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Beyond Hosting Capacity: Using Shortest Path Methods to Minimize Upgrade Cost Pathways

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Problem description and formulation

Shortest Path Tool

Algorithm

Results

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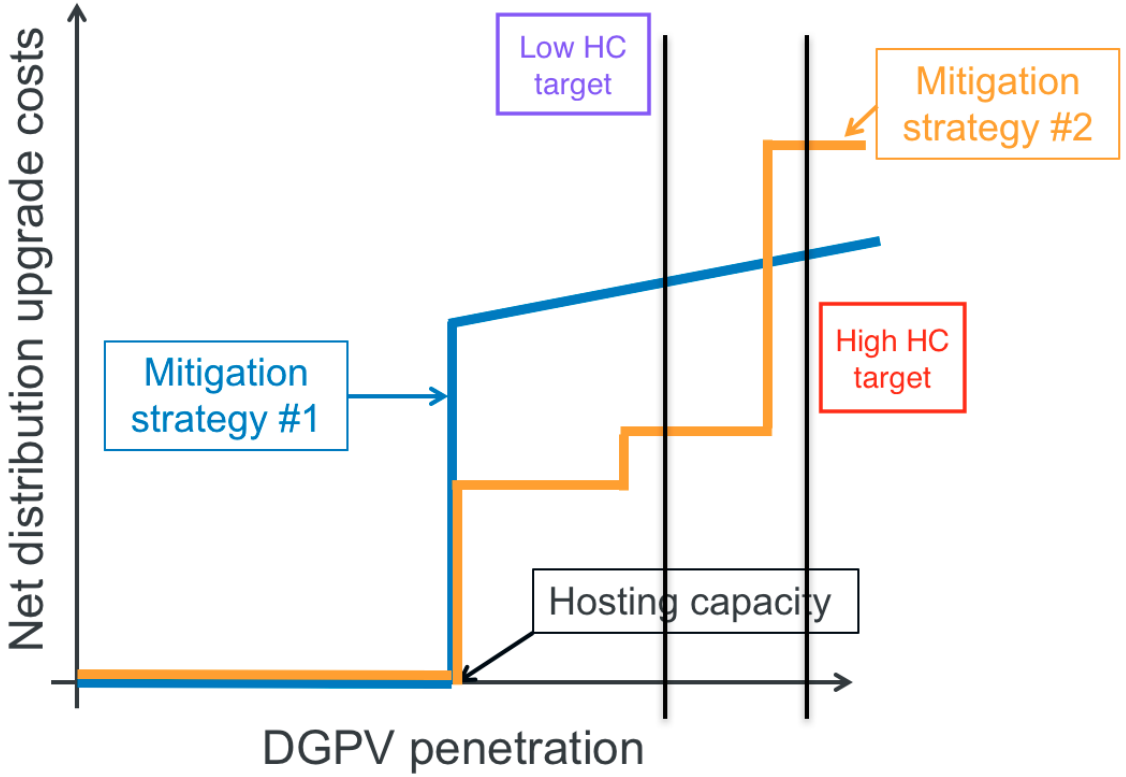
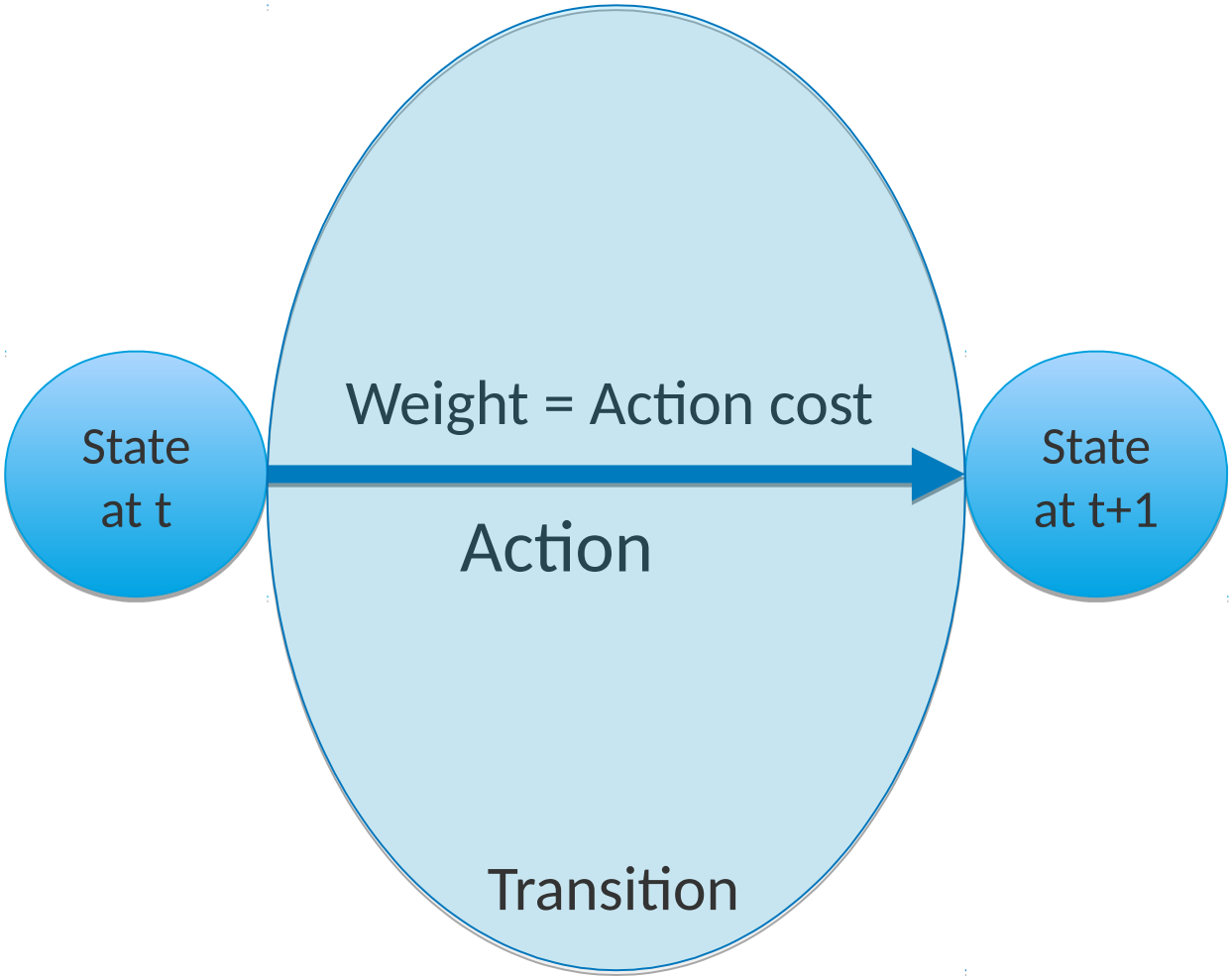
Target Hosting Capacity (THC) Options Beyond Hosting Capacity

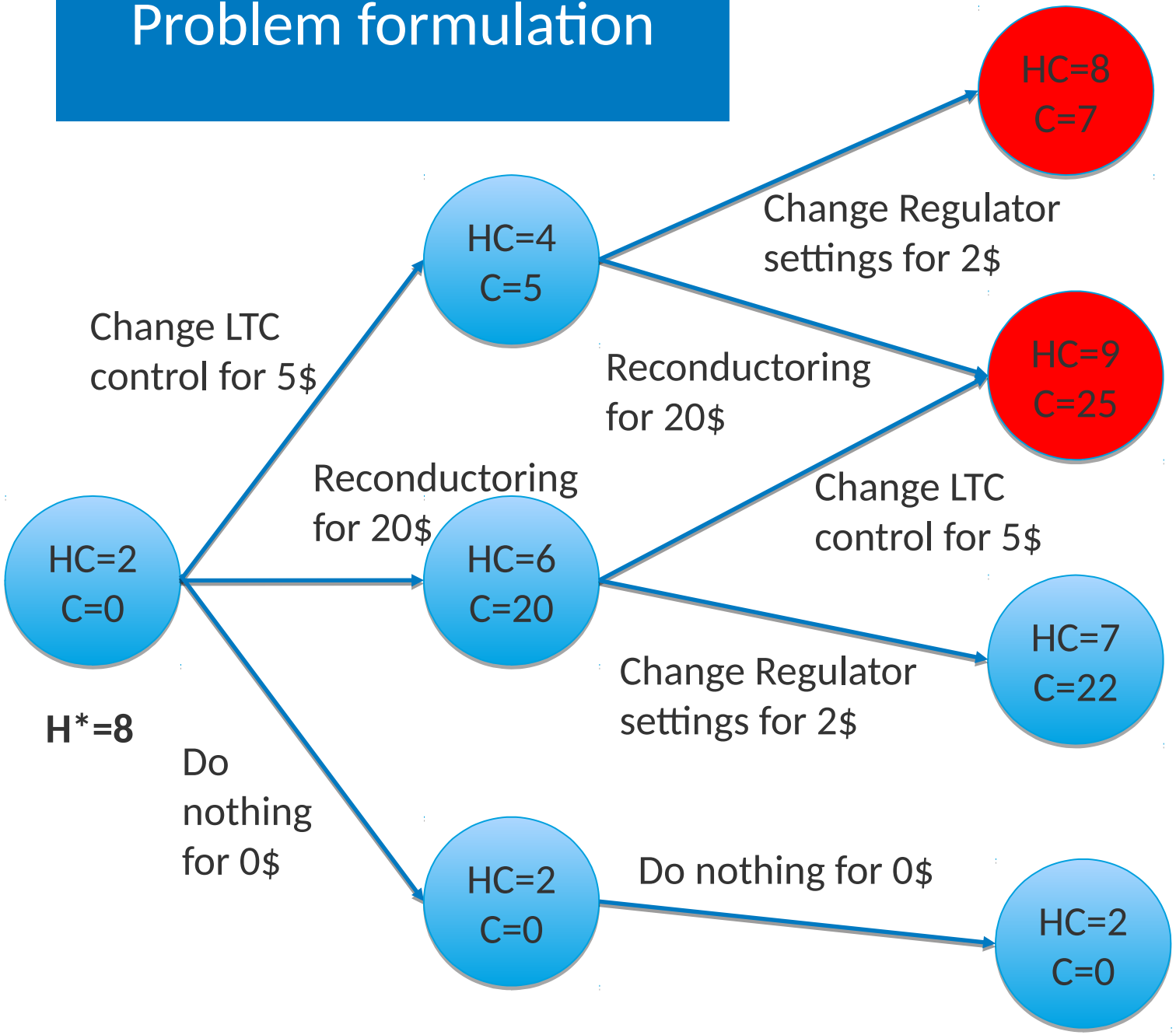
- **HC**: Hosting Capacity
- **THC**: Target HC
- **Goal**: Find the "best" sequence of system upgrades to reach a target HC
- Best = Cheapest
- Proactive vs. reactive approach



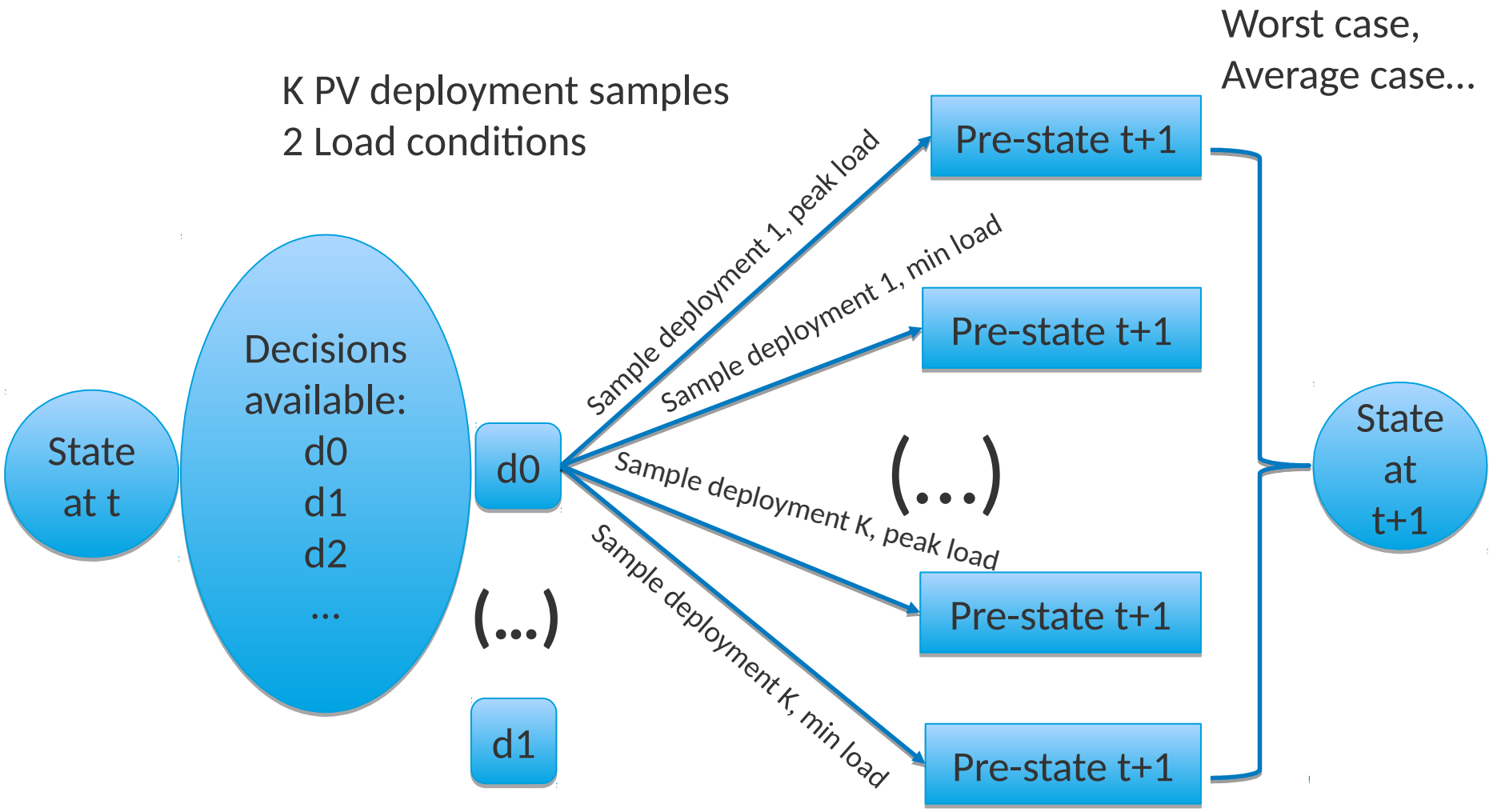
Problem formulation



Problem formulation



Transition Model



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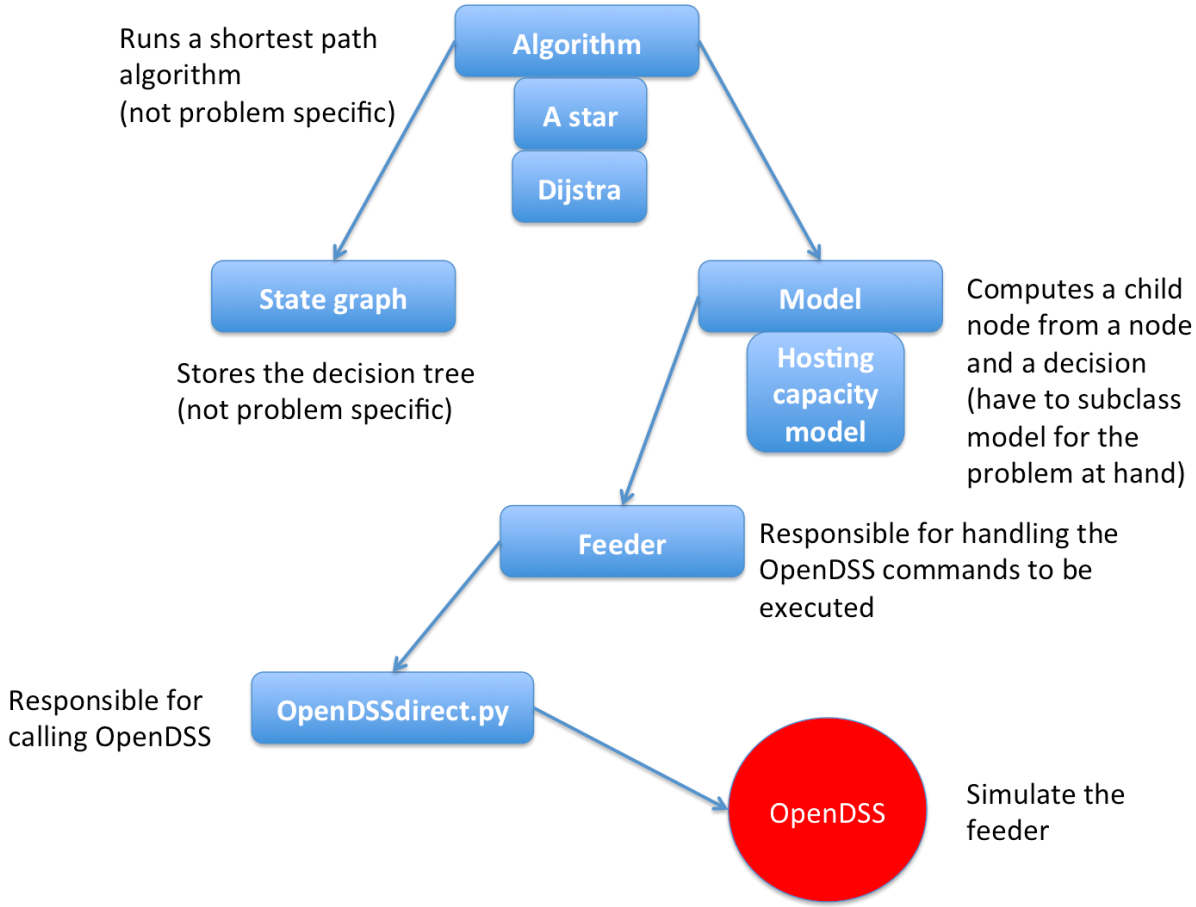
Shortest Path Tool

- Written in Python
- OpenDSS for co-simulation
- Generic components
- Cross-platform
- Still early development stage



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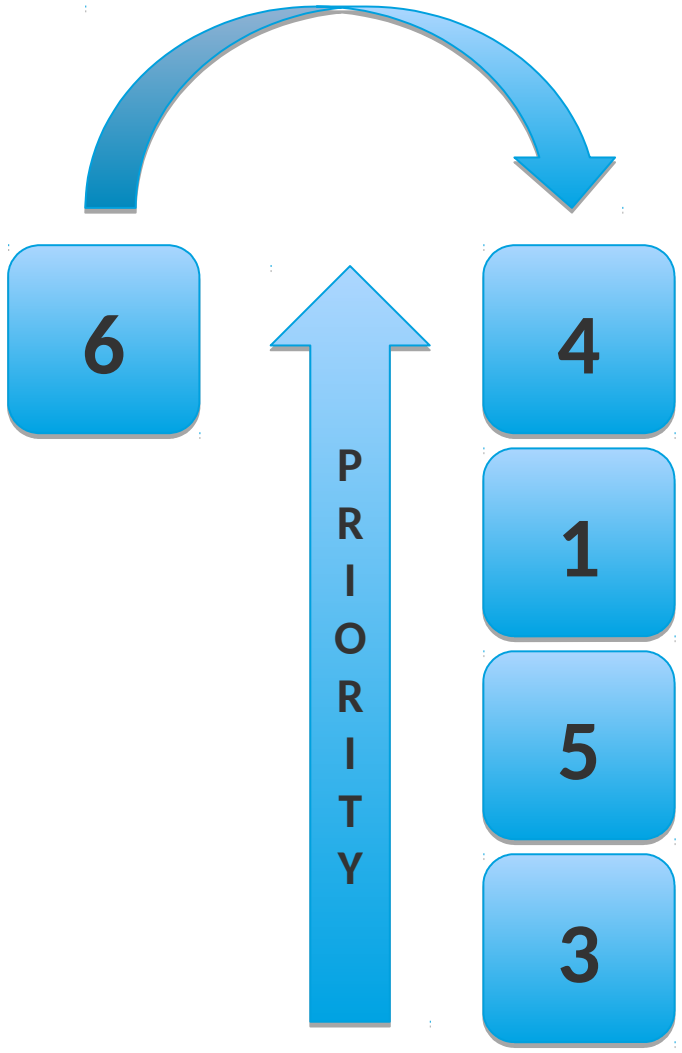
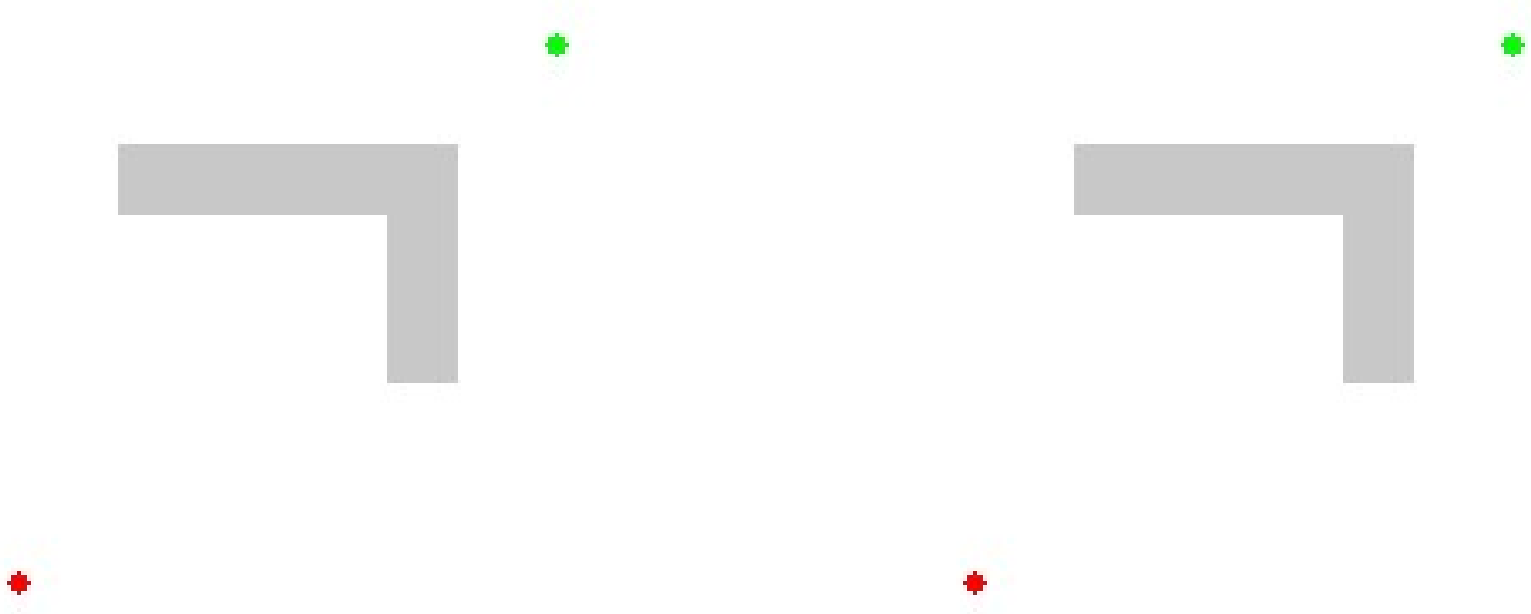
Shortest Path Tool

- Stack of nodes to expand
- Expand: Compute all child nodes
- **How to insert new nodes in the stack?**
- Ranking function F = C + U
- C: Cost to get to the node
- U: Heuristic cost to go to the destination from the node
- Famous examples: **Dijstra** and **A***

$$U(s_k) = (H^\star - H_{s_k}) \frac{C(s_k)}{H_{s_k} - H_0}$$

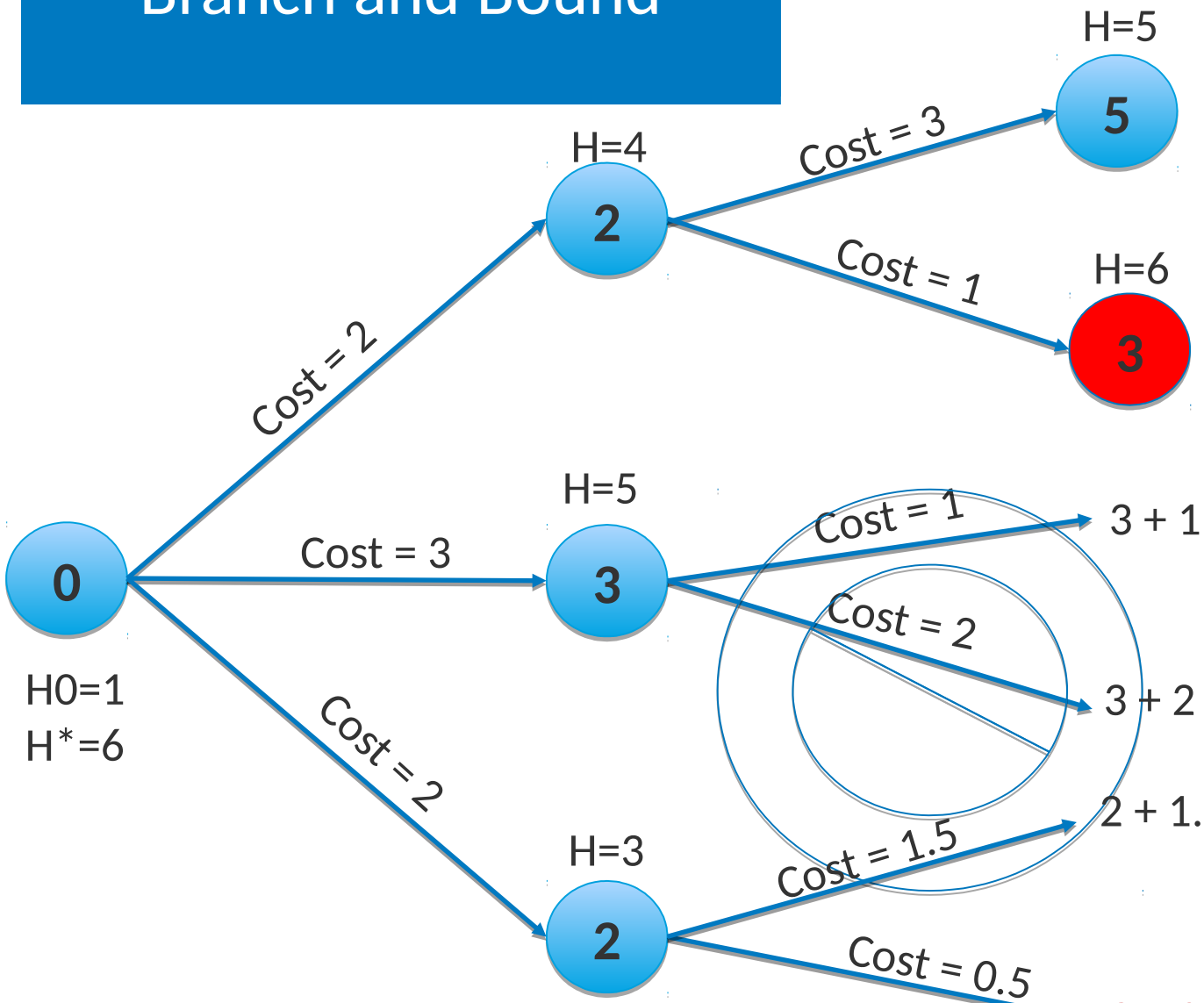


Dijstra (left) A* (right)



Source: Wikipedia

Branch and Bound



Solution node with a cost of 3

These decisions can be removed

But this one has to be evaluated…

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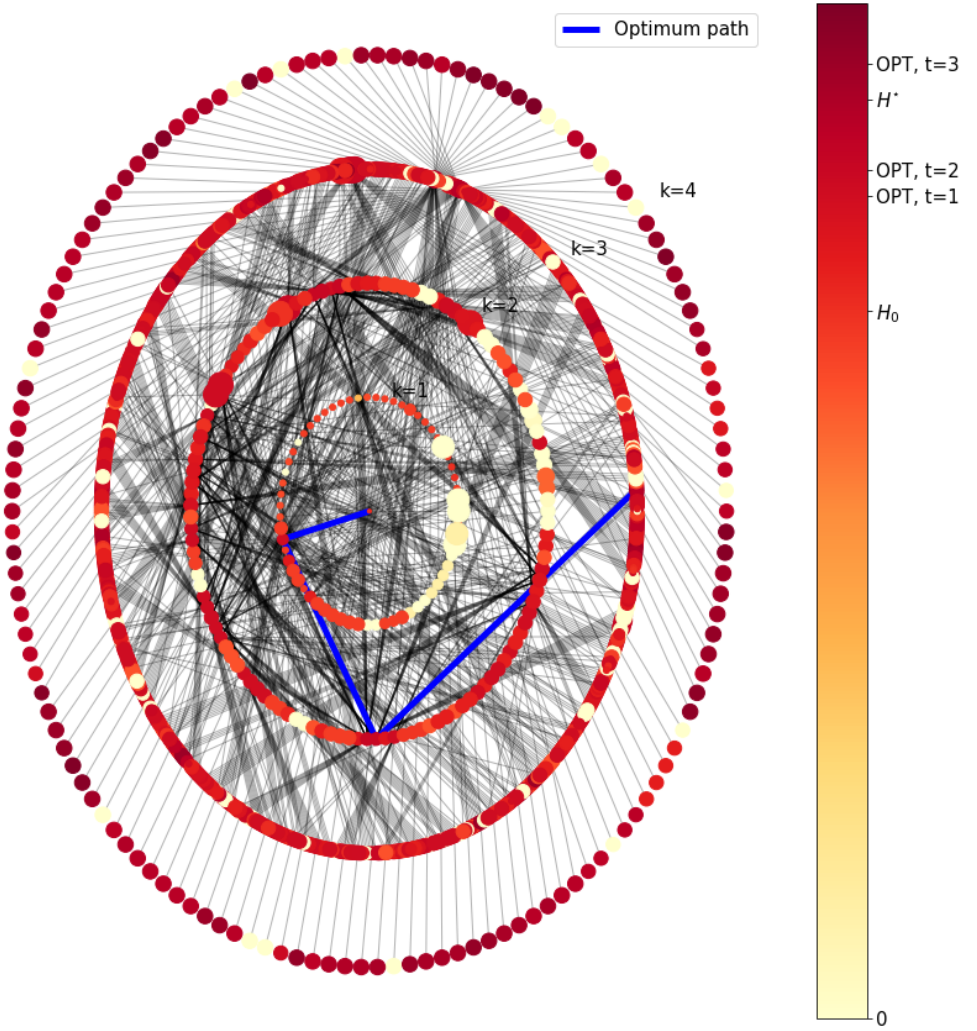
Decisions and costs

• Change the setpoints of existing regulators ……	$2.5k/unit
• Change the setpoints of existing cap. Banks……	$7.2k/unit
• Change the LTC control settings ……..	$8k/unit
• Add new capacitor banks	
– 600 kvar……..	$11k/unit
– 900 kvar……..	$14k/unit
– 1200 kvar……..	$32k/unit
• Add new regulator ……..	$55k/unit
• Remove existing capacitor……..	$3k/unit

K. Horowitz, "Distribution system upgrade unit cost database," National Renewable Energy Laboratory, Tech. Rep., 2017. [Online]. Available: https://www.nrel.gov/solar/distribution-grid-integration-unit-cost-database.html

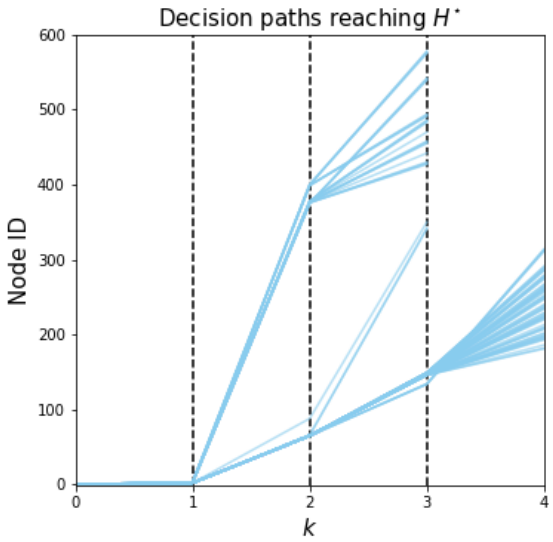
Results

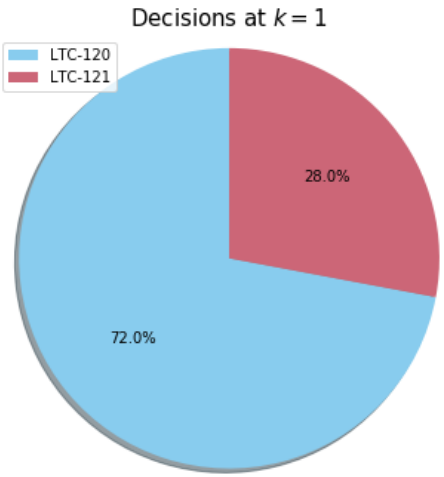
- EPRI J1 Feeder
- Decision set: 63 possibilities
- OPT path ($13k):
  - 1. LTC setpoint change
  - 2. Reg setpoint change
  - 3. Reg setpoint change
- Only 1195 nodes (0.0075%)

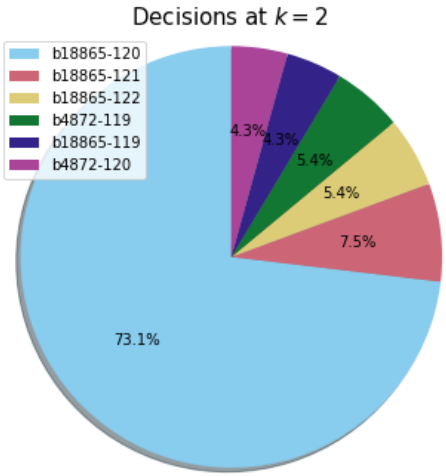


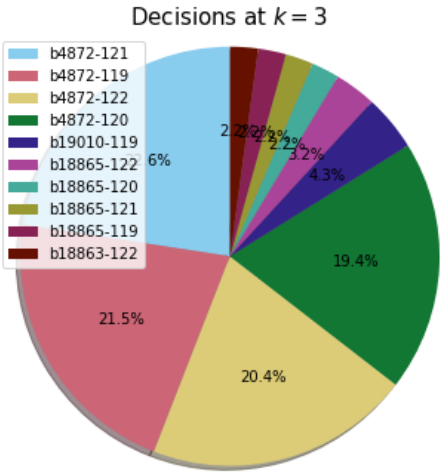
Results

- All decisions at k=1 are LTC
- All decisions after are Reg setpoint modifications
- Diversity increases with k
- First decision is expensive: greedy cost minimizing will fail here









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