CSC 539 Computational Epidemics
Summer 2022
Jackson State University
Exam 2
Instructor: Dr. Natarajan Meghanathan

Total Points: 125 **Due: July 6th, 2022, 11.59 PM in Canvas**

Q1: 20 pts) Consider a city whose 70% of the population is initially susceptible to a disease that spreads per the SIR model. The rest of the population are immune to the disease. Determine the basic reproduction number (R_0) for the disease (which could be anywhere from 1 to 20). Use the binary search approach as part of your solution strategy to determine R_0 with an appropriate threshold value for the absolute difference (as discussed in the class notes) to stop the algorithm.

Q2: 30 pts) Consider for the following real-time data obtained for the spread of the COVID-19 virus (per the SIR model) within a county of 156,000 people. Use the infection data for Week 0 for initialization purposes. State your assumptions for the appropriate initial values you use and the computational approach you use.

(a) Determine the R0 for the virus within the county.

(b) If the average number of contacts per person ($\langle k \rangle$) in the county is less than or equal to 8, would the infection probability (β) be greater than or lower than the recovering probability (μ) in order to obtain the R0 value you determined in (a)?

(c) What could be an approximate number of people who would have recovered from the virus infection by Week 5?

Week	Total Infected Cases
0	100
1	2000
2	10000
3	30000
4	60000
5	100000
6	90000
7	75000
8	50000
9	30000
10	10000
11	4000
12	1000
13	200
14	100
15	10

Q3: 20 pts) Consider the spread of an epidemic under the SIRS model such that the fractions of susceptible, infected and recovered nodes at the endemic state (i.e., $\bar{s}$, $\bar{i}$ and $\bar{r}$) are the same.

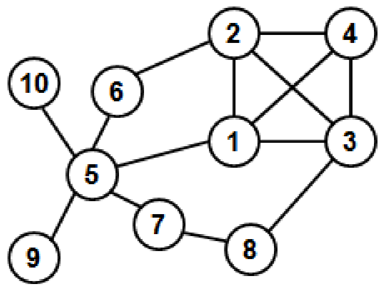
a) What would be the R0 value for such an epidemic?

b) If <k> = 1, use the endemic state formulations for $\bar{s}$, $\bar{i}$ and $\bar{r}$ to mathematically (and not using simulations) derive the values for the ratios β/μ, β/ξ and μ/ξ of the parameters of the SIRS model.

Q4: 25 pts) Let 99% and 1% of the nodes be initially susceptible and infected respectively. Simulate the working of the SIRS model using parameter values of $\beta = 0.9$, $\mu = 0.3$, $\xi = 0.3$ and $\langle k \rangle = 1.0$ for time units 1, 2, 3, ..., 50. Identify the fractions of susceptible, infected and recovered nodes in the endemic state.

Note: As part of your solution submission, you can submit separate Excel spreadsheet, labeled with the question number and upload in Canvas.

Q5: 30 pts) Consider the graph given below.



Simulate the working of the SIR model on the graph with **node 3 as the initially infected node** in round 0 and the rest of the nodes are susceptible. For each round, show the nodes that become infected or recovered as well as stay susceptible. The duration of infection is $1/\mu = 2$ rounds and the link infection probability (β) is 0.5.

Use the random numbers chart included here to decide which nodes become infected in a round. You can generate random numbers for more rounds, if needed.

Random numbers in the range of 0...1 generated for each link

Links	Round 1	Round 2	Round 3	Round 4	Round 5
1...2	0.540248	0.037269	0.539082	0.22241	0.488438
1...3	0.50178	0.537089	0.357936	0.129051	0.957115
1...4	0.733169	0.682445	0.438104	0.487376	0.992214
1...5	0.256378	0.220853	0.075314	0.659316	0.321978
2...3	0.978049	0.701358	0.671188	0.758375	0.286315
2...4	0.57333	0.679456	0.553619	0.170008	0.564355
2...6	0.068427	0.742157	0.28669	0.287777	0.437032
3...4	0.045431	0.069523	0.766988	0.065264	0.970803
3...8	0.420928	0.751161	0.707017	0.946536	0.242076
5...6	0.852163	0.314352	0.280231	0.657614	0.882565
5...7	0.170949	0.542855	0.499618	0.260965	0.813819
5...9	0.678802	0.199807	0.843998	0.643189	0.189297
5...10	0.76882	0.597068	0.026241	0.200732	0.399823
7...8	0.157908	0.823308	0.135346	0.106023	0.900296

A node chosen to get infected during a round is considered to have become infected at the end of the round and stays infected for the next $1/\mu$ rounds, and is considered to recover in the subsequent round. For example, with $1/\mu = 2$ rounds, a node infected in round 1 will stay infected for the complete execution of rounds 2 and 3, and will recover at the beginning of round 4.

a) Show the changes in the status of the nodes for each round, keep track of the nodes that get infected in a round as well as the nodes supposed to recover at the beginning of a round. Continue your simulations until all susceptible nodes in the graph have changed their status to either infected or recovered.

b) Plot the distribution of the degrees of the nodes vs. the average number of rounds it takes for node(s) with a certain degree to get infected.

Note: You can answer (a) and (b) using Powerpoint slides as is done by the instructor in class and submit/ upload in Canvas a clearly labeled file corresponding to the Question number.