

# Annual Review

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2022-06-21

# Motivation

## Patients forced to wait for 24 hours in ambulances, data shows

Ambulance crews forced to wait outside A&Es for 24 hours, according to chiefs

Rebecca Thomas Health Correspondent • Tuesday 17 May 2022 08:26 • Comments



(AFP/Getty)

'Appalling' waits for ambulances in England leaving lives at risk

Exclusive: Royal College of Emergency Medicine president says NHS is breaking its agreement to treat sickest in a timely way  
The staff, this is heart-breaking - senior doctor's view on crisis  
I feel we let down - long waits for ambulances on the south-west



Ambulance handover delays highest since start of winter  
© iStockphoto.com



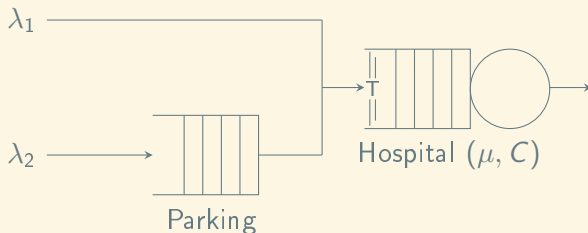
**NHS 'on its knees' as ambulance response times for life-threatening calls rise to record high**

Average response time to deal with Category 1 cases – such as cardiac arrest – is now nine minutes and 20 seconds, with rises across all categories.



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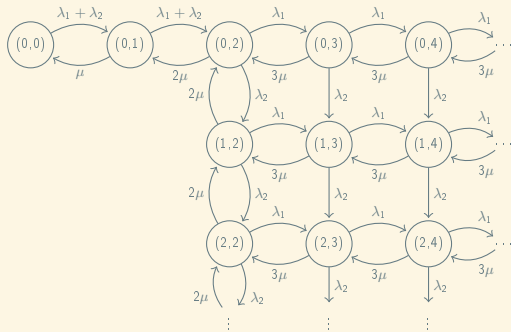
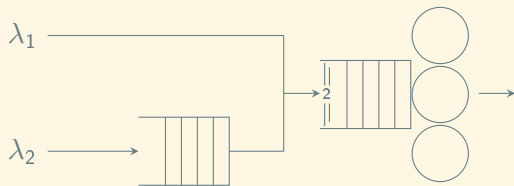
## Queues - Custom network of queues



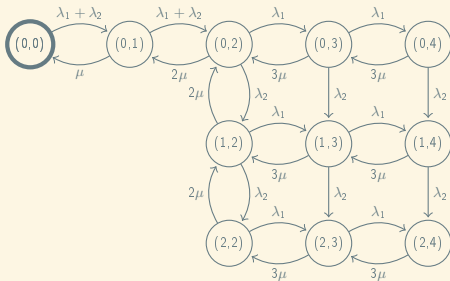
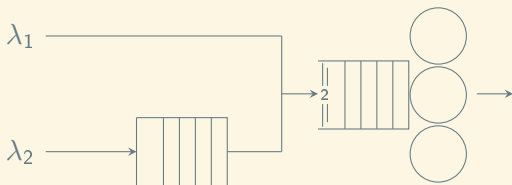
Parameters:

- ▶  $\lambda_1$ : Arrival rate of type 1 individuals
- ▶  $\lambda_2$ : Arrival rate of type 2 individuals
- ▶  $\mu$ : Service rate
- ▶  $C$ : Number of servers
- ▶  $T$ : Threshold

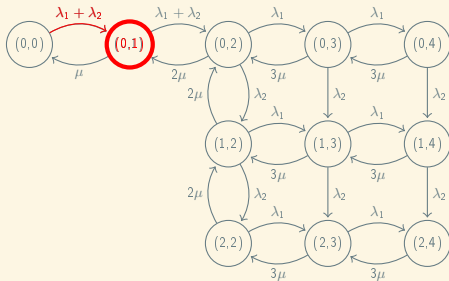
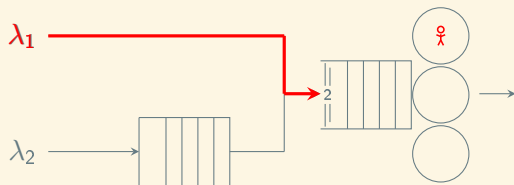
# Markov Chain - Custom network



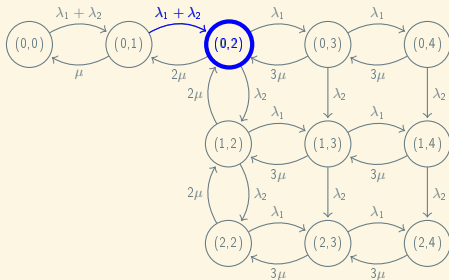
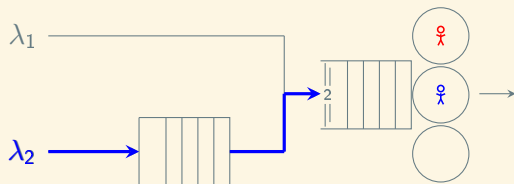
# Markov Chain - Custom network - $N = 4, M = 2$



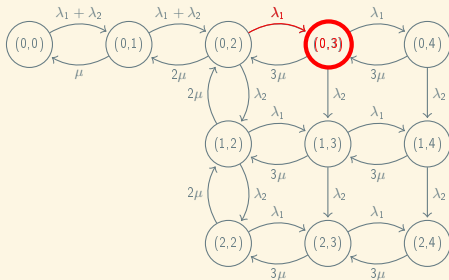
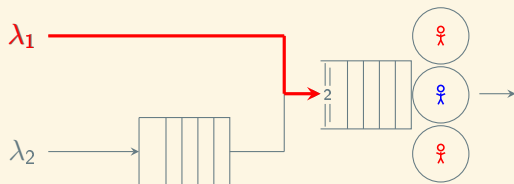
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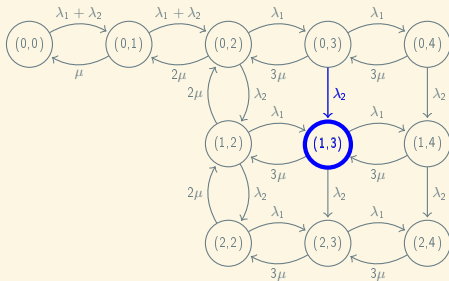
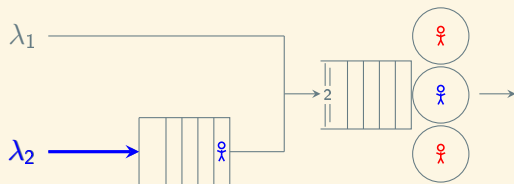


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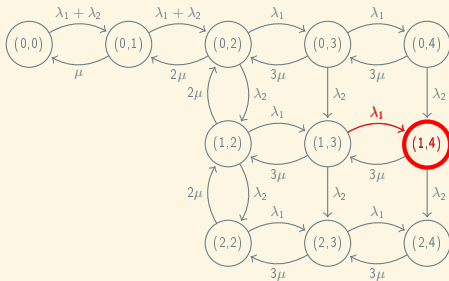
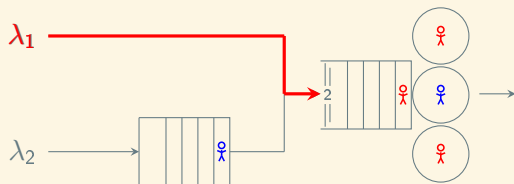




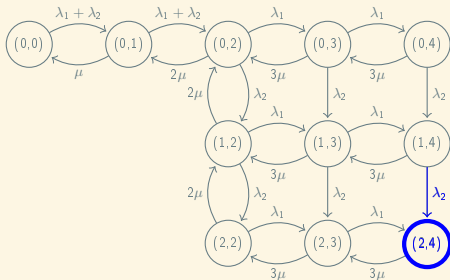
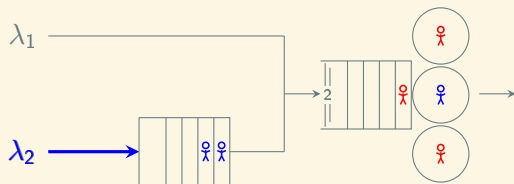
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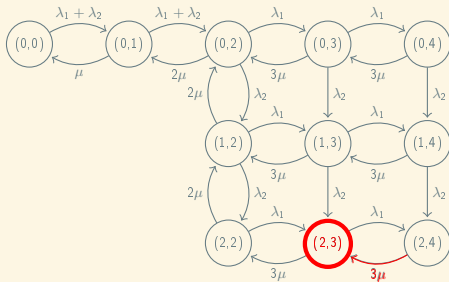
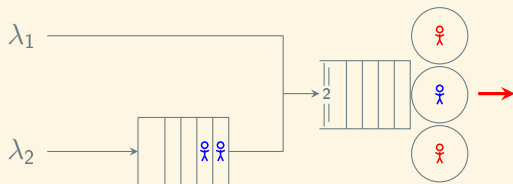
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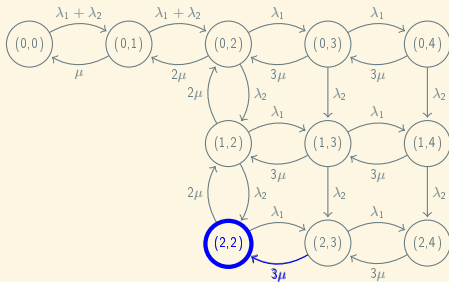
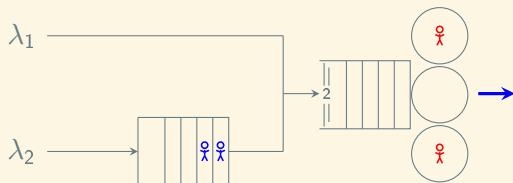
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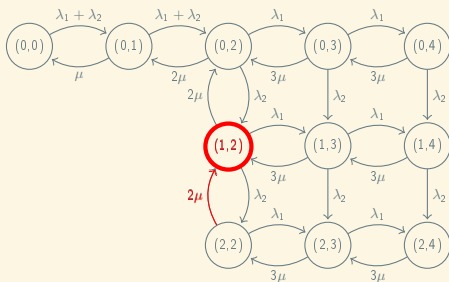
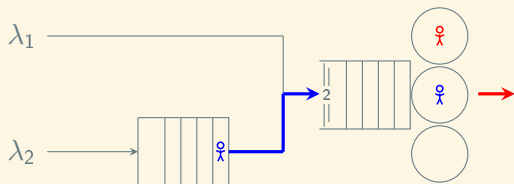
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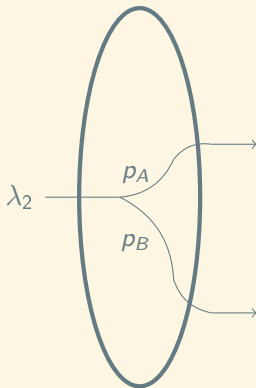


# Game - Motivation

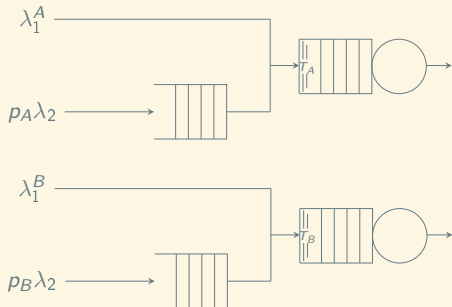


# Game - Formulation

Blocking time



Proportion of individuals within target



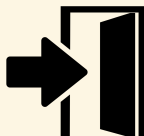


# Game - Players, Strategies and Objectives



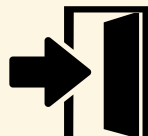
$$p_A, p_B \in [0, 1]$$
$$p_A + p_B = 1$$

$\min B$



$$T_A \in [1, N_A]$$

$$P(W^{(A)} < t) > 0.95$$



$$T_B \in [1, N_B]$$

$$P(W^{(B)} < t) > 0.95$$

# Reinforcement Learning - Server's behaviour



1



2



2



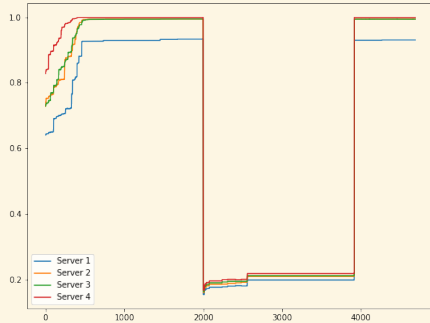
3

Utility

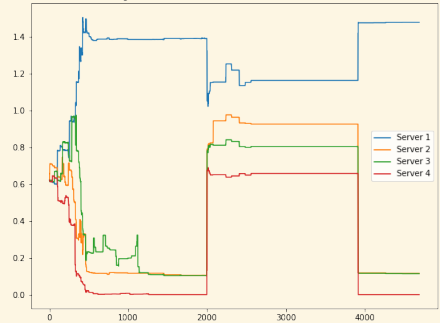
Idle time + Lost inds

# Reinforcement Learning - Server's behaviour when flooding

Utilities of all servers over all iterations



Weighted mean rates of all servers over all iterations



# Thesis structure

1. Introduction
2. Literature review
3. Queueing model
4. Game theoretic model
5. Methodology
6. EMS/ED application
7. Agent based extension
8. Results
9. Conclusion

# Timeline

- ▶ Final revision for paper publication
- ▶ Simulated Annealing version of reinforcement learning algorithm
- ▶ Get some more results
- ▶ Thesis write-up