Homework is due at the start of class on 12/2. Please turn in a hardcopy. It can be handwritten. Please show all computations.

Reading: Schroeder, Wierman, Harchol-Balter, *Open Versus Closed: A Cautionary Tale*, NSDI 2006.

Exercises:

1. (Analysis) Problem 7.5 from your book.

2. [**Comparing Open vs. Closed Systems: The effect of MPL**] In this problem you will primarily use simulation, however a few pieces will be doable via analysis (as marked). Your system throughout will be the simple single-server FCFS queue shown in Figure 1. Throughout, the job size distribution will be $S \sim \text{BoundedPareto}(k = 1333.33, p = 5 \cdot 10^8, \alpha = 1.8)$. Also throughout, the think time will be $Z \sim \text{Exp}(\lambda)$, where you will be determining λ.

   (a) **Think time as a function of load.**

   i. For the Open System, in Figure 1(a), the arrival process is a Poisson Process with rate λ. Use analysis to create a table for the value of λ which corresponds to loads $\rho = 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9$. Now create a plot where the y-axis is the mean inter-arrival time and the x-axis is the load ρ.

   ii. For the Closed System, in Figure 1(b), the load will be determined by the Think Time $Z \sim \text{Exp}(\lambda)$ and the MPL, N.

   - For the case of $MPL = N = 10$, use simulation to determine the value of λ which corresponds to loads $\rho = 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9$. Now create a plot where the y-axis is the *mean* think time and the x-axis is the load ρ.
   - Make sure to describe how your measured ρ in your simulation. There are many ways to do this: you can use an independent Poisson Process, or take a time-average, or measure throughput X and convert that to ρ. Please describe in detail what you did.
   - Repeat for the case of $MPL = N = 100$ and add this to your plot of mean think time versus ρ.
   - Repeat for the case of $MPL = N = 1000$ and add this to your plot of mean think time versus ρ.
   - Your plot should now have 3 curves, corresponding to $N = 10, 100, 1000$. Explain WHY your curves are ordered as they are. Note that you might need a log scale on your y axis to make all the 3 curves visible. Make sure that your graphs are clear. We should be able to easily read the numbers off of your graphs.

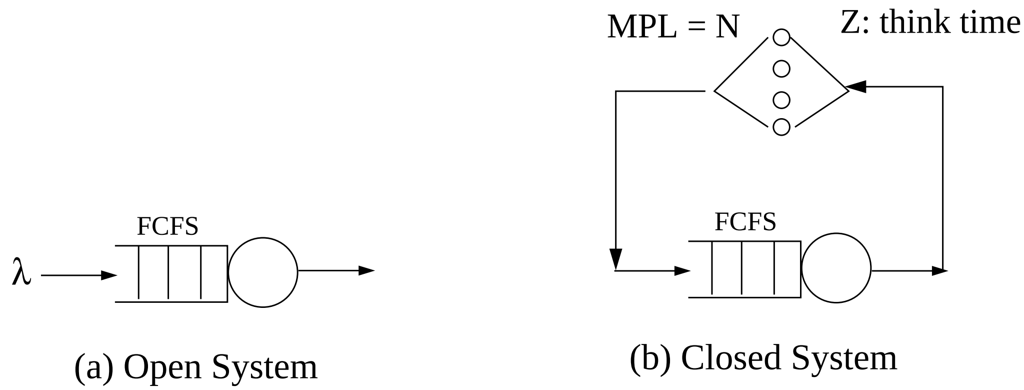

Figure 1: *For problem 2.*

(b) **Response time as a function of load.**
Use simulation to create a plot of mean response time, $\mathbf{E}[T]$, as a function of load ρ for 4 cases:

- open system
- closed system with $N = 10$
- closed system with $N = 100$
- closed system with $N = 1000$

For the case of the open system, use analysis to check that your plot is correct. Explain WHY the curves are ordered as they are.

3. **Comparing Open vs. Closed Systems: The effect of Scheduling** Repeat problem 2(b) in full but this time the scheduling policy at the queue is SRPT.

(i) Again produce a graph of $\mathbf{E}[T]$ versus ρ for the 4 cases:

- open system
- closed system with $N = 10$
- closed system with $N = 100$
- closed system with $N = 1000$

Make sure that your graphs are clear. We should be able to easily read the numbers off of your graphs. [Note that there's no need to repeat part 2(a) for SRPT because the numbers won't change much in going from FCFS to SRPT for part (a).]

(ii) When load $\rho = 0.9$, what is the improvement of SRPT over FCFS in each of the above 4 cases? Specifically, compute the ratio:

$$\text{Scheduling Improvement Factor} = \frac{\mathbf{E}[T]^{FCFS}}{\mathbf{E}[T]^{SRPT}}$$

in each of the above 4 cases.

(iii) Explain WHY the improvement factor is so much higher for the open system.