Slicing in 5G networks

Update 15/09/2020

Alessandro Spallina

A slice simulator with MDP resolution

Last Call

- Bugfix
- Support for bigger histograms
- Support for bigger queue
- Support for servers > 1
- Conservative agent (always use the maximum of available servers)
- New plots: jobs in the system, active servers, policy table, histograms
- New cost formulation: $\mathbf{alpha * C_j * j + beta * C_s * n + gamma * E[L] * C_l}$

where E[L] - expected number of lost jobs

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What's new?

- Implemented smart conservative agent

Figure: smart conservative policy (0 - do nothing,
1 - allocate one server
2 - deallocate one server)

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	0	2	2	2	2	2
1 jobs	1	0	2	2	2	2
2 jobs	1	1	0	2	2	2
3 jobs	1	1	1	0	2	2
4 jobs	1	1	1	1	0	2
5 jobs	1	1	1	1	1	0
6 jobs	1	1	1	1	1	1
7 jobs	1	1	1	1	1	1
8 jobs	1	1	1	1	1	1

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What's new?

- Normalization of alpha, beta and gamma (sum equal to 1)
- Plots of different mdp policies (discount factor)
- Plots of costs in detail (with and without multiplying factors alpha, beta, gamma)
- Bugfix

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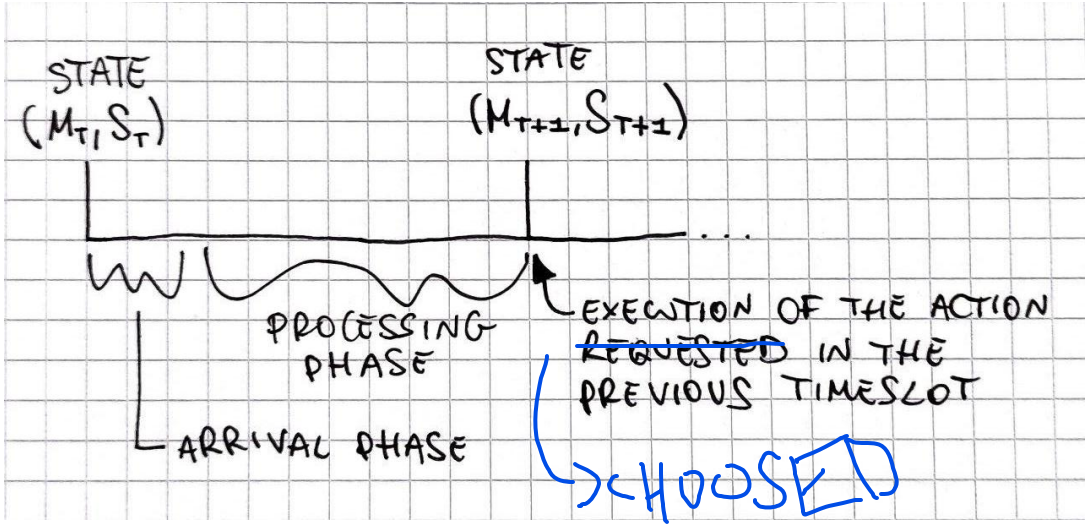
Formulation - Assumption

- The execution of the action takes place in the frontier between a timeslot and the next one
- Arrival Phase: incoming jobs are enqueued and here happens losses due the full queue
- Processing Phase: jobs in queue are processed



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Formulation - Transition Probability

$$Q(m_t, s_t \to m_{t+1}, s_{t+1}) = \sum_{a=[m_{t+1}-m_t]^+}^{\text{qsize}-m_t} P(\text{arr} = a) \cdot P(\text{proc} = m_t + a - m_{t+1} | a + m_t) \tag{2}$$

$$+ \sum_{a=\text{qsize}-m_t+1}^{\infty} P(\text{arr} = a) P(\text{proc} = \text{qsize} - m_{t+1} | \text{qsize}) \tag{3}$$

Where $P(\text{proc} = x|y)$ is the probability of processing x jobs given that y jobs are found in the queue the instant when the processor starts to pick jobs from the queue. Observe that

$$P(\text{proc} = x|y) = \begin{cases} H^{m_t}_{\text{departures}}(x) & \text{if } x < y \\ \sum_{x=y}^{\infty} H^{m_t}_{\text{departures}}(x) & if x \geq y \end{cases}$$

Notice that is the number of current servers s is equal to 0, then the departure histogram will be just [1., 0., ..., 0.]

(2) non full queue
(3) full queue but we have missing probabilities due the histograms

Simulation Results

Common Parameters

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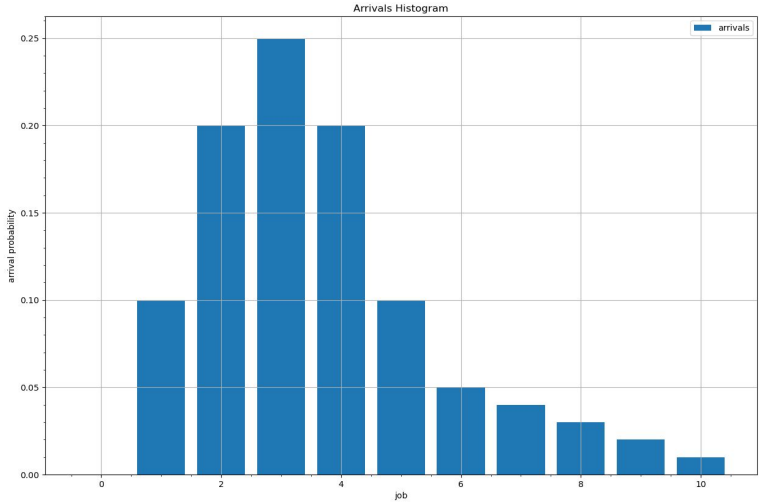
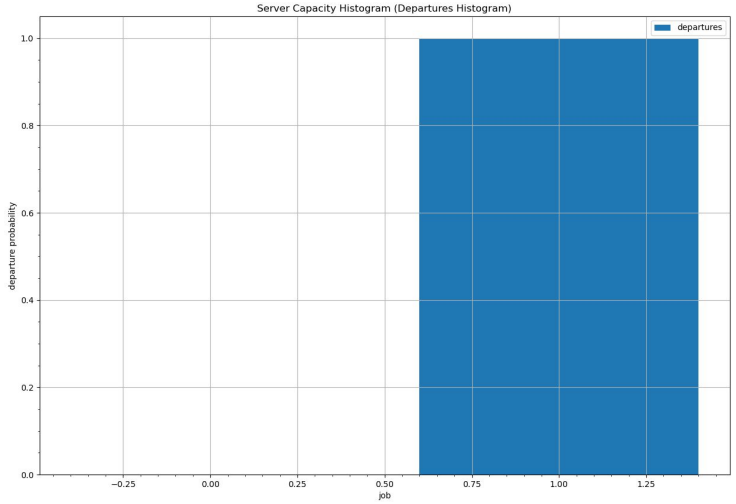
Simulation Results - Common Parameters





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Simulation Results - Common Parameters

- Queue size: 50
- Max allocated servers: 5
- C_s: 1
- C_i: 1
- C_j: 1
- Number of simulations: 10
- Simulation Time: 10k time slots
- MDP discount values: [0.8 - 0.99999]

Scenario 1

Alpha, Beta and Gamma equal to 1 (-> 0.3333)

Remember: Costs = alpha * C_j * j + beta * C_s * n + gamma * E[L] * C_l

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Simulation Results - Scenario 1: Alpha, Beta and Gamma equal to 1

Discount value 0.8

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	0	2
1 jobs	1	1	1	1	0	2
2 jobs	1	1	1	1	1	2
3 jobs	1	1	1	1	1	0
4 jobs	1	1	1	1	1	0
5 jobs	1	1	1	1	1	0
6 jobs	1	1	1	1	1	0

0.9

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
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5 jobs	1	1	1	1	1	0
6 jobs	1	1	1	1	1	0
7 jobs	1	1	1	1	1	0
8 jobs	1	1	1	1	1	0

0.99999999999999

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	1	2
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2 jobs	1	1	1	1	1	0
3 jobs	1	1	1	1	1	0
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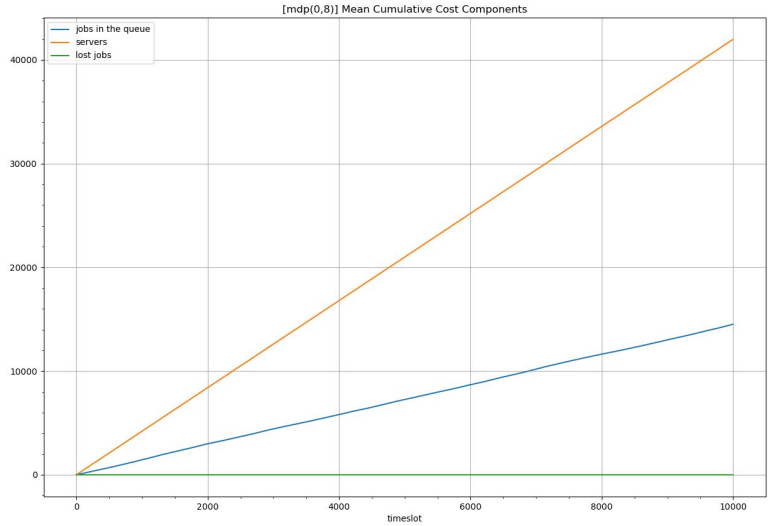
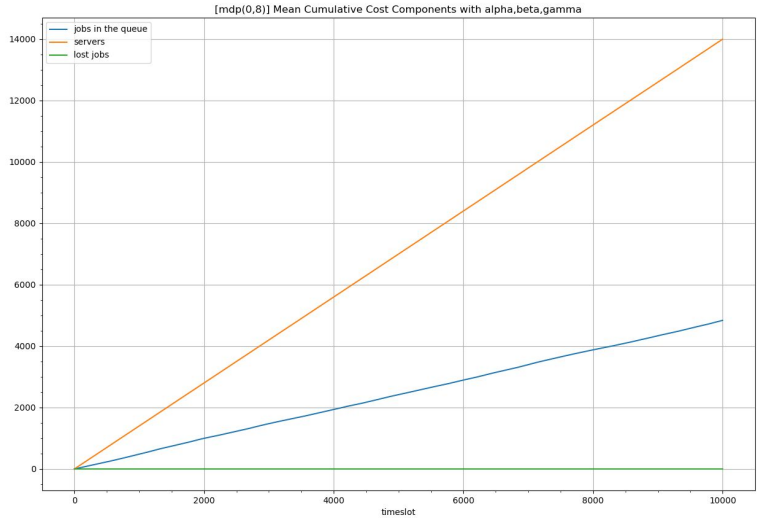
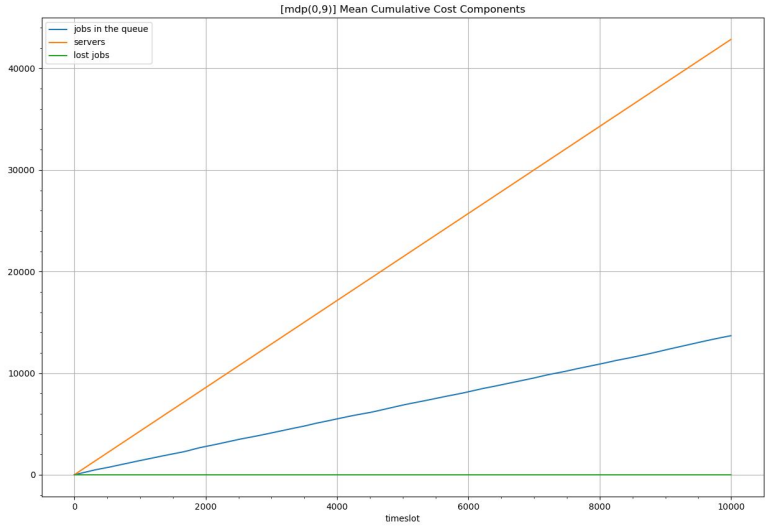
Scenario 1: Alpha, Beta and Gamma equal to 1 - MDP discount 0.8 Cost in Details

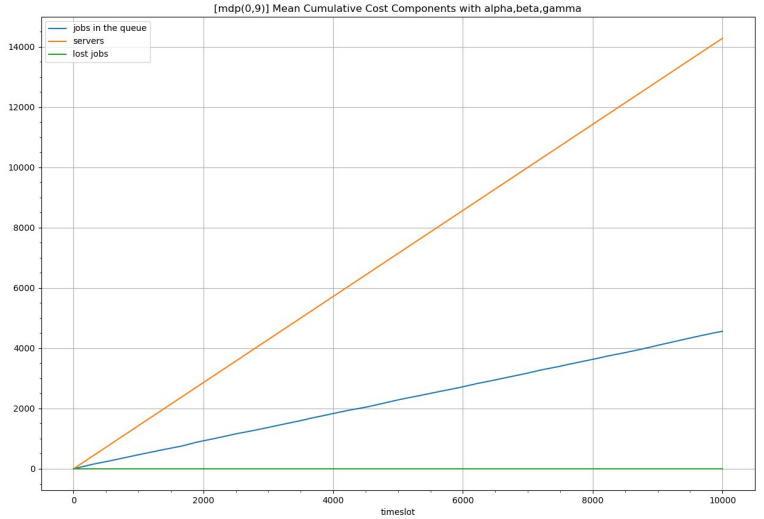




A slice simulator with MDP resolution

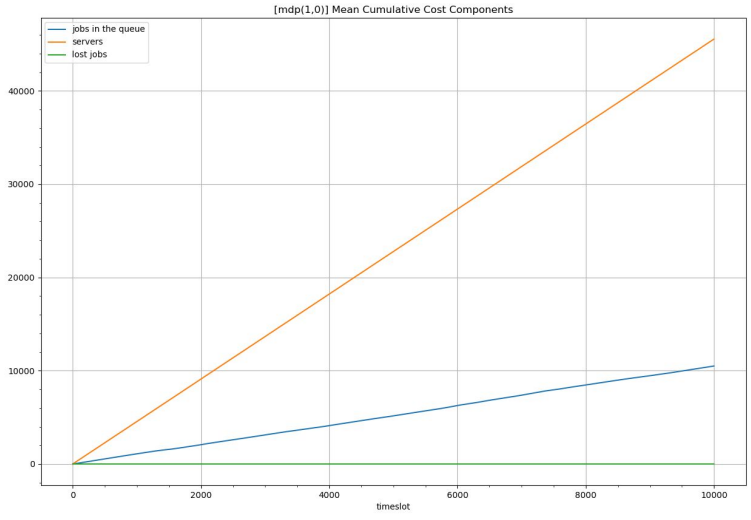
Scenario 1: Alpha, Beta and Gamma equal to 1 - MDP discount 0.9 Cost in Details

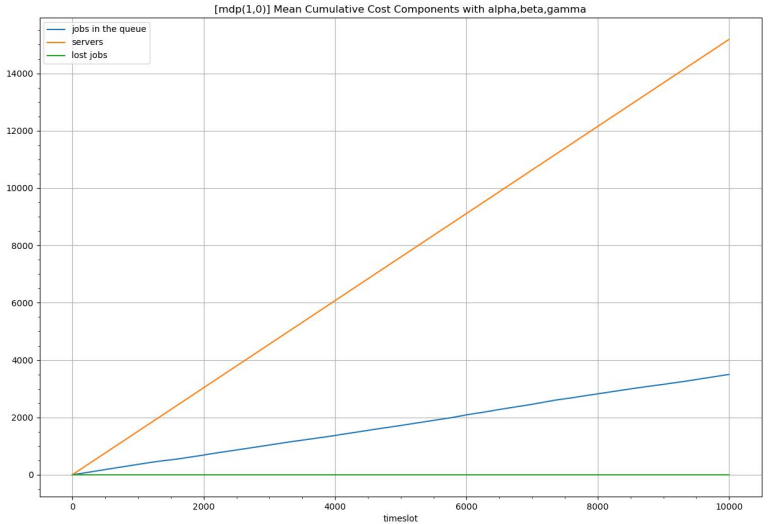




A slice simulator with MDP resolution

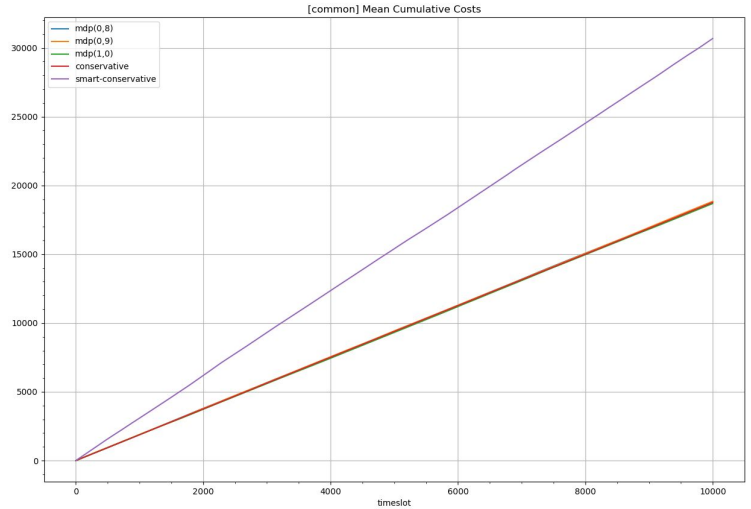
Scenario 1: Alpha, Beta and Gamma equal to 1 - MDP discount 0.9999 Cost in Details

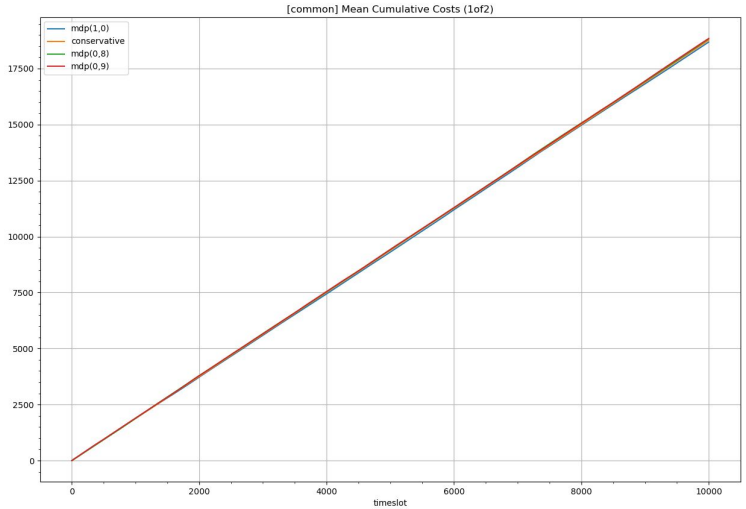




A slice simulator with MDP resolution

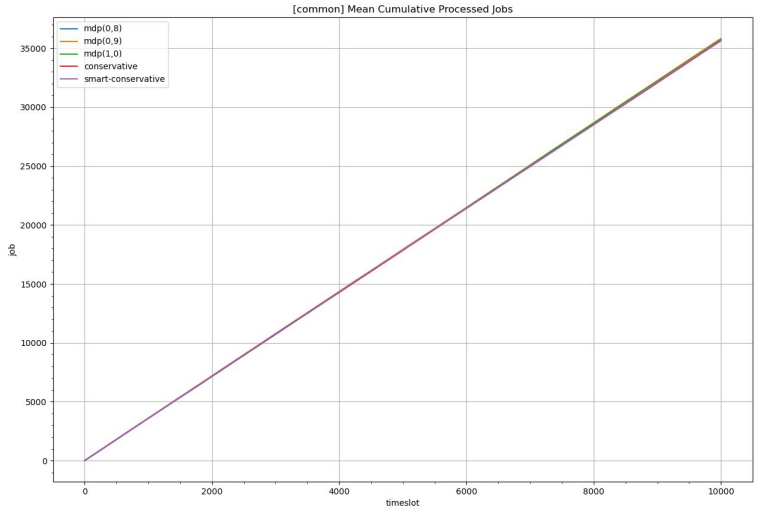
Scenario 1: Alpha, Beta and Gamma equal to 1 - Mean Cumulative Costs

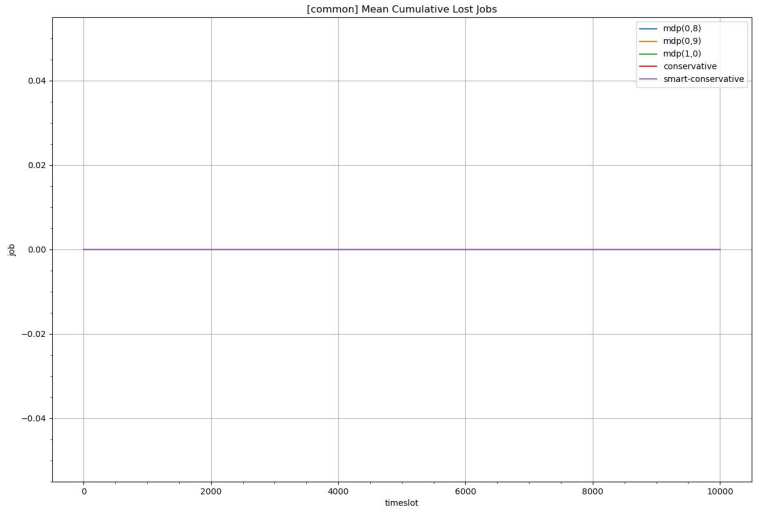




A slice simulator with MDP resolution

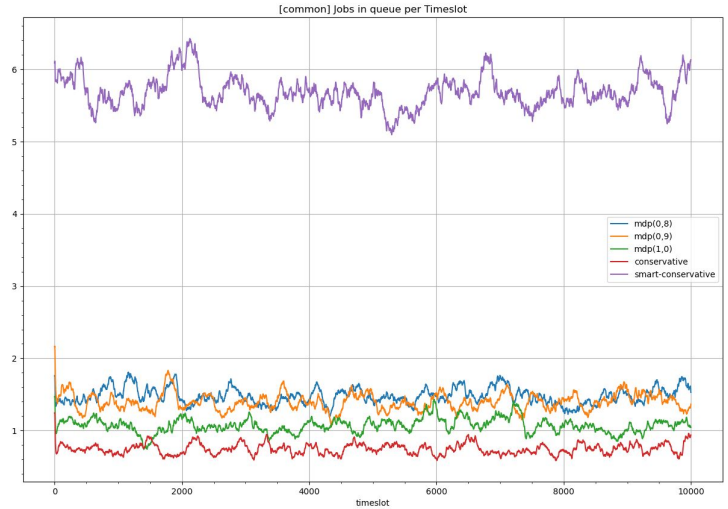
Scenario 1: Alpha, Beta and Gamma equal to 1 - Processed and Lost Jobs

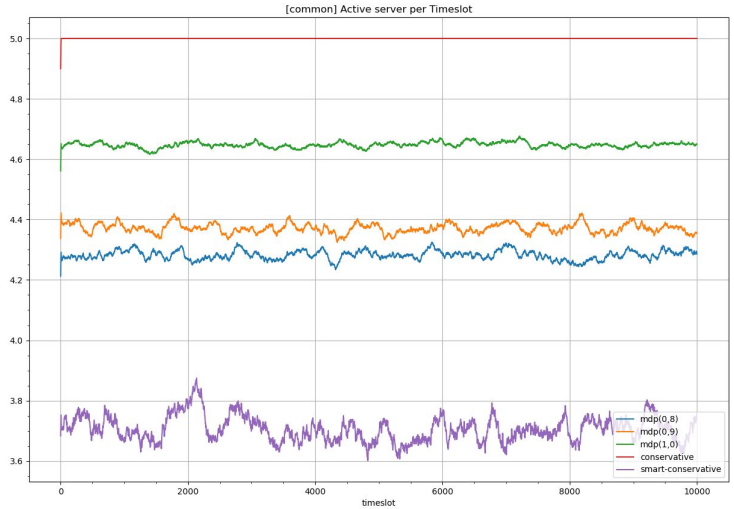




A slice simulator with MDP resolution

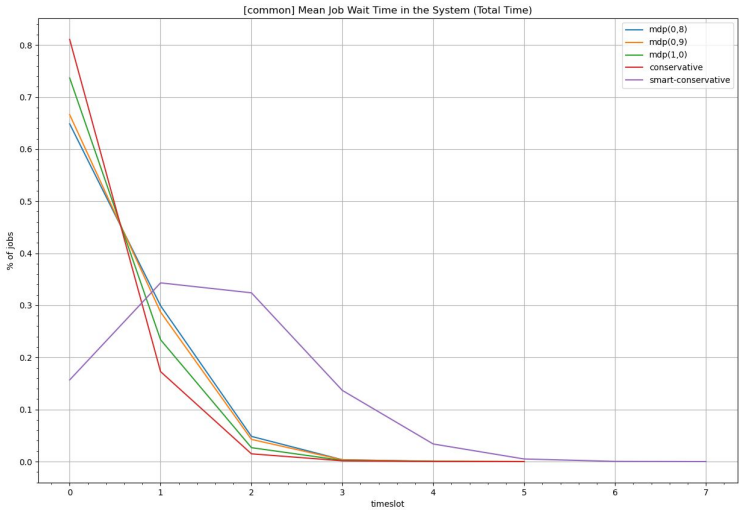
Scenario 1: Alpha, Beta and Gamma equal to 1 - Jobs in the Queue and Active Servers





A slice simulator with MDP resolution

Scenario 1: Alpha, Beta and Gamma equal to 1- Wait Time in the Queue and in the System



Mean job wait time in the queue and in the system are the same (H_d=[0., 1.])

Scenario 2

Very Energy Sensitive, beta=5 (-> 0.7143)

Remember: Costs = alpha * C_j * j + beta * C_s * n + gamma * E[L] * C_l

A slice simulator with MDP resolution

Simulation Results - Scenario 2: Very Energy Sensitive, beta=5

Discount value 0.8

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	0	2	2	2	2	2
1 jobs	0	2	2	2	2	2
2 jobs	0	2	2	2	2	2
3 jobs	0	2	2	2	2	2
4 jobs	0	2	2	2	2	2
5 jobs	0	2	2	2	2	2
6 jobs	0	2	2	2	2	2
7 jobs	0	2	2	2	2	2
8 jobs	0	2	2	2	2	2

0.9

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	2	2	2
1 jobs	1	1	1	0	2	2
2 jobs	1	1	1	0	2	2
3 jobs	1	1	1	1	2	2
4 jobs	1	1	1	1	0	2
5 jobs	1	1	1	1	0	2
6 jobs	1	1	1	1	1	2
7 jobs	1	1	1	1	1	0
8 jobs	1	1	1	1	1	0

0.99999999999999

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	0	2	2
1 jobs	1	1	1	1	2	2
2 jobs	1	1	1	1	0	2
3 jobs	1	1	1	1	0	2
4 jobs	1	1	1	1	1	2
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6 jobs	1	1	1	1	1	0
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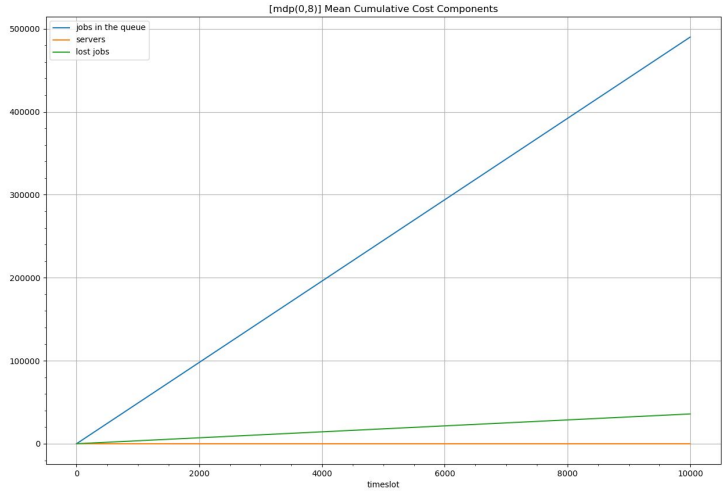
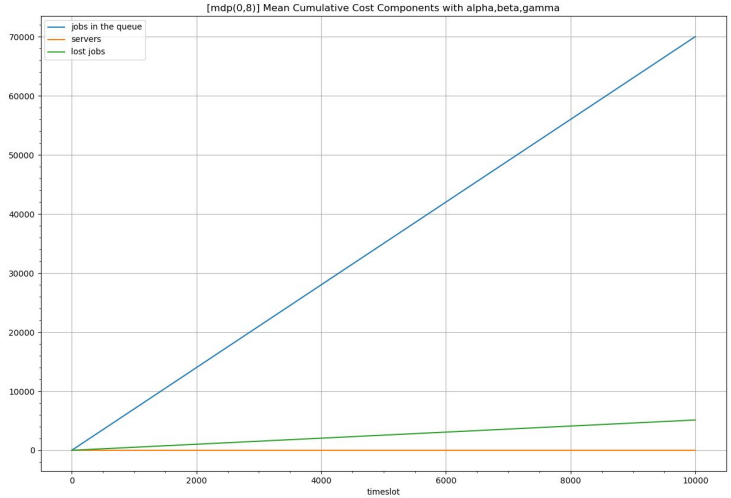
8 jobs	1	1	1	1	1	0

A slice simulator with MDP resolution

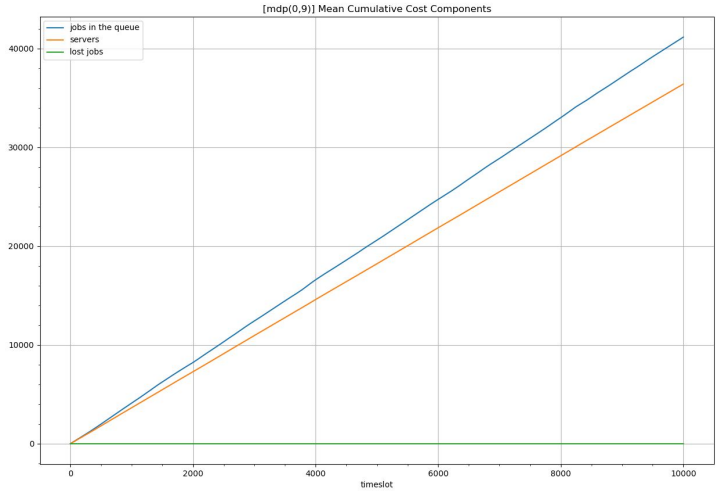
Scenario 2: Very Energy Sensitive, beta=5 - MDP discount 0.8 Cost in Details

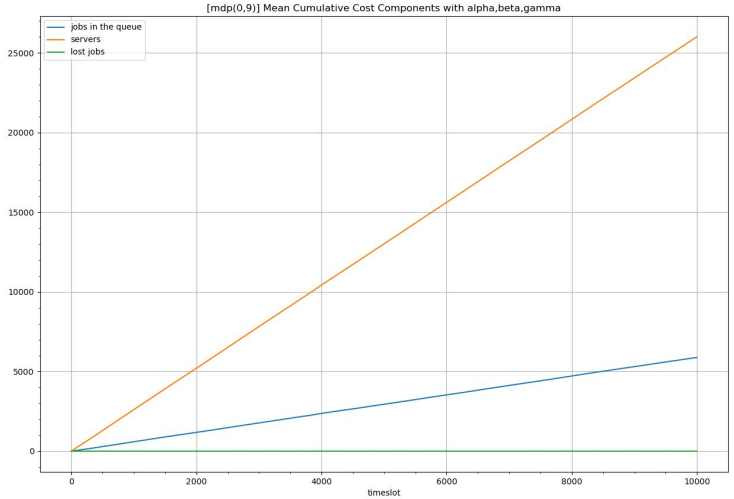




A slice simulator with MDP resolution

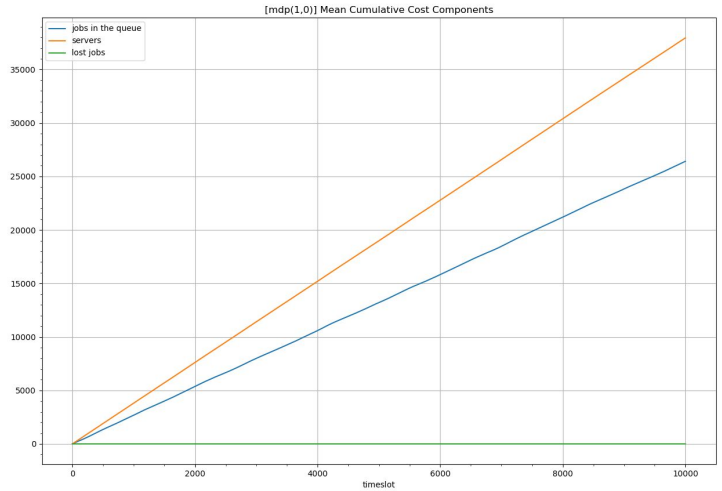
Scenario 2: Very Energy Sensitive, beta=5 - MDP discount 0.9 Cost in Details

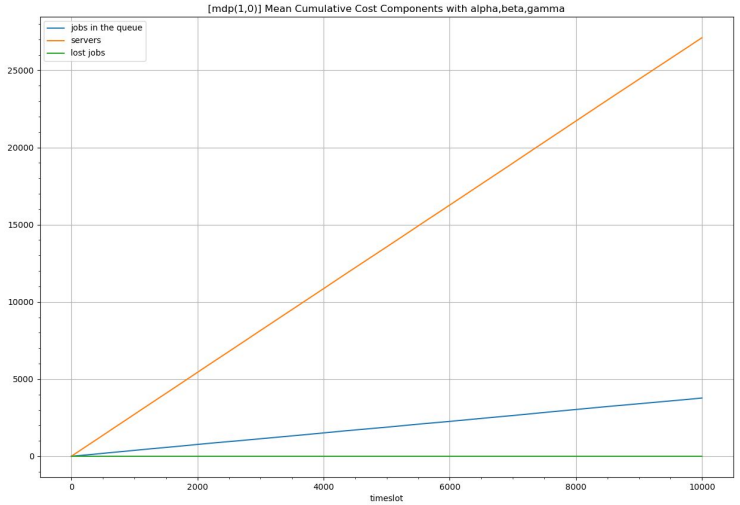




A slice simulator with MDP resolution

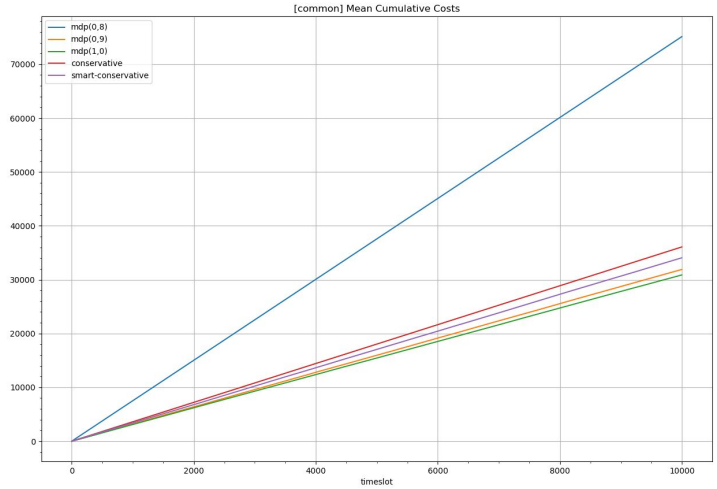
Scenario 2: Very Energy Sensitive, beta=5 - MDP discount 0.9999 Cost in Details

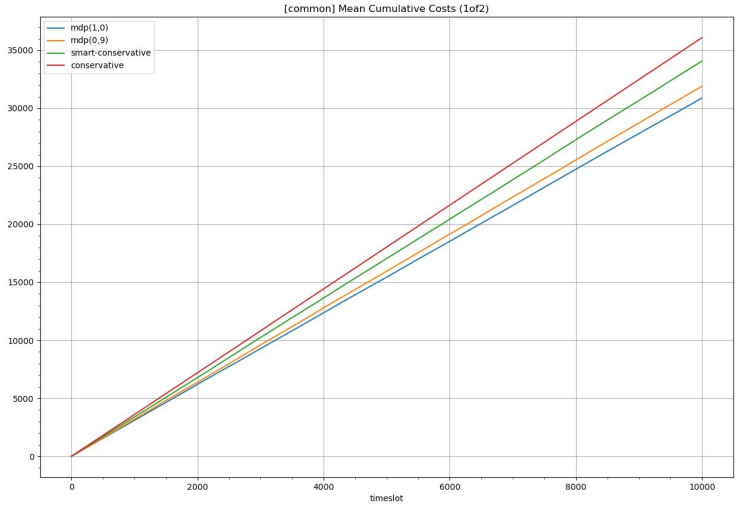




A slice simulator with MDP resolution

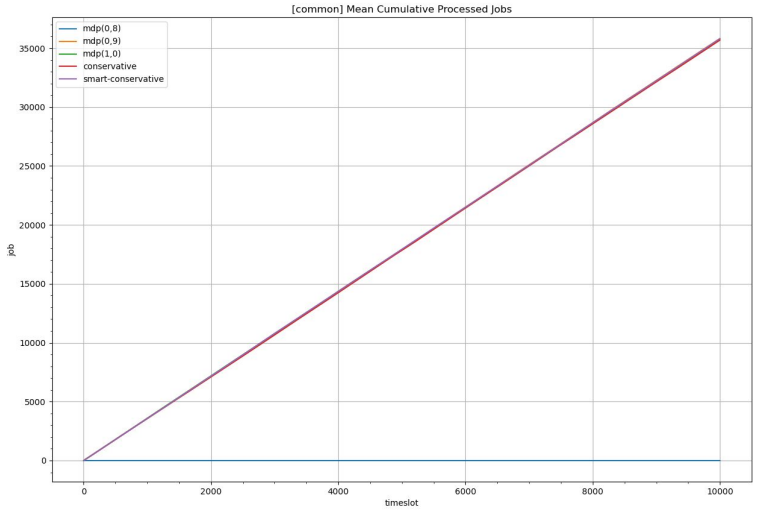
Scenario 2: Very Energy Sensitive, beta=5 - Mean Cumulative Costs

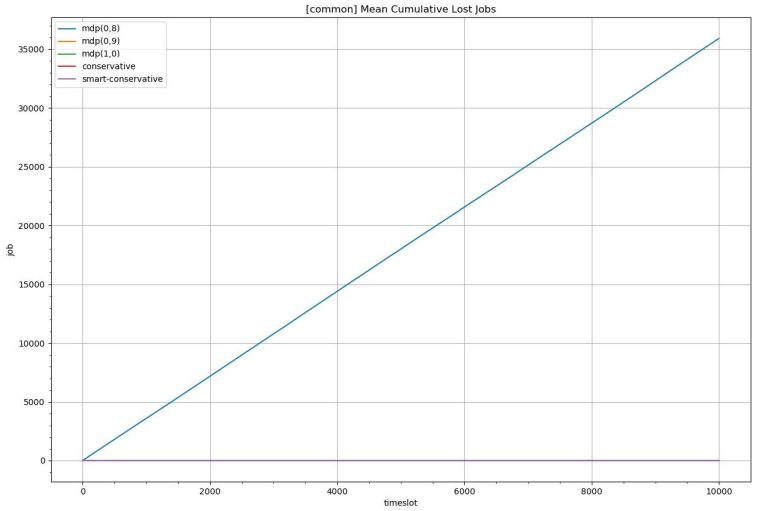




A slice simulator with MDP resolution

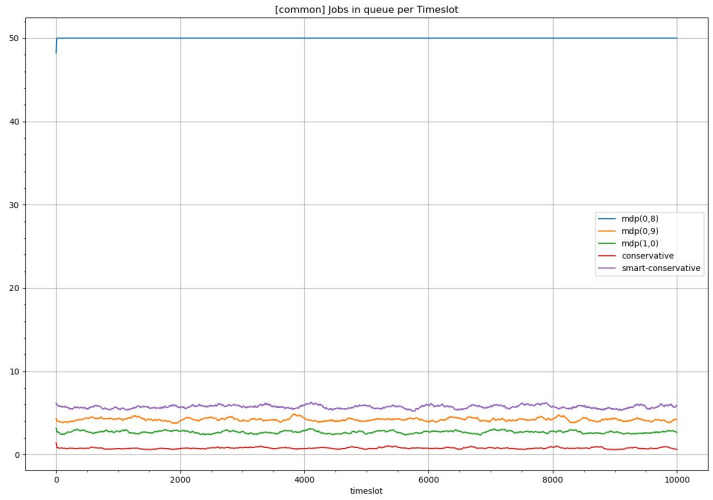
Scenario 2: Very Energy Sensitive, beta=5 - Processed and Lost Jobs

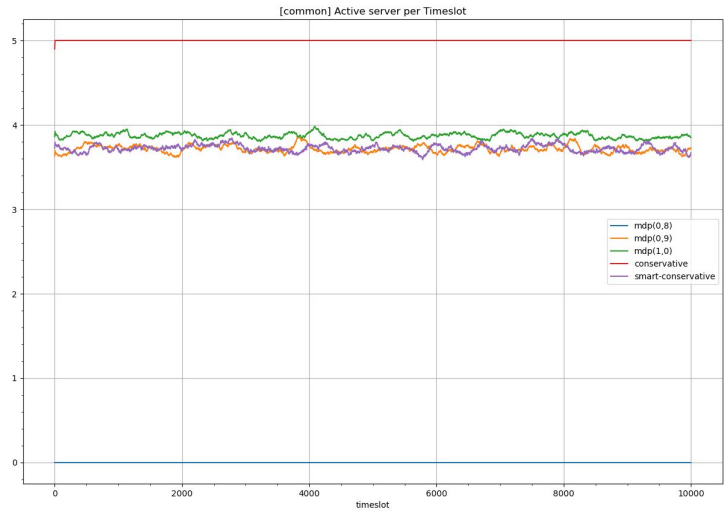




A slice simulator with MDP resolution

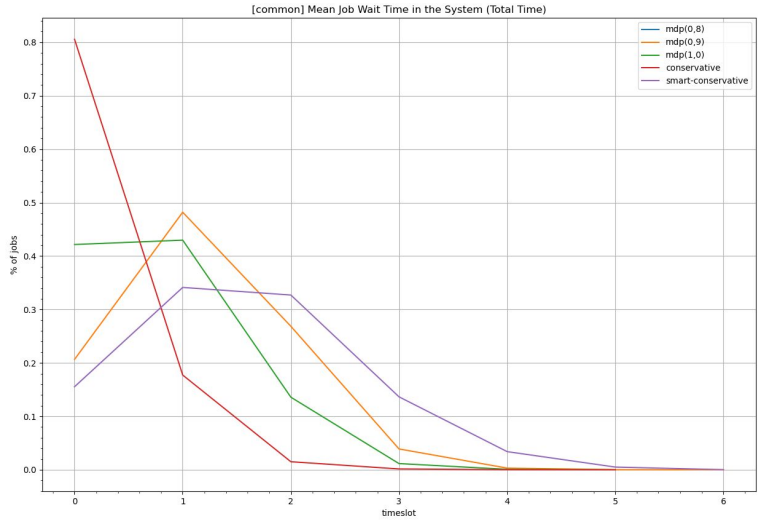
Scenario 2: Very Energy Sensitive, beta=5 - Jobs in the Queue and Active Servers





A slice simulator with MDP resolution

Scenario 2: Very Energy Sensitive, beta=5 - Wait Time in the Queue and in the System



Mean job wait time in the queue and in the system are the same (H_d=[0., 1.])

Scenario 3

Very Loss Sensitive, gamma=5 (-> 0.7143)

Remember: Costs = alpha * C_j * j + beta * C_s * n + gamma * E[L] * C_l

A slice simulator with MDP resolution

Simulation Results - Scenario 3: Very Loss Sensitive, gamma=5

Discount value 0.8

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	0	2
1 jobs	1	1	1	1	0	2
2 jobs	1	1	1	1	1	2
3 jobs	1	1	1	1	1	0
4 jobs	1	1	1	1	1	0
5 jobs	1	1	1	1	1	0
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0.9

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
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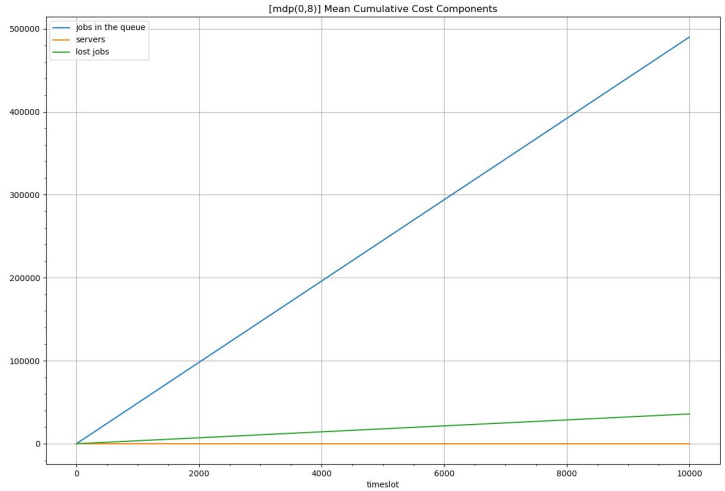
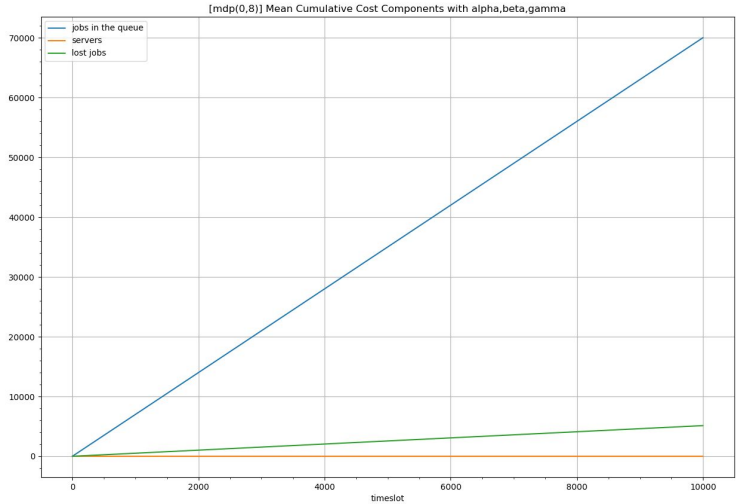
A slice simulator with MDP resolution

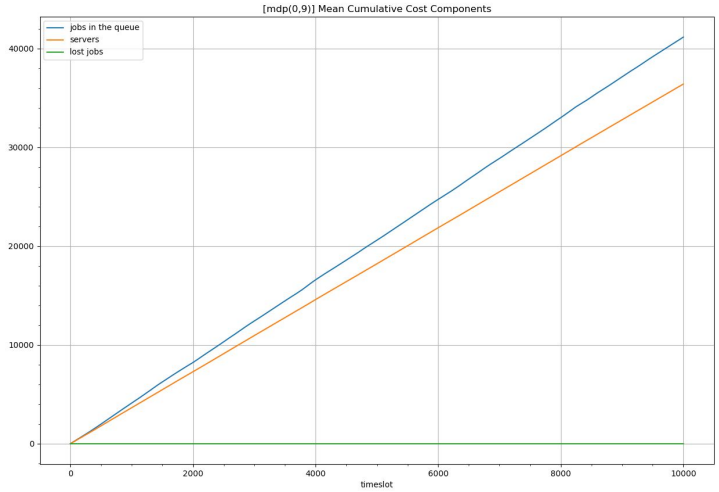
Scenario 3: Very Loss Sensitive, gamma=5 - MDP discount 0.8 Cost in Details

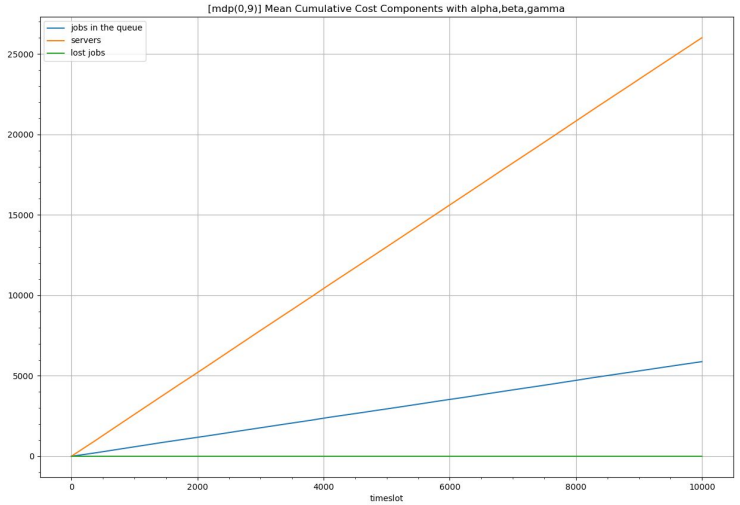




A slice simulator with MDP resolution

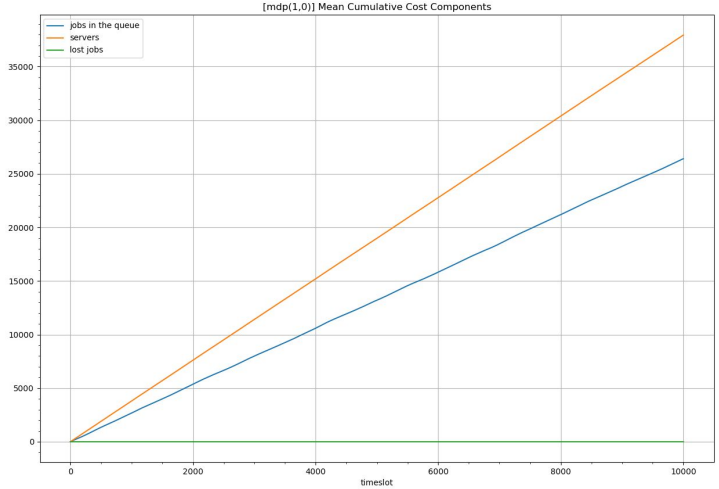
Scenario 3: Very Loss Sensitive, gamma=5 - MDP discount 0.9 Cost in Details

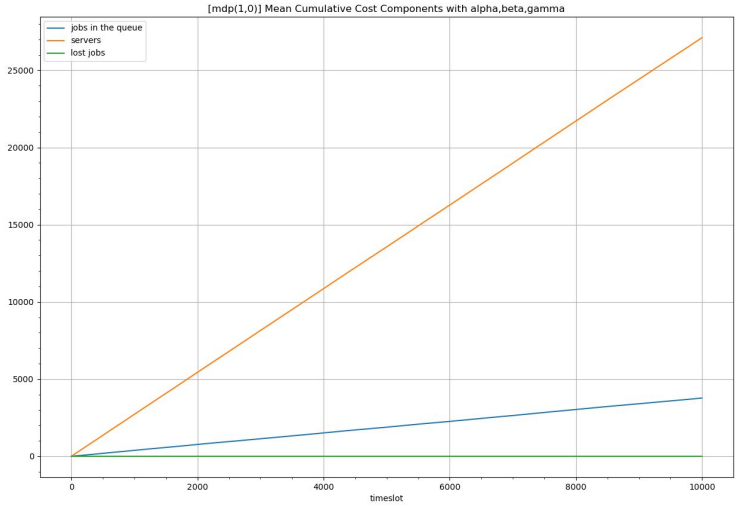




A slice simulator with MDP resolution

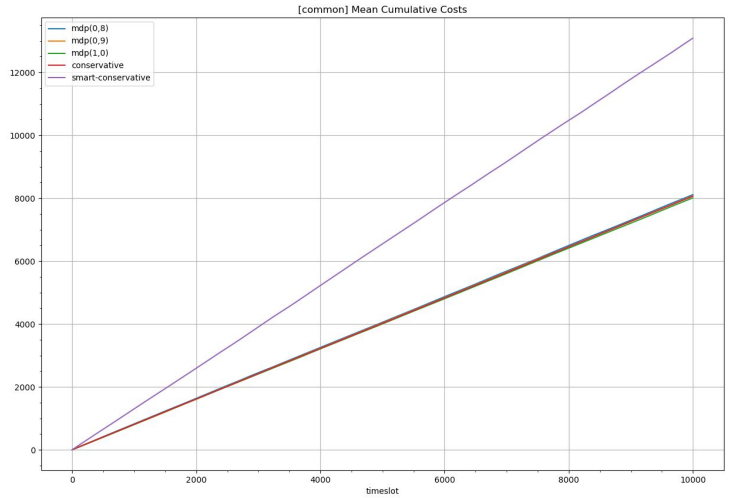
Scenario 3: Very Loss Sensitive, gamma=5 - MDP discount 0.9999 Cost in Details

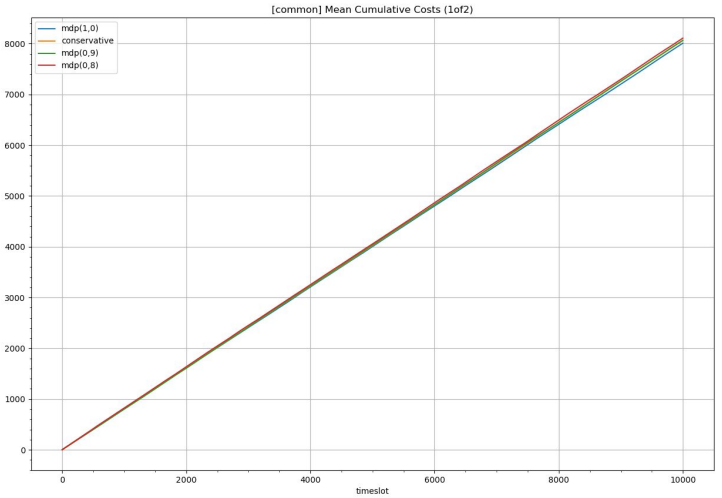




A slice simulator with MDP resolution

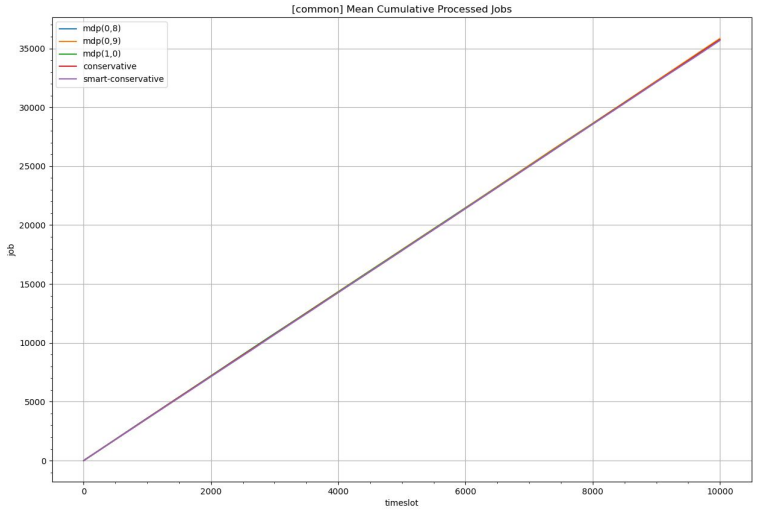
Scenario 3: Very Loss Sensitive, gamma=5 - Mean Cumulative Costs

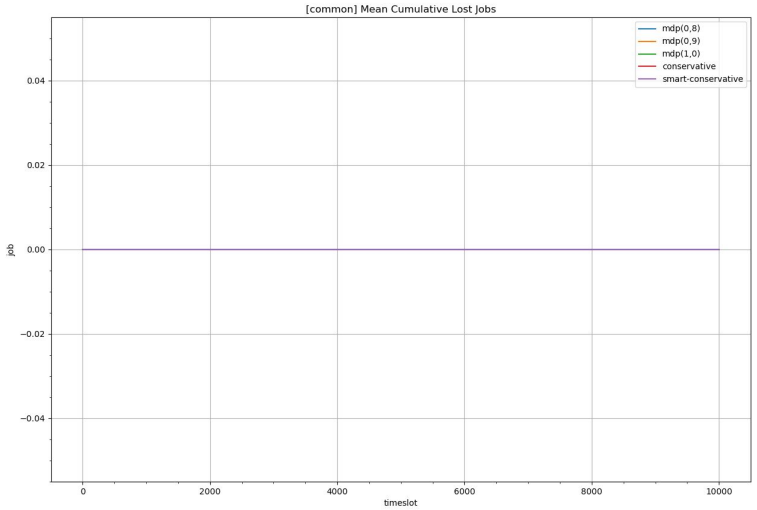




A slice simulator with MDP resolution

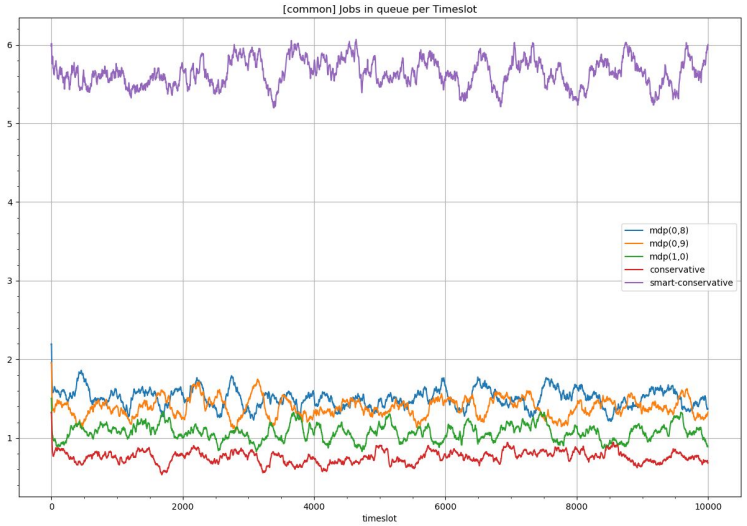
Scenario 3: Very Loss Sensitive, gamma=5 - Processed and Lost Jobs

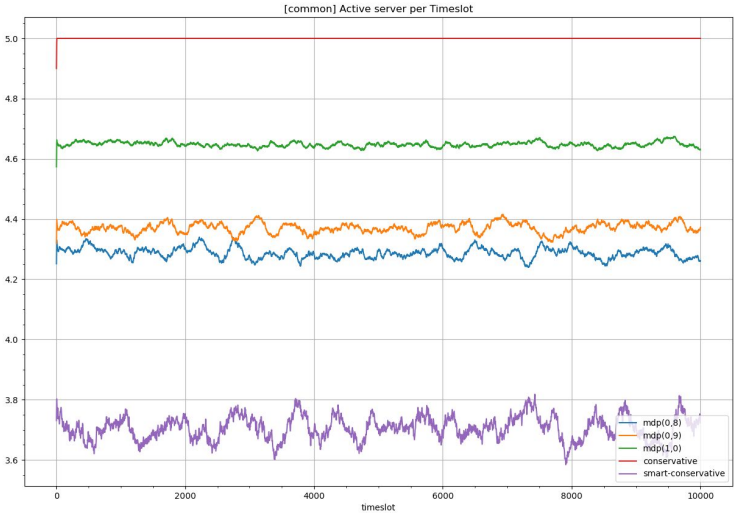




A slice simulator with MDP resolution

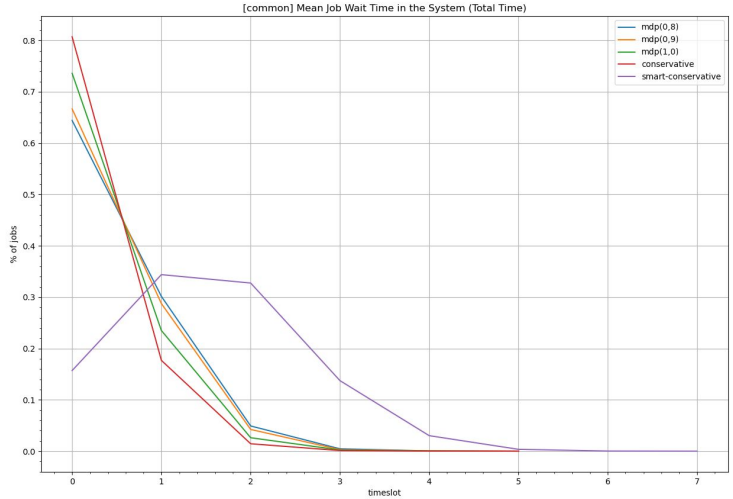
Scenario 3: Very Loss Sensitive, gamma=5 - Jobs in the Queue and Active Servers





A slice simulator with MDP resolution

Scenario 3: Very Loss Sensitive, gamma=5 - Wait Time in the Queue and in the System



Mean job wait time in the queue and in the system are the same (H_d=[0., 1.])

Scenario 4

Very Queue Sensitive, alpha=5 (-> 0.7143)

Remember: Costs = alpha * C_j * j + beta * C_s * n + gamma * E[L] * C_l

A slice simulator with MDP resolution

Simulation Results - Scenario 4: Very Queue Sensitive, alpha=5

Discount value 0.8

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	1	0
1 jobs	1	1	1	1	1	0
2 jobs	1	1	1	1	1	0
3 jobs	1	1	1	1	1	0
4 jobs	1	1	1	1	1	0
5 jobs	1	1	1	1	1	0
6 jobs	1	1	1	1	1	0
7 jobs	1	1	1	1	1	0
8 jobs	1	1	1	1	1	0

0.9

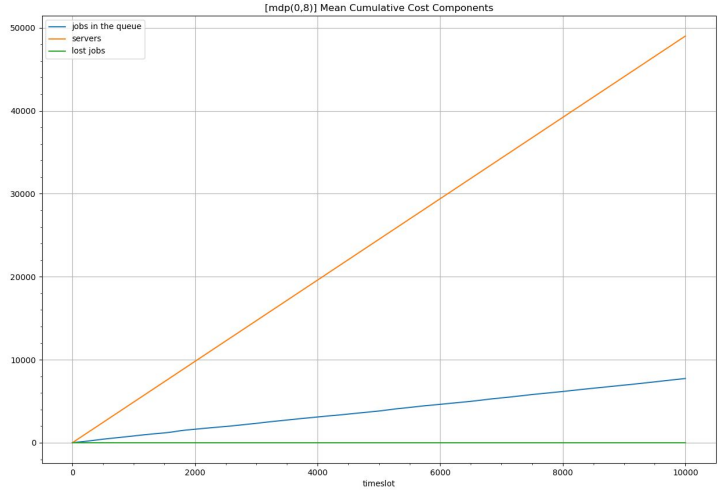
	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	1	0
1 jobs	1	1	1	1	1	0
2 jobs	1	1	1	1	1	0
3 jobs	1	1	1	1	1	0
4 jobs	1	1	1	1	1	0
5 jobs	1	1	1	1	1	0
6 jobs	1	1	1	1	1	0
7 jobs	1	1	1	1	1	0
8 jobs	1	1	1	1	1	0

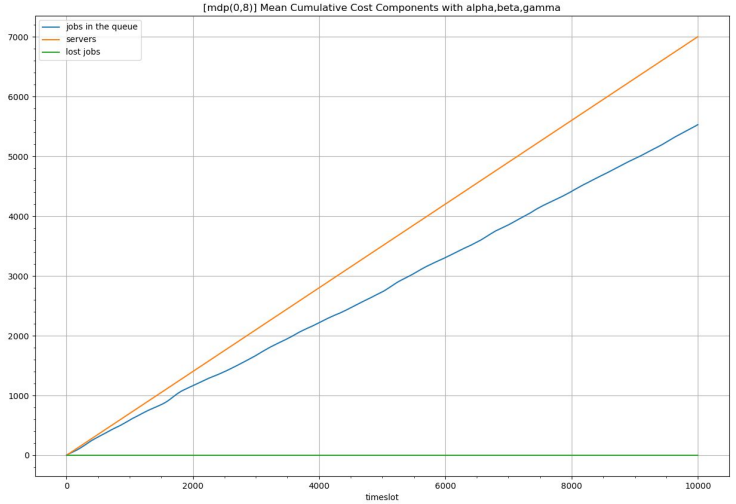
0.99999999999999

	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	1	0
1 jobs	1	1	1	1	1	0
2 jobs	1	1	1	1	1	0
3 jobs	1	1	1	1	1	0
4 jobs	1	1	1	1	1	0
5 jobs	1	1	1	1	1	0
6 jobs	1	1	1	1	1	0
7 jobs	1	1	1	1	1	0
8 jobs	1	1	1	1	1	0

A slice simulator with MDP resolution

Scenario 4: Very Queue Sensitive, alpha=5 - MDP discount 0.8 Cost in Details





A slice simulator with MDP resolution

Scenario 4: Very Queue Sensitive, alpha=5 - MDP discount 0.9 Cost in Details

The same as MDP discount 0.8

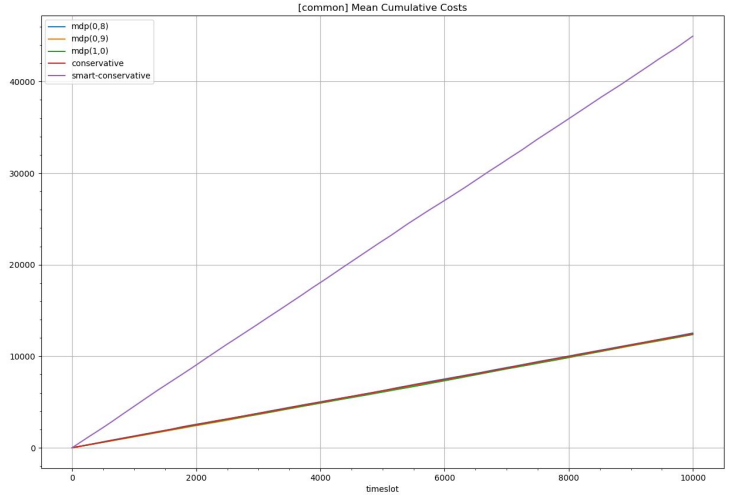
A slice simulator with MDP resolution

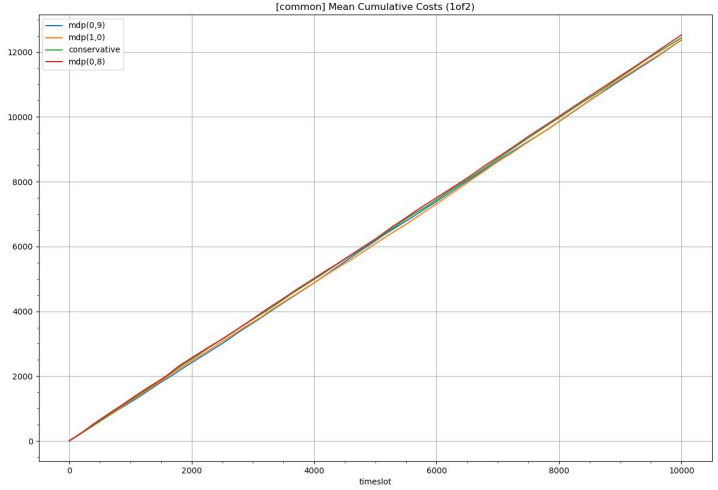
Scenario 4: Very Queue Sensitive, alpha=5 - MDP discount 0.9999 Cost in Details

The same as MDP discount 0.8

A slice simulator with MDP resolution

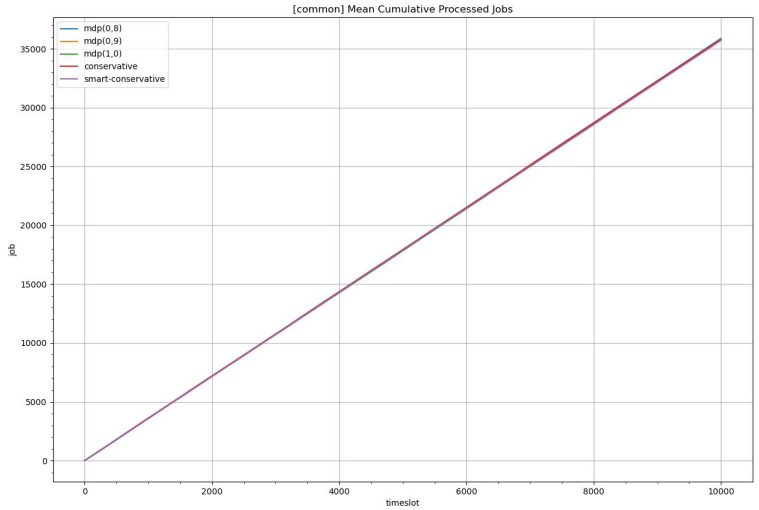
Scenario 4: Very Queue Sensitive, alpha=5 - Mean Cumulative Costs

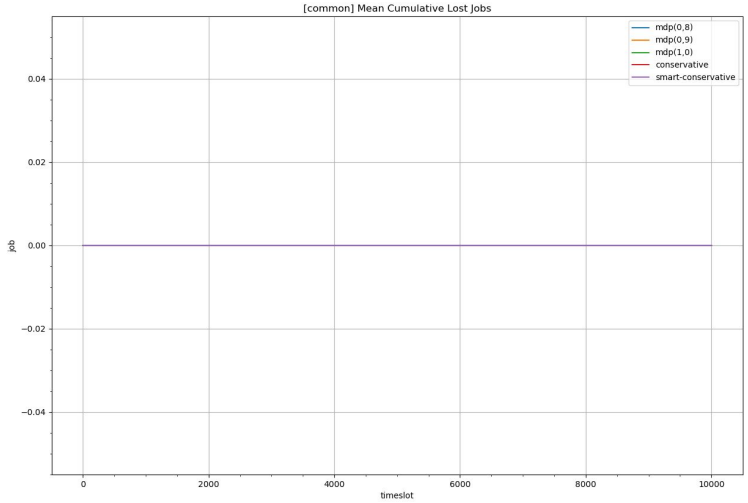




A slice simulator with MDP resolution

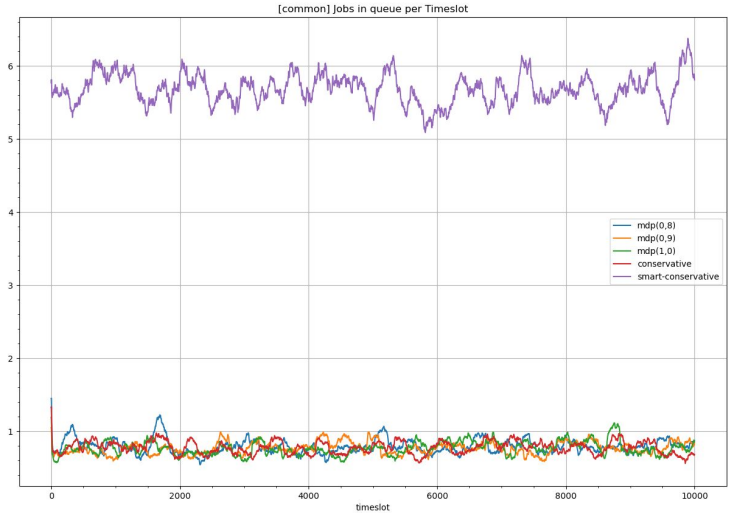
Scenario 4: Very Queue Sensitive, alpha=5 - Processed and Lost Jobs

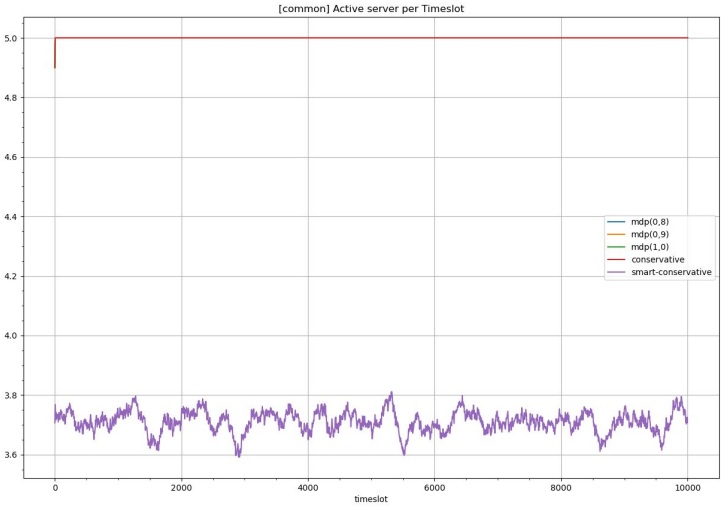




A slice simulator with MDP resolution

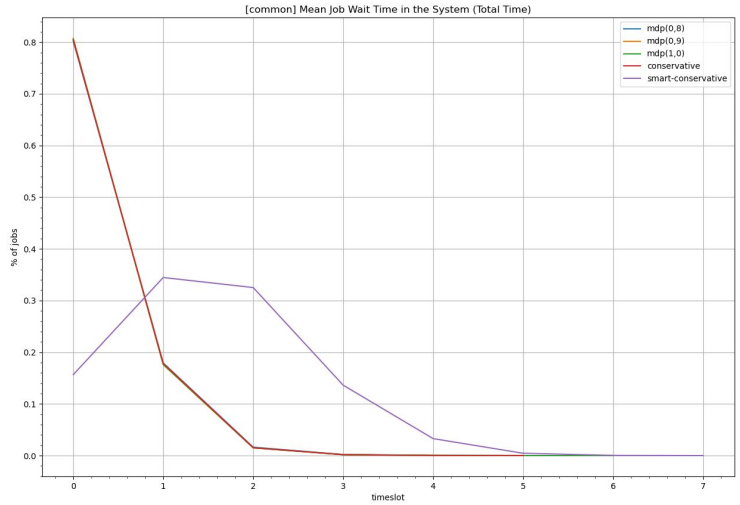
Scenario 4: Very Queue Sensitive, alpha=5 - Jobs in the Queue and Active Servers





A slice simulator with MDP resolution

Scenario 4: Very Queue Sensitive, alpha=5 - Wait Time in the Queue and in the System



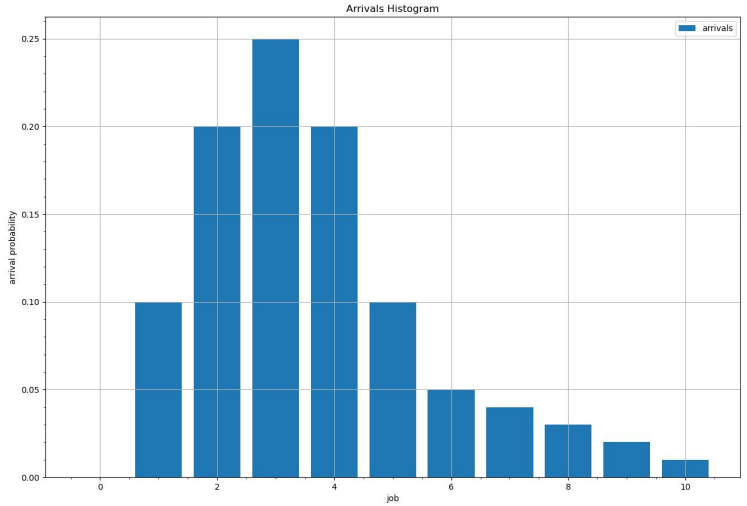
Mean job wait time in the queue and in the system are the same (H_d=[0., 1.])

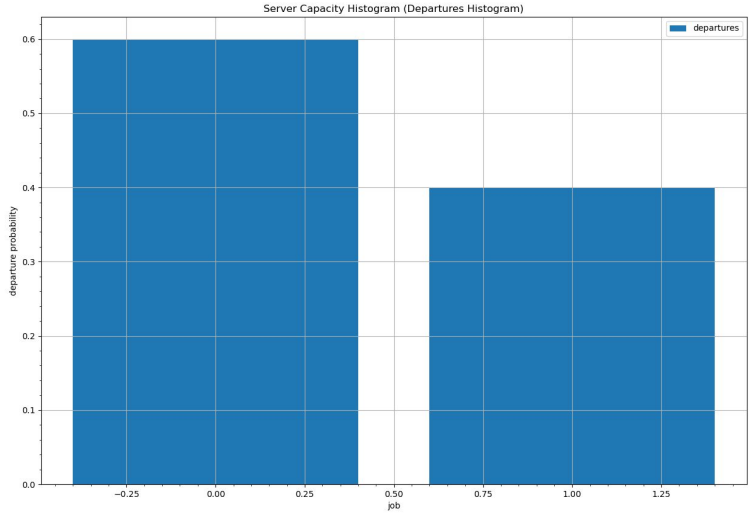
Scenario 5

Throw in the Towel

A slice simulator with MDP resolution

Simulation Results - Scenario 5: Throw in the Towel





A slice simulator with MDP resolution

Simulation Results - Scenario 5: Throw in the Towel

- Queue size: 100
- Max allocated servers: 5
- C_s: 1
- C_l: 1
- C_j: 1
- Number of simulations: 1
- Simulation Time: 10k time slots
- MDP discount values: [0.8 - 0.9]
- Alpha: 1; Beta: 2 (energy); Gamma: 1

A slice simulator with MDP resolution

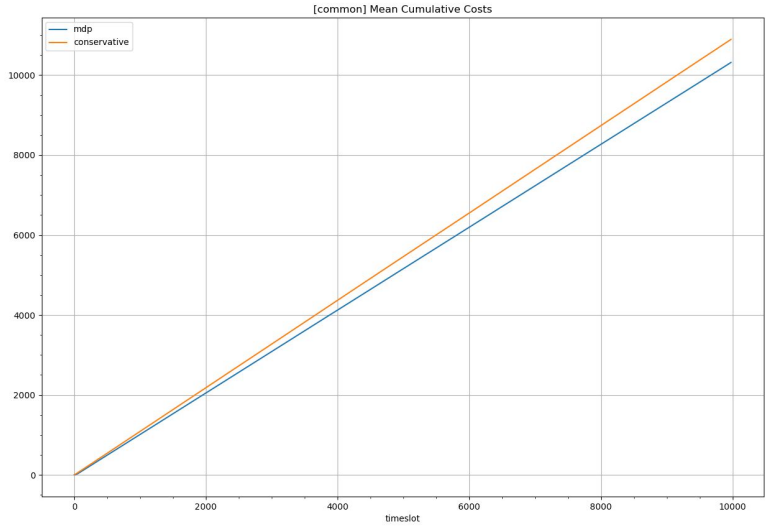
Simulation Results - Scenario 5: Throw in the Towel

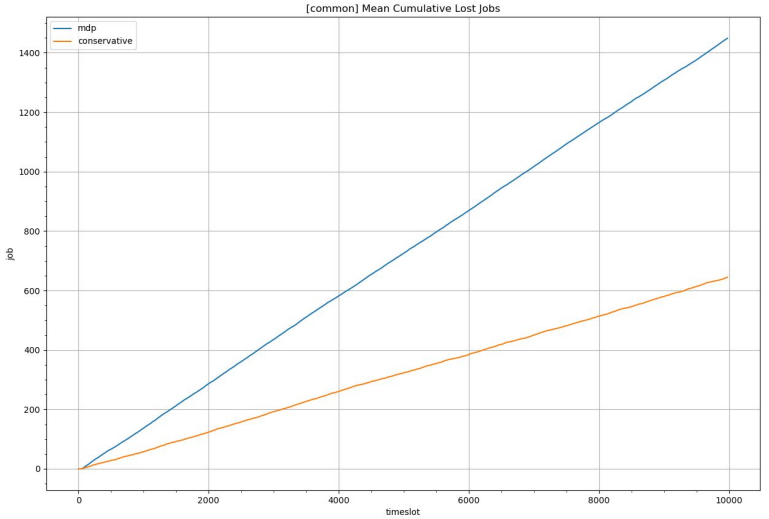
	0 servers	1 servers	2 servers	3 servers	4 servers	5 servers
0 jobs	1	1	1	1	1	1
1 jobs	1	1	1	1	1	1
2 jobs	1	1	1	1	1	1
3 jobs	1	1	1	1	1	1
4 jobs	1	1	1	1	1	1
5 jobs	1	1	1	1	1	1
6 jobs	1	1	1	1	1	1
7 jobs	1	1	1	1	1	1
8 jobs	1	1	1	1	1	1

70 jobs	1	1	1	1	1	0
71 jobs	1	0	2	2	2	0
72 jobs	0	2	2	2	2	2
73 jobs	0	2	2	2	2	2
74 jobs	0	2	2	2	2	2
75 jobs	0	2	2	2	2	2
76 jobs	0	2	2	2	2	2
77 jobs	0	2	2	2	2	2
78 jobs	0	2	2	2	2	2

A slice simulator with MDP resolution

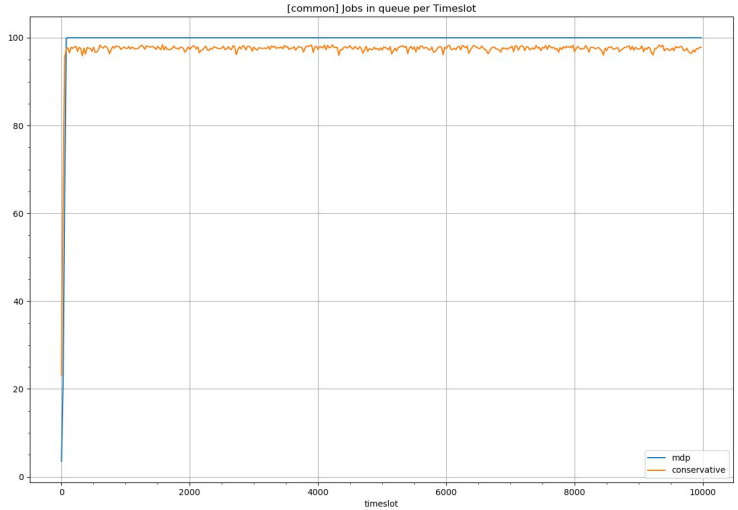
Scenario 5: Throw in the Towel - Mean Cumulative Costs and Lost Jobs

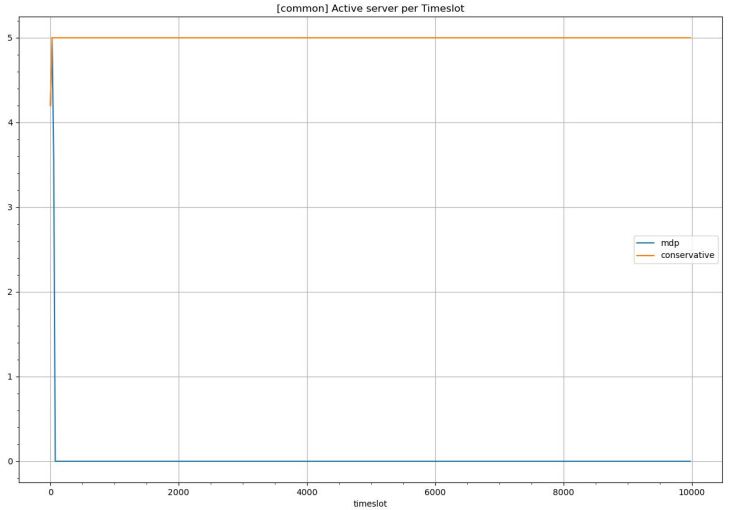




A slice simulator with MDP resolution

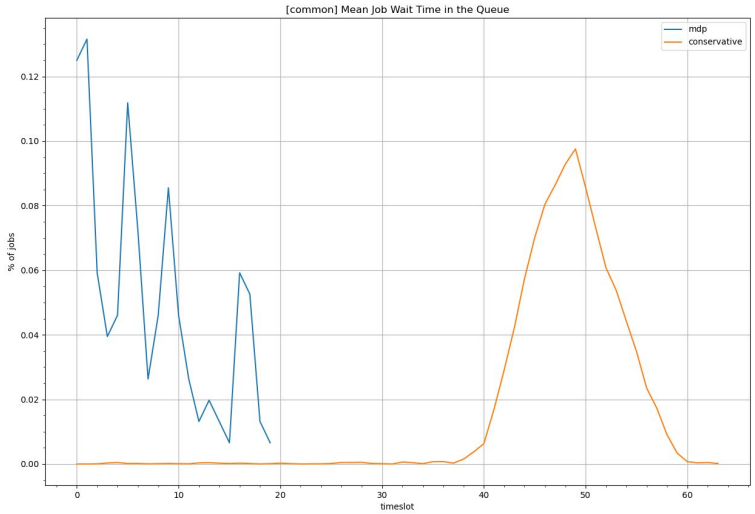
Scenario 5: Throw in the Towel - Jobs in the Queue and Active Servers

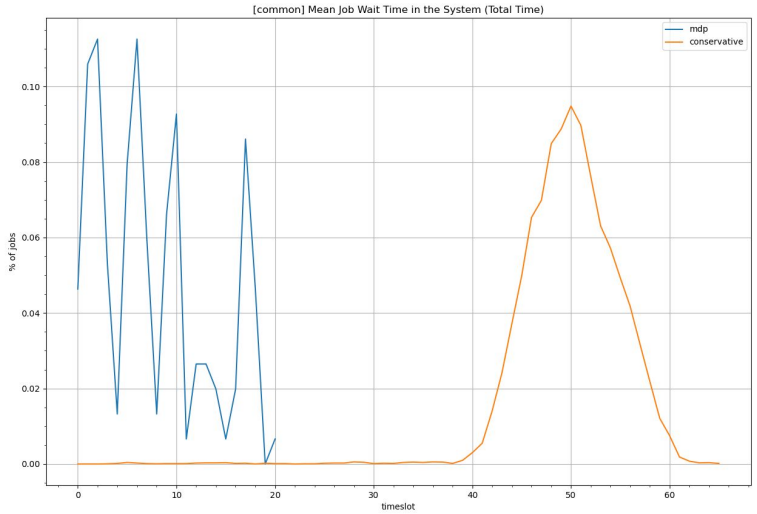




A slice simulator with MDP resolution

Scenario 5: Throw in the Towel - Wait Time in the Queue and in the System





Questions

A slice simulator with MDP resolution

Questions

- What discount value should we choose?
- What histogram use for the next calls?
- Switch to action taken immediately?
- Switch to async arrivals?