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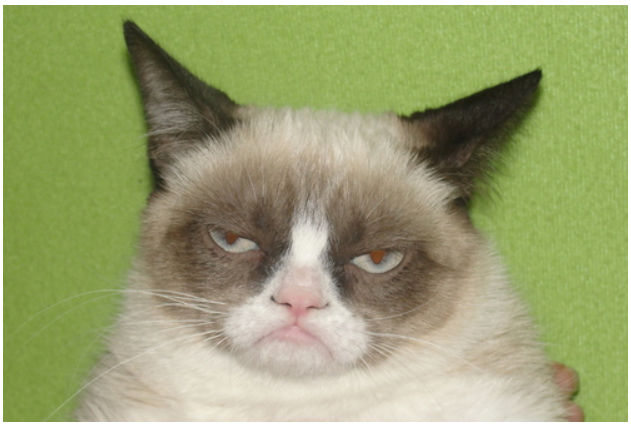

Understanding the effect of selfish behaviour in a series of two queues.

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Abstract

Hierarchical queues in HC; PoA; Simulation model; Heuristics developed to obtain optimal policies;

1 Introduction

- Hierarchy in real life queues;
- Review of papers in BQT;
- PoA;
- Discussion of situation being modelled in this paper.

Queues arise in a variety of settings: road traffic, data transfer and healthcare are just a few examples. A large quantity of literature has investigated strategic decision making (for example: whether or not to join a queue) with regards to queues stemming from []. When leaving one queue; customers (which we will refer to as players) often join a second queue and this is what is referred to as a hierarchical queueing system (as shown in Figure 1).

There is a wide range of literature evidencing the negative effect of selfish actions in queueing systems []. The following is a general conclusion of a majority of the literature:

> Selfish users make busier systems.

- Naor;
- VK+PH;
- RS;
- Bell Stidham;

- Hassani book;
- Rouhgharden;

The effect of selfish behaviour when compared to optimal behaviour can be quantified as the Price of Anarchy (PoA). This is defined as the ratio of the selfish ($\tilde{C}$) and optimal (C^*) costs:

$$\text{PoA} = \frac{\tilde{C}}{C^*}$$

The contribution of this paper is to consider two stations (to avoid confusion we will refer to a queue and service station as a station) in series allowing for two consecutive decisions: whether or not to join the station. Players who join the first station upon completion of service will potentially drop out from the entire system. A potential application of this is a healthcare system where patients must choose to see their general practitioner before obtaining care from a specialist/emergency centre. In Section 2, the model will be described. A novel aspect of this work is that the cost of a given policy is evaluated through the use of purpose built Agent Based Simulation (ABS). In Section 3 various heuristic approaches to obtaining optimal policies are considered. These range from random search algorithms to a more sophisticated approach that depends on the analytical formula for an $M/M/c$ queue [**?**].

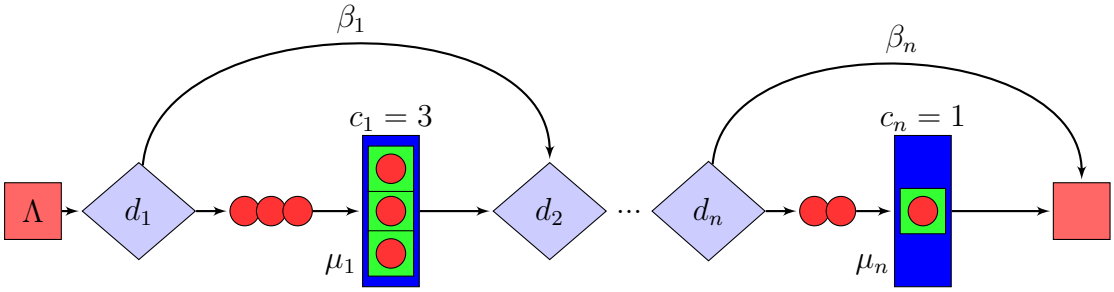

Figure 1: Diagram of n stations in series

2 Model

- Parameters;
- Optimal behaviour;
- Selfish behaviour.
- Cost (how to verify that cost is correct?).

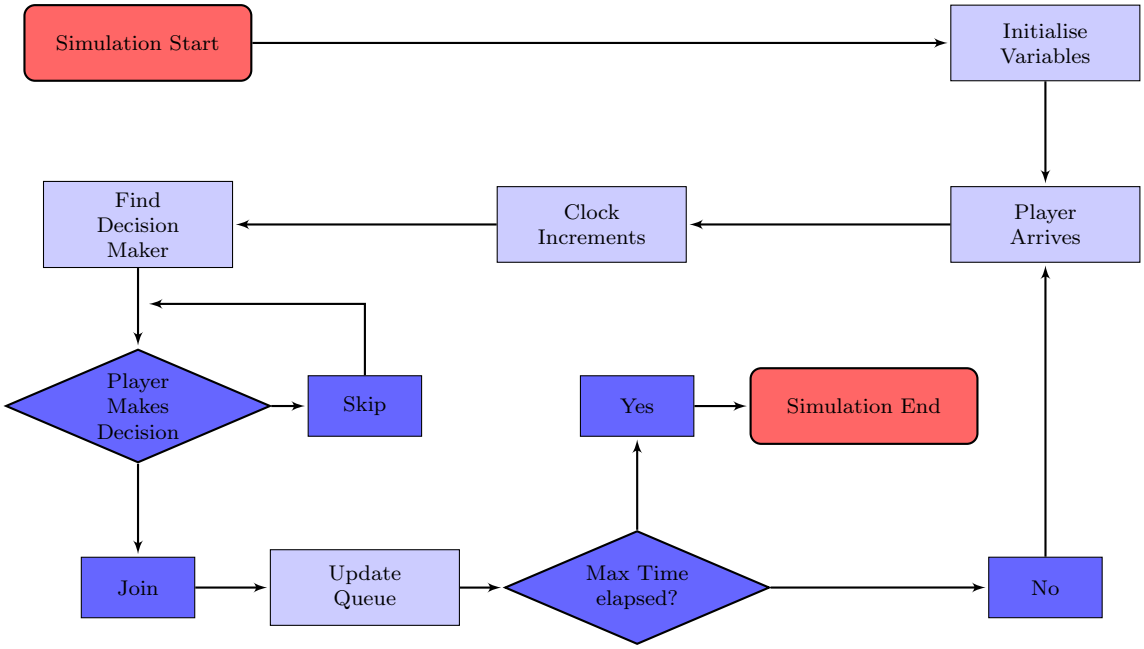

Figure 2: Flow chart describing the simulation model

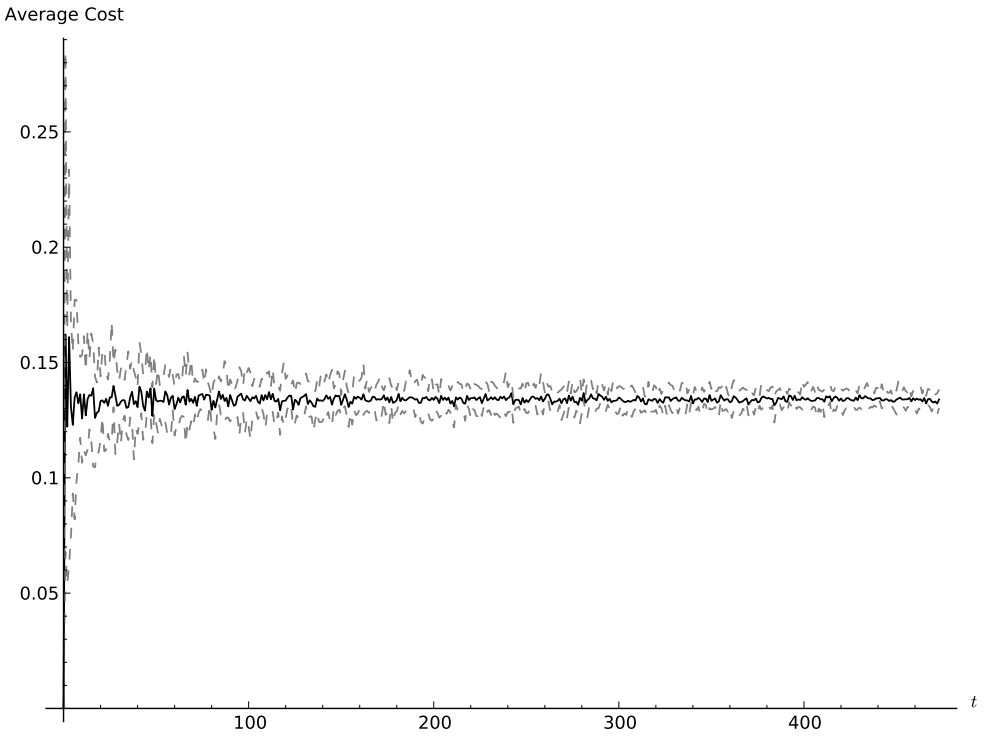

Figure 3: Run time

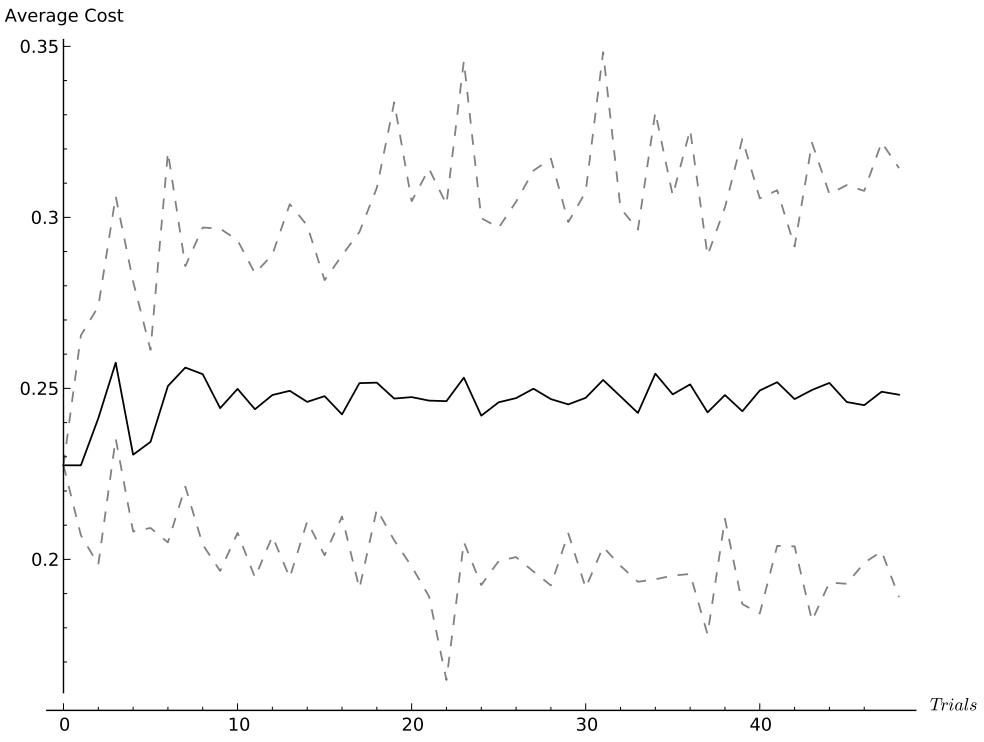

Figure 4: Trials

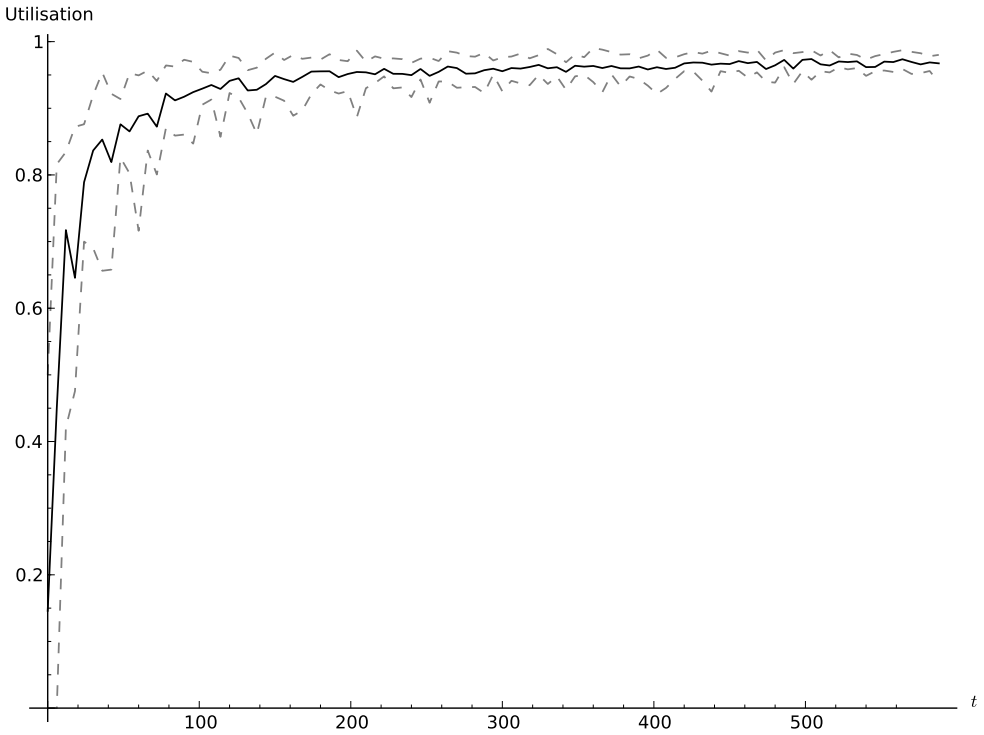

Figure 5: Warm up

3 Heuristic Optimal Policies

- Heuristic 1: basic search;
- Heuristic 2: based on assumption of Markovian arrival rate at second queue;
- Heuristic 3: Based on Naor which applies only for single server systems.

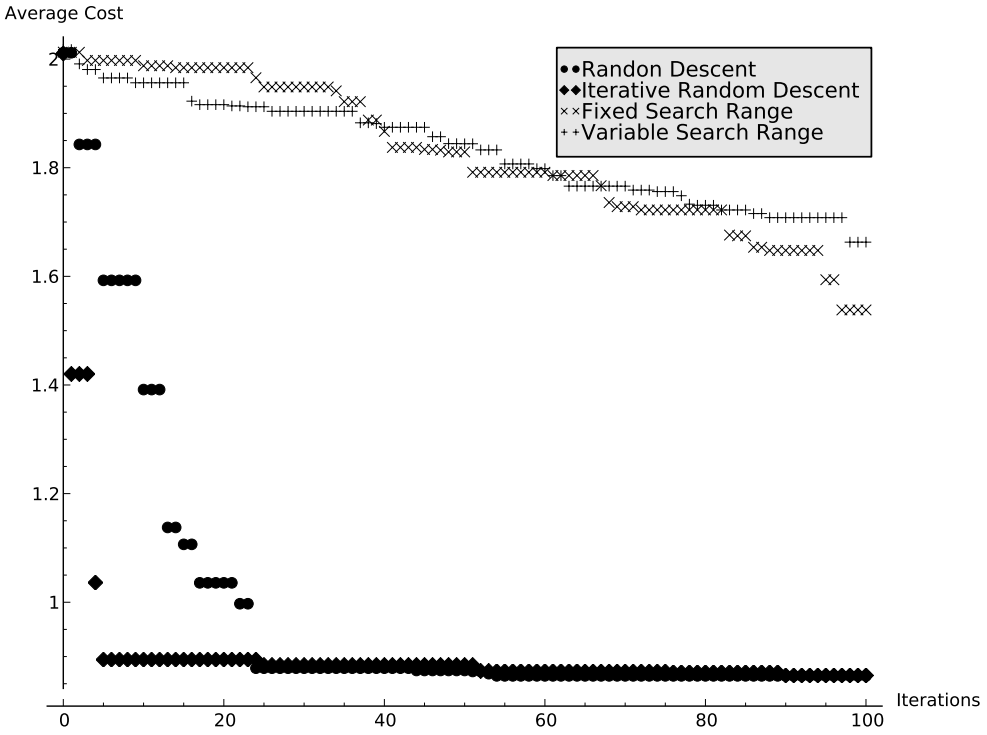

Figure 6: Comparing basic search

4 Results

- Scenarios...

5 Conclusions and Further work

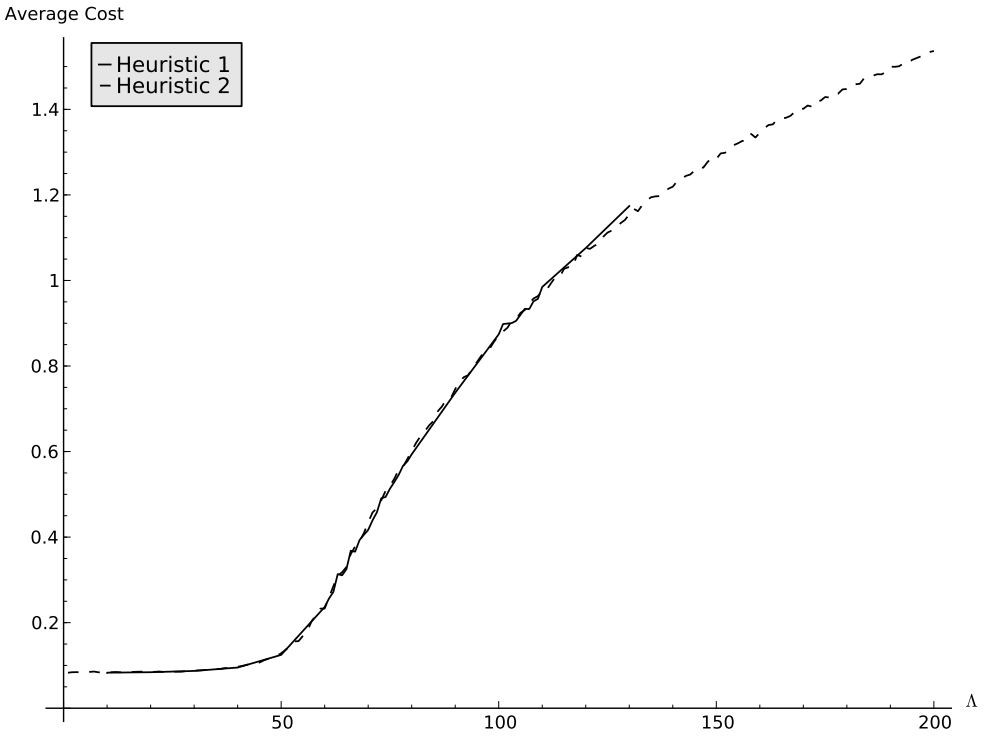

Figure 7: Comparing Heuristic 1 and 2

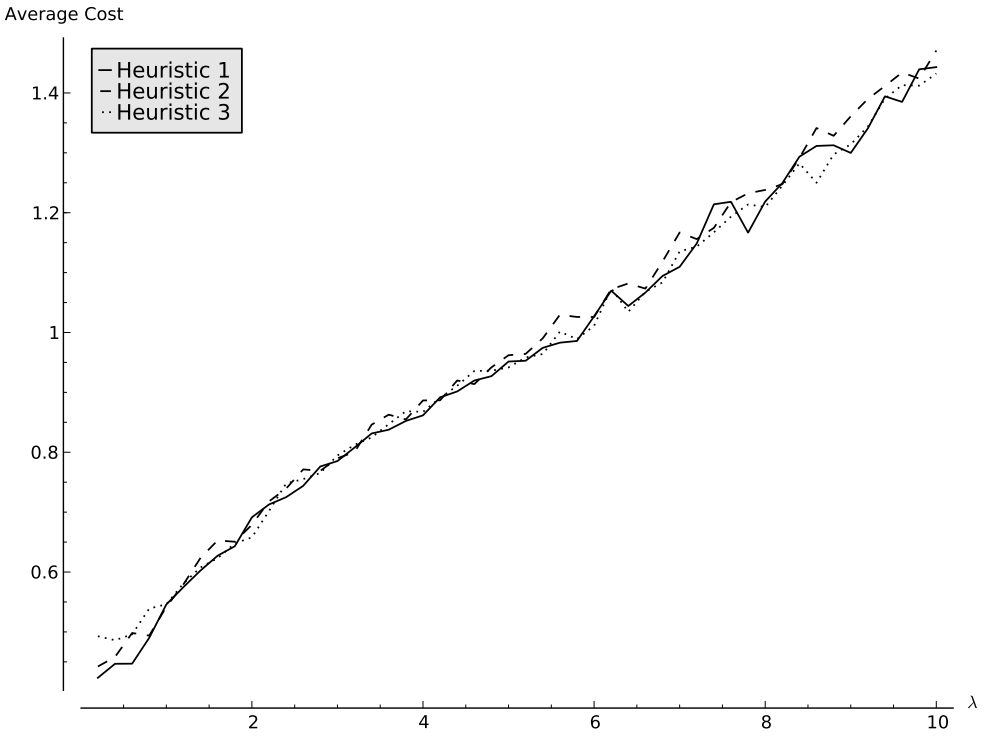

Figure 8: Comparing all heuristics

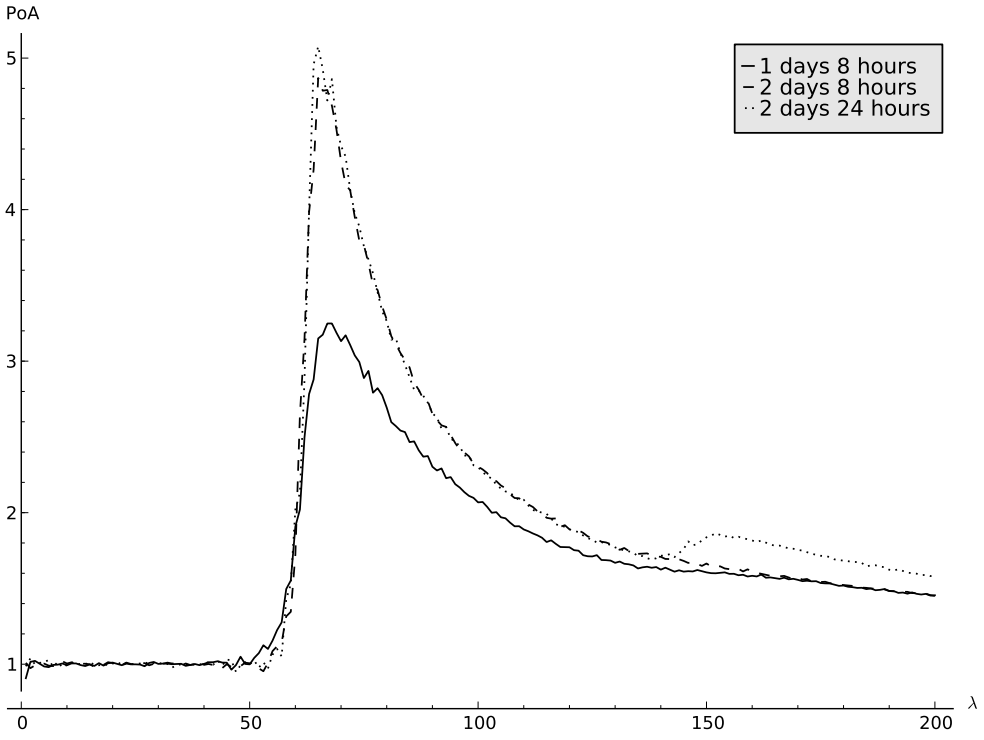

Figure 9: PoA for varying lambda

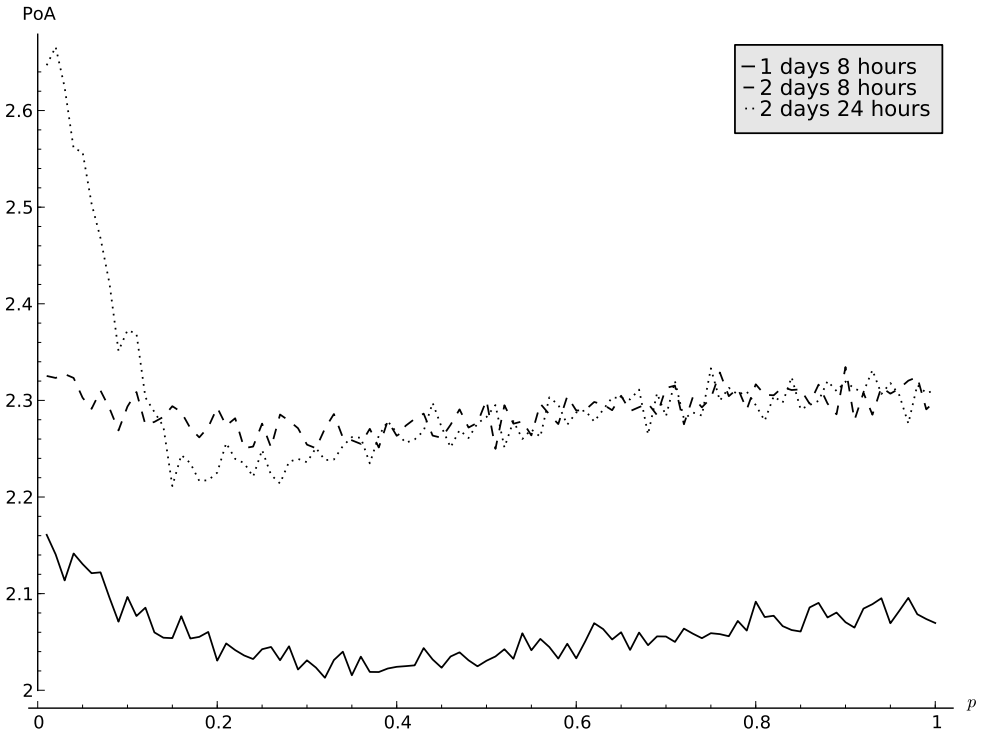

Figure 10: PoA for varying exit prob

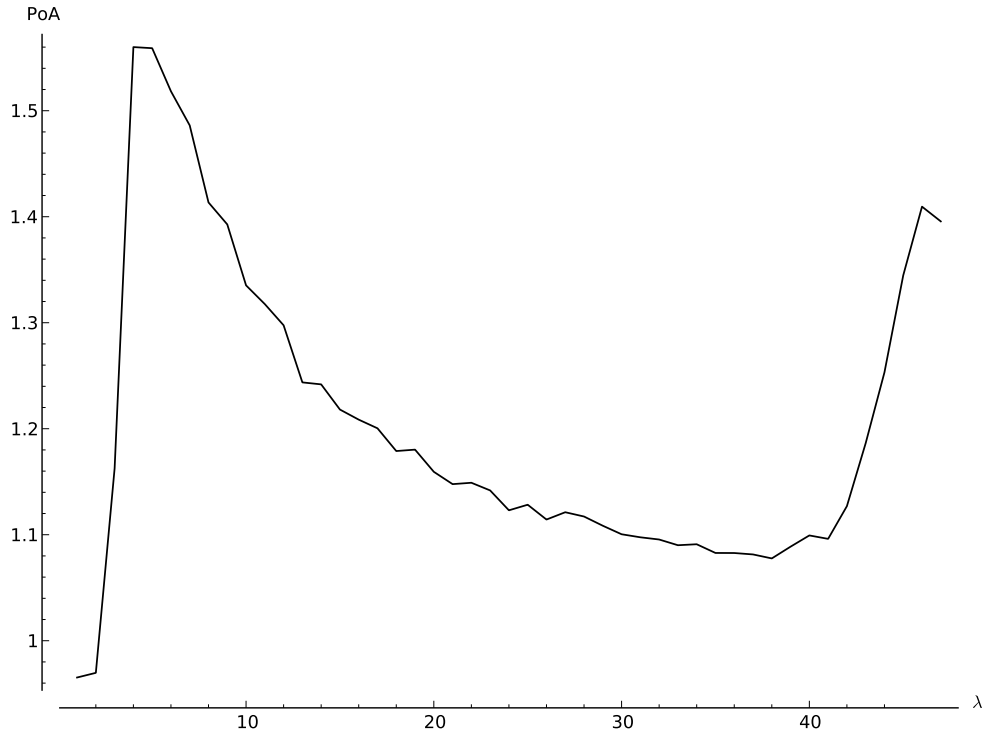

Figure 11: Another set of scenarios