Epidemics on Networks

Network Science Final Project

Bauer Jan, Iten Adrian and Jehoul Astrid

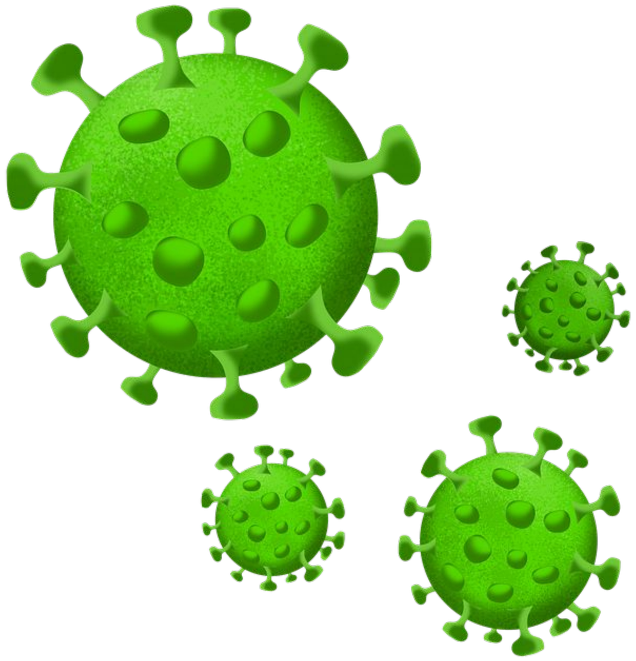
Table of Contents

- Introduction
- Theory
- Methods
- Results
- Discussion & Conclusion

1 Introduction

Introduction

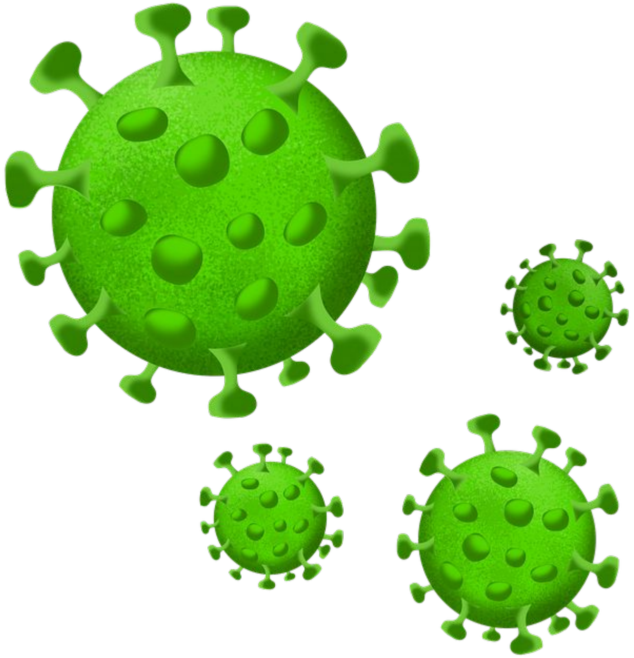
- Vulnerability of networks
- Recently: Computervirusses and SARS-CoV-2
- How do viruses spread on networks?
- Epidemic models
- Synthetic and real-world networks
- More effective intervention



2 Theory

Theory

- Simple contagion
- Homogeneous mixing assumption
- Basic reproduction number R_0

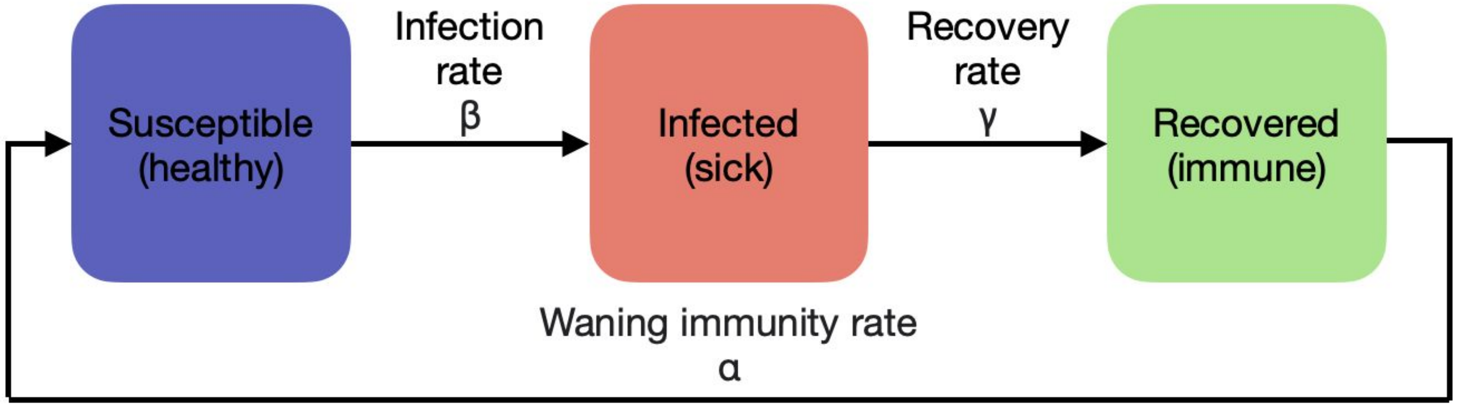


Theory

- Compartmental models
  - SI
  - SIR
  - SIRS

- Agent-based models

- Gillespie algorithm



3 Methods

Methods - Networks

- Synthetic graphs
  1. Barabasi-Albert
  2. Erdos-Renyi
  3. Watts-Strogatz
- Real-world networks
  4. Facebook Friendships
  5. Sex Escorts
  6. Contact Tracing Graph (from Haslemere, England)

Methods - Metrics

- Average Degree
- Degree distribution
- Scale-free property
- Graph Density

Table 3: Analysed networks

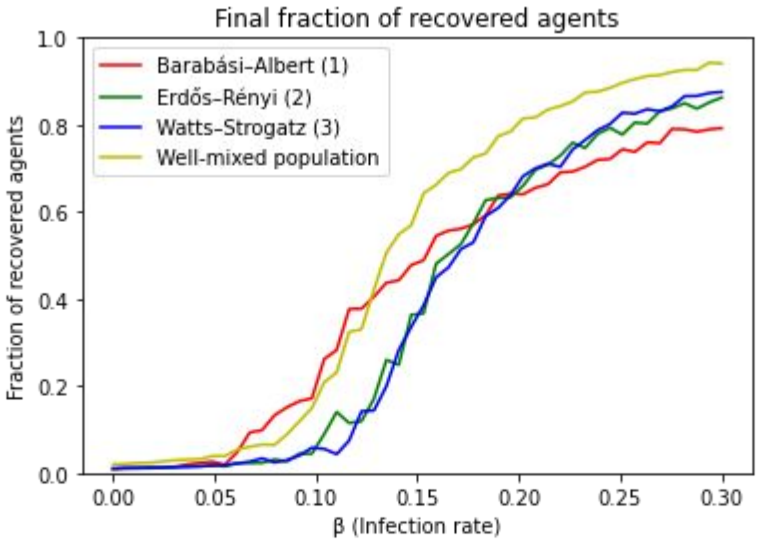
Network	$< k >$	Scale-free	Density
1 (BA)	9.95	True (2.72)	0.9960%
2 (ER)	9.86	False (8.22)	0.9872%
3 (WS)	10.0	False (10.13)	1.0010%
4 (FF)	43.69	True (2.51)	1.0820%
5 (SE)	4.67	True (2.87)	0.0279%
6 (CT)	6.46	False (3.0)	1.5490%

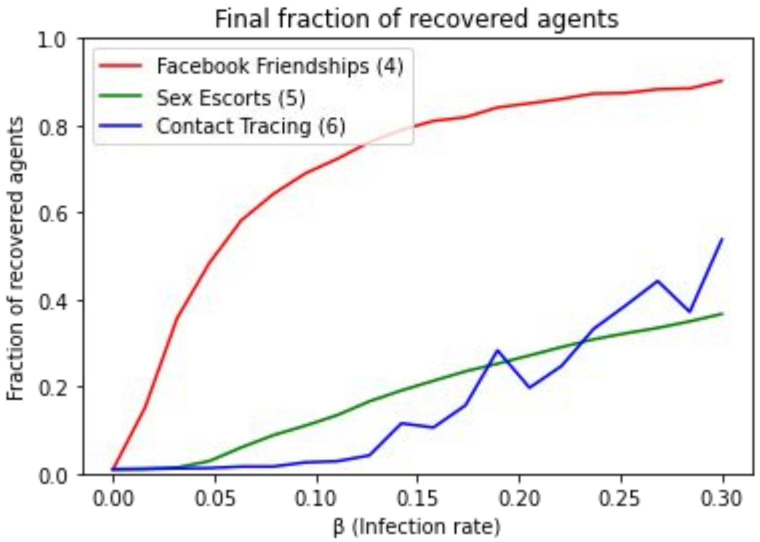
4 Results

Experiment 1

- Measuring the influence of infection rate of the disease on its spreading in the SIR model
- Agent-based modelling: average of n = 10 runs for each infection rate
- x-axis: Infection rate (0- 30%),
  y-axis: Final fraction of recovered agents

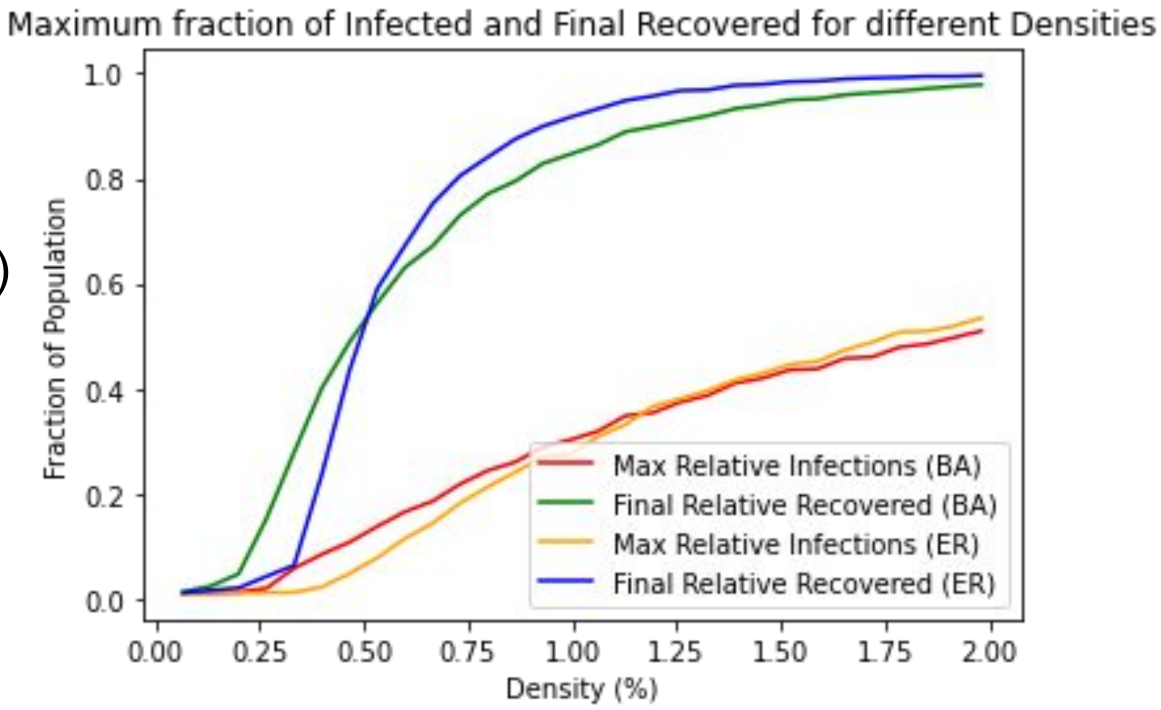
- Scale-free networks (facebook) show no epidemic threshold





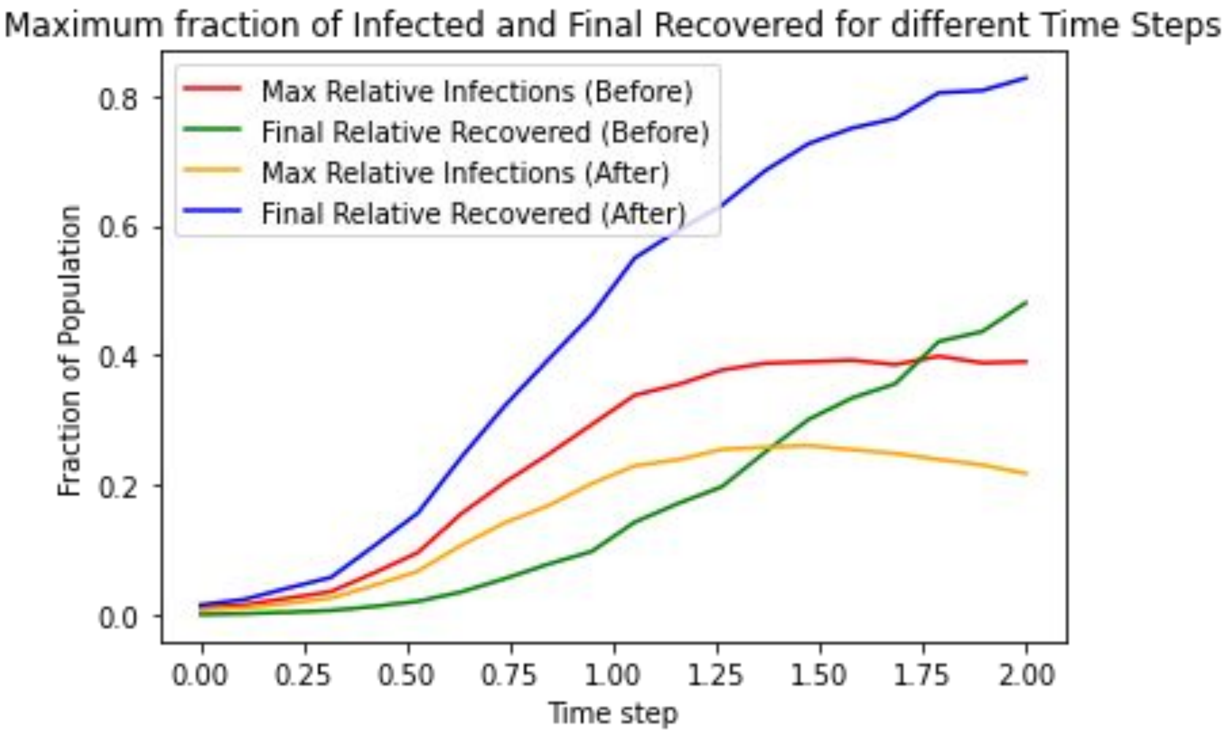
Experiment 2

- Idea: Measure the influence of two important network properties in the SIR model: density and whether it is scale-free
- How: Using synthetic graphs as they can be created for any given size, fix infection rate (10%) and recovery rate (100%)
- Goal: get a feeling of what measures relating to the network structure need to achieve
- Disease already spreads for low densities, hence very low density has to be achieved by measure
- For those low densities, getting rid of the scale-free property may additionally be beneficial (large degree = potential superspreader)



Experiment 3

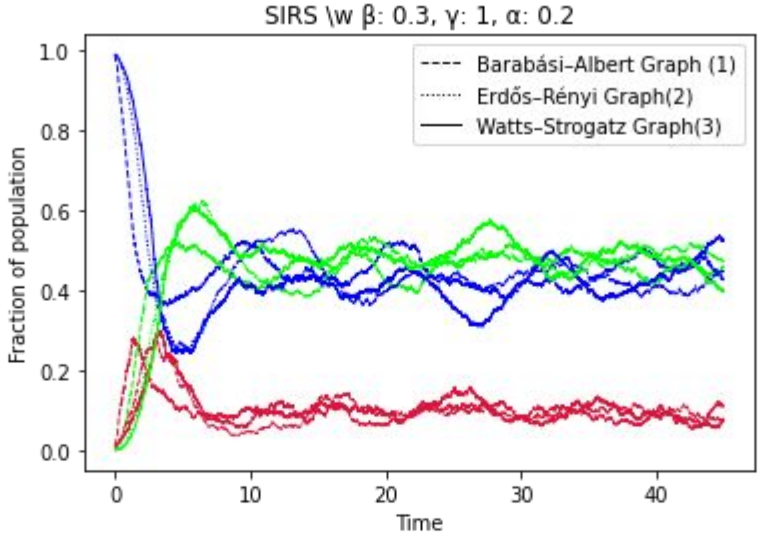
- Goal: assess the efficiency of a method that introduces contact restrictions (cuts edges) and tries to eliminate high-degree nodes
- Implementation: add a ceiling to the degree
  - maximum n=5 edges per node (out of 3'000 with original density of 1.33%)
  - density afterwards < 0.33%
  - from scale-free to scale-rich
- Compare Rates after the introduction of the measure with a timely delay
  - recovered naturally higher
  - maximum infected lower, early introduction important

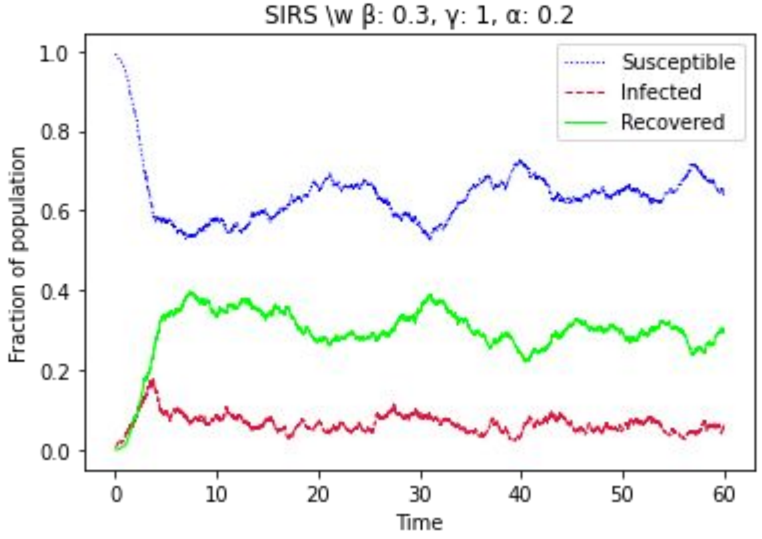


Experiment 4

- SIRS model: Extension of SIR with possibility of reinfection (α), further extension possible to include death cases, hospitalizations etc.
- Less importance of network topology and whether it is scale-free

- Wave-form spreading on lower value for real-world Contact Tracing Graph





University of Zurich[UZH]

Faculty of Business, Economics and Informatics

5 Discussion and Conclusion

Discussion and Conclusion

- Showed inexistence of epidemic threshold in scale-free networks, also for real-world networks
- Experimented with different network properties in order to see influence on spread in SIR model: in addition to the SIR infection rate, both the degree distribution as well as the density are influential
- Simulated a simplified measure to show that acting quick is of big importance due to the exponential spread of diseases
- Extending the model (SIRS) leads to different results, but can explain more phenomena