Jun 25 2011
ERC Summer Workshop

복잡계 망에서의 정보 흐름 모델과 분석

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Information Diffusion

- Various networks play fundamental roles as a medium for diffusion of information, ideas, and influence among its members.
  - World Wide Web
  - Infection networks
  - Co-authorship networks
  - Social Networks

- Understanding how information flows on networks, how often and when it results in large spreadings are important problems.

Threshold phenomenon

- Some kinds of influences spread greatly compared to others.
  - Public protests in Tunisia, Egypt, and Libya in 2001
  - The tipping point of Harry Potter in 2000

- Threshold phenomenon (appearance of large spreading)
  - When an information spreads rapidly and dramatically at a certain moment.
  - In sociology, this moment is called tipping point.

Applications

- Maximization of spreading of influences
  - Advertisement
  - Opinion spreading

- Minimization of spreading of bad information
  - Prevention of epidemics (vaccination)
  - Public abnormality control

Studies on Information Diffusion

- Traditionally the diffusion of innovation studied in Sociology
  - Adoption of hybrid corn (Ryan and Gross, 1943)
  - Diffusion of innovations among physicians (Coleman et al., 1957)
  - Innovation decision process theory (Rogers, 1962)
- Lots of models have been investigated
  - Linear threshold model
  - SIR model

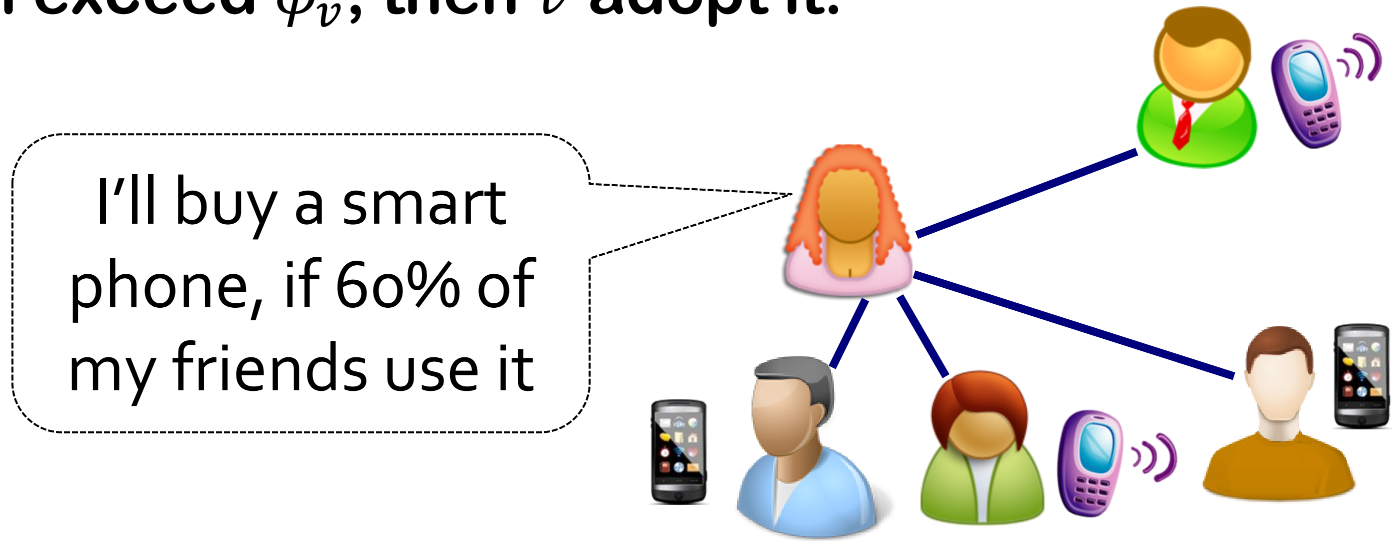
Information Diffusion Models

- A network is represented as a graph. Each user is considered as a node.
- Each node can be either active or inactive.

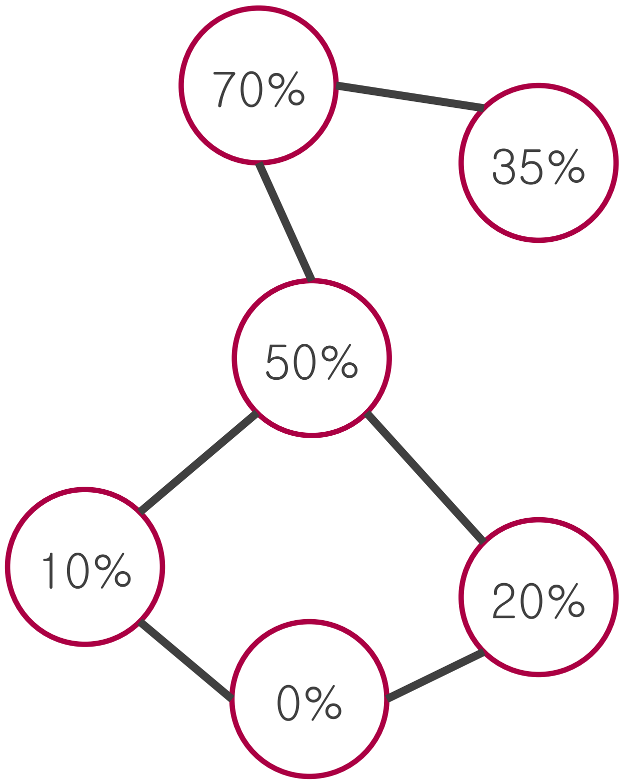
- By the "word-of-mouth" effects, each node's tendency to become active increases monotonically as more of its neighbors become active.
  - A node can switch to **active** from **inactive**, but does not switch in the other direction.

Linear Threshold Model

- Individuals make their decisions based on their **neighbor's decisions.**
- Each individuals have threshold value $\phi_v \in [0,1]$
  - Drawn from a distribution $f \in C^1$ in an i.i.d. manner.
- If the number of neighbor nodes that accepted the innovation exceed ϕ_v, then v adopt it.



Linear Threshold Diffusion Process



Initial adopter: 1

Final cascade size: 4

Stop!

Previous Work on Linear Threshold Model

- Information spreading and the occurrence of a tipping point have been analyzed for special cases
  - Complete graph with any f
    (Granovetter, *The American Journal of Sociology*, 1978)
  - Infinite and locally tree-like graph with any f
    (Watts, *PNAS*, 2002)
  - Erdős-Rényi random network with constant f
    (Whitney, *Phys. Rev. E*, 2010)

Main Question

- Let $t(k)$ be the cascade size with k proportion of initial adopters.
- Select k proportion of initial adopters uniformly at random and independently

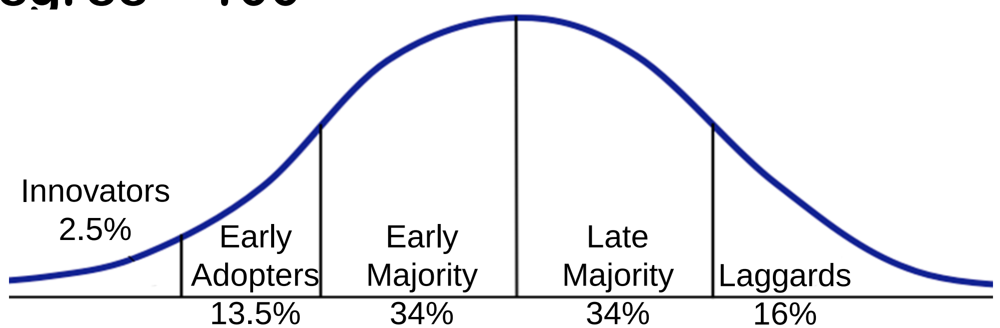
Can we predict $t(k)$ with high probability for a more general class of network structures and threshold distribution f?

Based on this analysis, can we predict when a tipping point will appear?

- We provide positive answers
  - Work with Seulki Lee and Hyuna Kim

Experiments

- Dataset
  - **Facebook** network
    - New Orleans regional network
    - |V| = 60,290, |E| = 1,545,686, average degree = 23
  - **MySpace** network
    - |V| = 100,000, |E| = 6,854,231, average degree = 137
  - **Erdős-Rényi random** network
    - |V| = 100,000, average degree = 100
  - **Complete** graph
    - |V| = 100,000

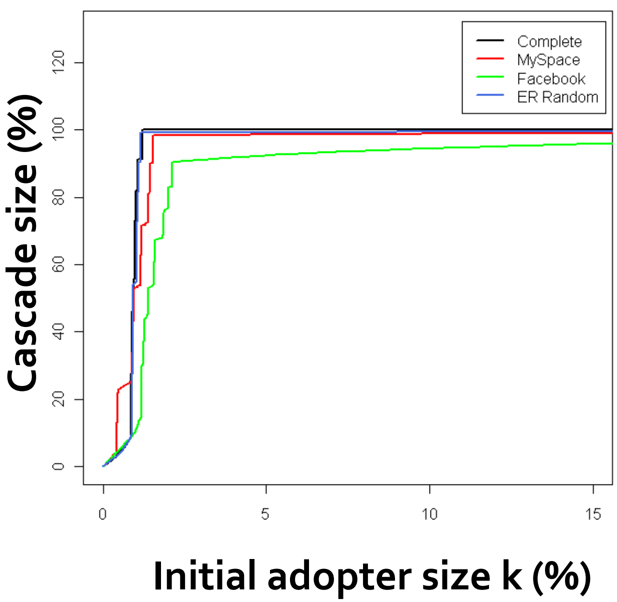


Diffusion of innovations curve
(Rogers, 1962)

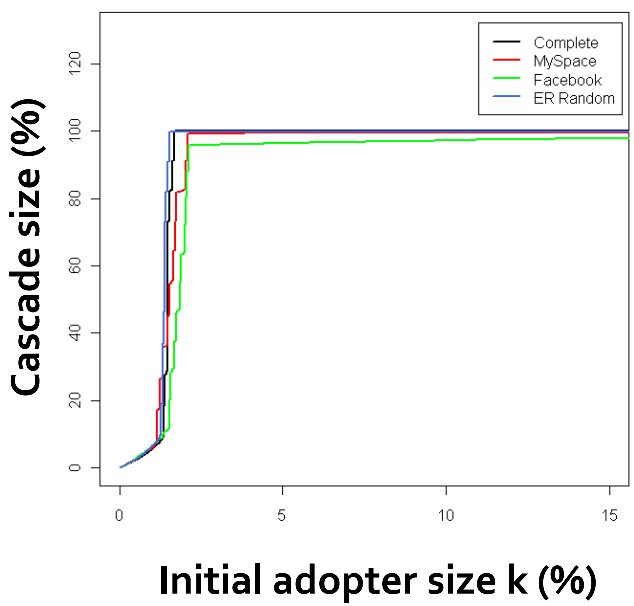
- Setup
  - $f \sim N(\mu, \sigma)$ with various μ and σ values

Experiment Results

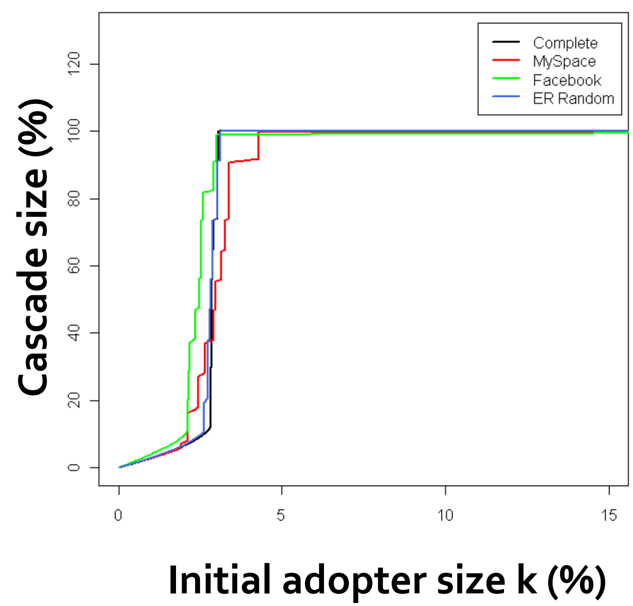
$\mu = 0.4 \quad \sigma = 0.5$



$\mu = 0.4 \quad \sigma = 0.4$



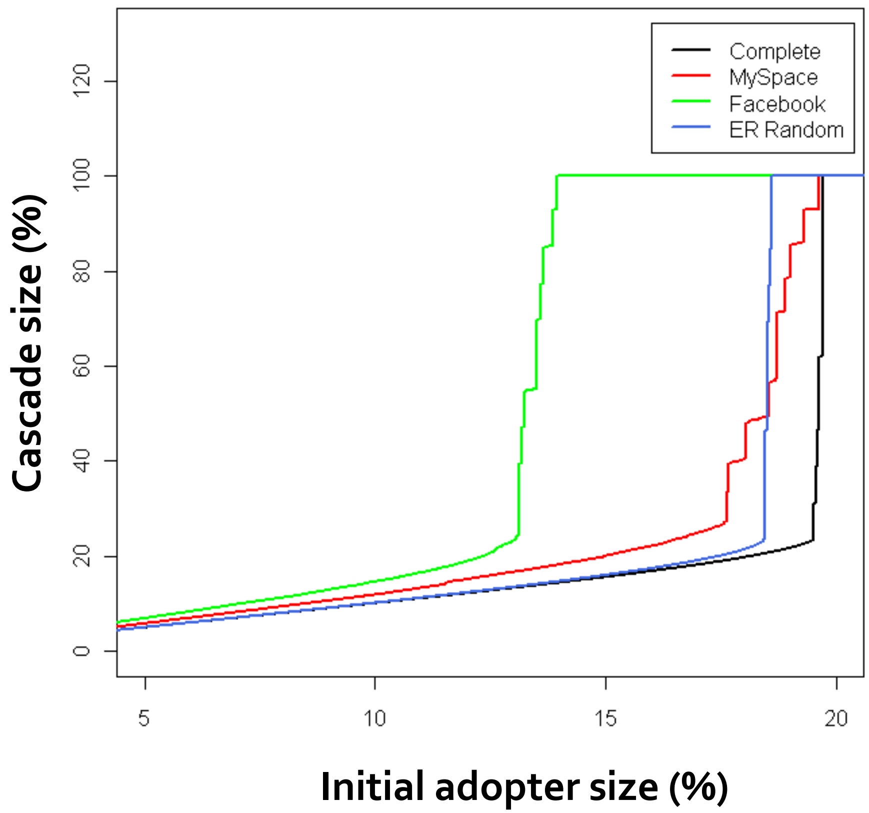
$\mu = 0.4 \quad \sigma = 0.3$



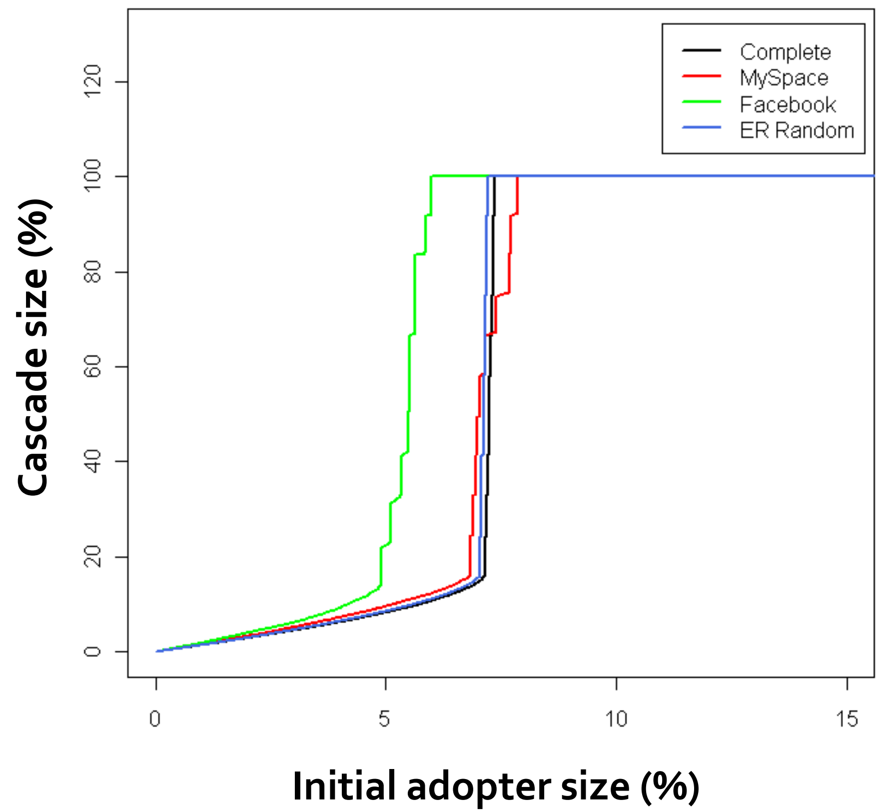
- For many values of μ and σ, we observe that tipping point occurs for both real world social networks and synthetic networks

Experiment Results

$\mu = 0.4 \quad \sigma = 0.1$



$\mu = 0.4 \quad \sigma = 0.2$



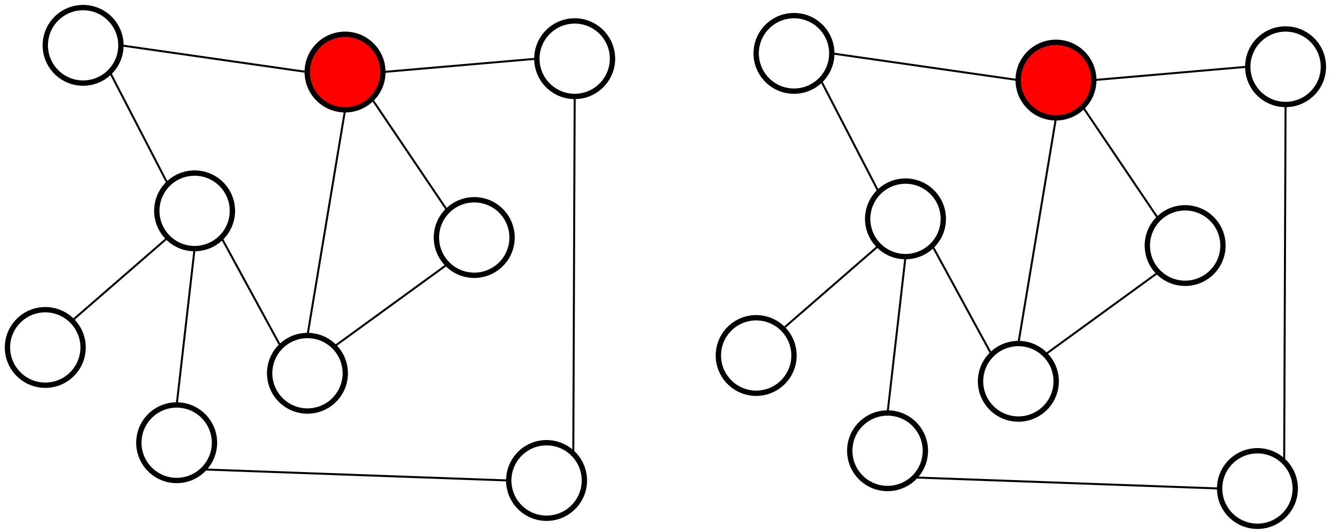
SIR Model

- The SIR model is originally used to model diffusion of epidemics.
- An individual in a network is susceptible for the first time, having a possibility to be infected. After infected, it remains infected for a while, infecting contactees. Finally, it is cured (removed).

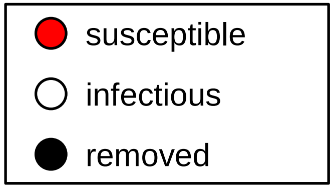
- This process explains a *simple* way of information diffusions or social interactions.
  - Facebook, Twitter retweet, information spreading in the blog space, etc

SIR Model

- The SIR spreading procedure examples



$p_{i,j} = 0.5$ $p_{i,j} = 0.75$



Our Interests

- We are interested in …
  - Probabilities of large spreading
  - Sizes of large spreading
  - Conditions under which large spreading occurs

Outline of Our Results

- Work with Sungsu Lim and Namju Kwak

- Previous work considers only the case when the diffusion probability is a constant for each edge.
- We consider when the diffusion probability depends on the local information of the two end nodes
  - which appears often in social networks and complex networks

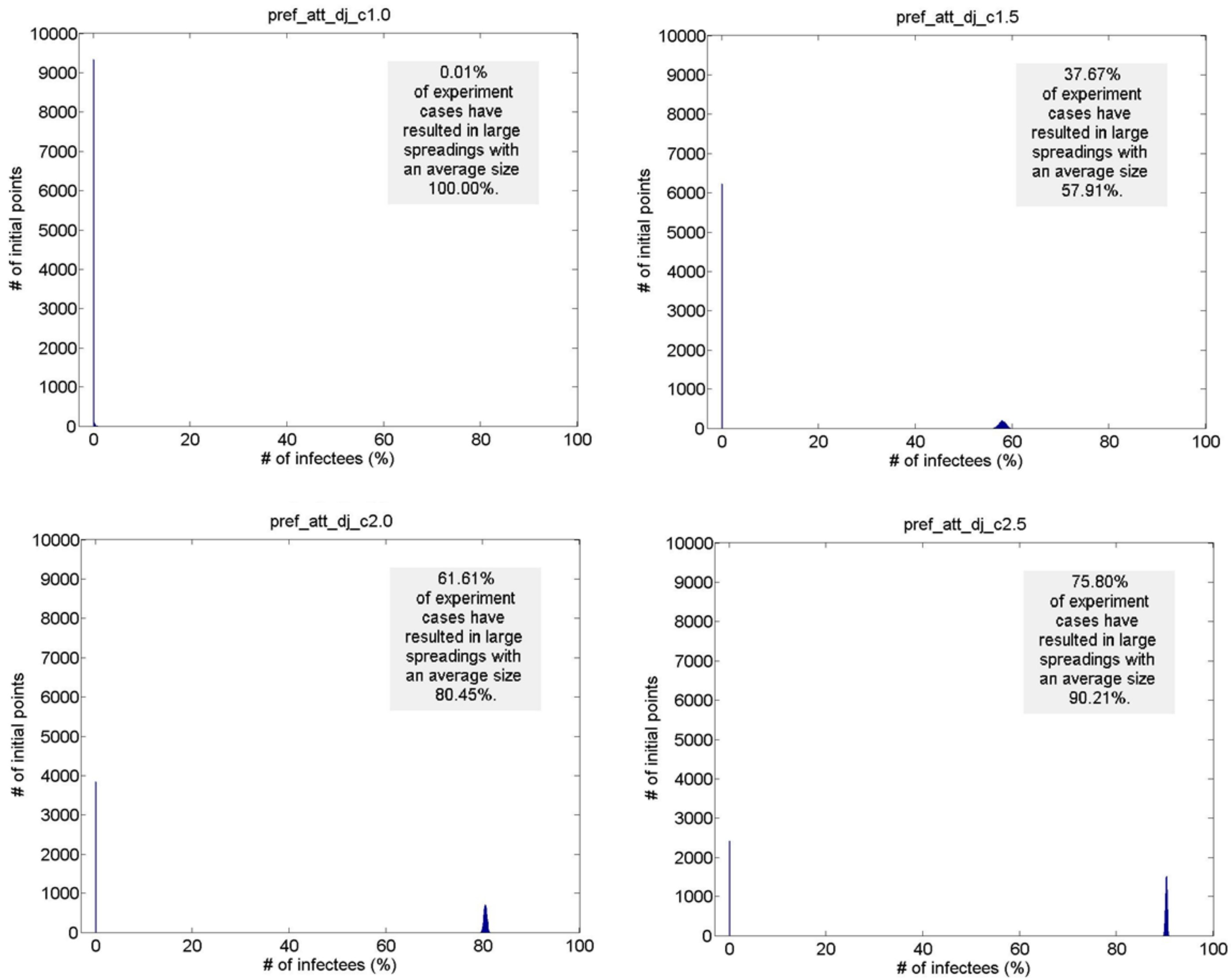
- We obtain formula to exactly compute probabilities and sizes of large spreading of a network under the SIR model using the degree distribution of the network.

- The results of our mathematical calculations are very similar to the empirical results.

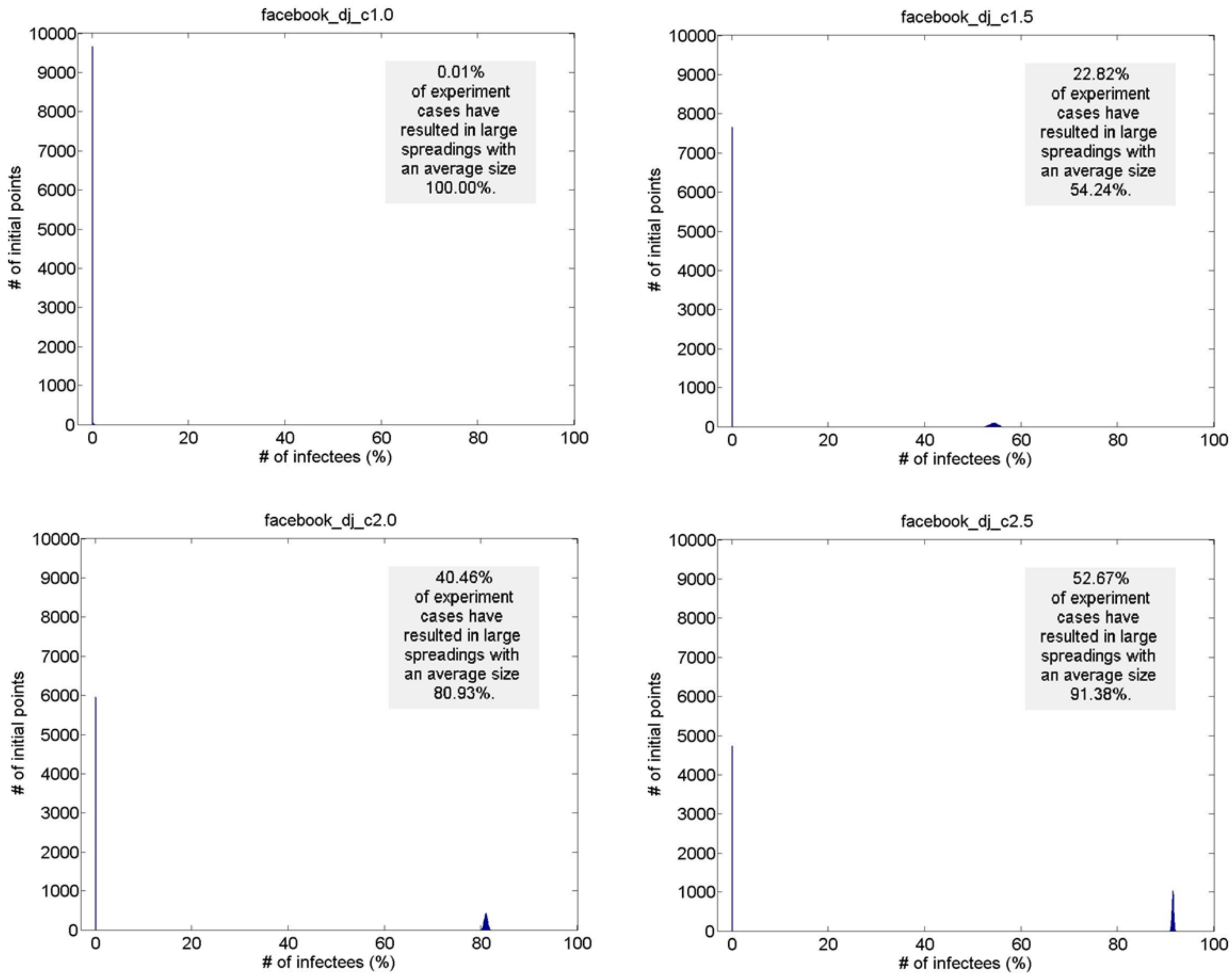
Simulations

- Use the SIR spreading model.
  - $p_{i,j} = f(d_i, d_j) = \frac{c}{d_i}$ and $p_{i,j} = f(d_i, d_j) = \frac{c}{d_j}$
- Simulations are performed on …
  - Preferential attachment graph
  - General random graph
  - Facebook and Myspace friendship graph
- A single initial infectious (I) node is randomly picked. All the other nodes are susceptible (S).
- Observe probabilities and sizes of large spreading at the end of the procedure.

Simulations



Simulations



Simulations