Outbreak Diversity Through Contact Networks!

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Infections! Infections! Infections!

- Humans are social creatures, and a result, they tend to interact with one another
- More interactions amongst people is always a good thing! However, one downside to more interactions, is that diseases are spread!
- I would imagine that people would love to know how quickly the disease would spread and many people look to the basic reproductive number(R_0) for information. If it is less than 1, the disease is likely to spread slowly and die out. If greater than 1, it will spread quickly and likely cause an epidemic
- Unfortunately, that number is not always accurate because it treats all humans the same in terms of susceptibility of catching a disease and spreading one. As we all know everyone is different because some people have a smaller social network than others
- It is important to understand that the way this disease spreads, like many others, varies person to person.

Research Paper

- This paper focused on 3 contact networks and simulated data for the city of Vancouver, British Columbia using simulations
- Severe Acute Respiratory Syndrome

Network theory and SARS: predicting outbreak diversity

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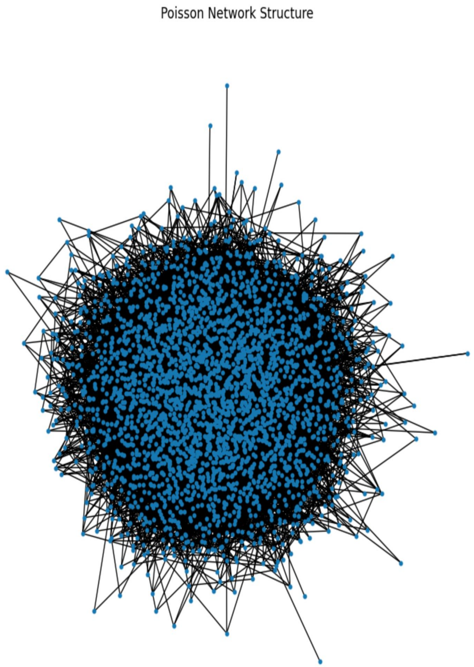
Question:

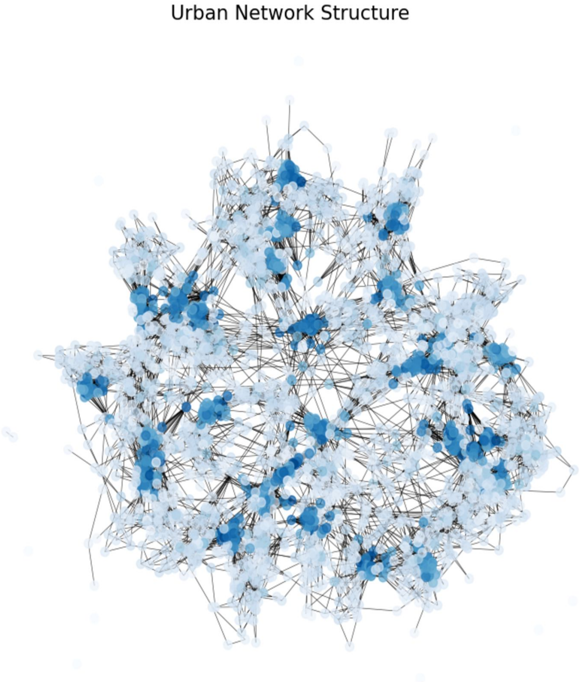
How do the different types of contact networks affect the spread of diseases in general?

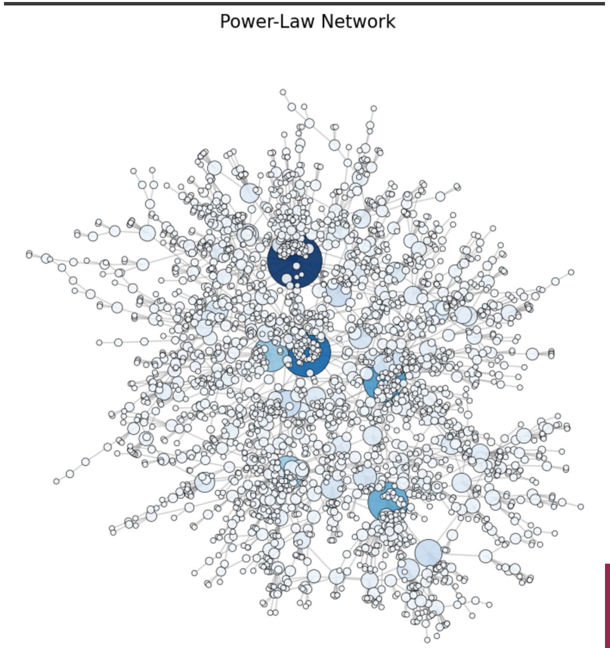
Where Do People Meet?

- Common places people meet are at schools, work, hospitals.
- In the study, people are assigned to hospitals, workplaces, schools, and other public places based on age in a simulation
- Teachers were assigned to schools and nurses and doctors to hospitals
- For every 30 students there was one teacher and at each ward 20% of the people are doctors and 30% of the people are nurses
- Probability connections for each place were given to us:
  - Households = 1
  - Schools = 0.3
  - Hospitals = 0.3
  - Workplace = 0.03
  - Other Public Places = 0.003

Results of Simulation(3 Network)

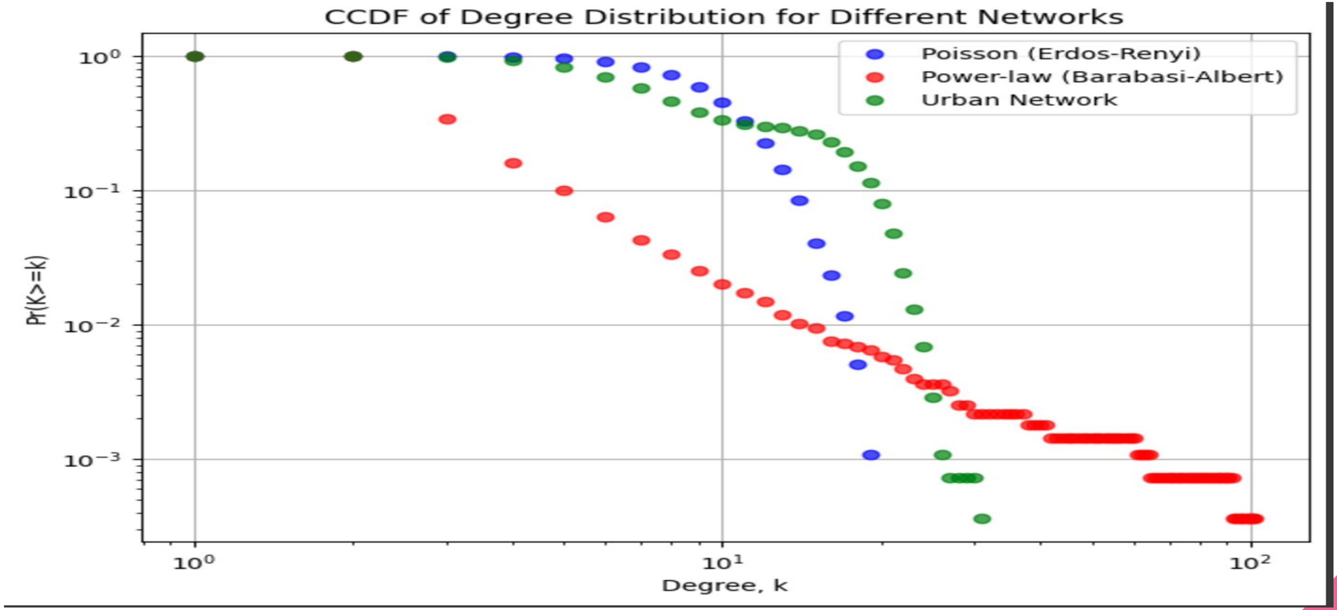






Degree Distributions

- Used the plot_CCDF function from the homeworks



What Do the Networks Tell Us?

- You can see the first network is fully clustered with a few outliers surrounding it.
- People interact a good amount with one another in their own household, at schools, work, and at hospitals which explains the large cluster of nodes in the middle
- As a result, it is more likely that the disease spreads in the giant cluster in the middle due to the larger number of connections and for the nodes on the outside, have a lower chance of spreading or receiving diseases
- Overall, the graph is not very helpful to look at
- Urban Network is similar to Poisson Network in terms of having high connectivity
- Clusters of nodes represent the public places we simulated
- Still much more homogeneous than power law but less than Poisson
- The Clusters signify the different areas of interest such a schools, workplace, hospitals, households, and other publics spots
- Differs from poisson network where individuals connect to one another independently and randomly.

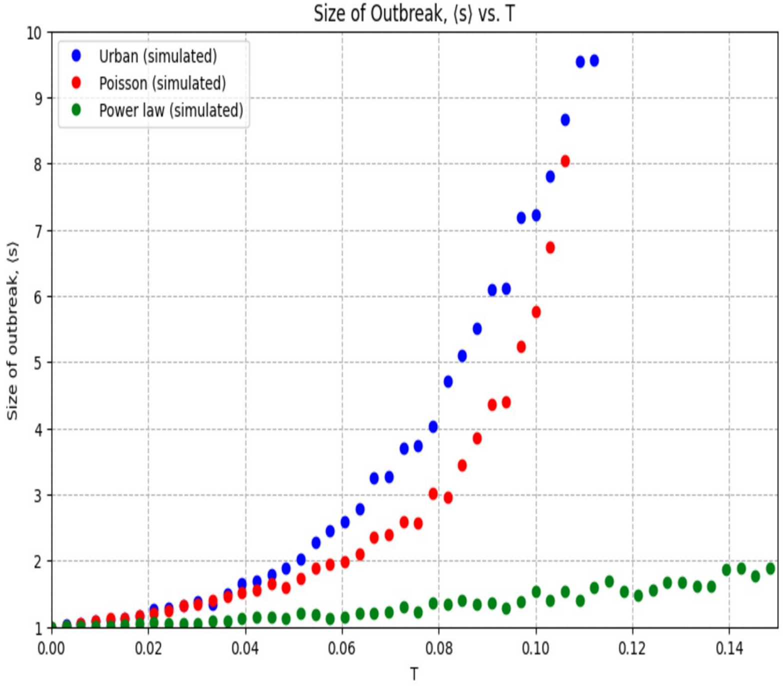
Cumulative Degree Distributions

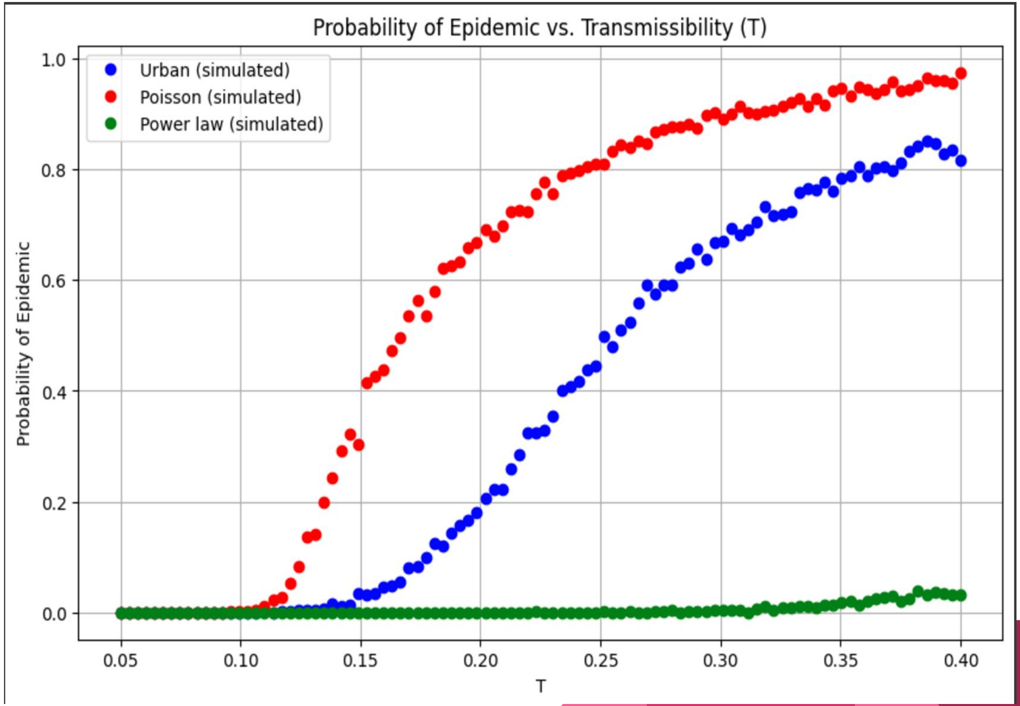
- Poisson Network:
  - Most nodes connect to similar number that other nodes do which highlights the uniform degree distribution
  - If a node were too be removed, the impact would be less on this distribution
- Power Law:
  - A heavy tail illustrates that Hubs are present but many low degree nodes are present
  - Hubs have a pivotal role in the network's connectivity and overall behavior
  - Removing a node would significantly impact the results
- Urban Network:
  - Similar to Poisson Network
  - As k increases, P(k>=k) decreases

Predicting Future Outbreaks!

- Basic reproduction number has limitations
  - Doesn't factor in different types of contact patterns that different groups of people have
- Use more efficient tool- Transmissibility(T)
  - Average probability that an infectious individual will spread to a susceptible person
    - Instead of looking at total number of new cases
  - Lets us understand number of new infections and number of contacts the person has
    - Gives us more context on the transmission dynamics
  - Is a good way to predict outbreaks so that's exactly
  - Used transmissibility for each distribution and plotted the results
- Before looking at the results, we can make a few predictions:
  - Poisson network returns larger numbers of affected people as T increases compared to Power Law Distribution
  - Poisson Distributions are more uniform
    - Allows disease to spread more quickly
  - Power Law distributions have hubs so it's less likely for multiple hubs to get it if the degree between them is small
  - Urban Network results should fall somewhere in between the 2 other networks
- Used SIR model from class to plot the graphs

Results of Simulations





Interpret Them

Differences in the networks

- Differences stem from the “differences in the patterns of interpersonal contact”.
    - Power contacts, as seen, have a small minority of superspreaders with high degrees
    - Meanwhile the Poisson network is homogeneous and any two outbreaks are essentially the same
    - Urban network is somewhere in the middle
    - Outbreaks are less likely to reach epidemic proportions in Power Law Network
    - Power Networks have many vertices with few contacts and have a small minority of super spreaders.

What we have left to do:

- Create a simulations that measure the probability of an epidemic given the initial degree of a person and initial size of outbreak
- We want to look at if there is a possibility that the chance of there being a full blown epidemic is possible given the initial degree of a person is higher.
- In terms of outbreak from initial size, we assume that the chance of an epidemic is higher if the size of the initial outbreak is higher.

Why does this matter

- Important to find best network to accurately model outbreaks
    - Difficult task to do globally due to large population
    - Helps a lot since can predict and control spreads of infectious diseases
    - Better data helps generalize predictions, better suggestions for epidemiological control

Resources

L.A. Meyers et al., **Network theory and SARS: predicting outbreak diversity.** *J. Theoretical Biology* **232**(1), 71-81, 2025,https://www.sciencedirect.com/science/article/pii/S0022519304003510

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