Physical Mechanism Underlying Opinion Spreading

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J. Shao, S. Havlin, and H. E. Stanley, Phys. Rev. Lett. **103**, 018701 (2009).

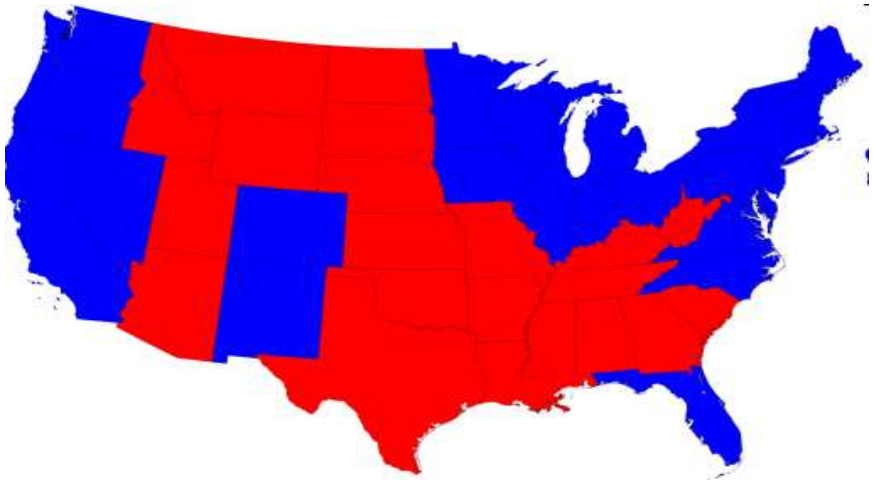
Questions

- *How do different opinions influence each other in human society?*
- *Why minority opinion can persistently exist?*

Motivation

- Public opinion is important.
- Simulation of opinion formation is a challenging task, requiring reliable information on human interaction networks.

US presidential elections



Instead of using individual level network, we propose a community level network to study opinion dynamics.

- There is a gap between existing models and empirical findings on opinion formation.

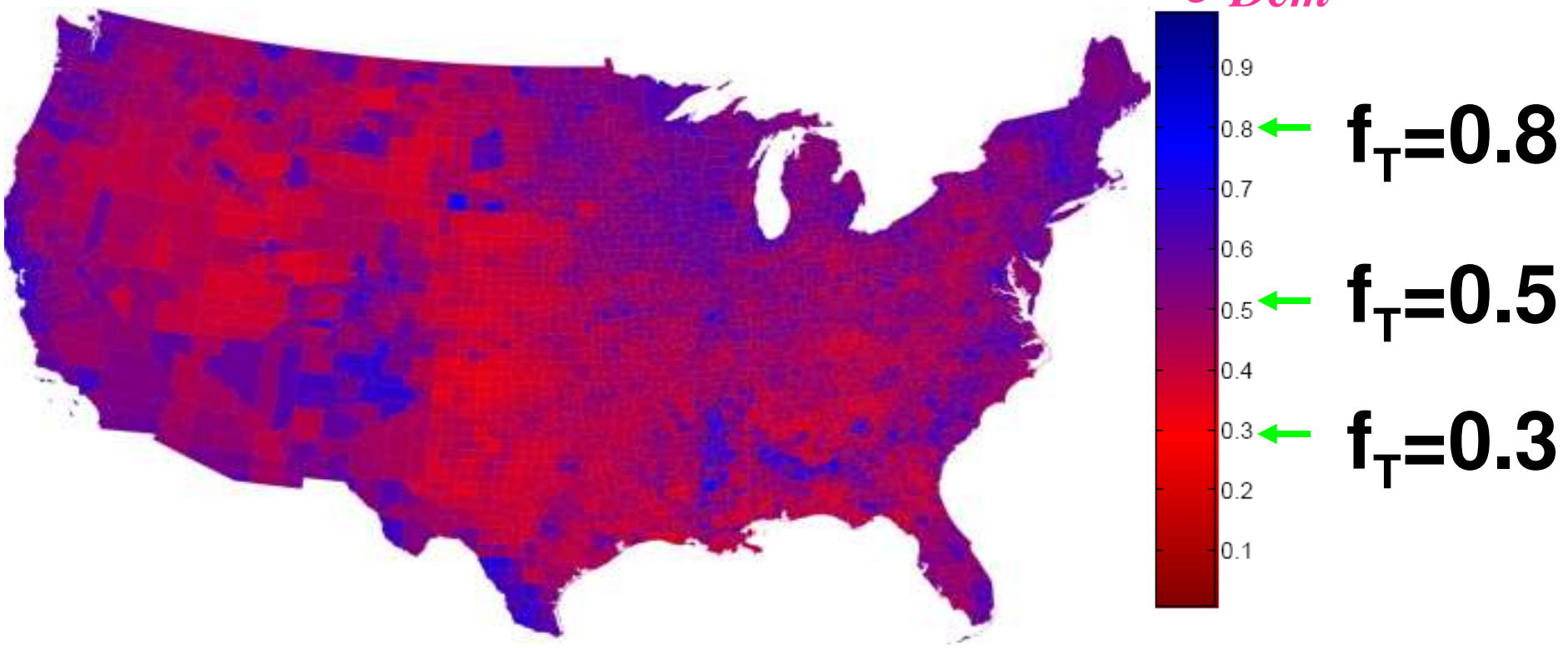
Outline

- Part I: Empirical findings from presidential election
- Part II: Invasion Percolation
- Part III: We propose a dynamic opinion model which can explain the empirical findings

Part I

2008 Presidential Election

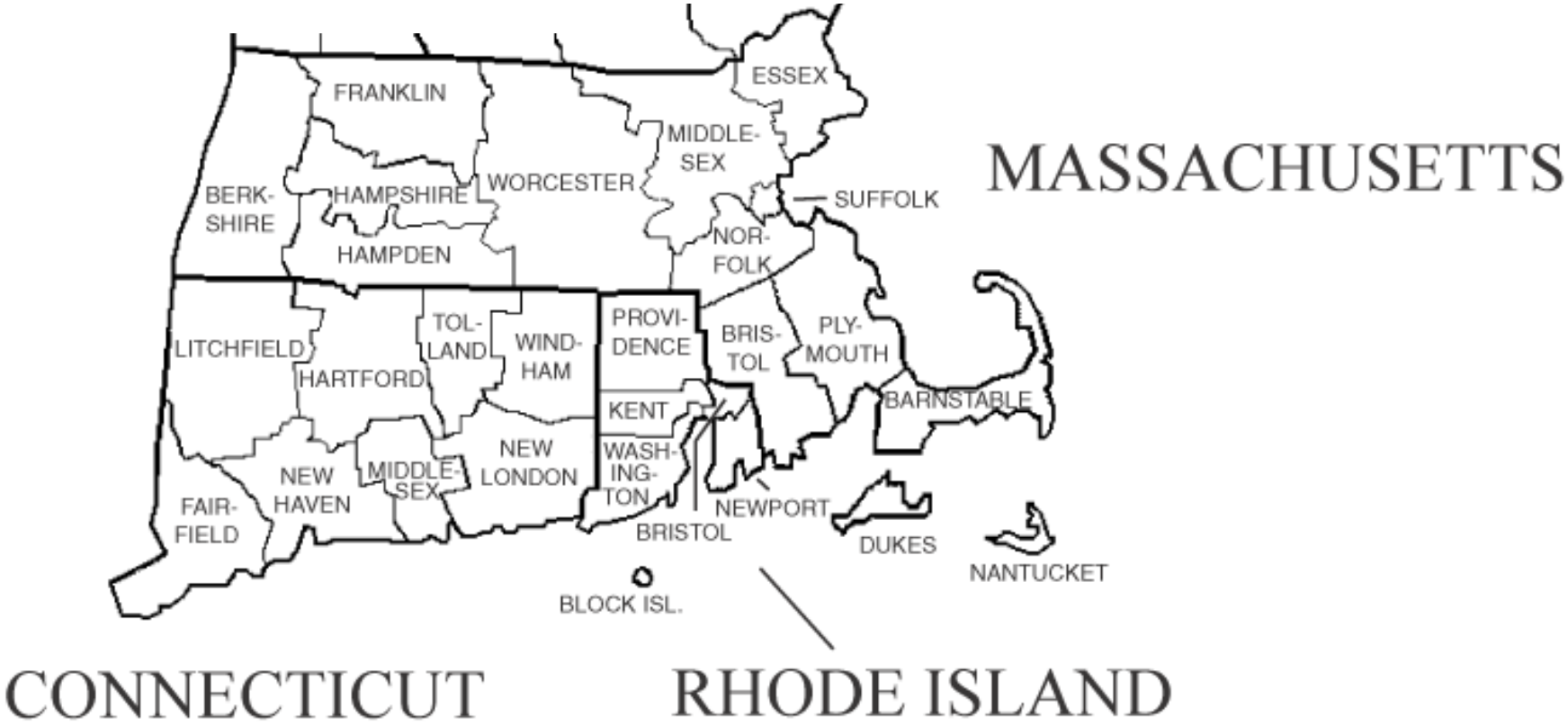
We study counties with $f > f_T$



http://www-personal.umich.edu/~mejn/election/2008/

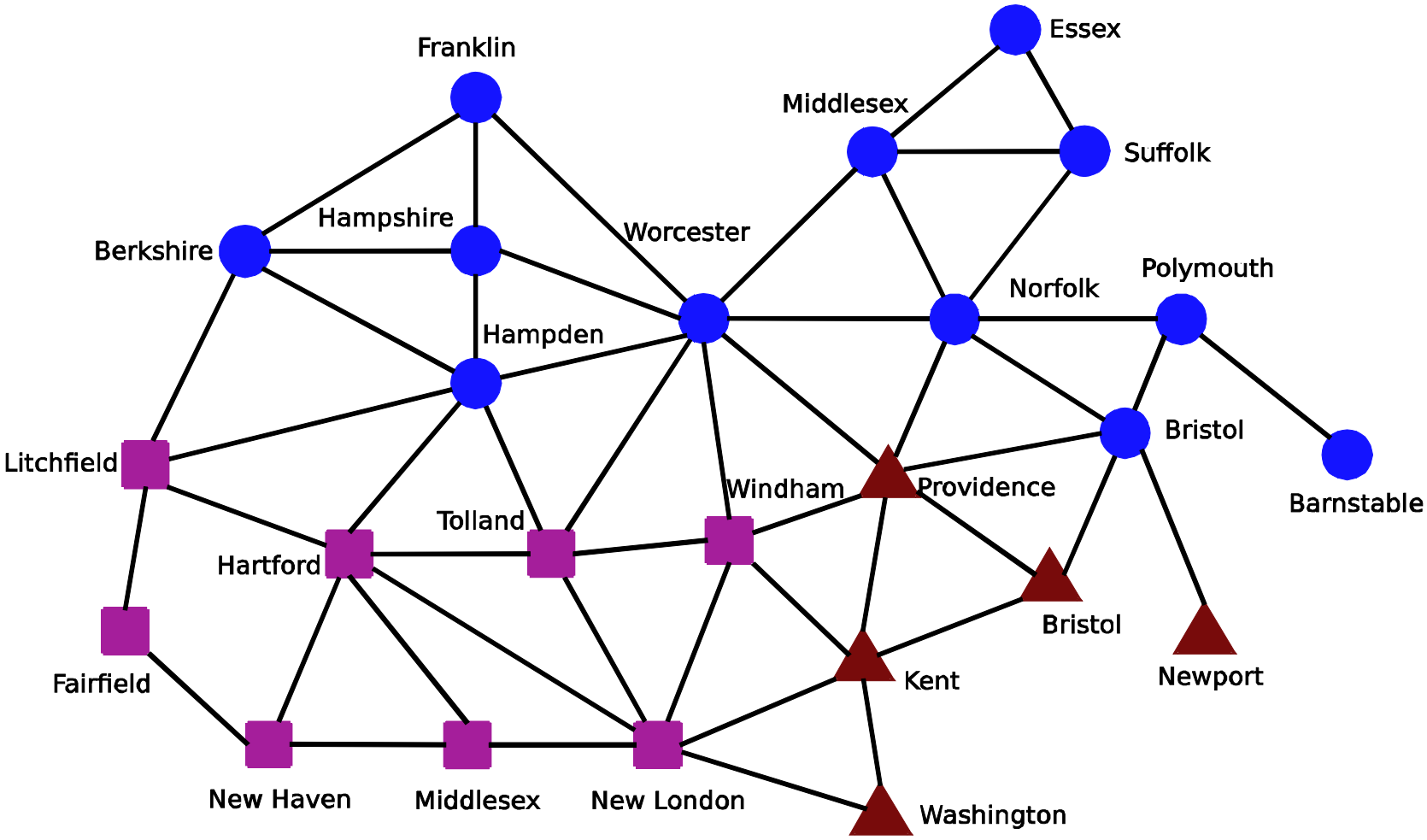
Part I

Counties in southern New England



Part I

Counties in southern New England

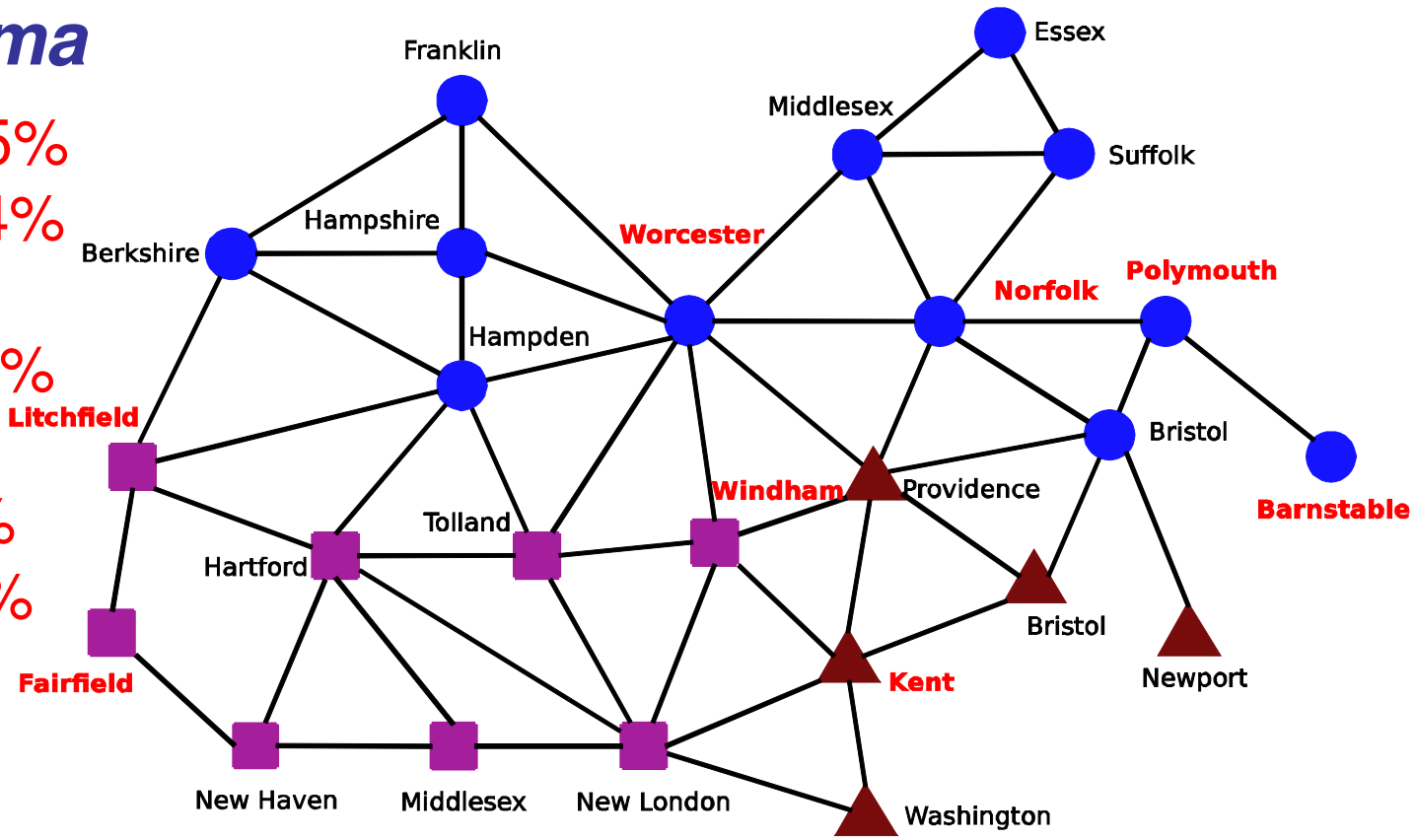


Part I

Counties in southern New England

Vote for Obama

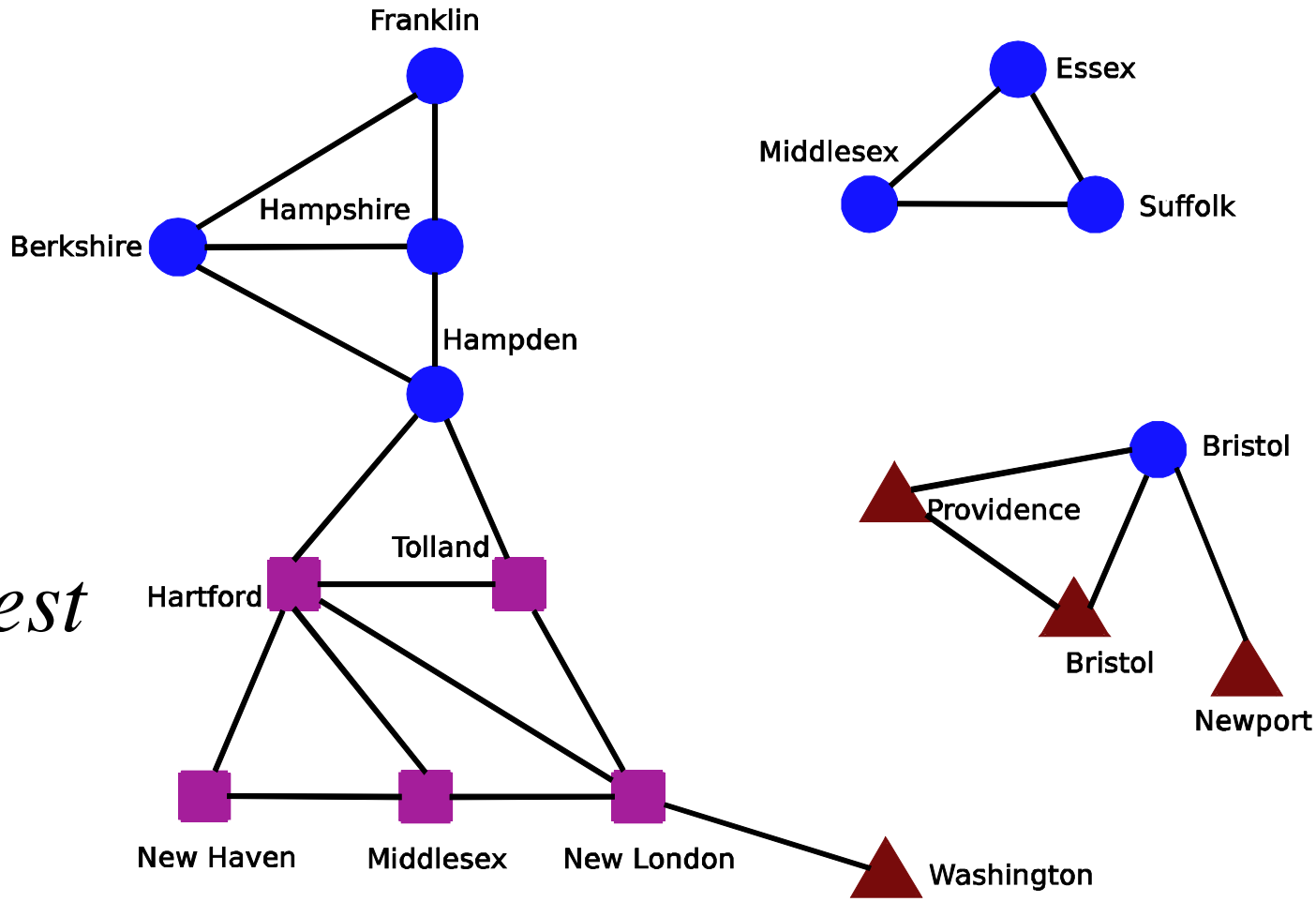
Barnstable f=55%
Polymouth f=54%
Norfolk f=54%
Worcester f=57%
Fairfield f=52%
Litchfield f=47%
Windham f=53%
Kent f=56%



Part I

Counties in southern New England

County network of $f > f_T = 0.6$

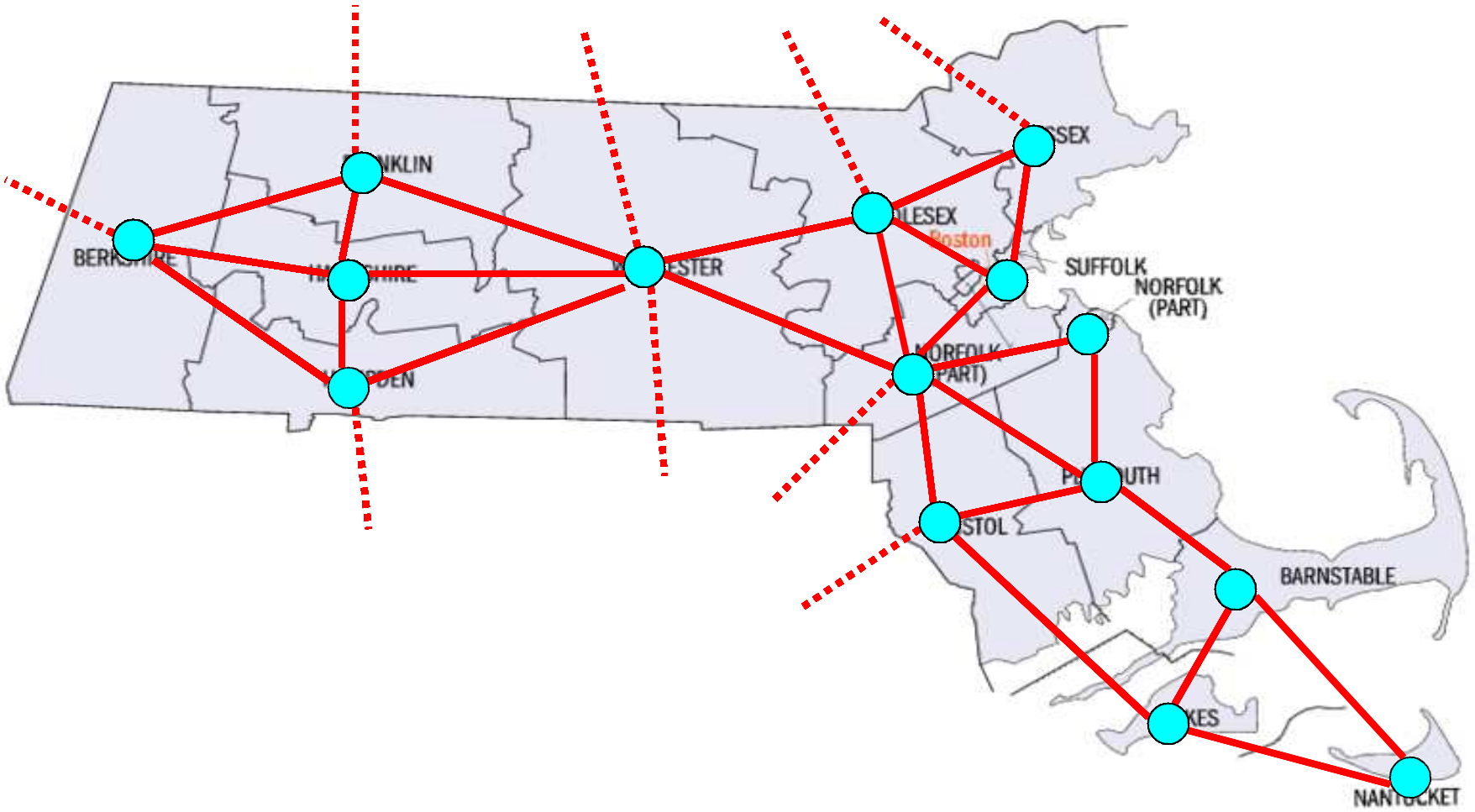


Number of counties: 17

Size of largest cluster: 10

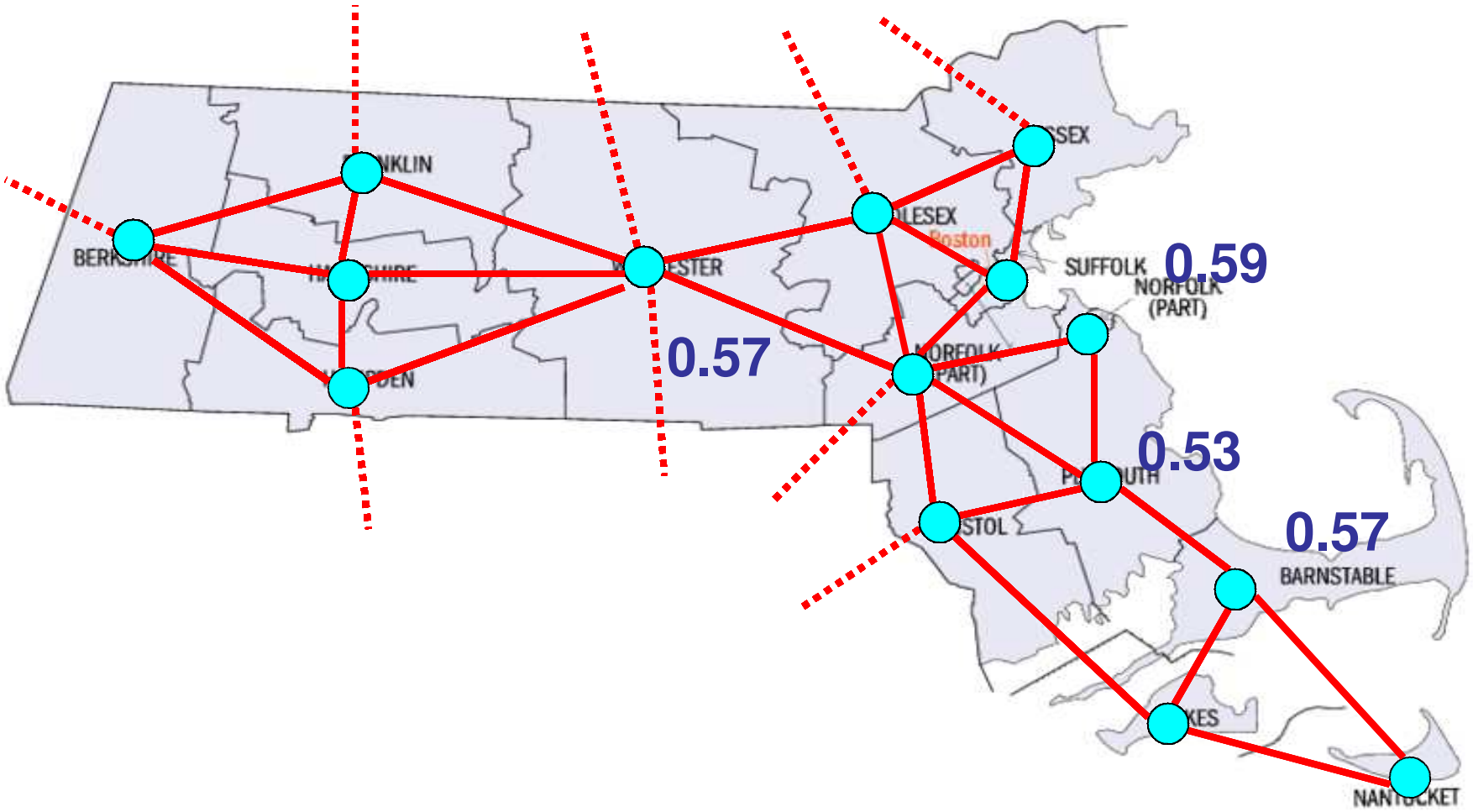
Part I

Counties in Massachusetts



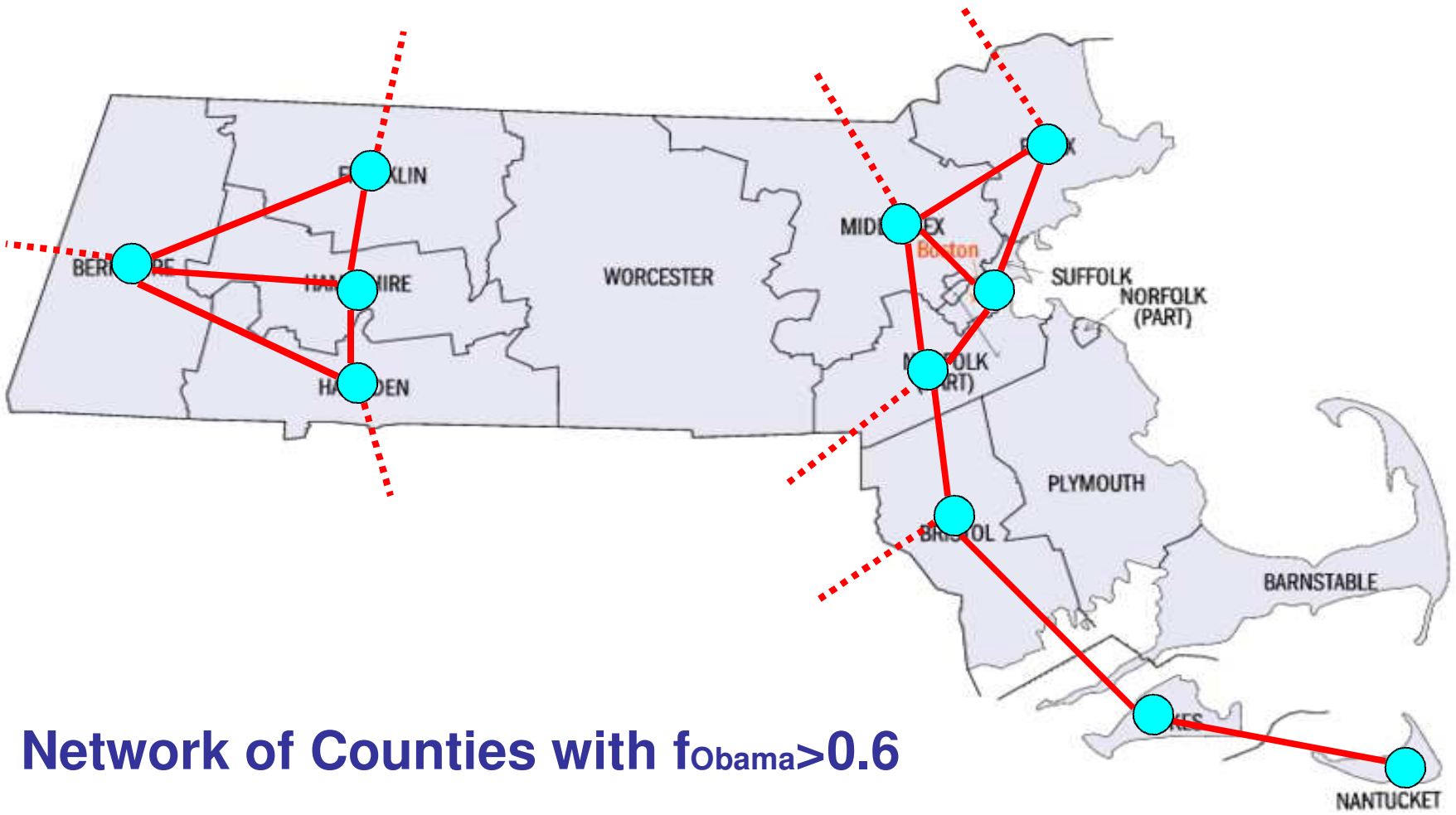
Part I

Counties in Massachusetts



Part I

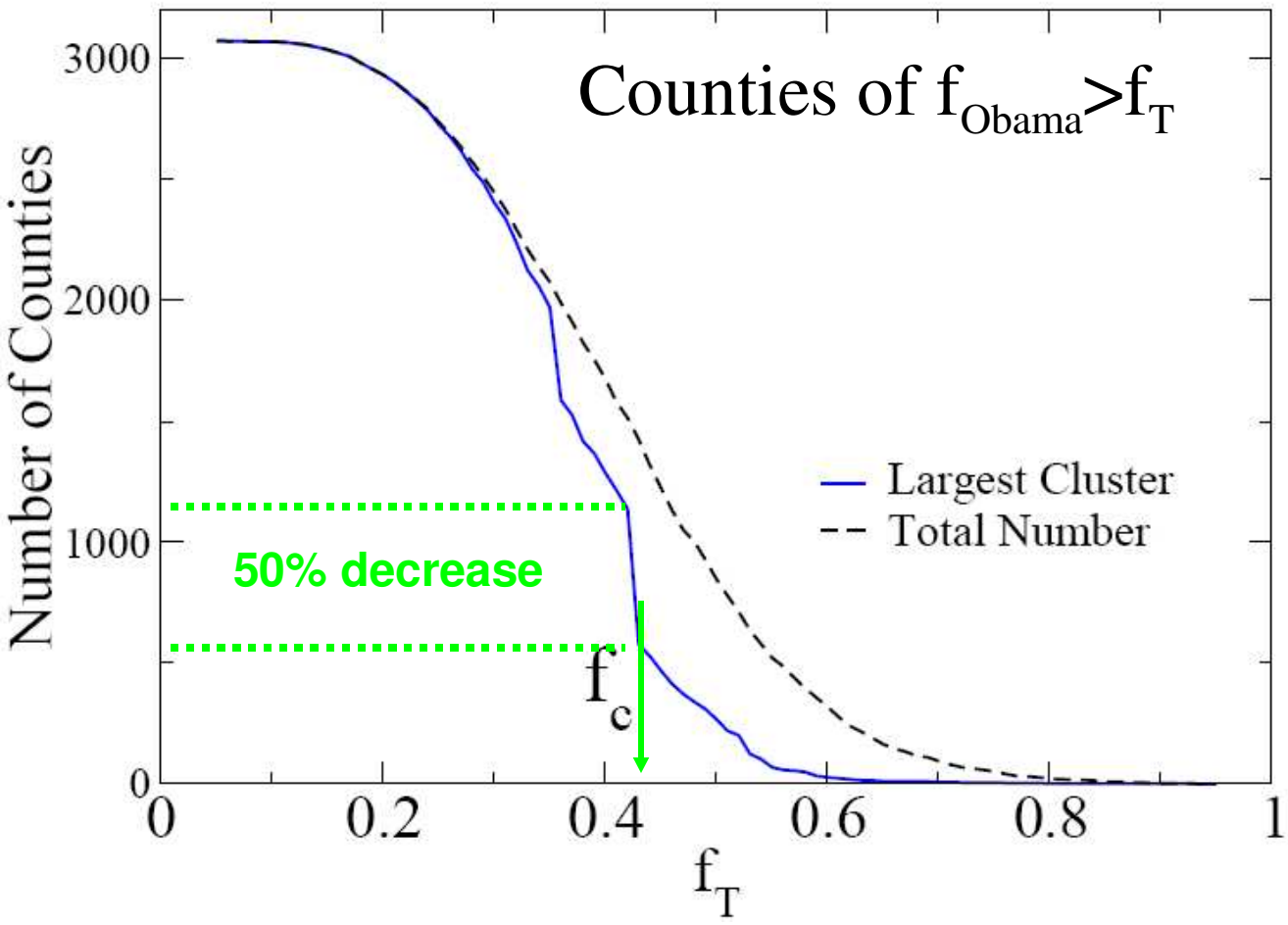
Counties in Massachusetts



Network of Counties with $f_{Obama}>0.6$

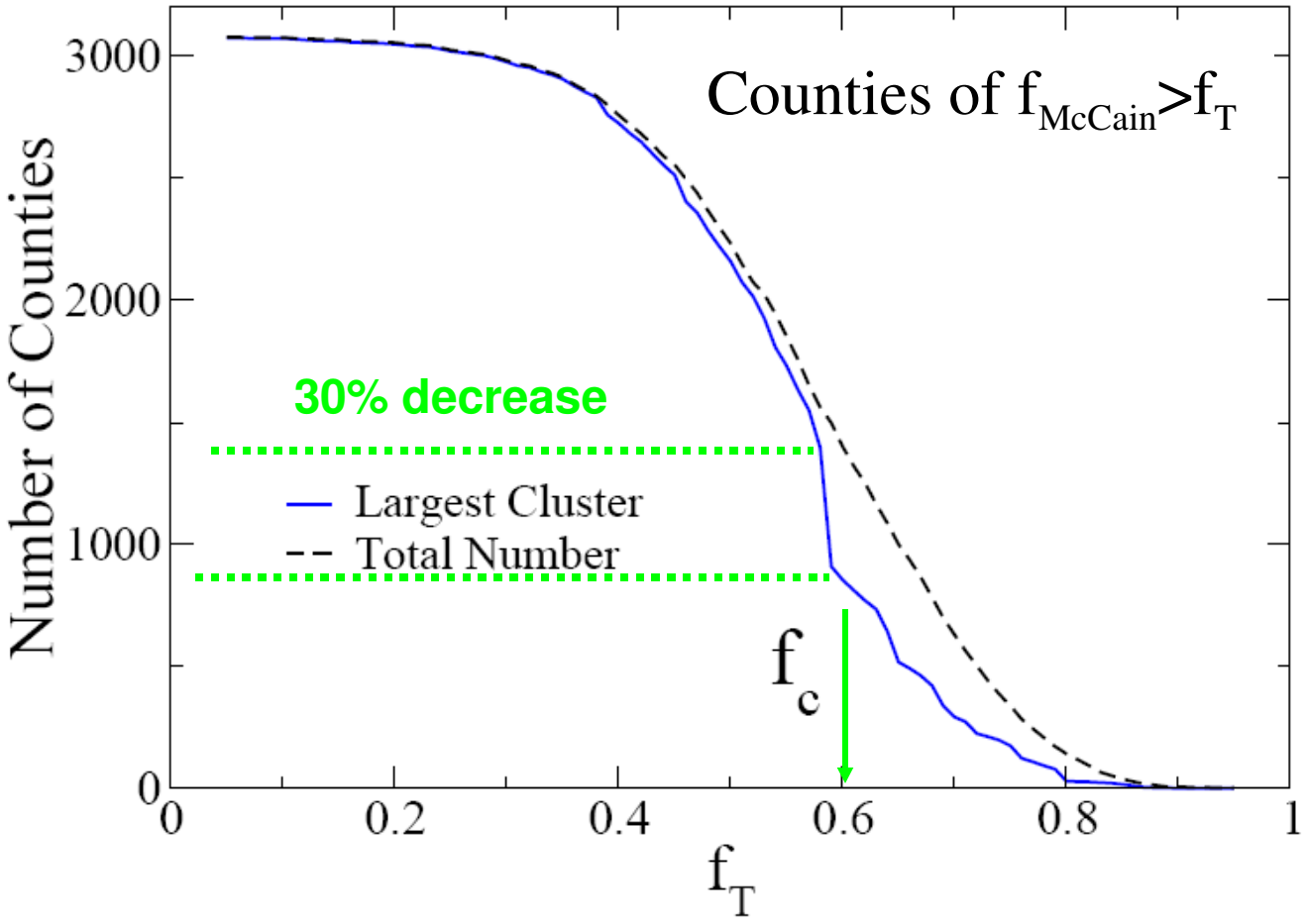
Part I

County Network of Obama



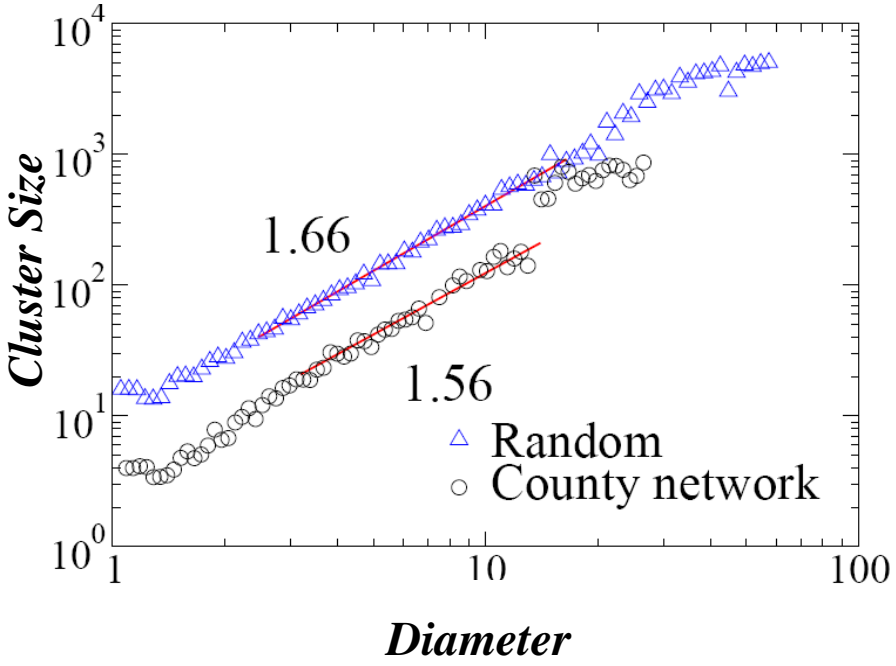
Part I

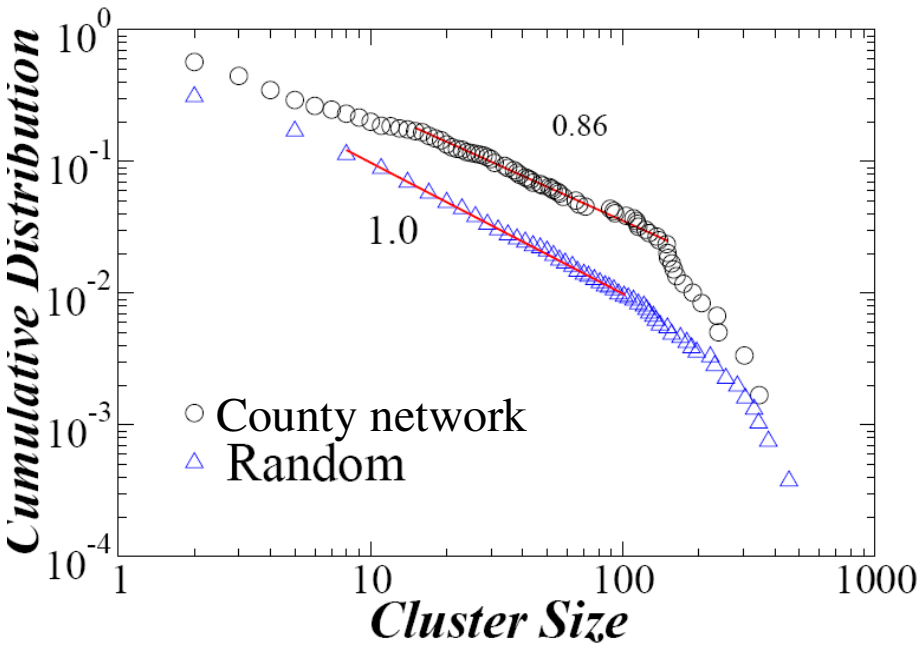
County Network of McCain



Part I

Clusters formed by counties when $f_T=f_c$





Fractal dimension: d_l=1.56 τ =1.86

The phase transition in county network is different from randomized county network.

- The real life county election network demonstrates a percolation-like phase transition at $f_T=f_c$.
- This phase transition is different from random percolation.

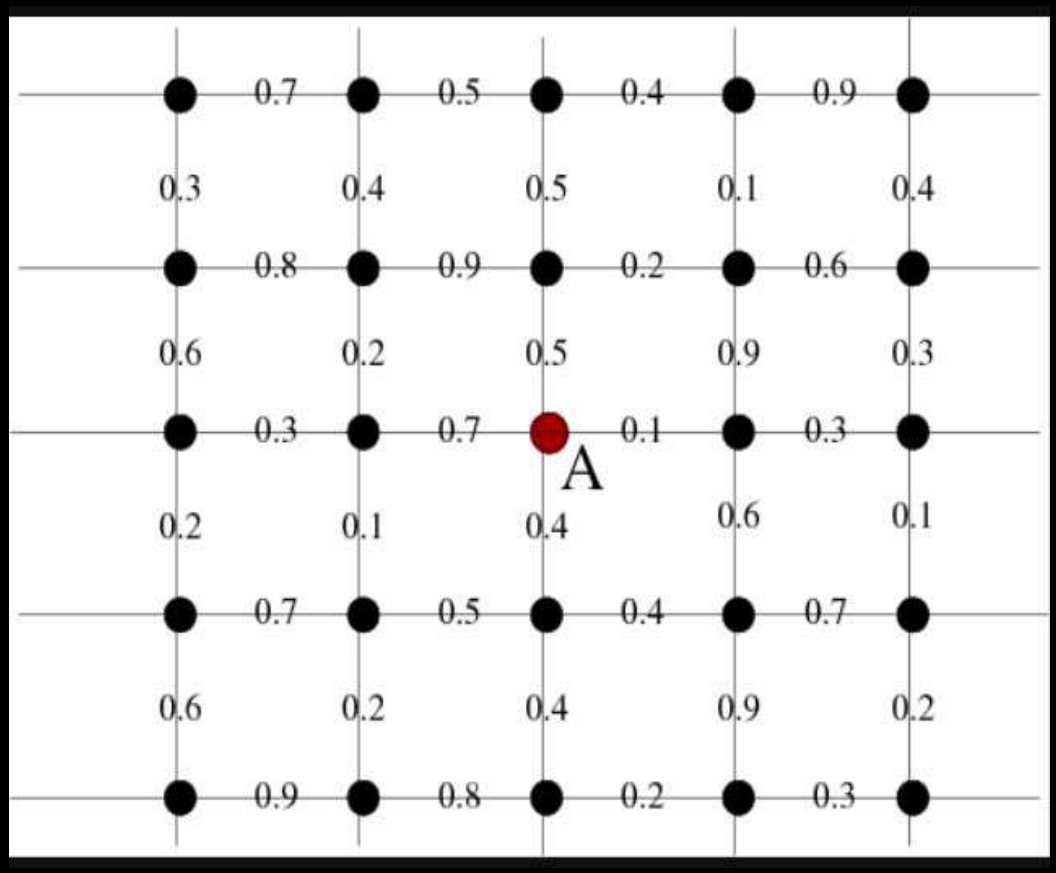
What class of percolation does this phase transition belong to?

Part II

Invasion Percolation

Example: Inject water into earth layer containing oil

- Invasion percolation describes the evolution of the front between two immiscible liquids in a random medium when one liquid is displaced by injection of the other.
- Trapped region will not be invaded.

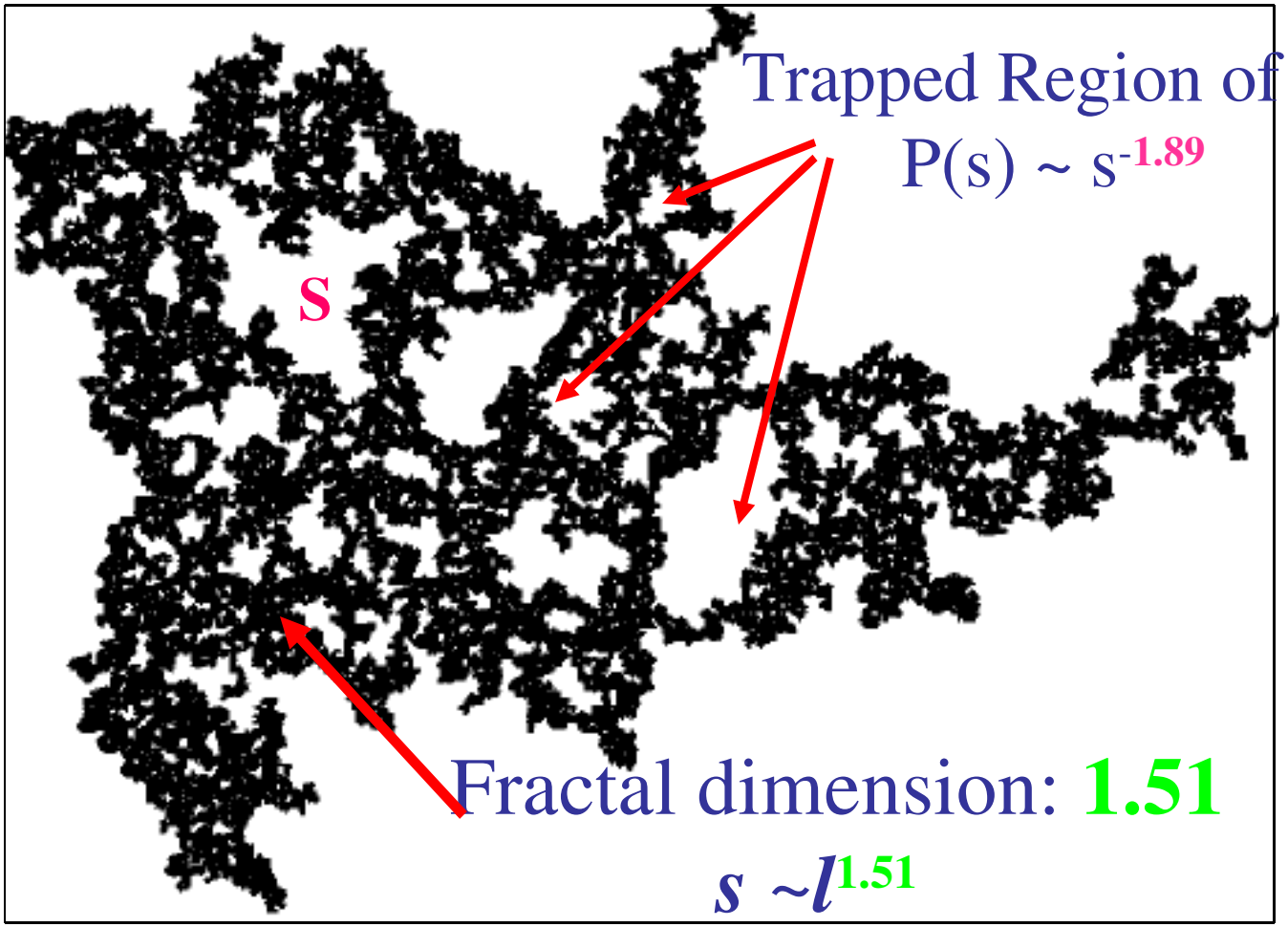


A: Injection Point

P. G. de Gennes and E. Guyon, *J. Mech.* **17,** 403(1978).
D. Wilkinson and J. F. Willemsen, *J. Phys.* A 16, 3365 (1983).

Part II

Invasion Percolation

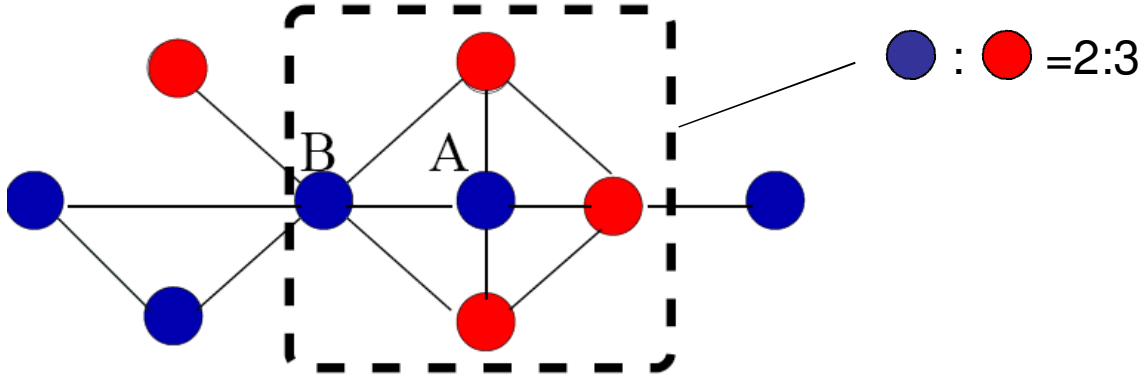


S. Schwarzer et al., Phys. Rev. E. 59, 3262 (1999).

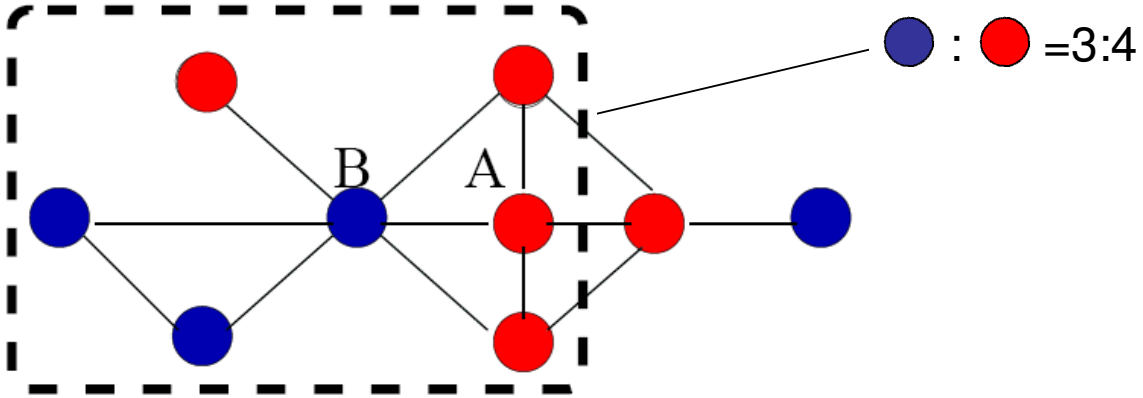
- The phase transition of the county election network belongs to the same universality of invasion percolation.
- *Why invasion percolation?*
- *How can we simulate the dynamic process of opinion formation?*

Evolution of mutually exclusive opinions

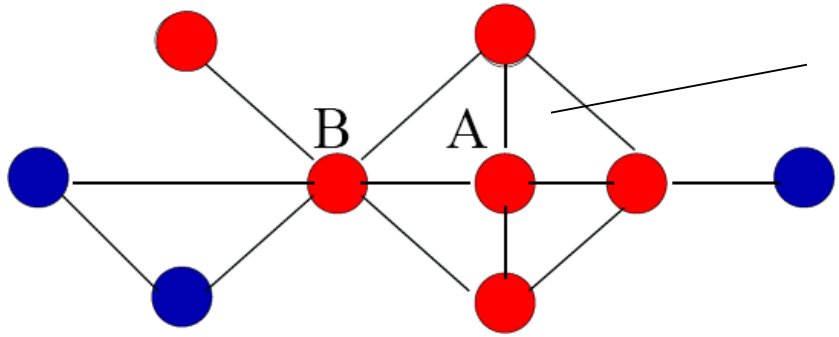
Time 0



Time 1

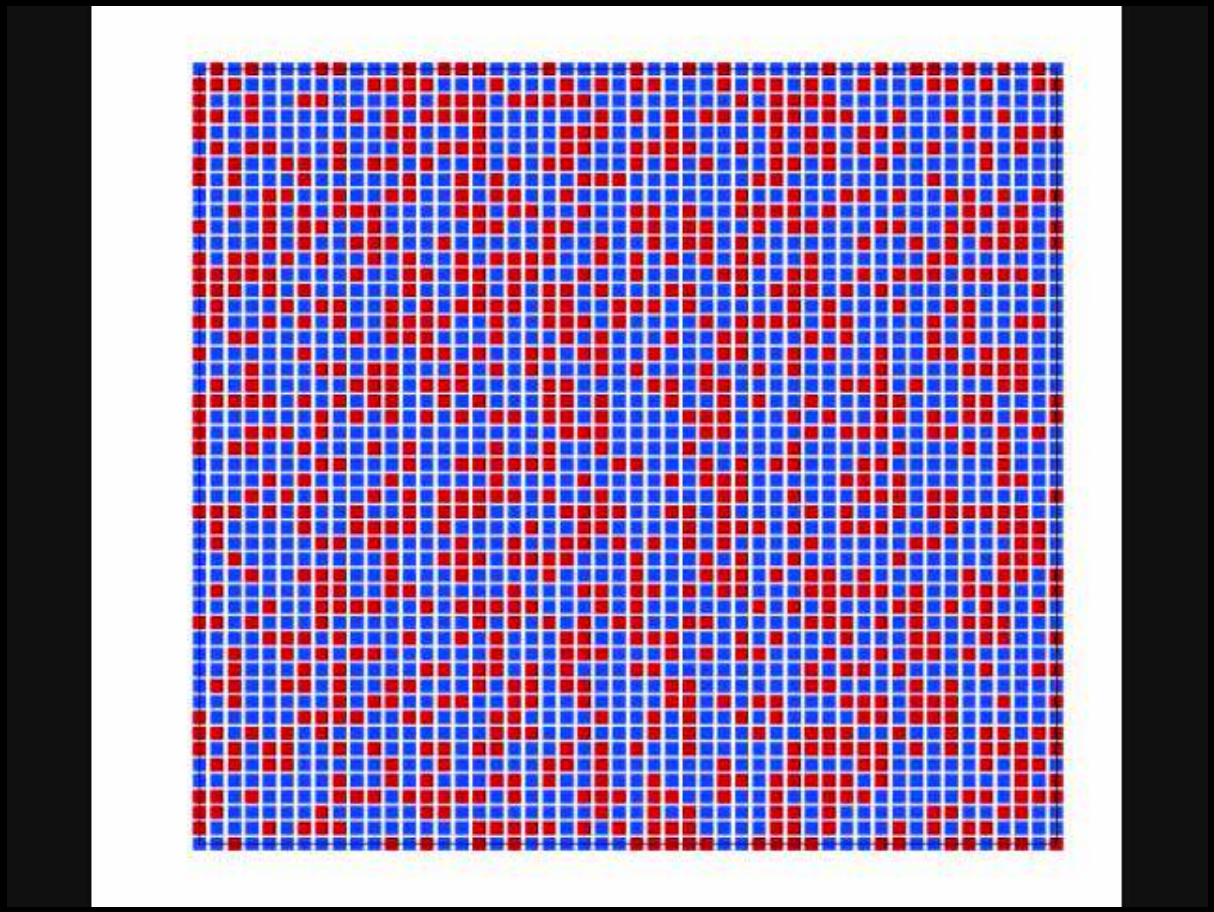


Time 2



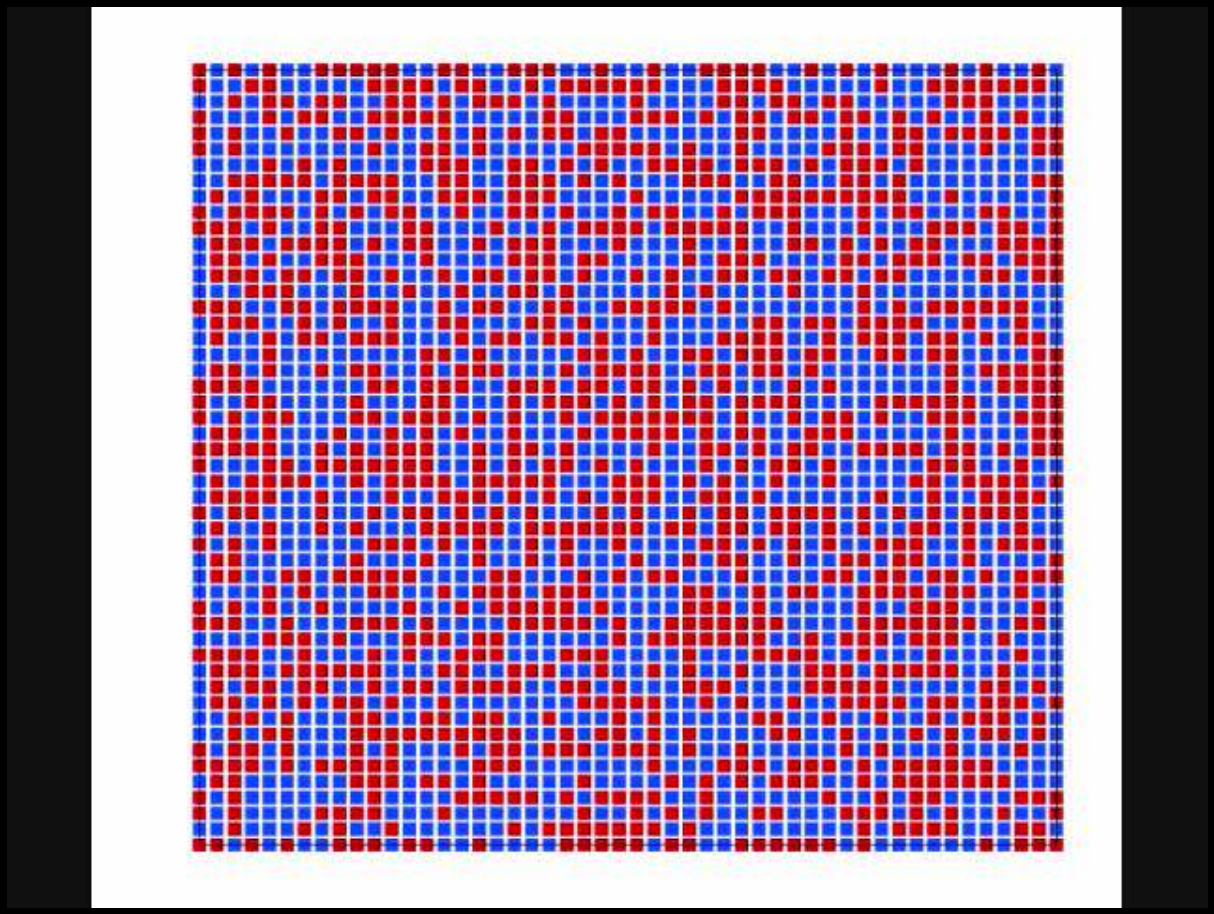
stable state
(no one in local minority opinion)

A. Opinion spread for ■:■ =2:3 initially



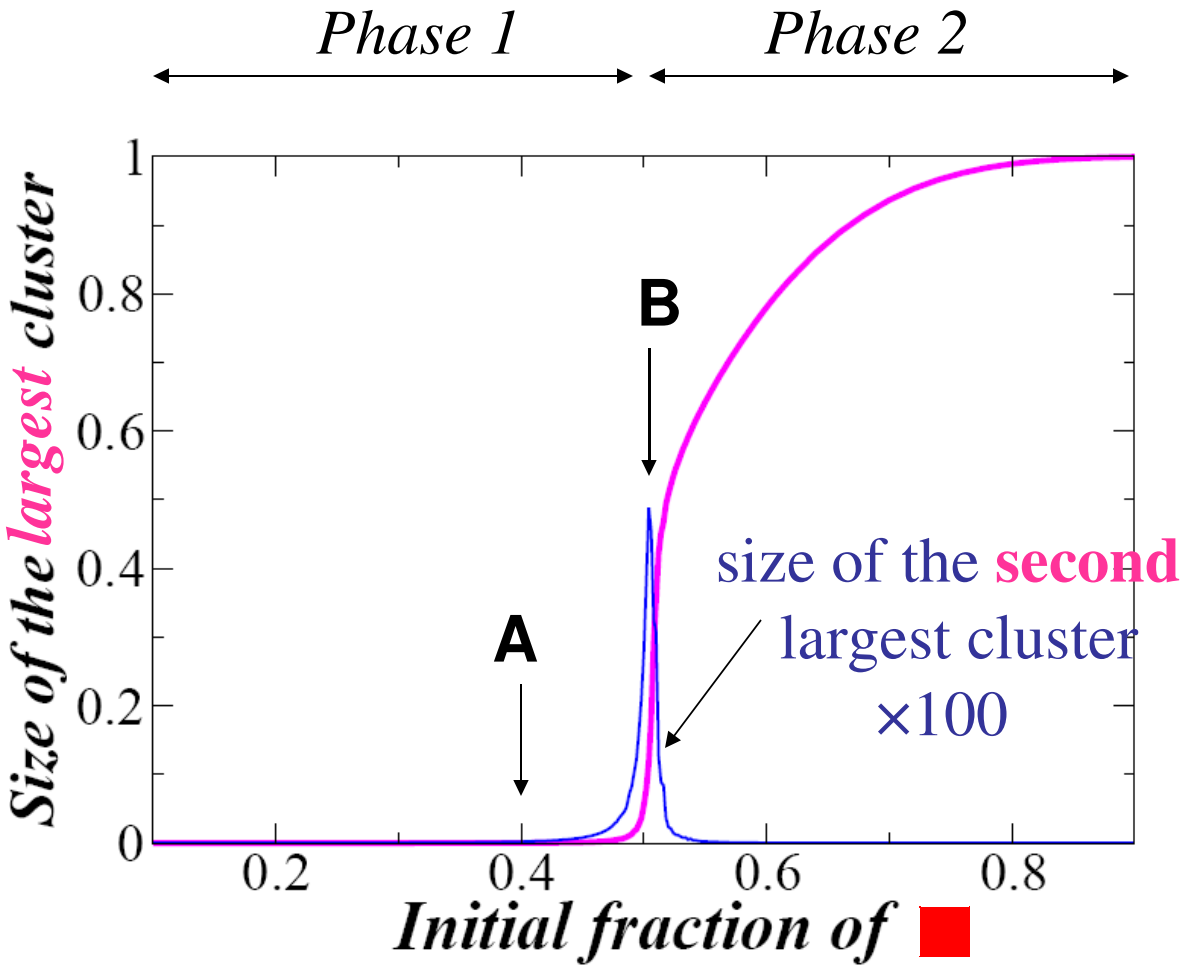
stable state ■:■ =1:4

B. Opinion spread for ■ : ■ =1:1 initially



stable state ■:■ =1:1

“Phase Transition” on square lattice



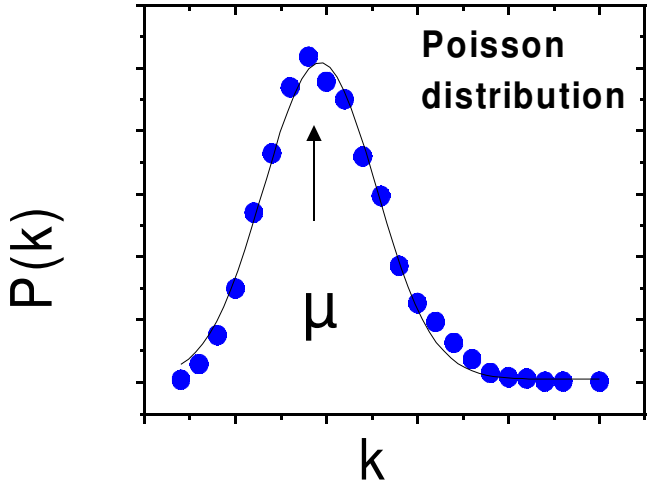
critical initial fraction f_c=0.5

2 classes of network: differ in degree *k* distribution

(i) Erdős-Rényi

Poisson distribution:

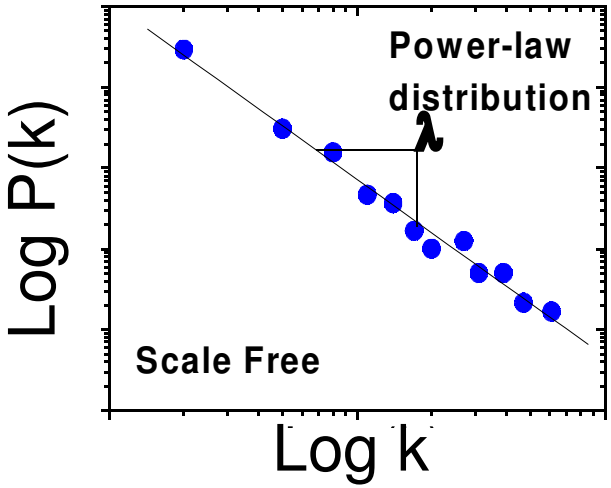
$$P(k) \sim \exp(-\mu)\frac{\mu^k}{k!}$$

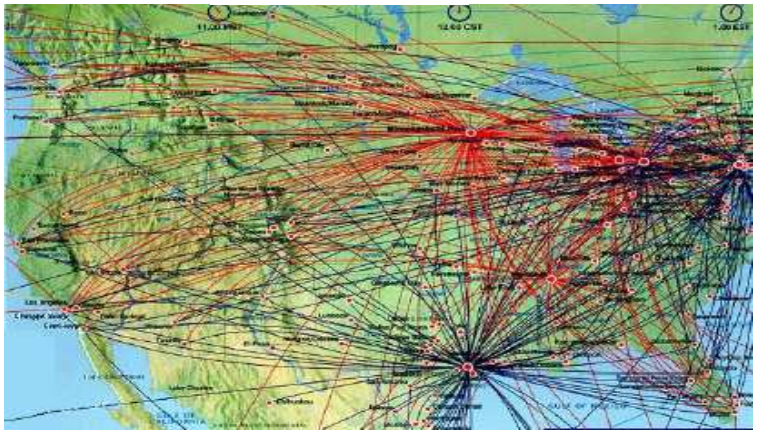


(ii) scale-free

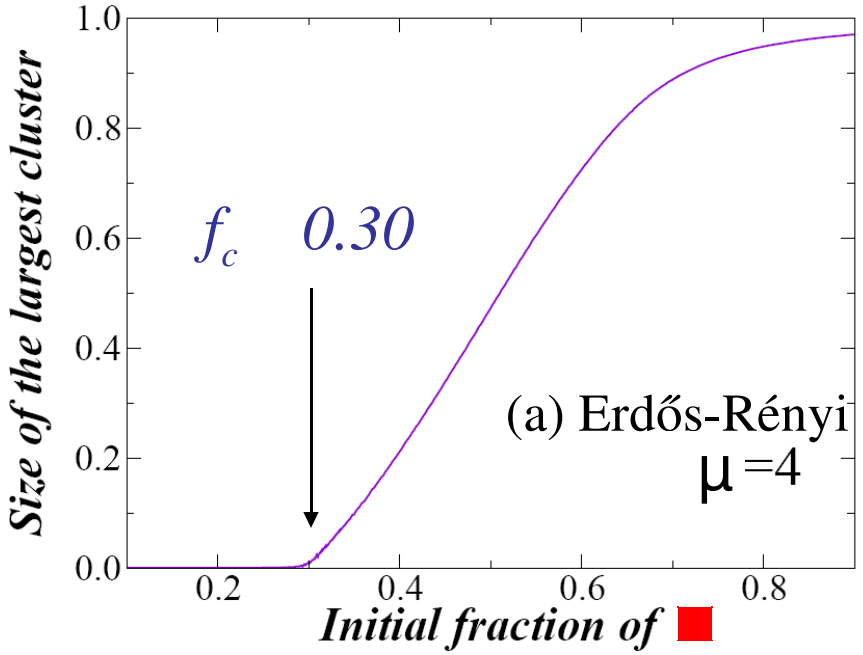
Power-law distribution:

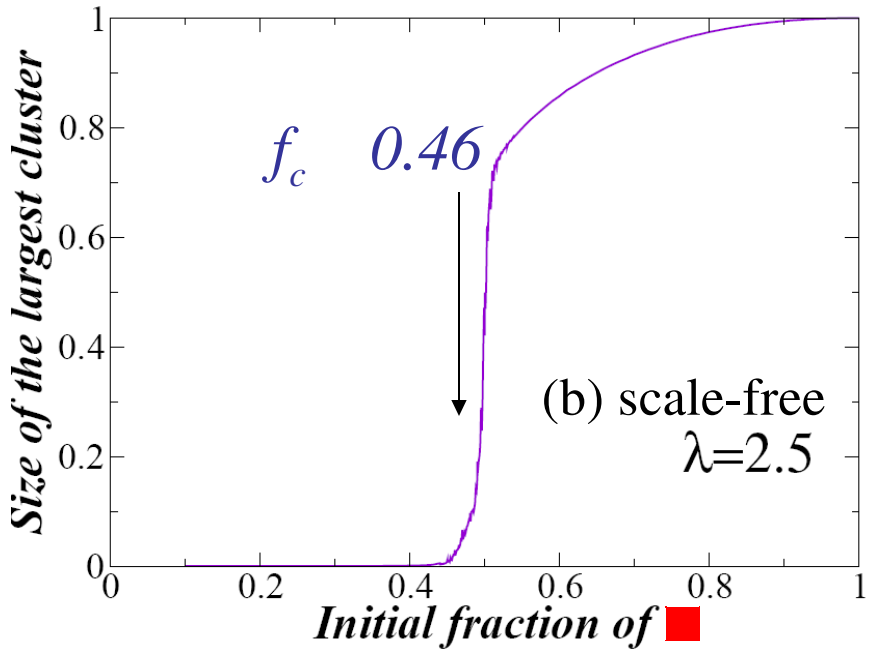
$$P(k) \sim k^{-\lambda}$$





“Phase Transition” for both classes of network

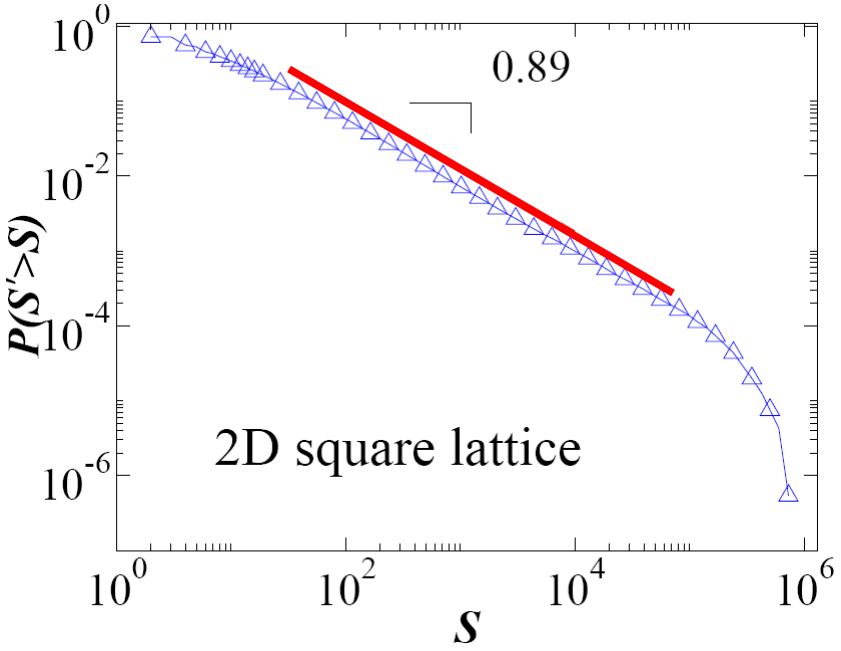


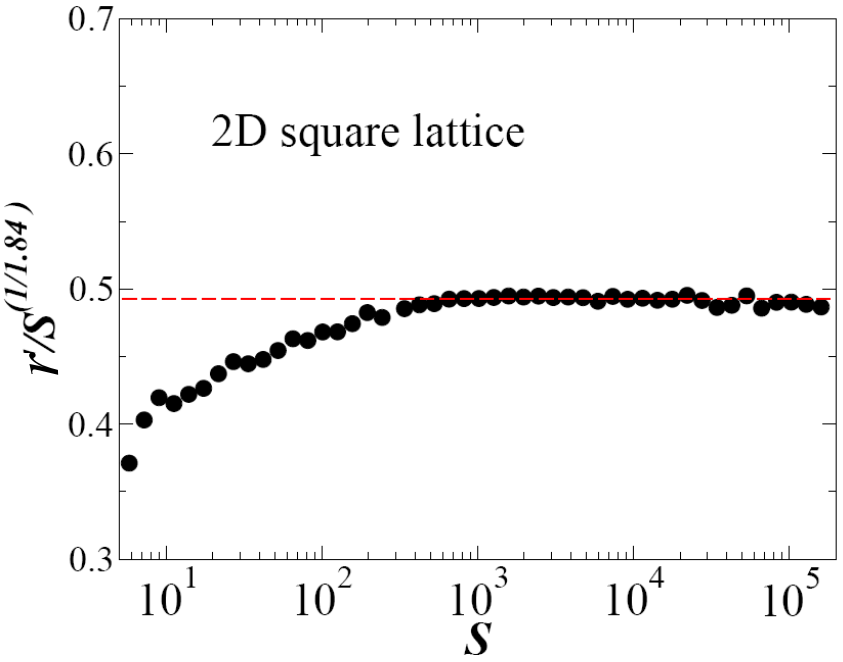


Q1: At f_c, what is the distribution of ***cluster size*** *“**s**”?*

Q2: What is the ***average distance*** *“**r**” between nodes belonging to the same cluster?*

Clusters formed by minority opinion at f_c





Cumulative distribution function

$P(s'>s) \sim s^{-0.89}$

PDF $P(s) \sim s^{-1.89}$

$r/s^{(1/1.84)} \longrightarrow$ Const.

$s \sim r^{1.84}$

Summary

- There exists a phase transition in the county election network when changing f_T.
- The phase transition of county network can be mapped to oil-field-inspired physics problem, “invasion percolation”.
- We propose a network model which can explain the empirical findings.