Modelling spreading phenomena in real-world networks

Changwang ZHANG and Shi ZHOU
Computer Science, UCL

Spreading phenomena

- Widely exist in the real world
  - Computer virus in the Internet
  - Epidemics in human population
  - Information dissemination in society
    - Advertisement campaign
    - Riot incitement via tweeter, facebook etc.

Existing models

- A popular example: SIR model
  - Susceptible, Infectious, Recovered
  - Sound mathematical theories
  - Convenient for simulation experiments
- Purpose: to predict and control spreading

Problems of existing models

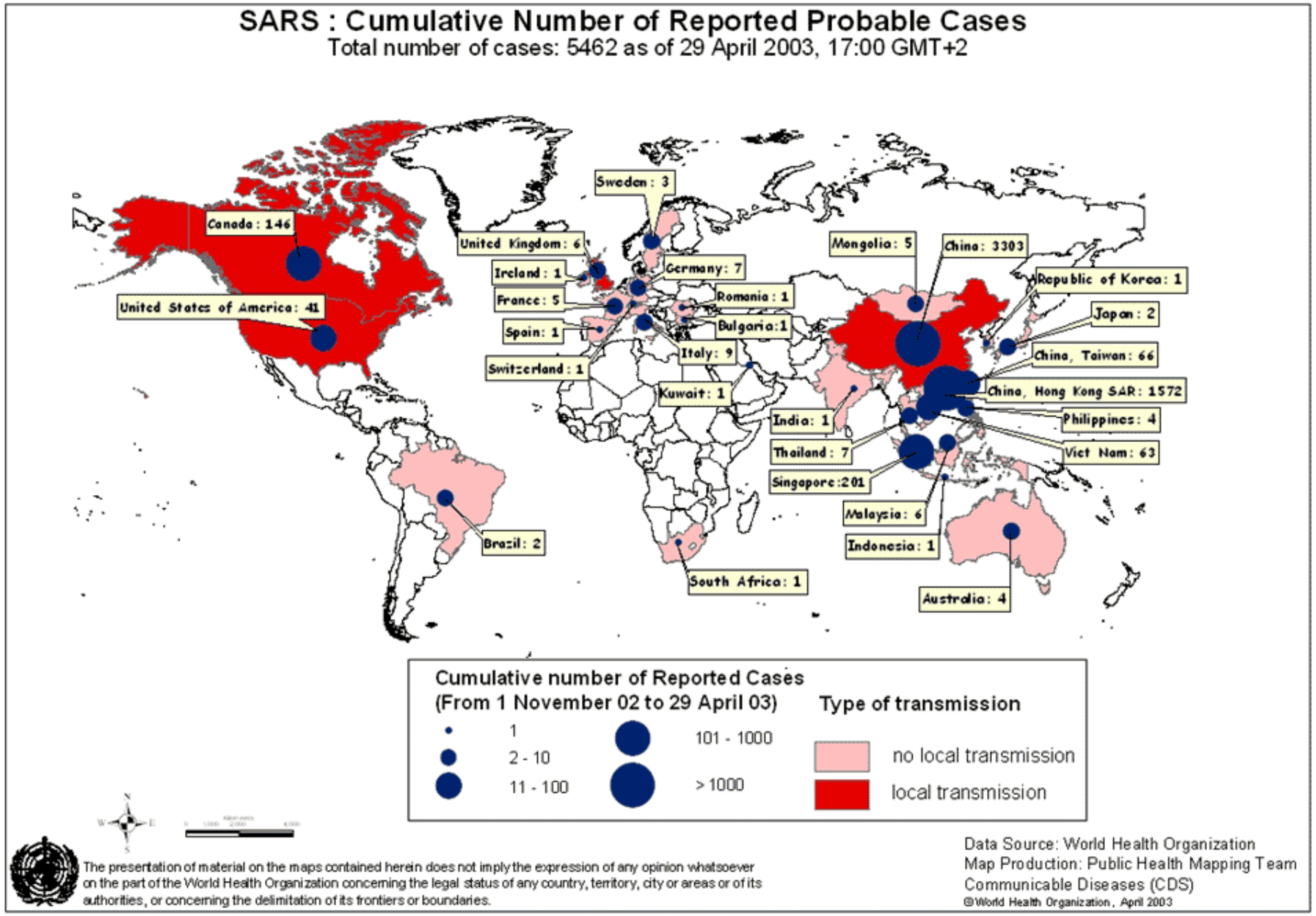
- Too simplistic
- Consider only one spreading process on one network

Spreading phenomena in real-world networks

- Much more complex
- Often involve multiple spreading processes on multiple networks
  - Happen simultaneously
  - Interact with each other

Example 1 - Epidemics

- SARS

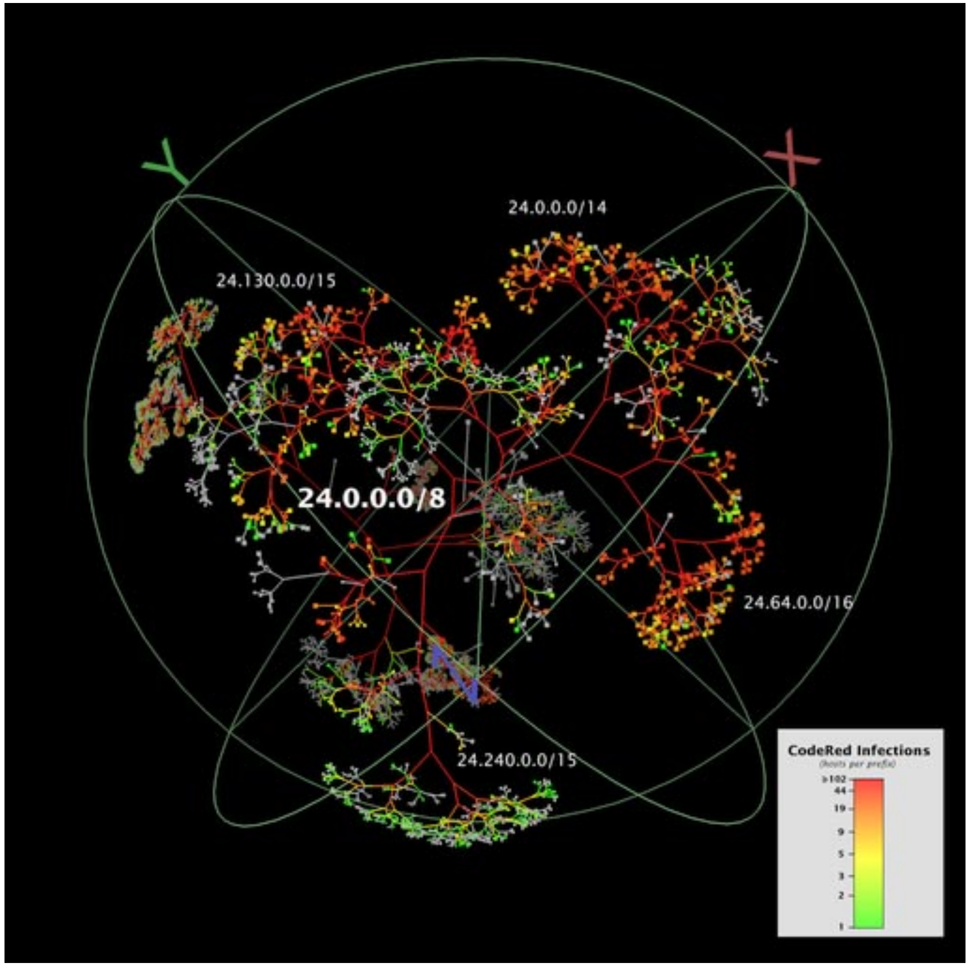


Example 1 - Epidemics

- SARS
  - Local spreading
    - following human mobility patterns within communities and cities
      - Lots of accidental contacts
    - Shall we immunise the whole population?
  - Global spreading
    - via the global aviation network
      - long-haul flights, well-defined structure
    - Shall we cancel all flights?

Example 2 – Computer Virus

- CodeRed



Example 2 – Computer Virus

- CodeRed
  - Global spreading
    - $^1/_8$ of the time it probes a completely random IP address
  - Local spreading
    - The rest of the time it probes local IP addresses (with the same 24-bit or 16-bit prefixes)
  - Both processes are needed for an successful attack

Example 3 - Advertisement

- Local spreading
  - Word of mouth: gossip, Tweeter and Facebook
    - Infect friends/followers via social networks
- Global spreading
  - Broadcasting and publishing: TV, Radio, the Web
    - Accidental, anyone can be informed
- The two processes feed into each other.

Real-world scenarios

- Multiple spreading processes
  - Targeted spreading following network structures
  - Accidental spreading via universal access
- On multiple networks
  - Overlapped or partially overlapped networks
  - Networks at different granularity
- Interactions
  - Between spreading processes
  - Between networks

A new spreading model

- Starting with a typical scenario
  - Two processes on two overlapped networks
    - Local spreading following a network structure
      - Power-law network topology
    - Global spreading with random, universal access
  - Similar to the advertisement campaign
  - Independent, simultaneous and interactive

Theoretical analysis

- If the parameters of the spreading processes satisfy the critical threshold

$$\frac{\beta_1}{\gamma} > \frac{1}{\alpha(\langle k \rangle - \delta n) + \delta n}$$

- then the final size of an outbreak (in an infinite network) can be predicted as

$$\langle r(\infty) \rangle = \frac{[\beta_1 \alpha \langle k \rangle + \beta_2 (1-\alpha)(n-1)]/\gamma - 1}{[\beta_1^2 \alpha^2 \langle k^2 \rangle + 2\beta_1 \alpha \beta_2 (1-\alpha)(n-1)\langle k \rangle + \beta_2^2 (1-\alpha)^2 (n-1)^2]/(2\gamma^2)}$$

- otherwise the outbreak size approaches to zero, meaning the epidemic is ephemeral.

The critical threshold

Infection rate of local spreading

$$\frac{\beta_1}{\gamma} > \frac{1}{\alpha(\langle k \rangle - \delta n) + \delta n}$$

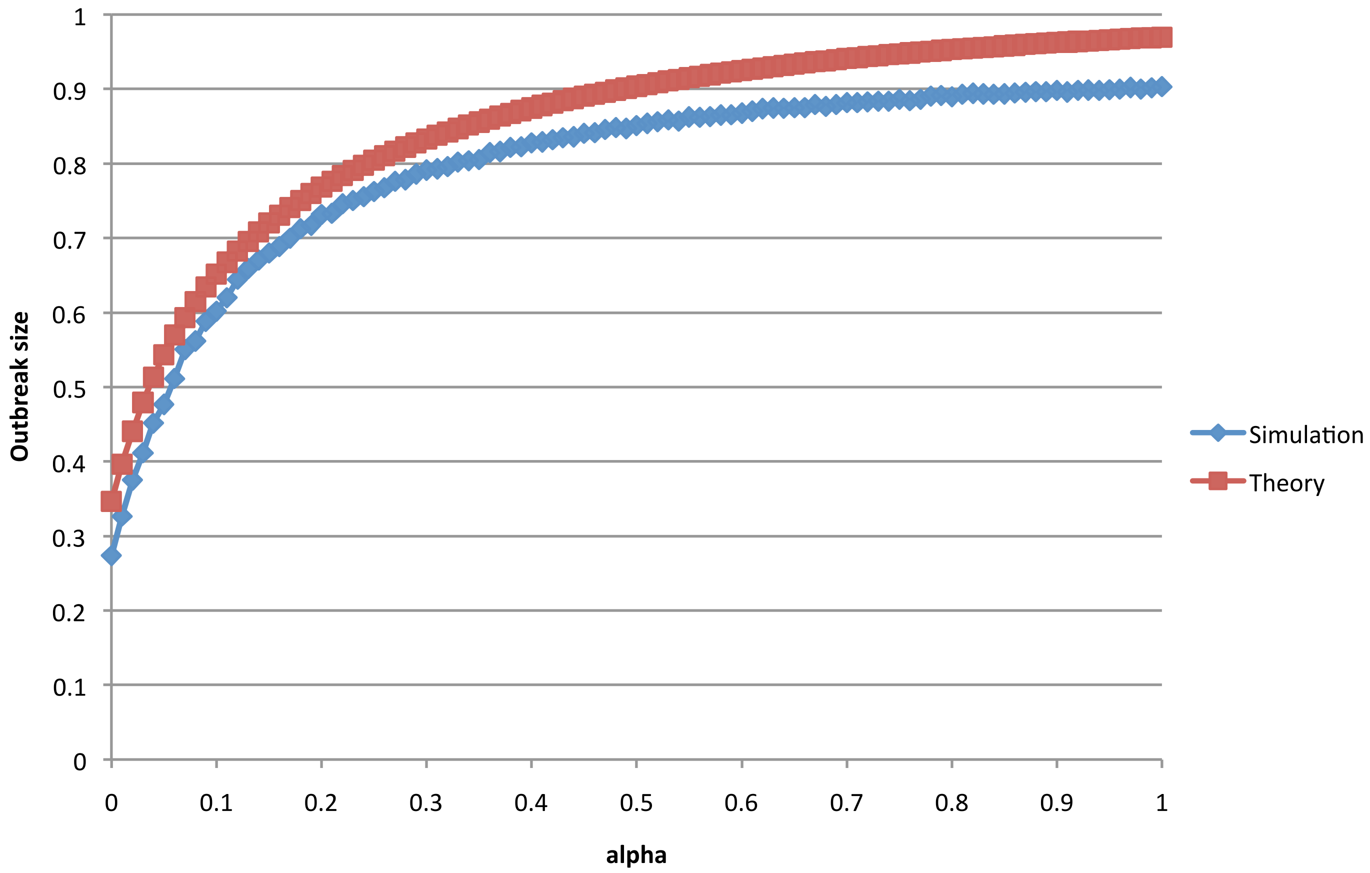
Recovery rate

The ratio of local infection rate (beta1) to the global infection rate (beta2).

The percentage of local spreading, i.e. the percentage of global spreading is 1 – alpha.
Previous models are equivalent to special cases of our model (when alpha is zero or 1).

The node average degree, i.e. the average number of connections a node has in the local spreading network.

Simulation results



Challenges and future work

- To study other measures and other parameters.
- To extend the model to more general scenarios.
- To improve the accuracy of predictions.
- To explore real applications.

Collaboration

- We call for collaboration
  - Real-world case study
  - Theoretical analysis
- In particular we need real datasets
  - Can you help?

Thanks

Changwang ZHANG c.zhang@cs.ucl.ac.uk

Shi ZHOU s.zhou@ucl.ac.uk