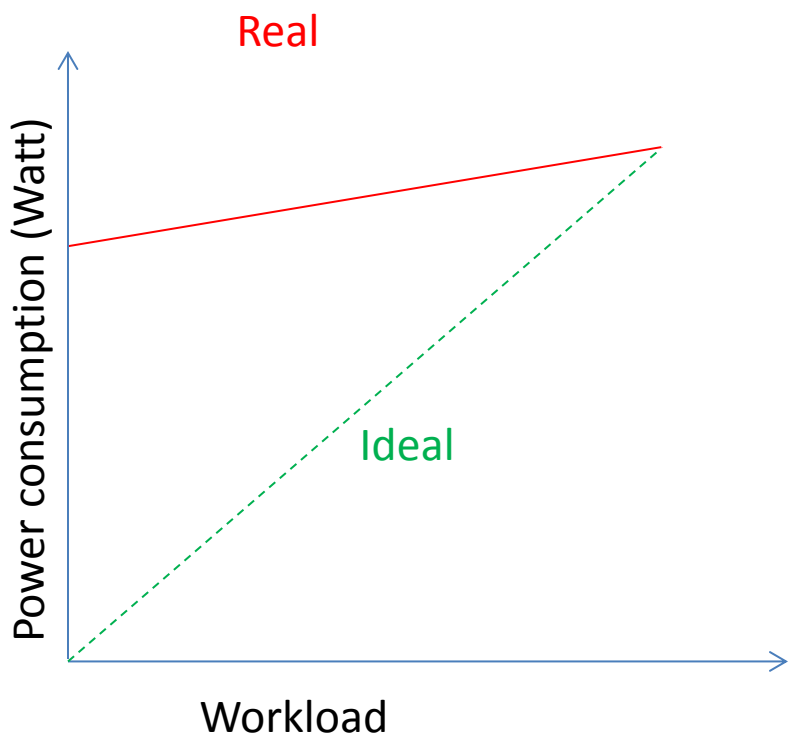

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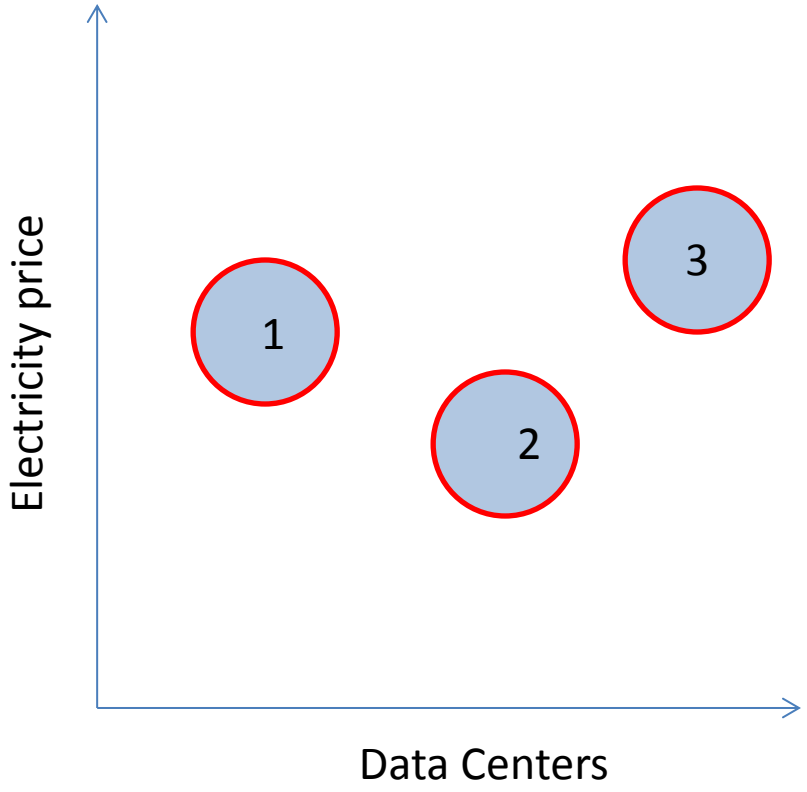

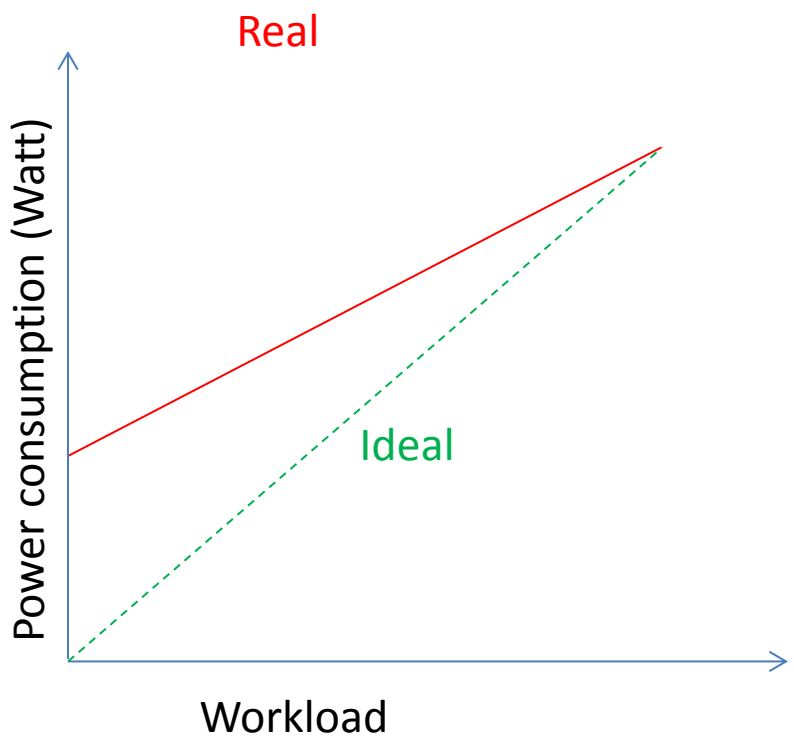

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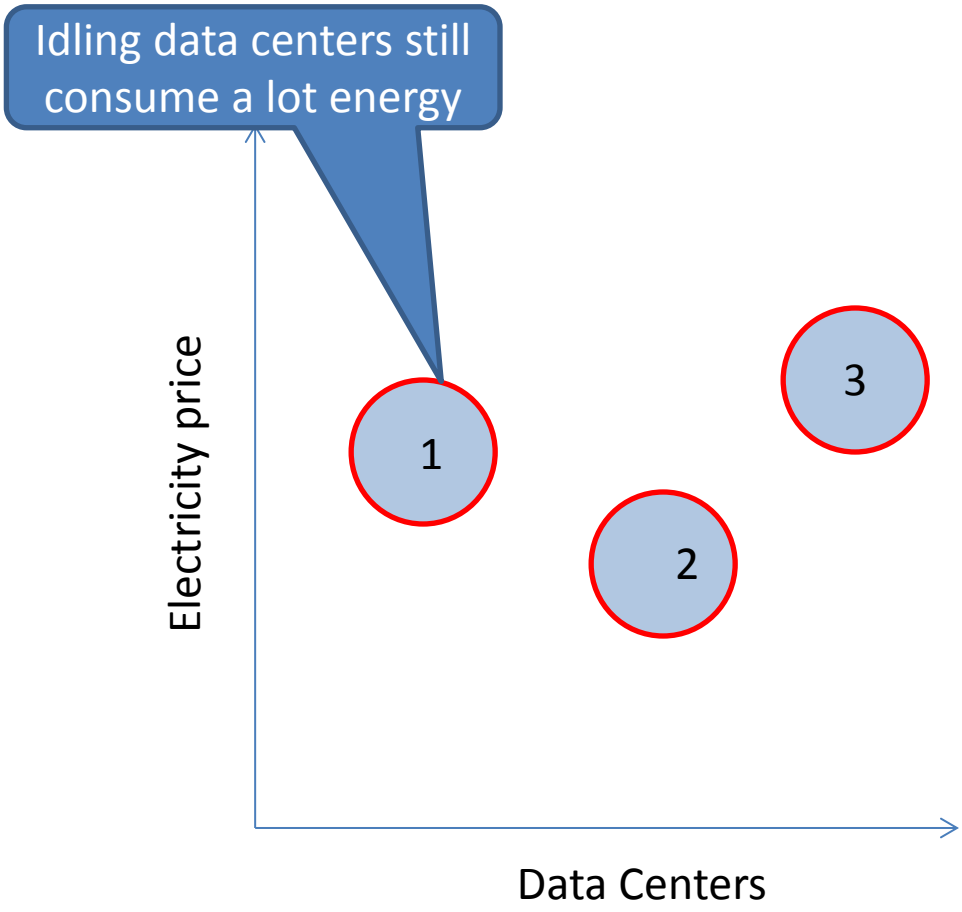

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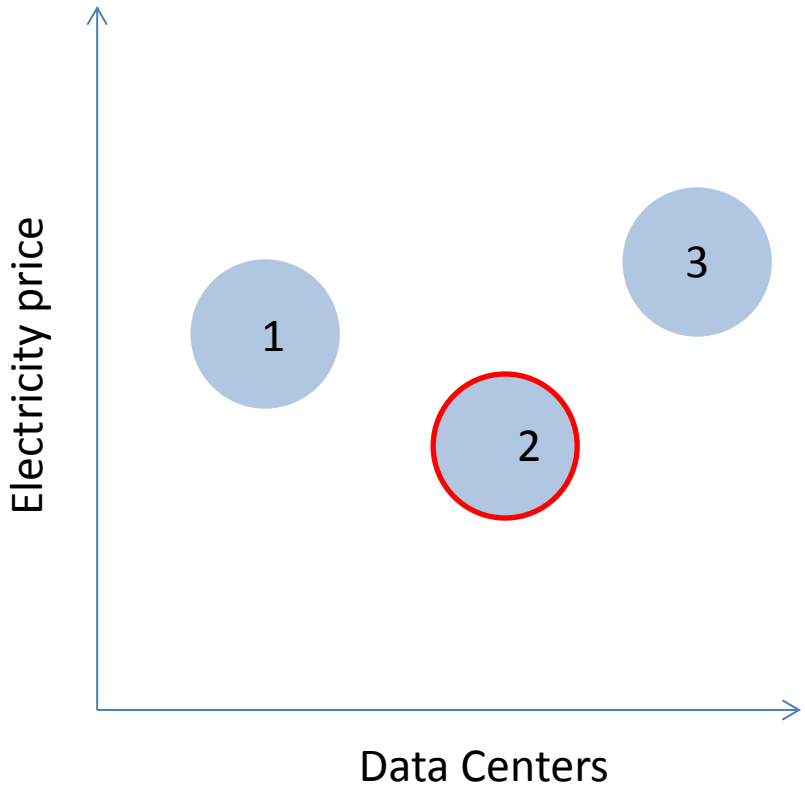

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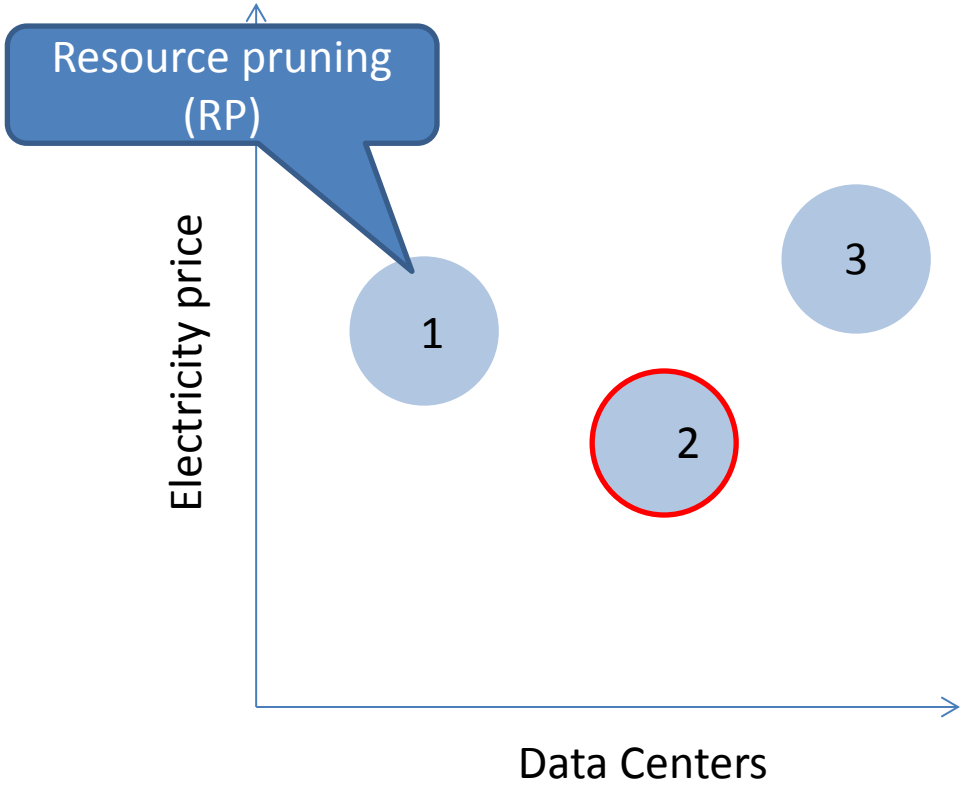

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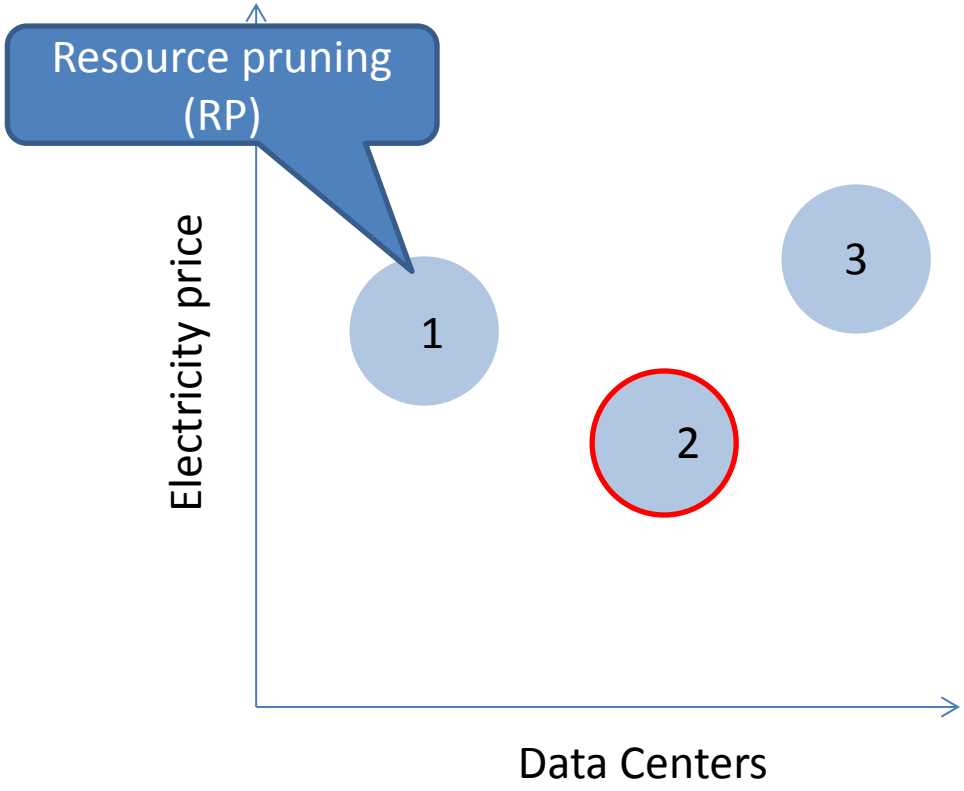


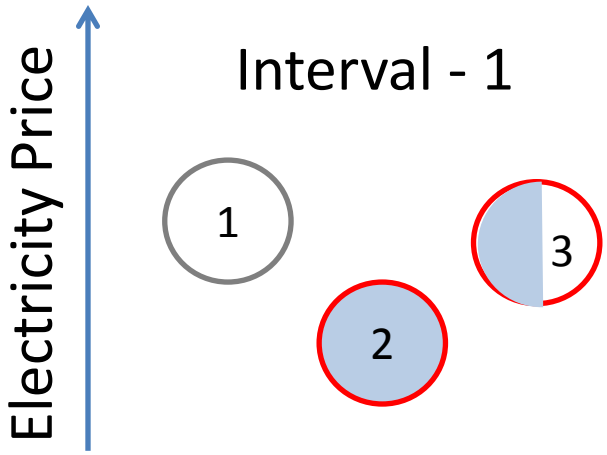
Workload relocation can help reduce electricity cost

Resource pruning can help further reduce electricity cost

This Thesis

- Cut network electricity costs by using:
  - Workload Relocation (WR)
  - Resource Pruning (RP)
- Generic – application to other networks
  - Cellular networks

Case Study I – Data Centers



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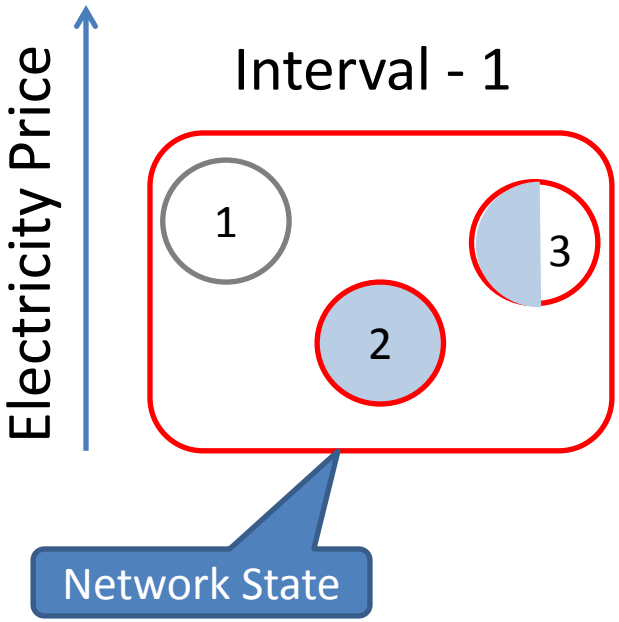

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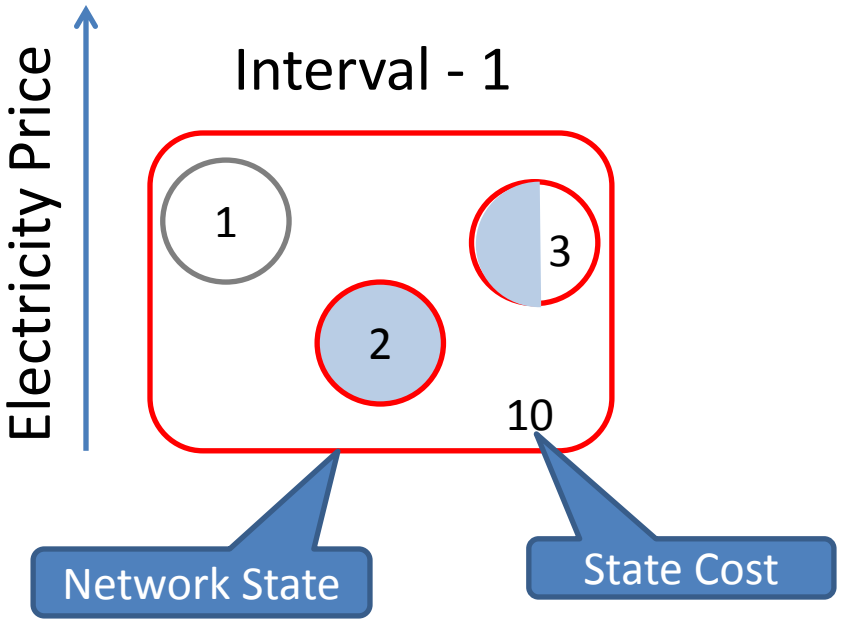

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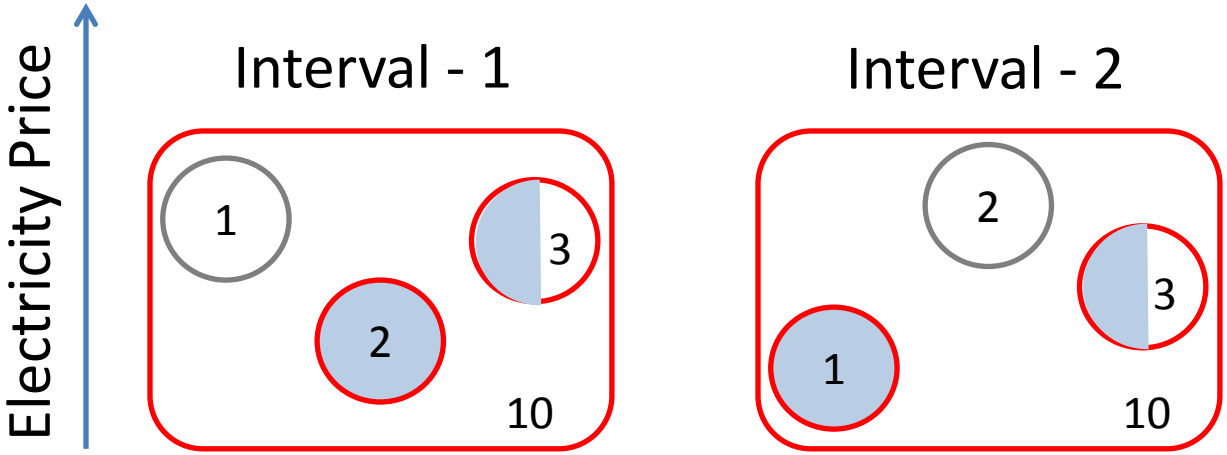

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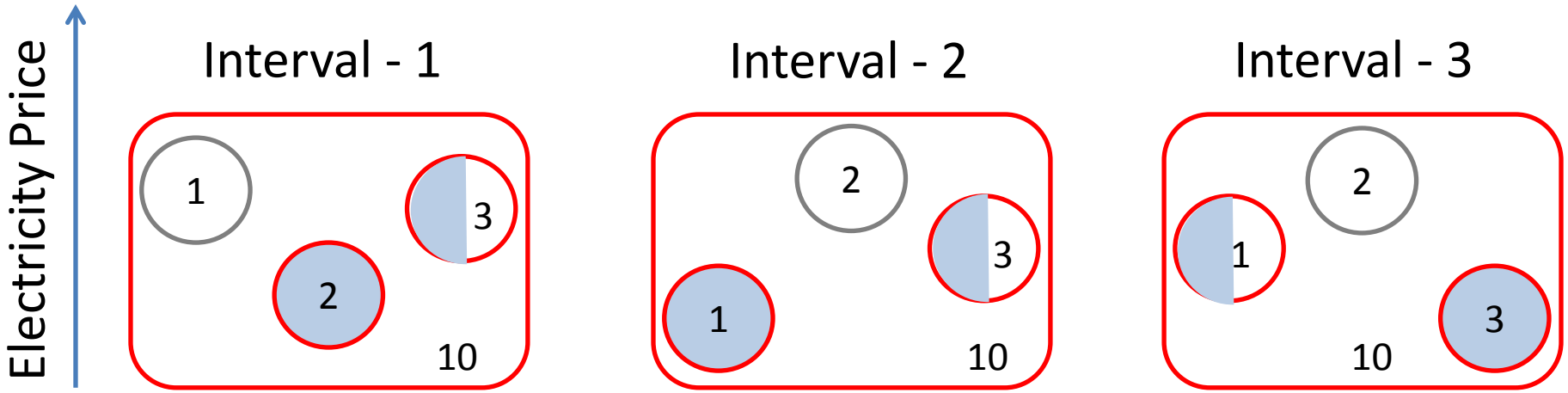

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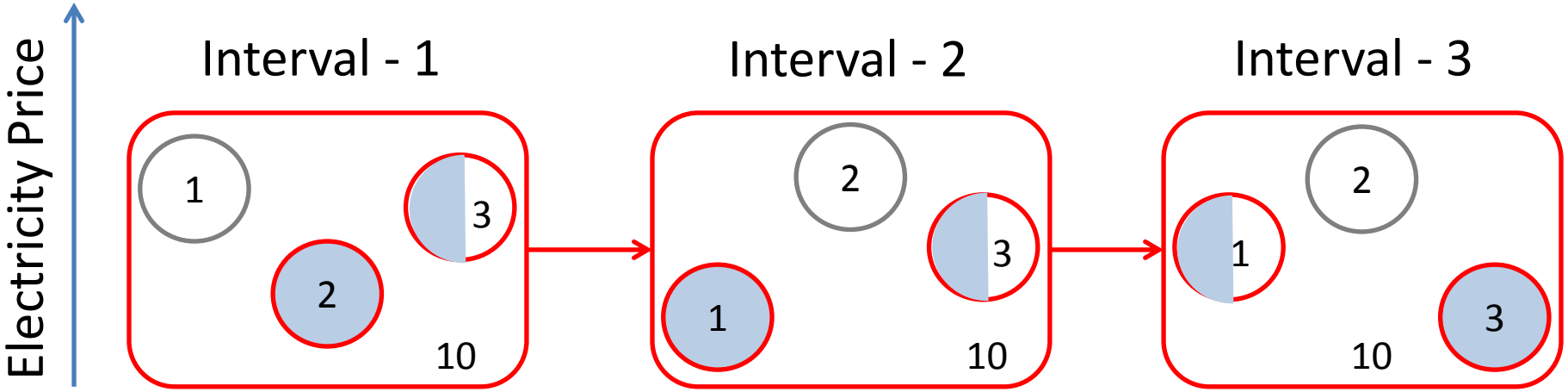

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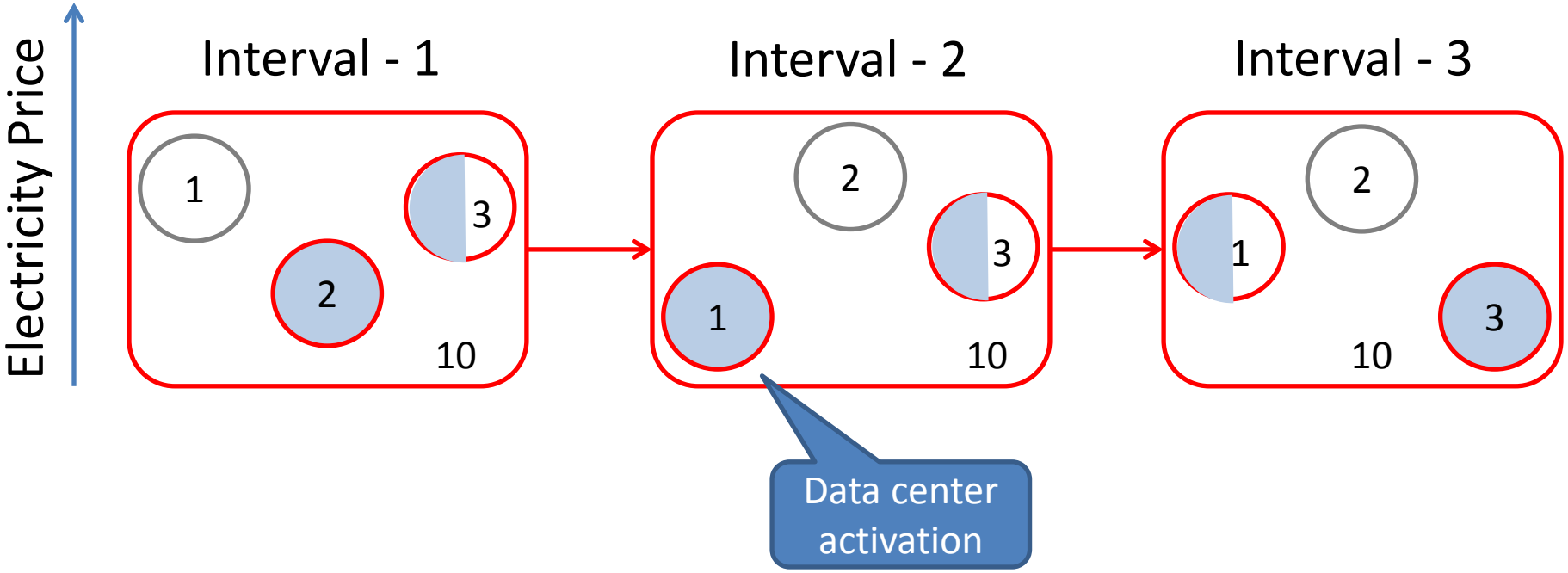

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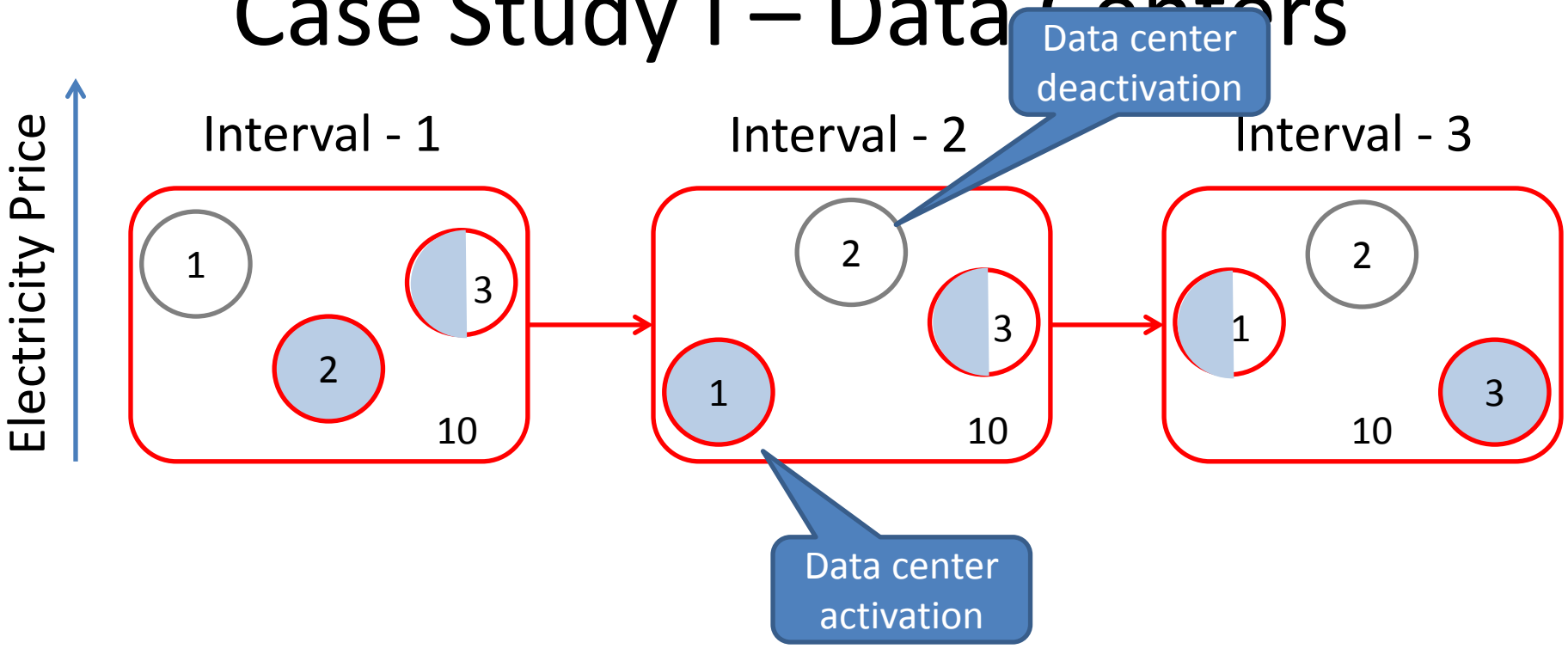

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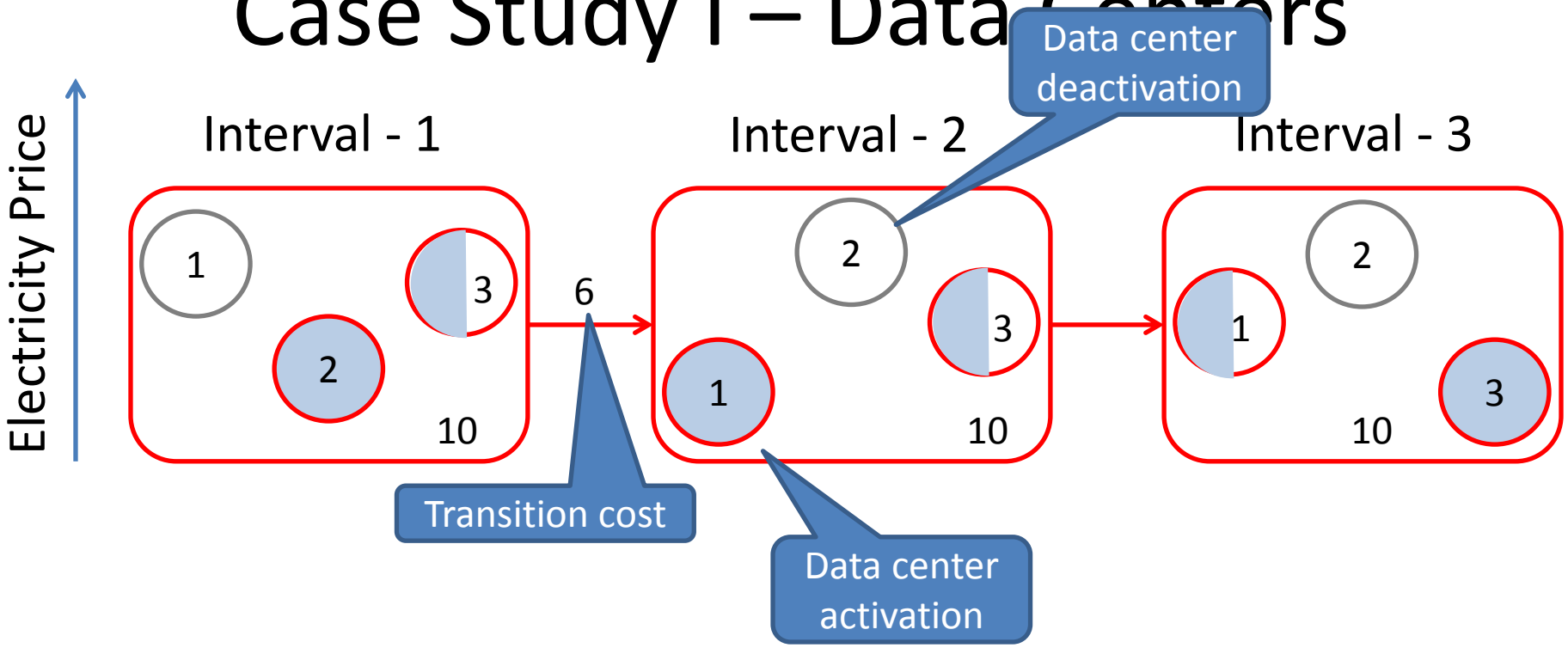

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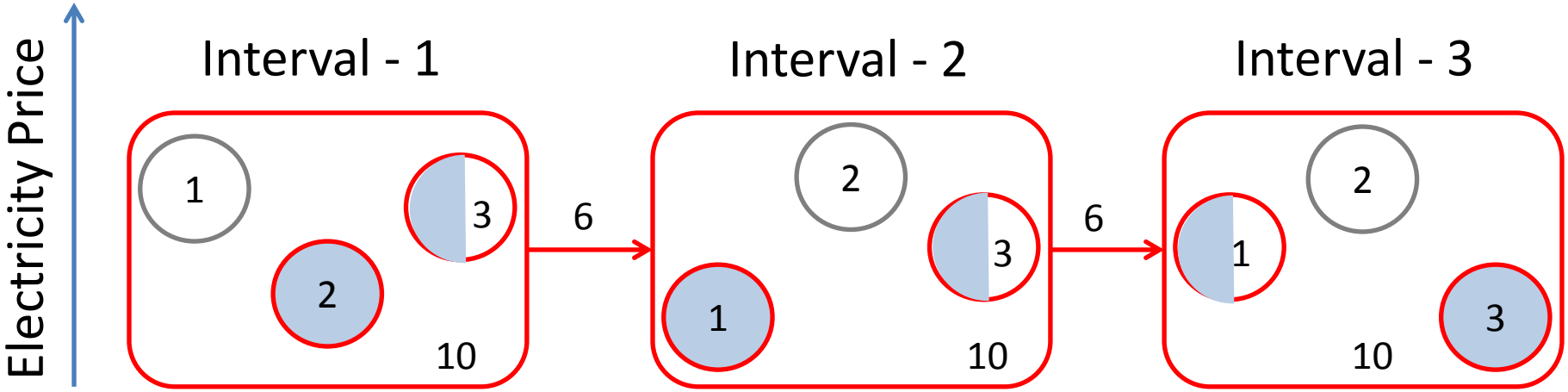

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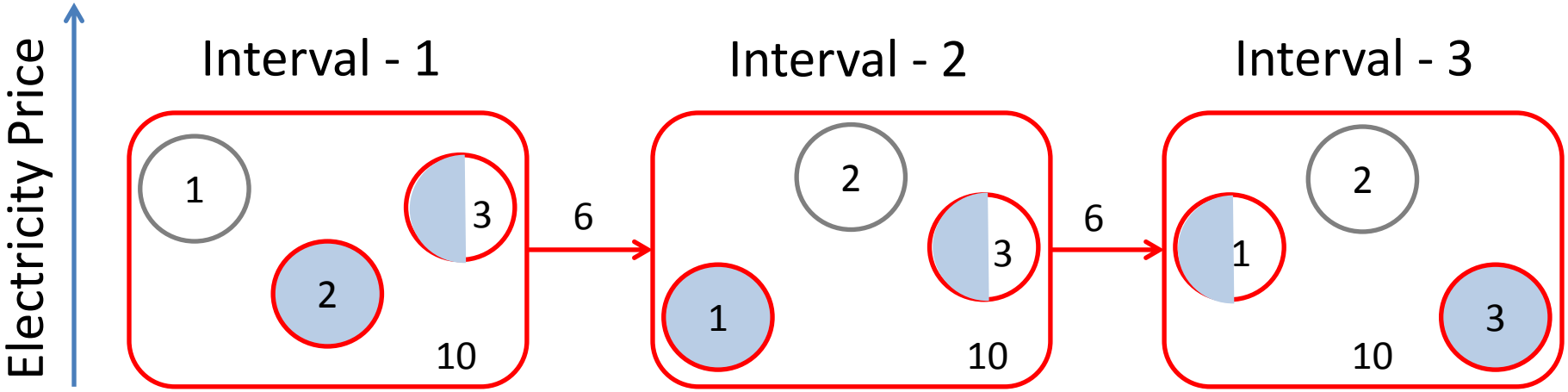
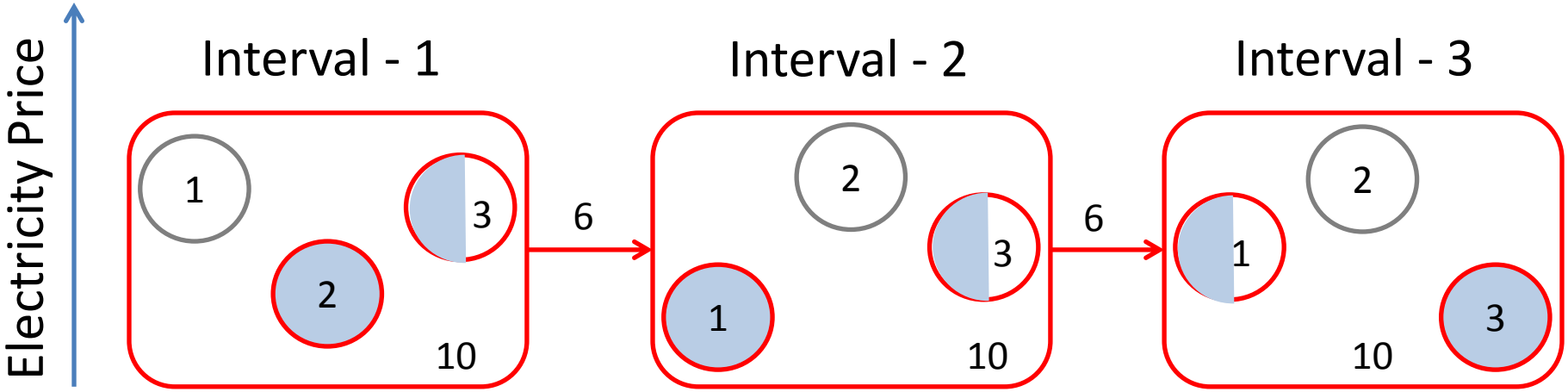


Optimal State Trajectory Problem

Case Study I – Data Centers



Optimal State Trajectory Problem

RED-CL might not be optimal

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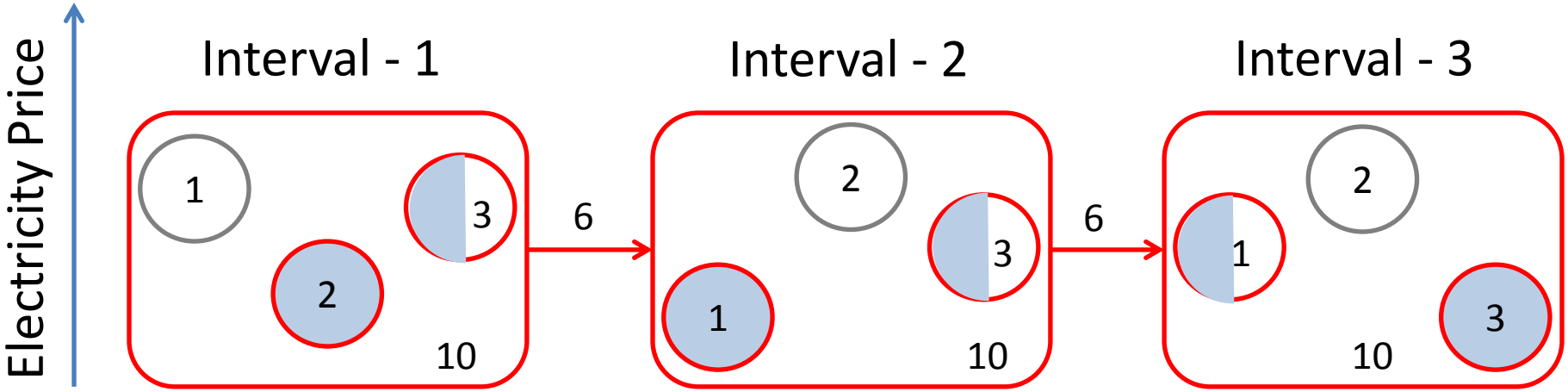

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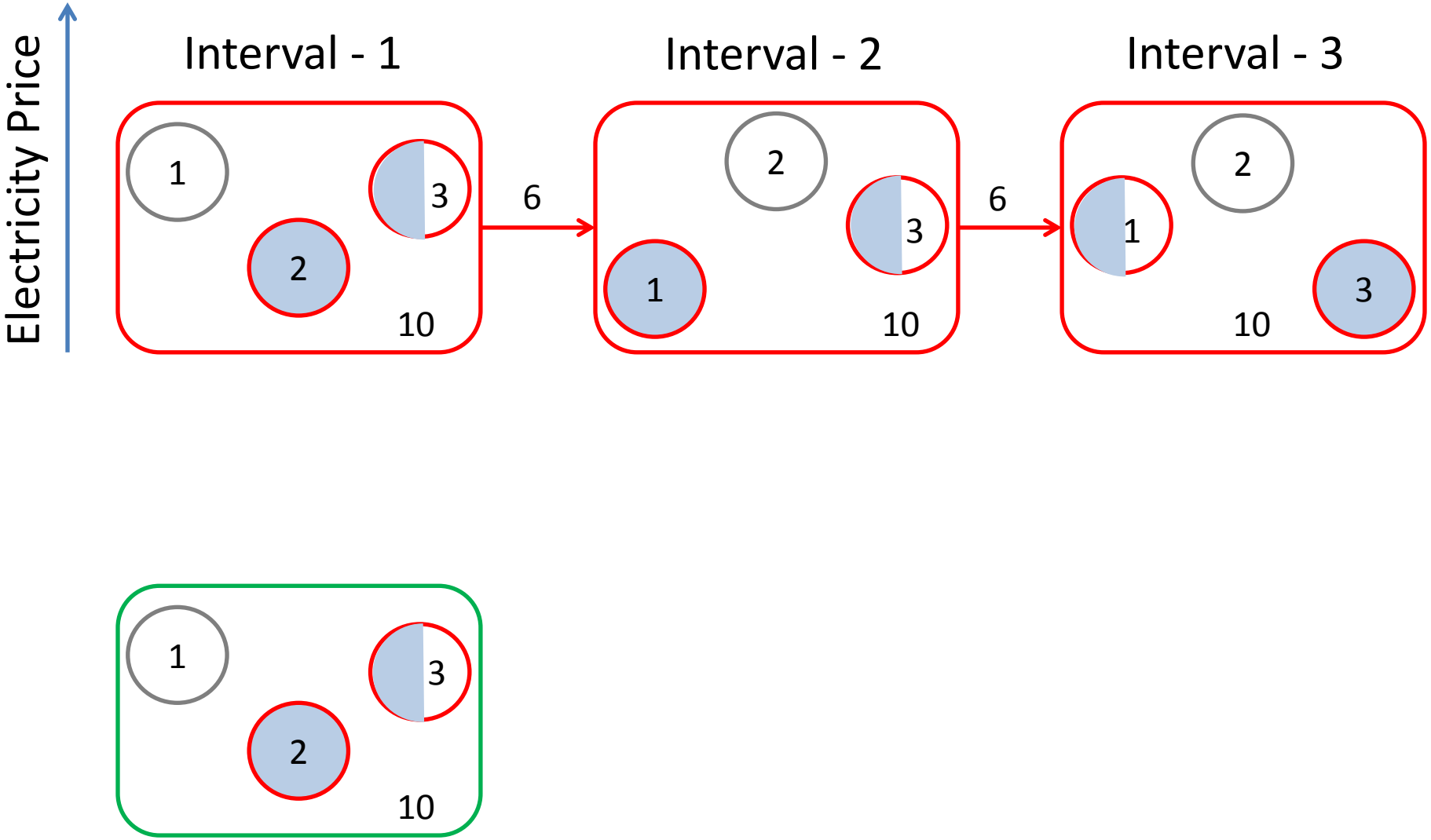

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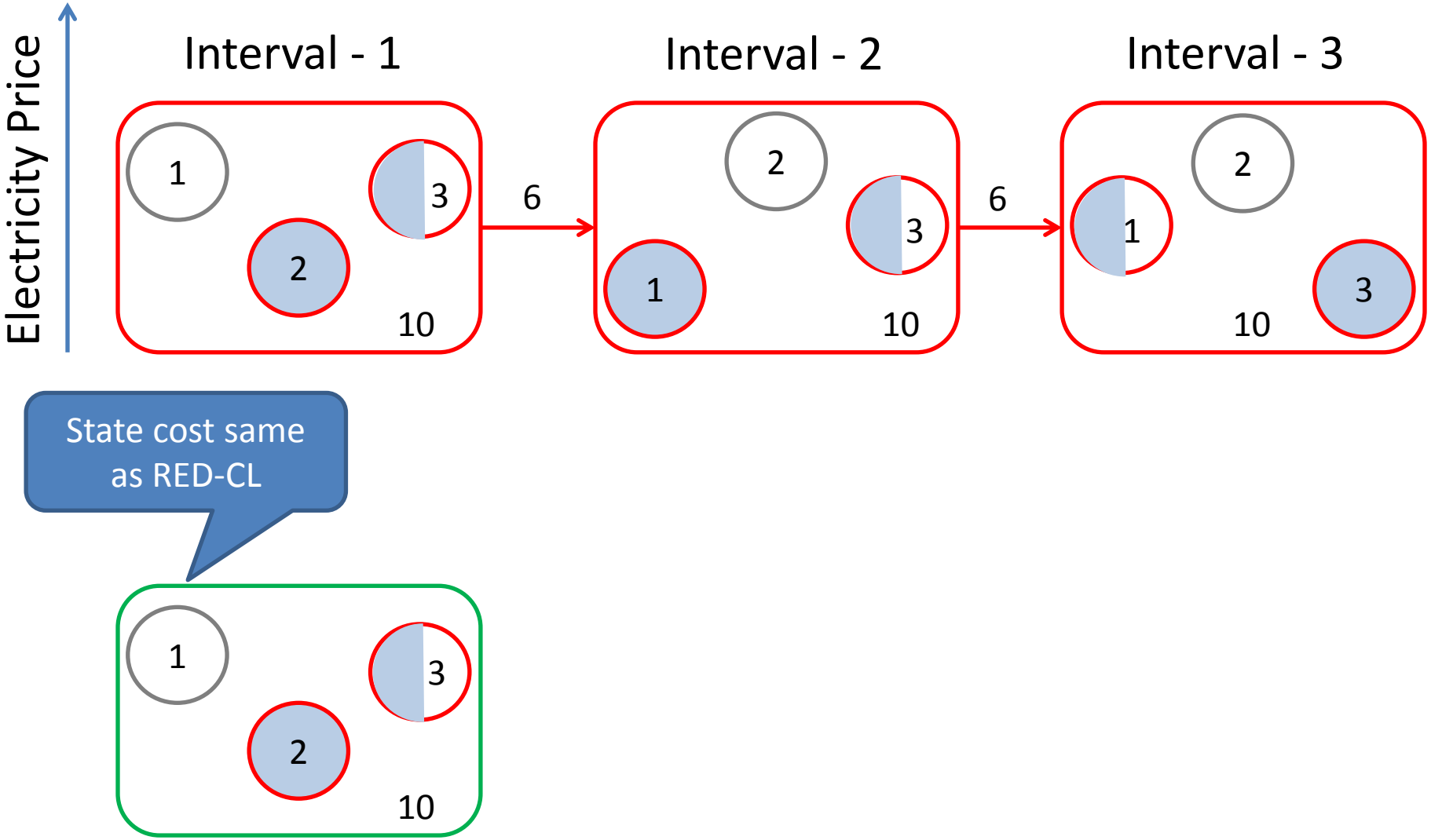

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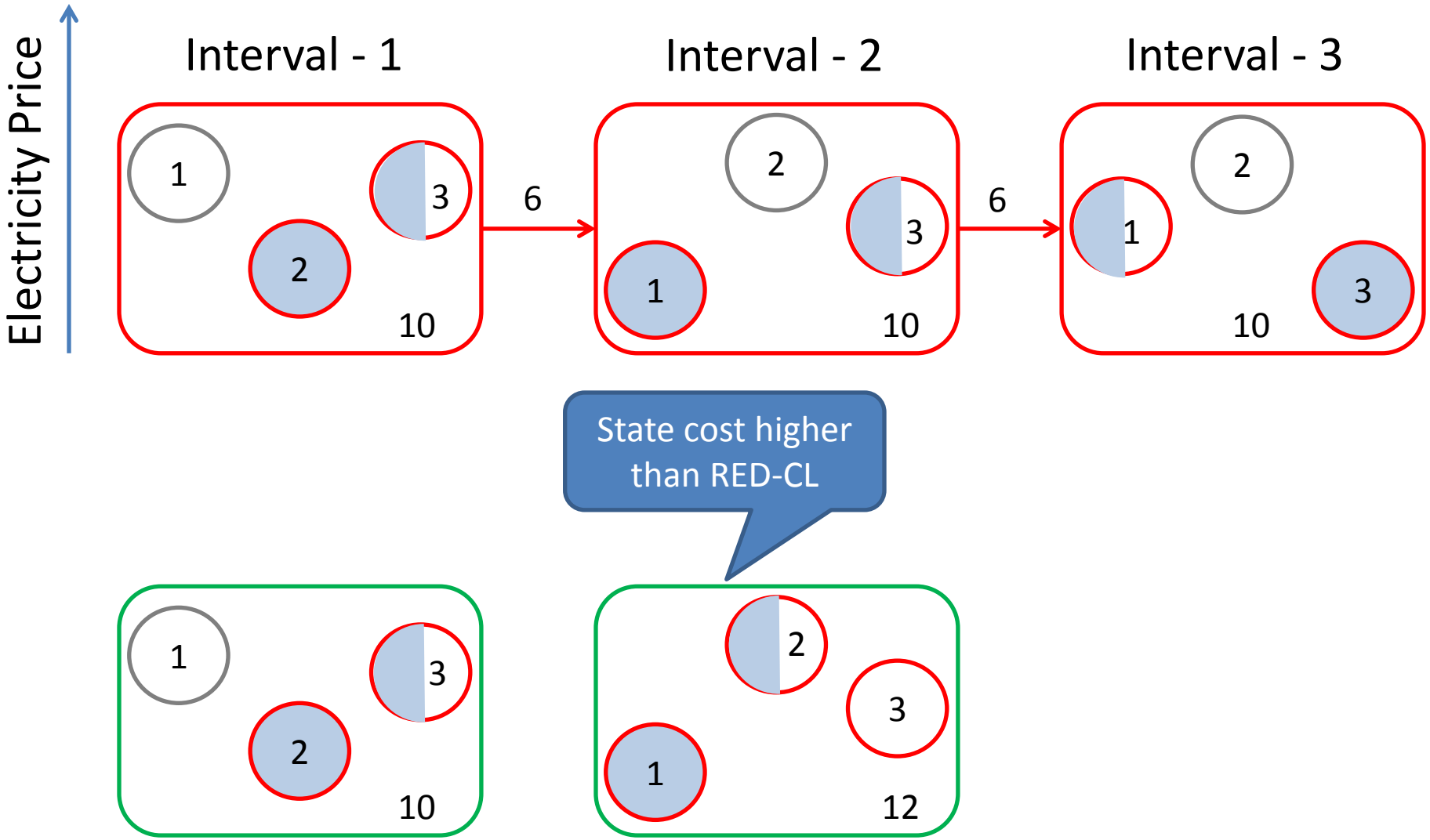

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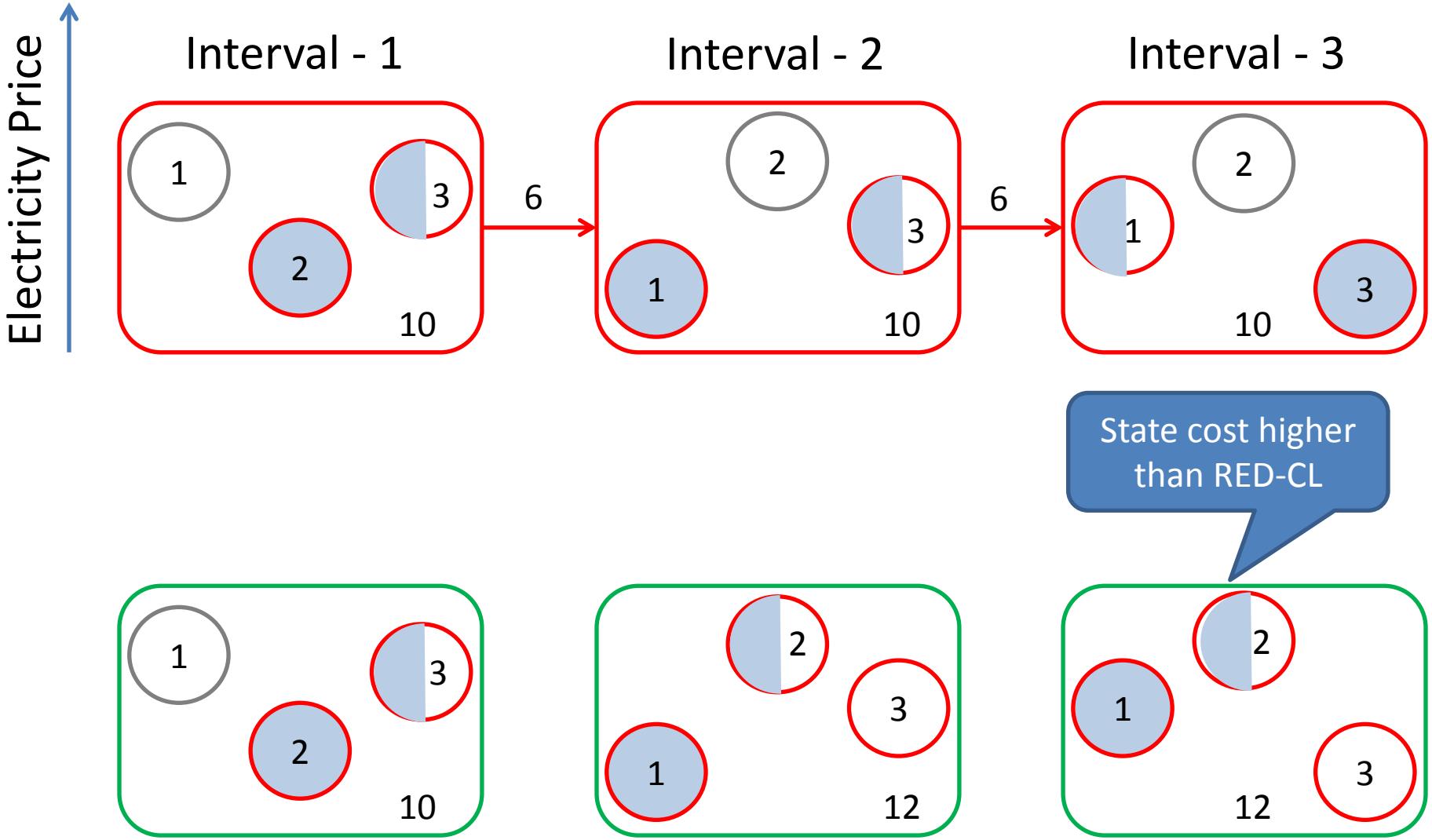

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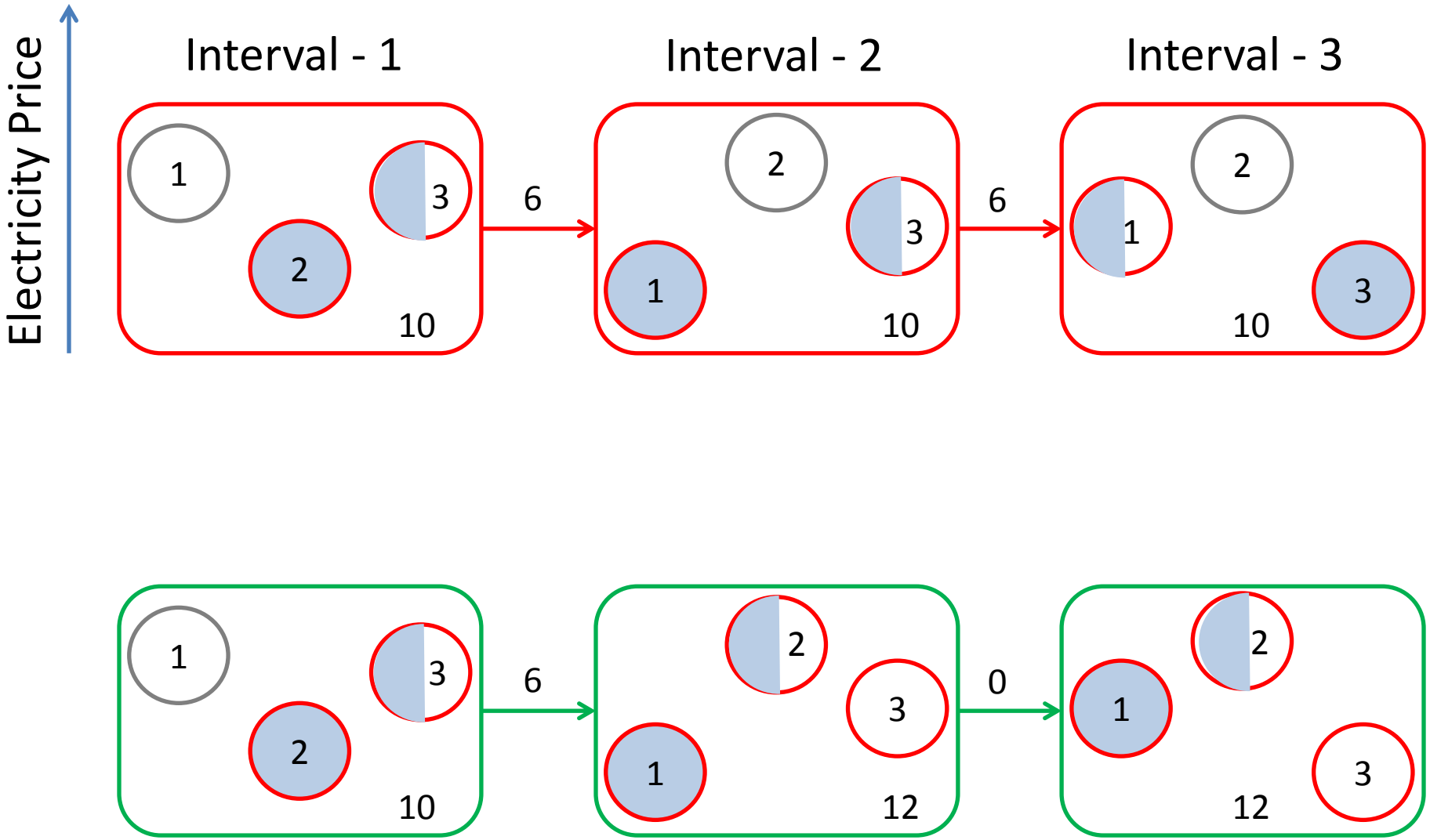

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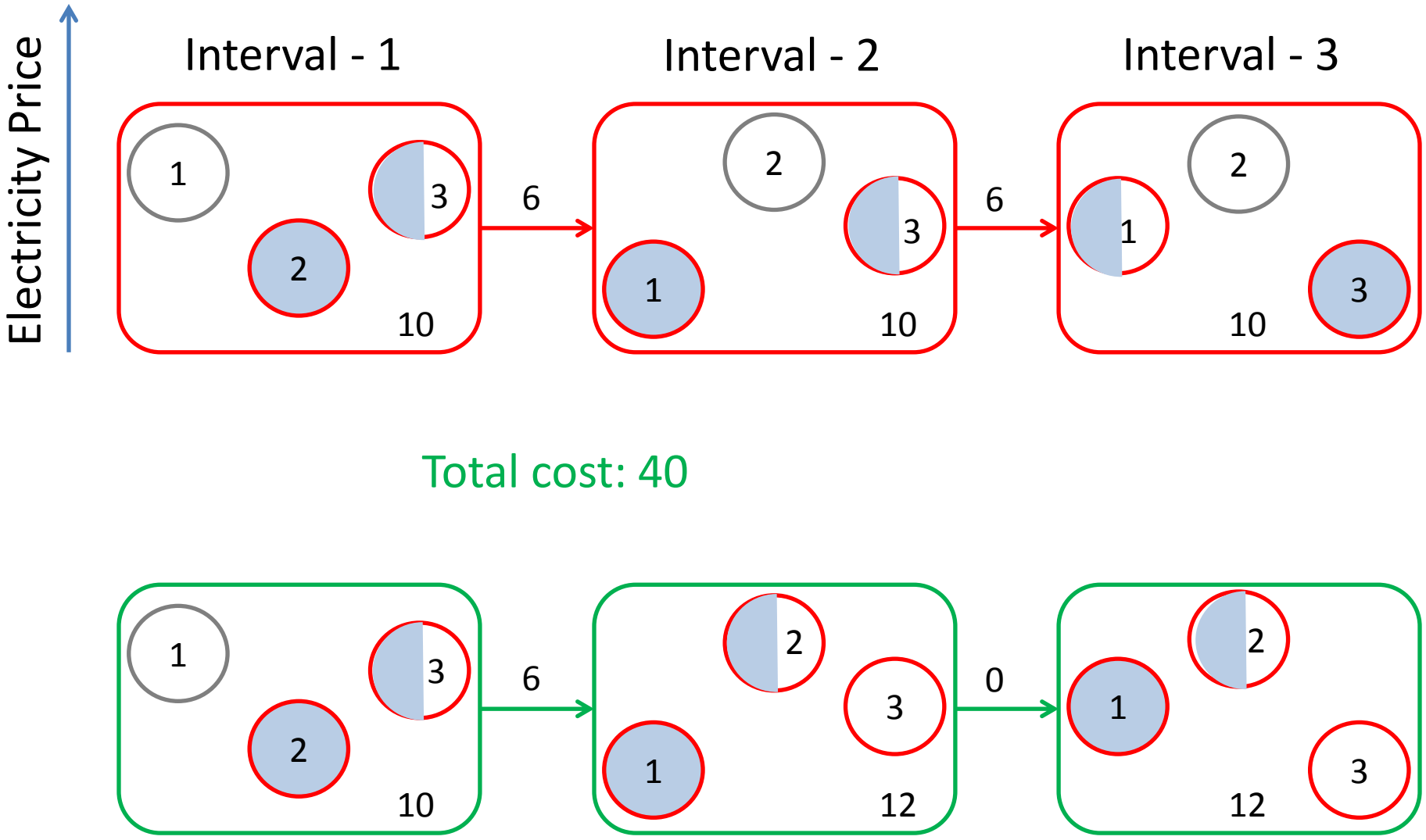

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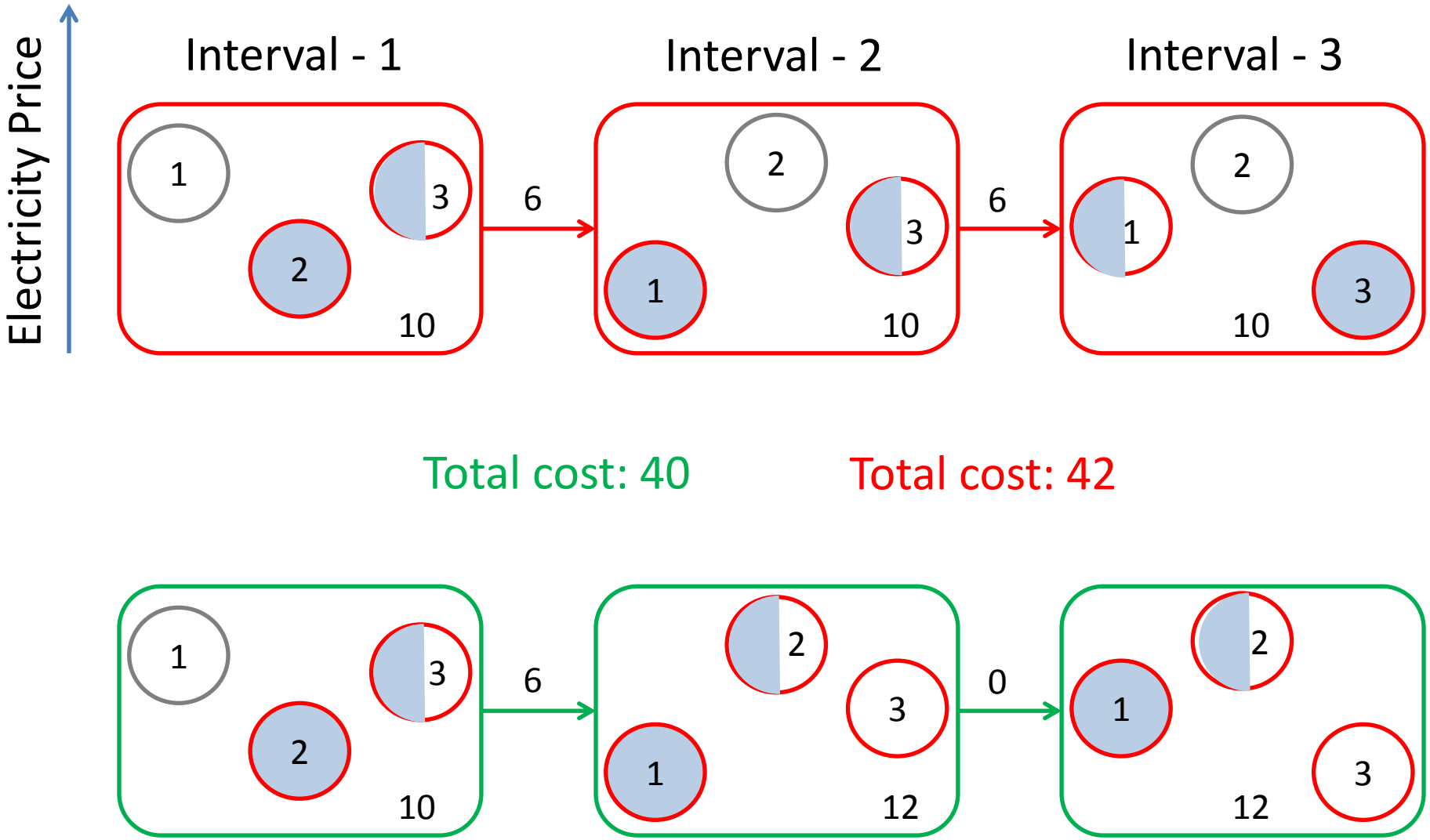

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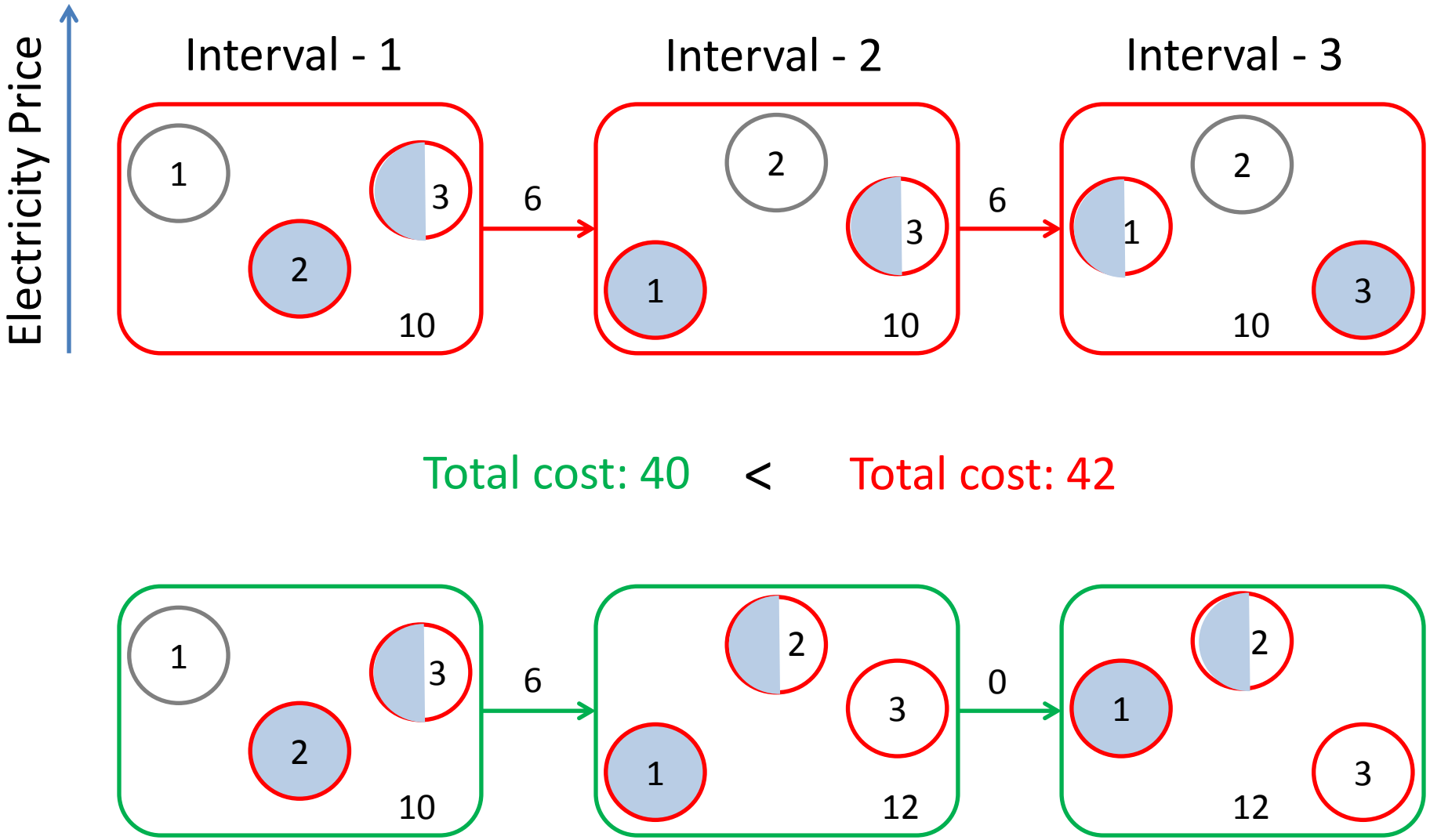

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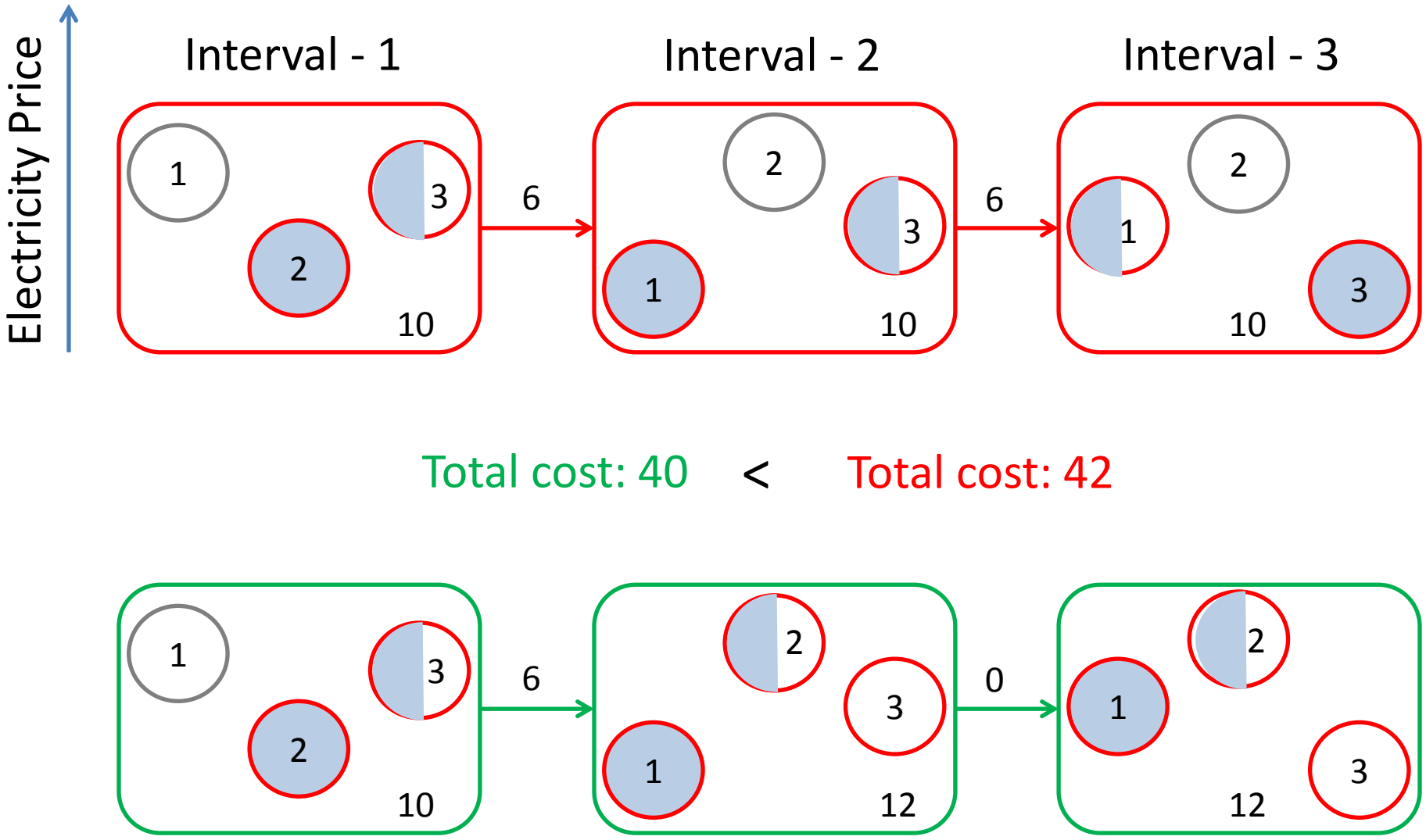


Optimization Formulation

$$\text{minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} c_i e_i^j (p_i^j \lambda (f + (1-f)\frac{x_i^j}{c_i}) + b_i^j \sigma + s_i^j \delta)$$

Optimization Formulation

Unit price of electricity

$$\text{minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} c_i e_i^j \left(p_i^j \lambda \left(f + (1-f)\frac{x_i^j}{c_i}\right) + b_i^j \sigma + s_i^j \delta\right)$$

Activation/deactivation energy

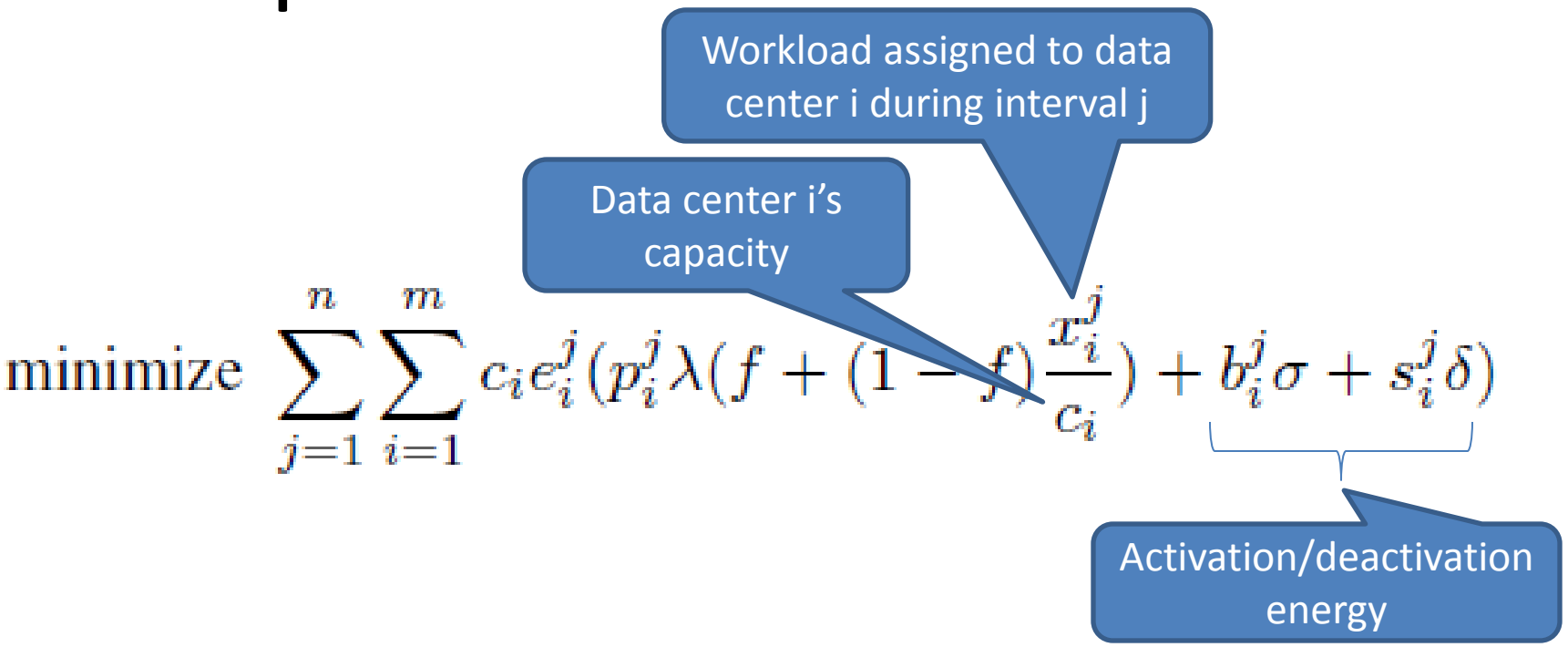
Optimization Formulation

Workload assigned to data center i during interval j

$$\text{minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} c_i e_i^j \left(p_i^j \lambda \left(f + (1-f) \frac{x_i^j}{c_i} \right) + b_i^j \sigma + s_i^j \delta \right)$$

Activation/deactivation energy

Optimization Formulation



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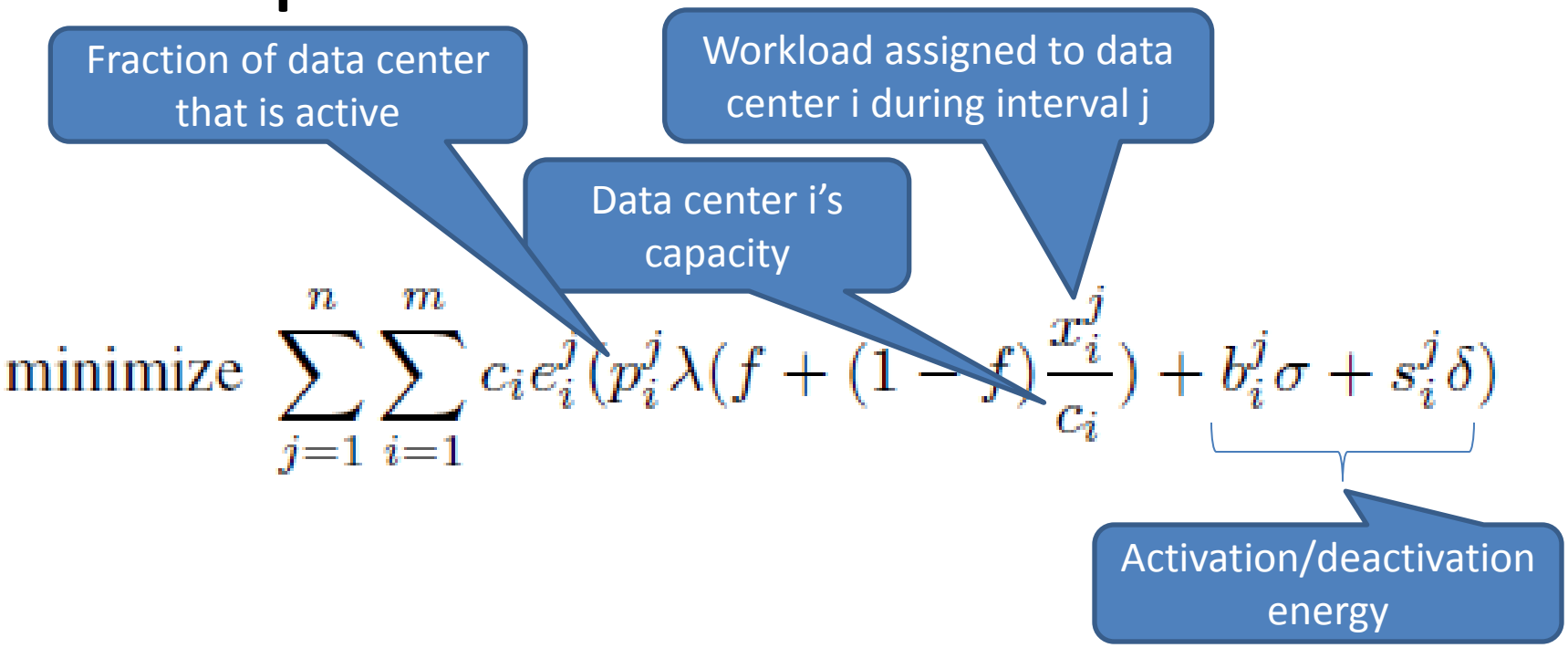

Optimization Formulation

$$\text{minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} c_i e_i^j \left(\underbrace{p_i^j \lambda \left(f + (1-f) \frac{x_i^j}{c_i} \right)}_{\text{State energy}} + \underbrace{b_i^j \sigma + s_i^j \delta}_{\text{Activation/deactivation energy}} \right)$$

Optimization Formulation

$$\text{minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} c_i e_i^j \left(p_i^j \lambda \left(f + (1-f) \frac{x_i^j}{c_i} \right) + b_i^j \sigma + s_i^j \delta \right)$$

Sum over all data centers

State energy

Activation/deactivation energy

Optimization Formulation

$$\text{minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} c_i e_i^j \left(p_i^j \lambda \left(f + (1-f) \frac{x_i^j}{c_i} \right) + b_i^j \sigma + s_i^j \delta \right)$$

Sum over all intervals

Sum over all data centers

State energy

Activation/deactivation energy

Subject to several constraints (please see the thesis)

Future Work

- Factor in other forms of transition costs:
  - Cost of change in latency
  - Cost of replication
  - Cost of increase in call blocking probability
- Implementation on software BTS
- Adaptation to recent generations of cellular networks