Internet-enabled Social Transformation: Social Networks, Crowd-Sourcing and Opinion Formation

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Outline

1. Three worlds intersect
2. Social network transformation issues:
   i. Evolution of opinions, socio-informational networks, bazaar of ideas, viral innovation
   ii. Synchronization limit for networked humans and their devices
   iii. Trust - how to replace human signals
   iv. Humans as sensors working together via internet
3. People's Internet and its challenges
   i. Technological limits: memory, processing, energy
   ii. Societal limits: privacy, security, law and financing

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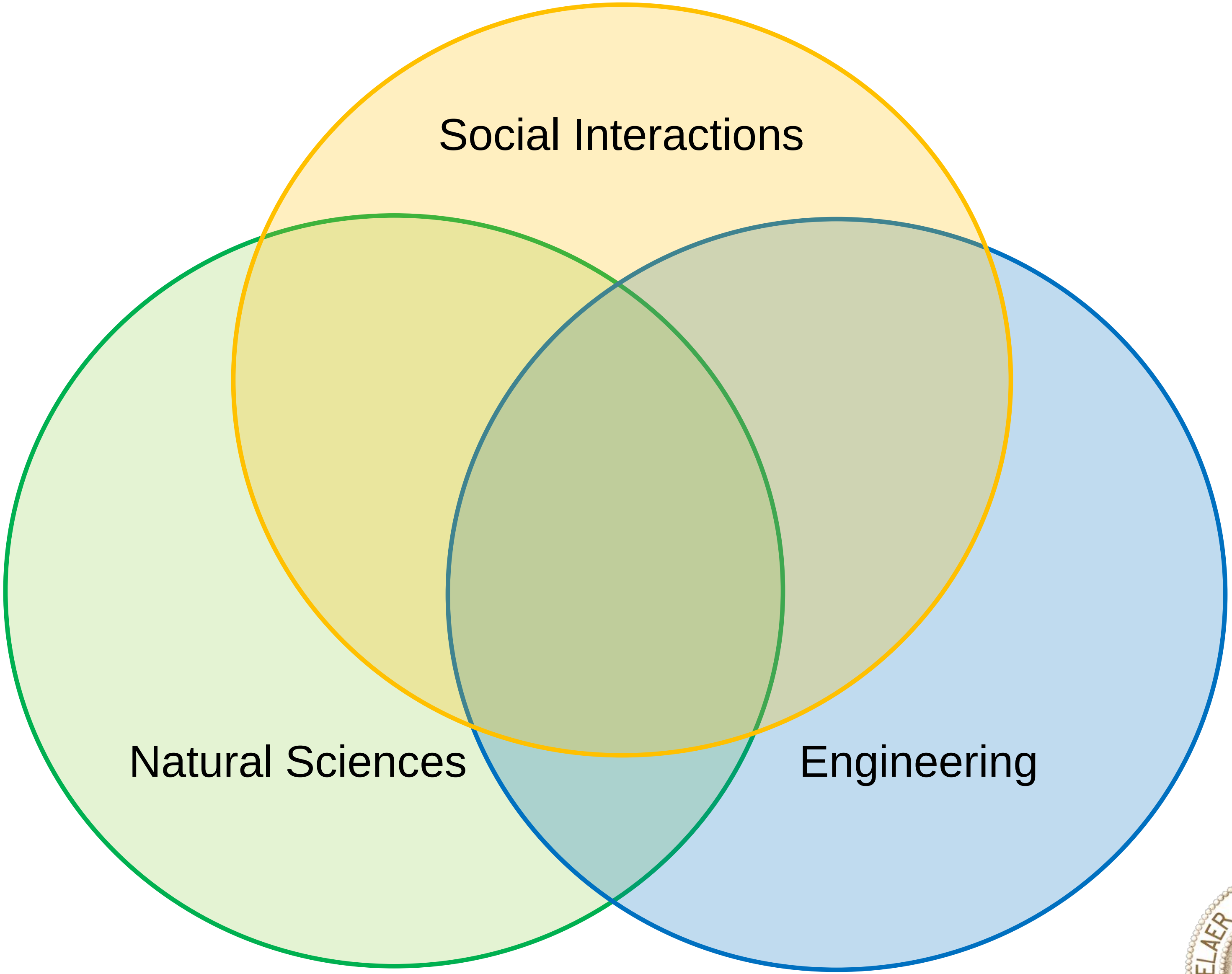
Man versus Machine



Networks Everywhere: the Web

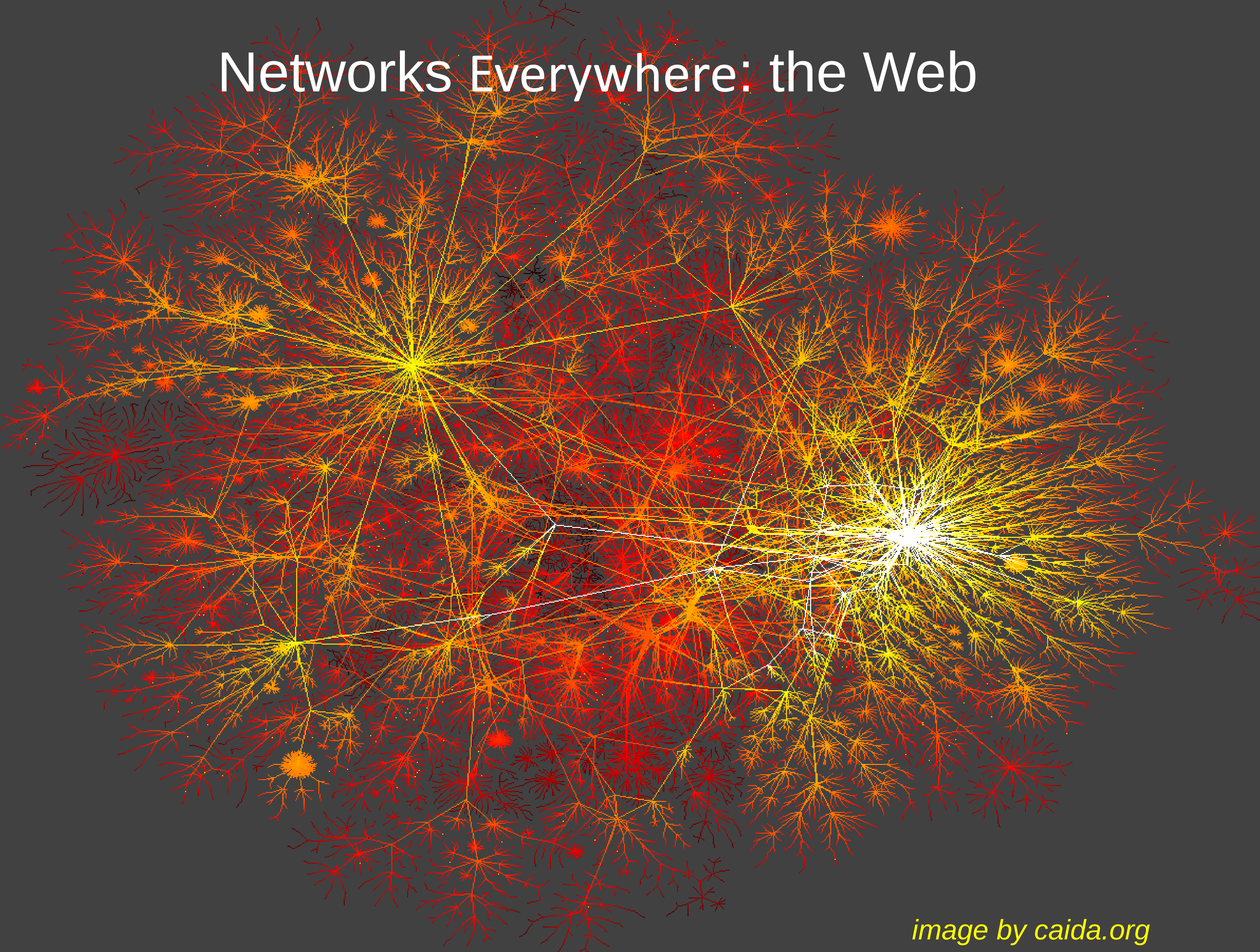
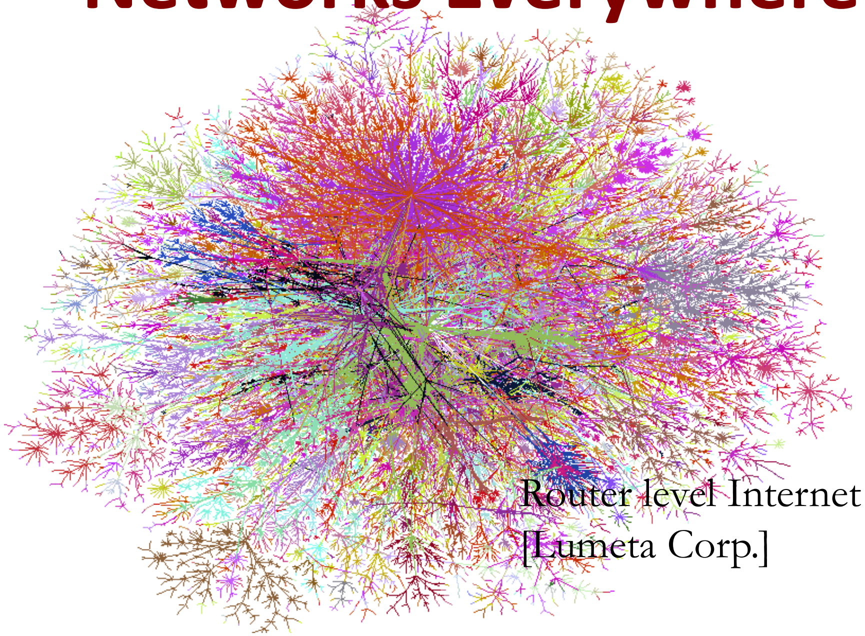
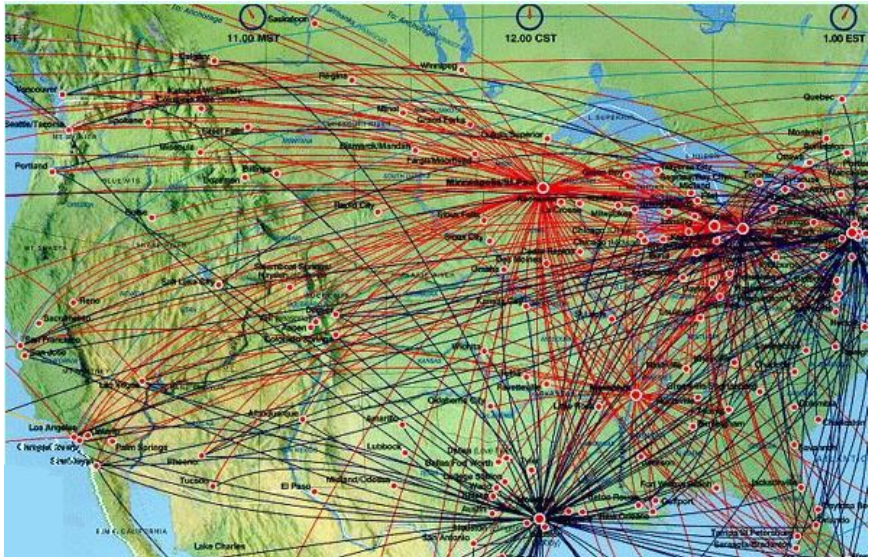


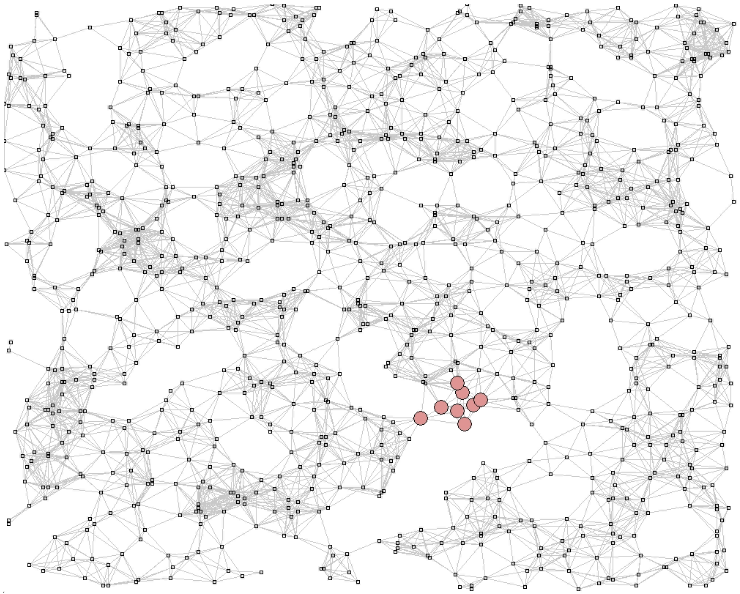
image by caida.org

Networks Everywhere: Mobile, Sensor, Social…

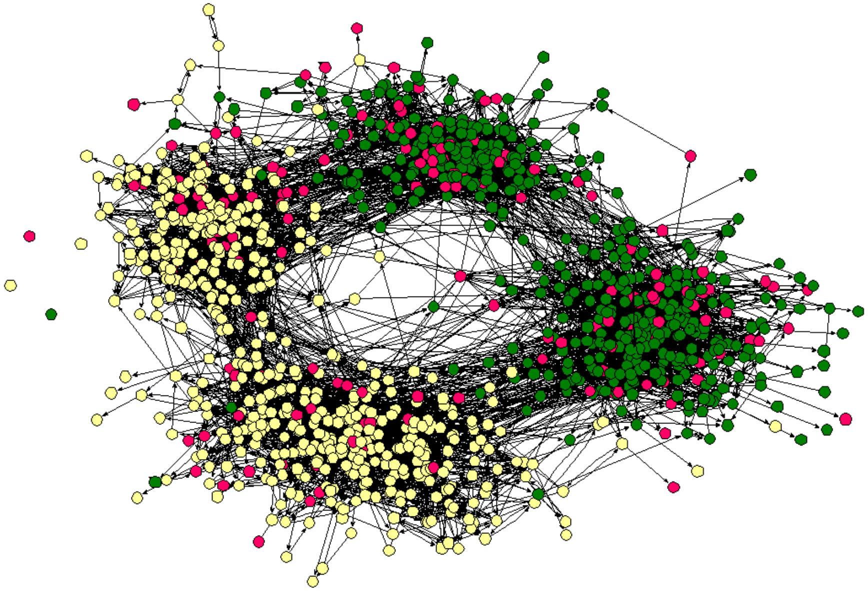


Router level Internet
[Lumeta Corp.]





wireless sensor networks
Qiming Lu et al., (2006)



High school friendship network [AddHealth]

Social Networks

Nodes: individuals

Links: social relationship (family, work, friendship)

Many individuals with diverse social interactions between them.

Big Question

How does existence of information networks (internet with its social networking tools, cell phone networks, and so on) change dynamics of human interaction?

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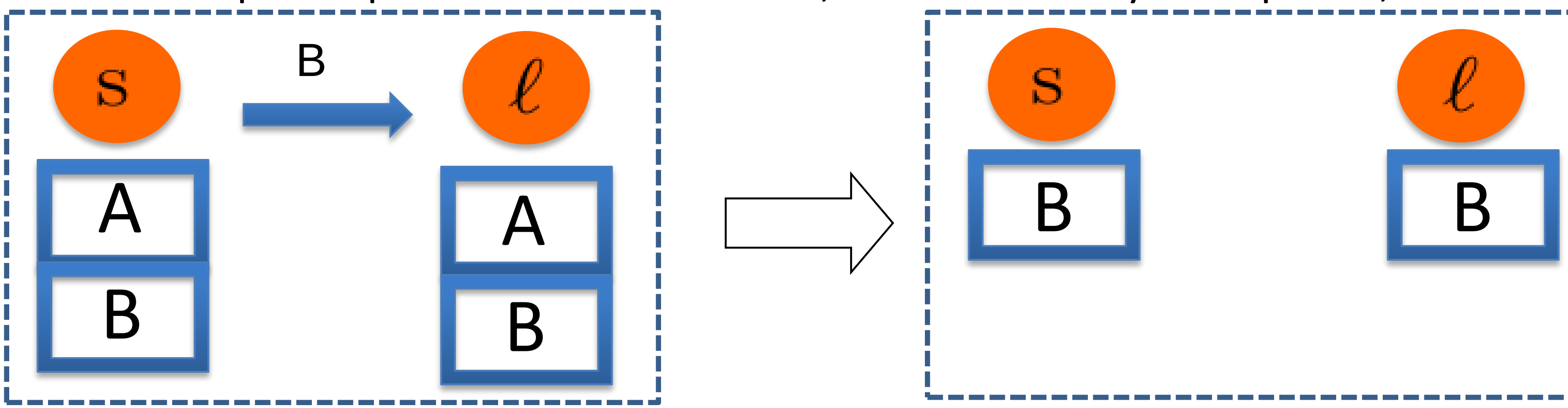
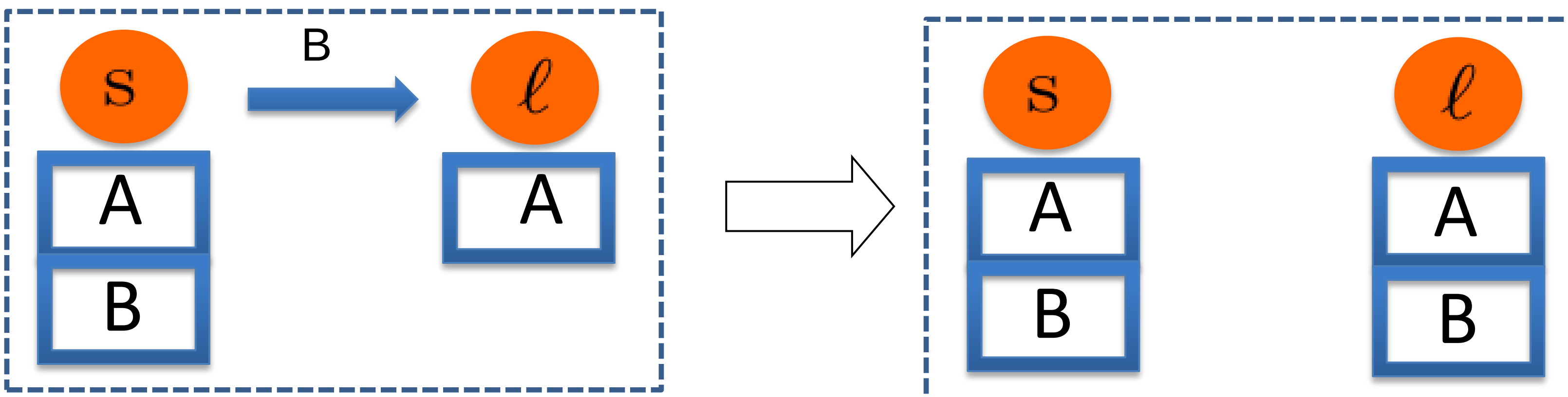
Modeling social/opinion dynamics

A model for negotiation/opinion dynamics: the Naming Game

1. At each step a *speaker* and a *listener* (neighbor of speaker) are chosen randomly.
2. Speaker sends an opinion randomly selected from his list.
   - if the sent opinion presents in listener's list, both retain only this opinion;



   - else, listener adds the sent opinion to his list.



Baronchelli et al., 2006

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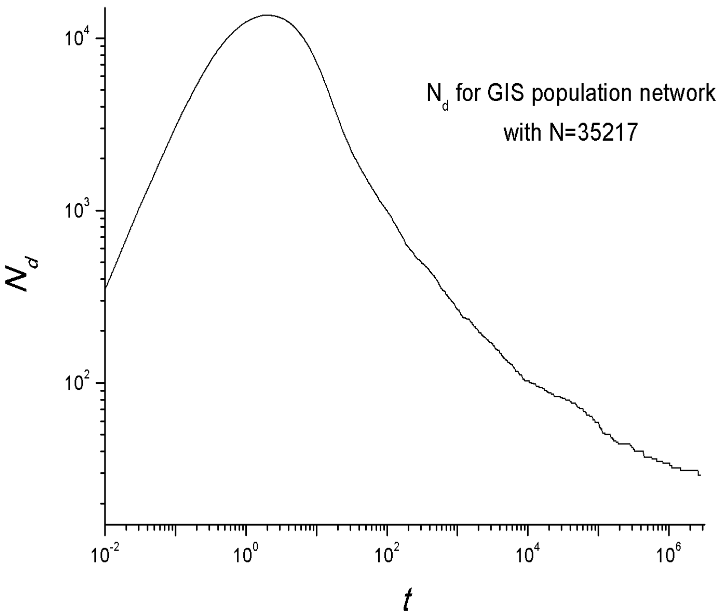
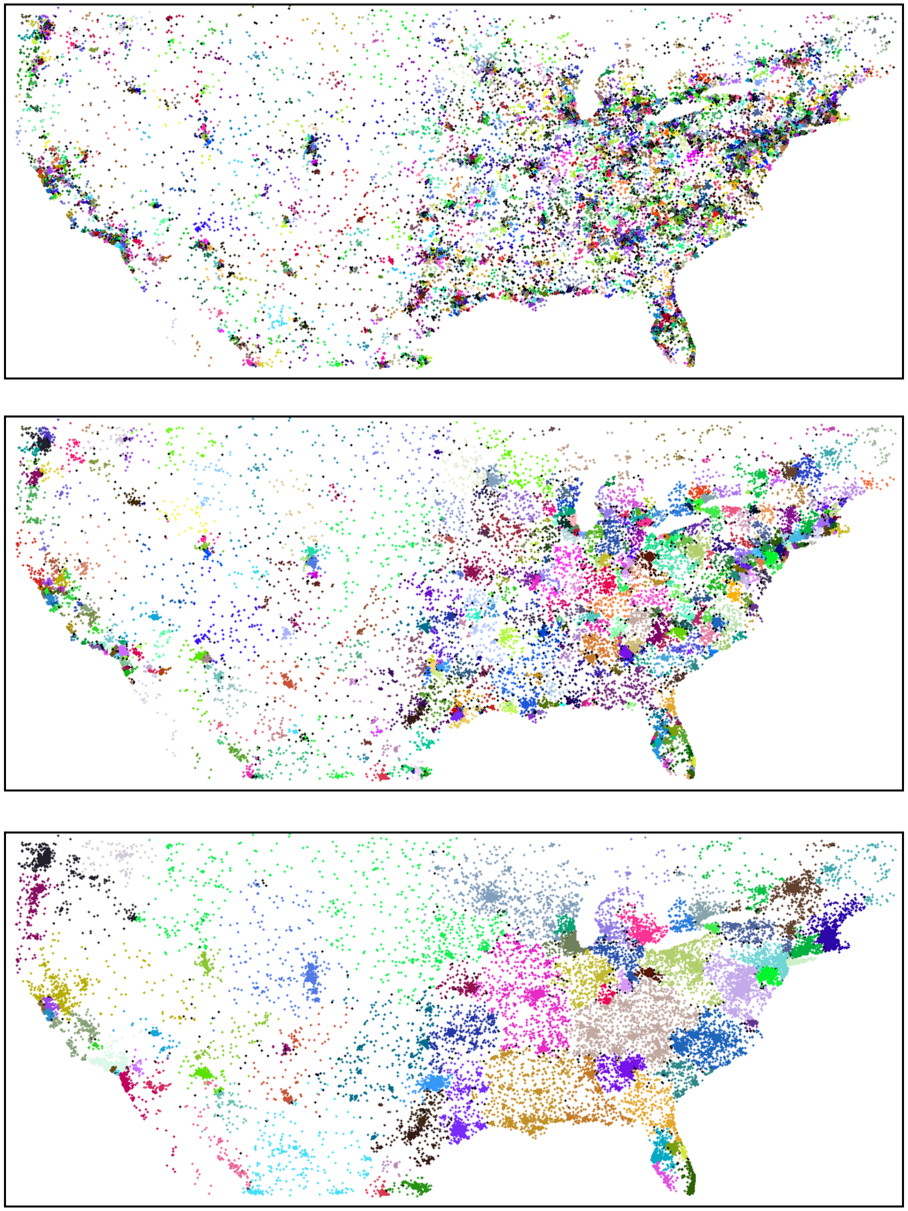
NG on Heterogeneous Spatial Networks

Using *LandScan*^{TM} US population data to construct a heterogeneous random geometric graphs





Thanks to Ahn and Barabási

What if we introduce committed agents that never change their opinions?

"Never doubt that a small group of thoughtful, committed, citizens can change the world. Indeed, it is the only thing that ever has."
Margaret Mead

How many are needed?

Initial condition we care about:

- Small fraction $p < 0.5$ of nodes *randomly chosen* are *committed* to opinion A

Committed nodes are un-influencable i.e. never change opinion

- Remaining fraction (1-p) of nodes have opinion B

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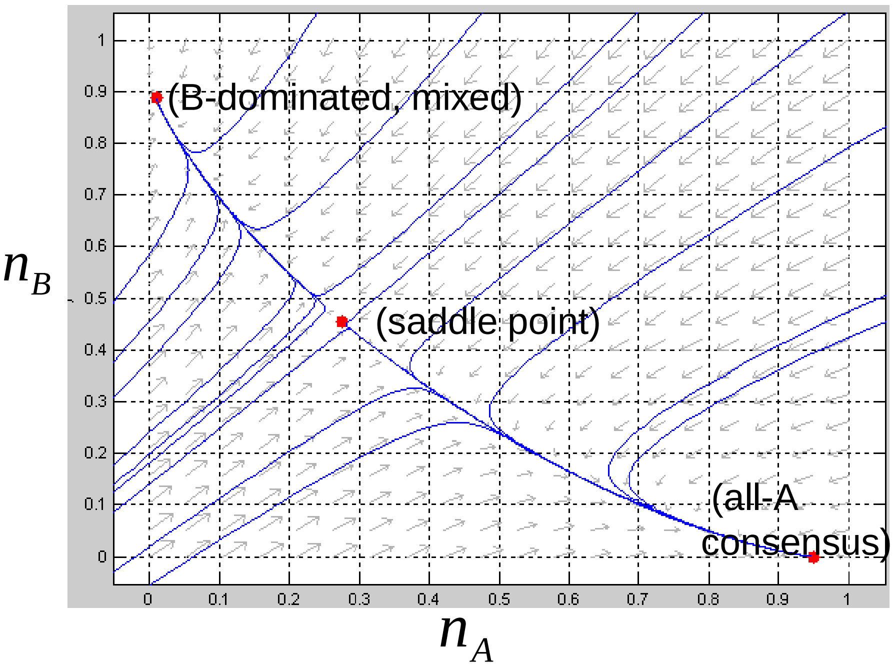
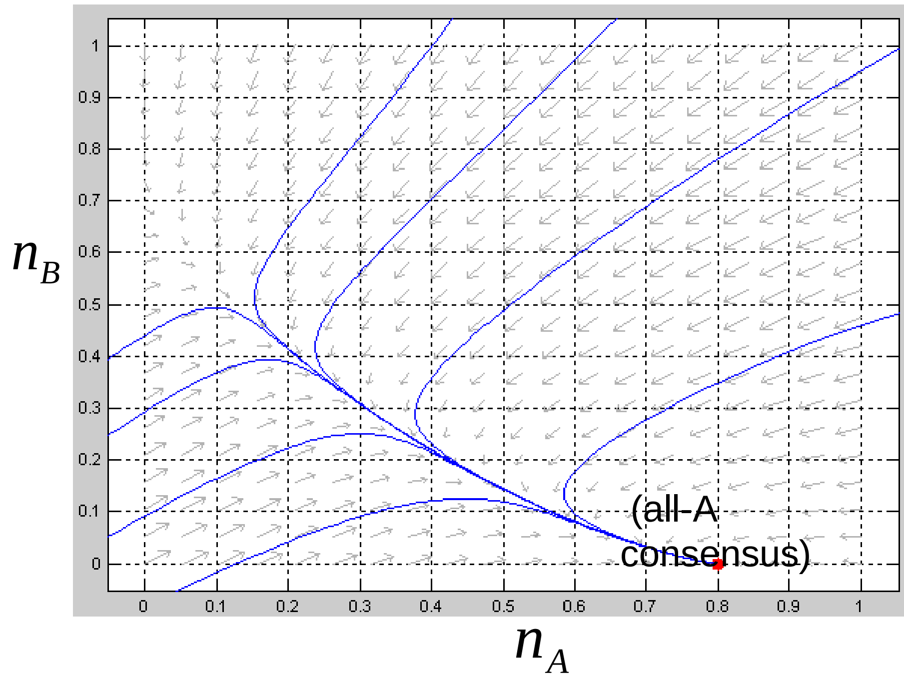
Tipping point in Social Networks

p: fraction of agents committed to opinion A

$p = 0.05 < p_c$ $p_c \approx 0.10$ $p = 0.2 > p_c$





A non-absorbing (B-dominated, mixed) stable fixed point exists;

All trajectories starting from initial condition $n_A = 0, n_B = 1 - p$ flow to the non-absorbing fixed point

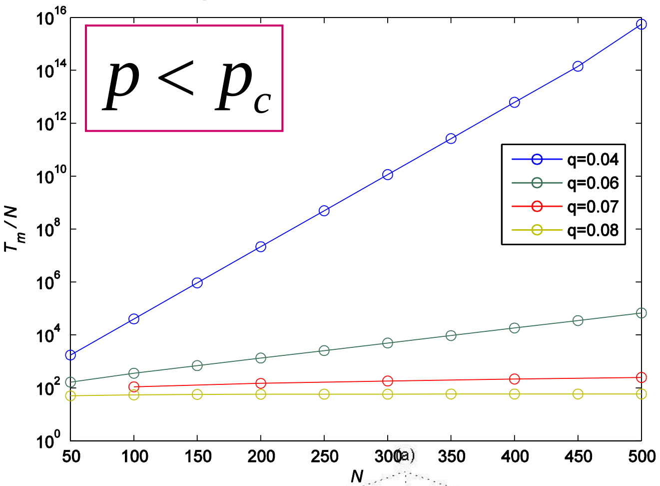
Only all-A consensus fixed point exists

All trajectories flow to consensus fixed point.

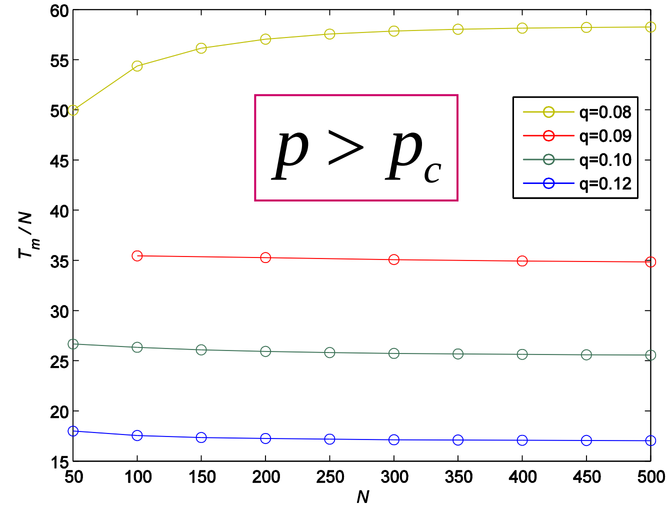
Asymptotic consensus times on the complete graph

Social influencing and associated ***random-walk*** models:

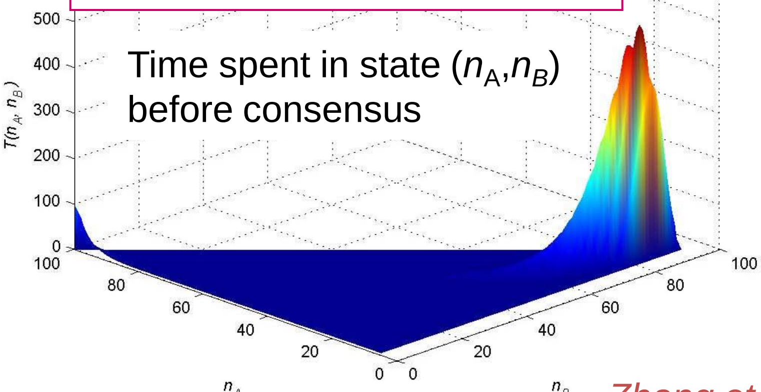
Time spent in meta-stable state



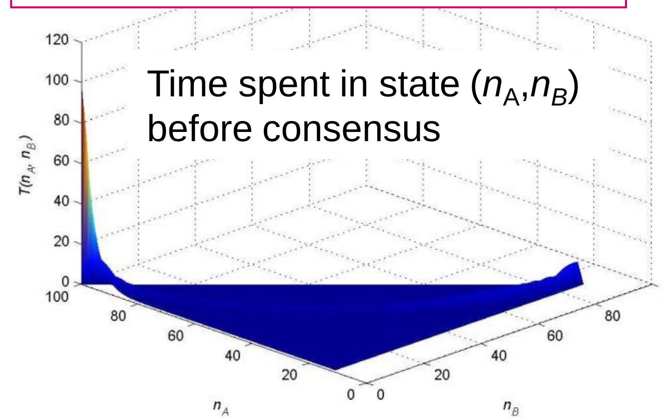
Time spent in meta-stable state



$$p < p_c : \quad \langle T_c \rangle \sim e^{cN}$$



$$p > p_c : \quad T_c \sim \log(N)$$



Zhang et al. (Chaos, 2011)

Tipping point in Social Networks

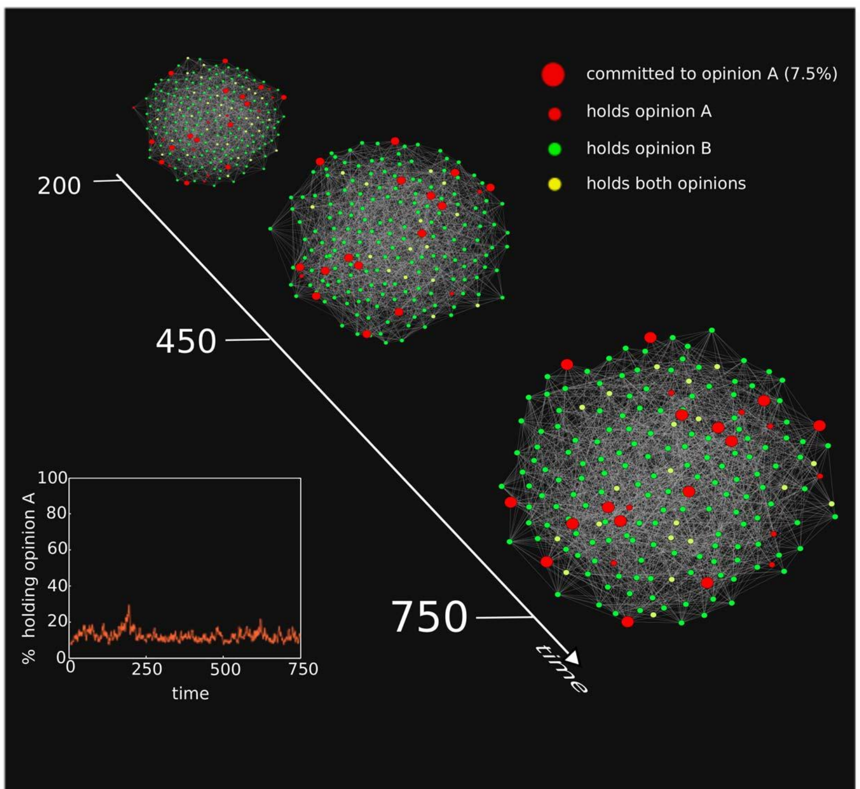
ER network (sparse random graph, N=200, $\langle k\rangle$=5)
Qualitatively results do not depend on graph topology

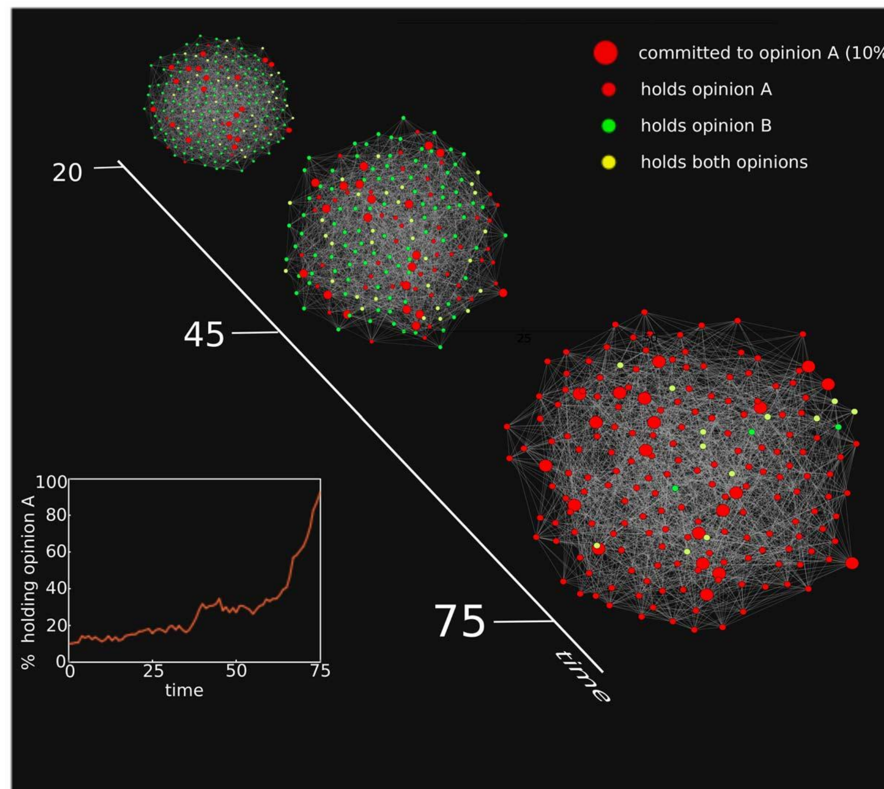
p: fraction of agents committed to opinion A

$$p = 0.075 < p_c$$

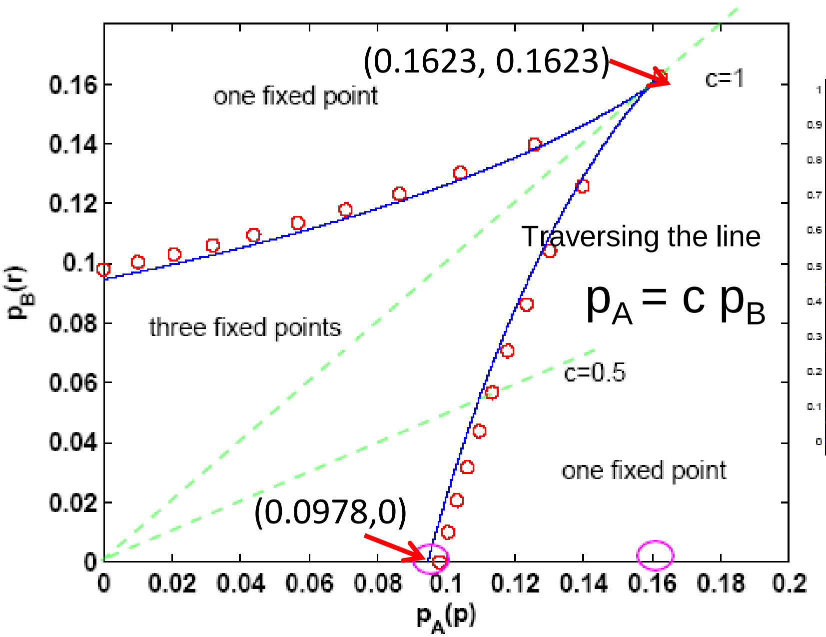
Xie et al. (PRE, 2011)

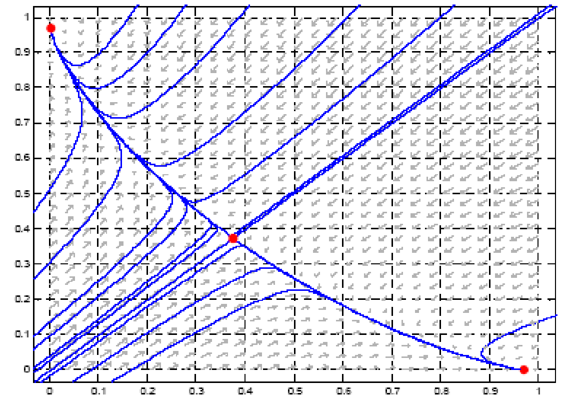
$$p = 0.10 > p_c$$



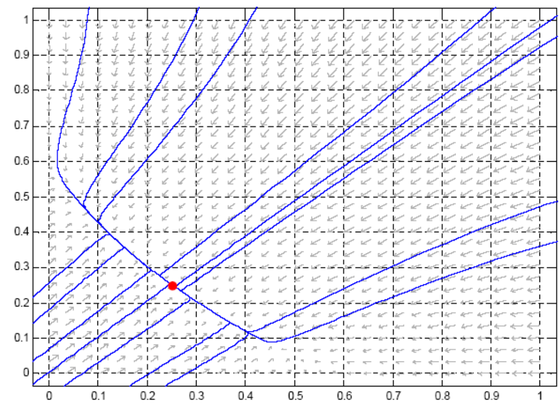


Two-committed Minorities in the Mean-Field

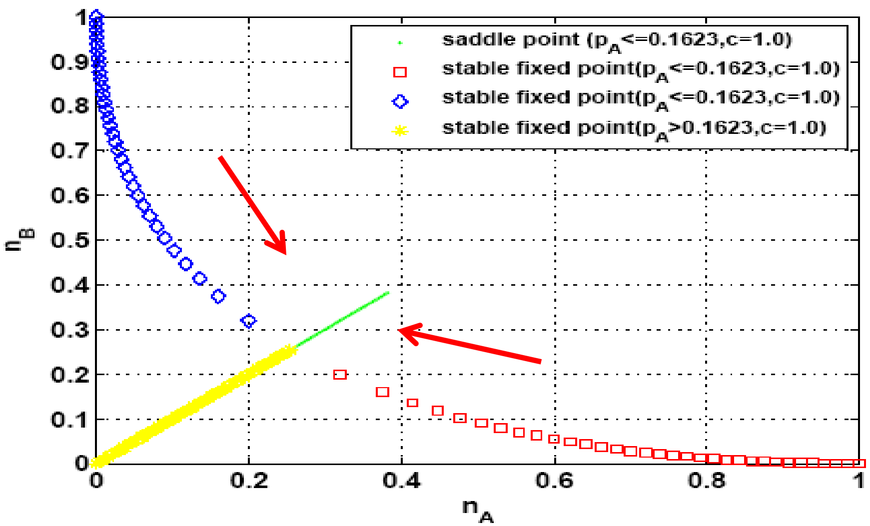


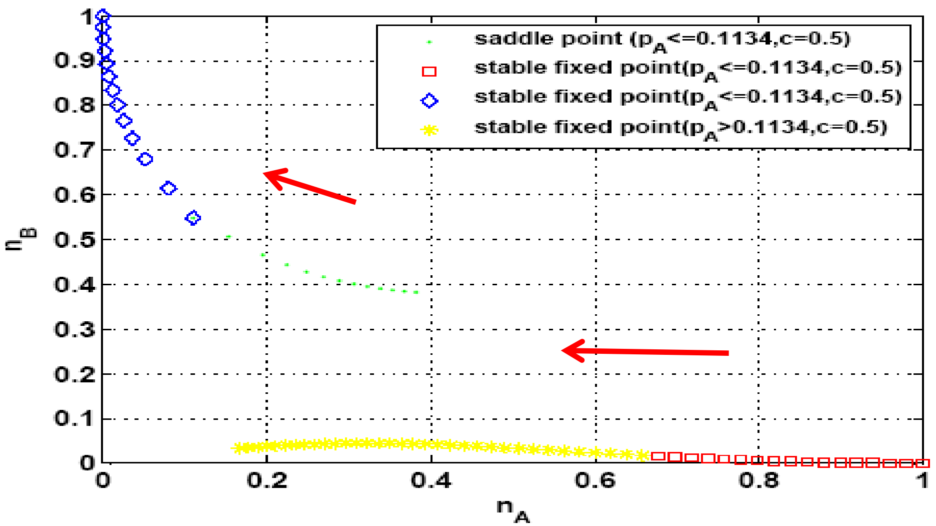


c=1, p_A=0.01<p_c



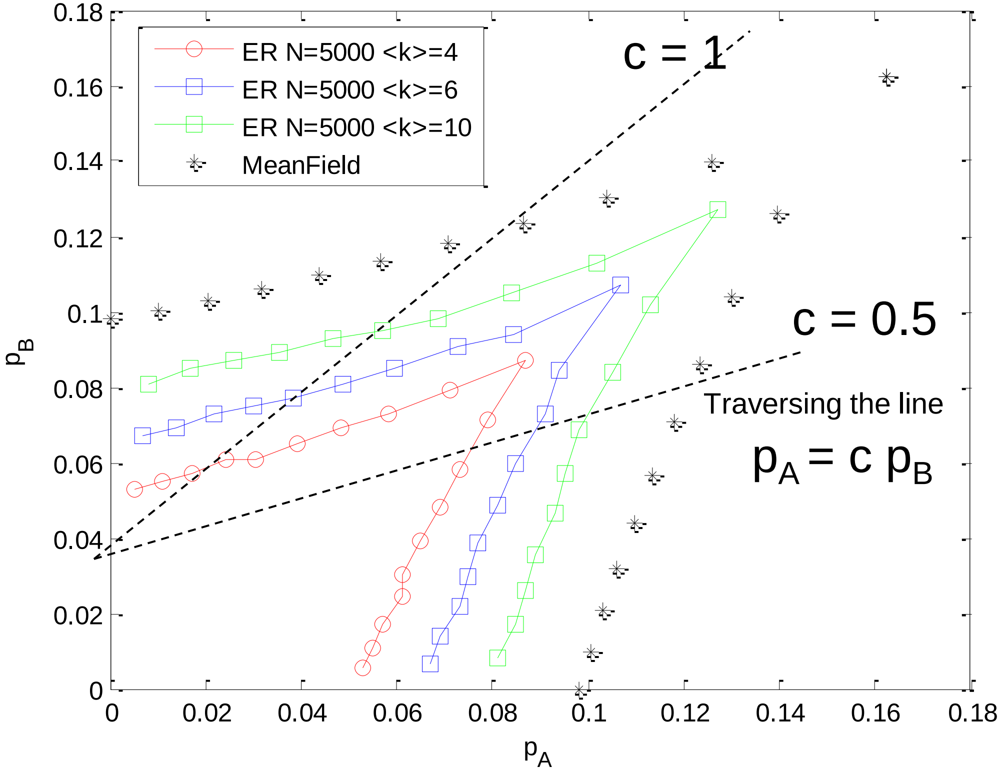
c=1, p_A=0.17>p_c

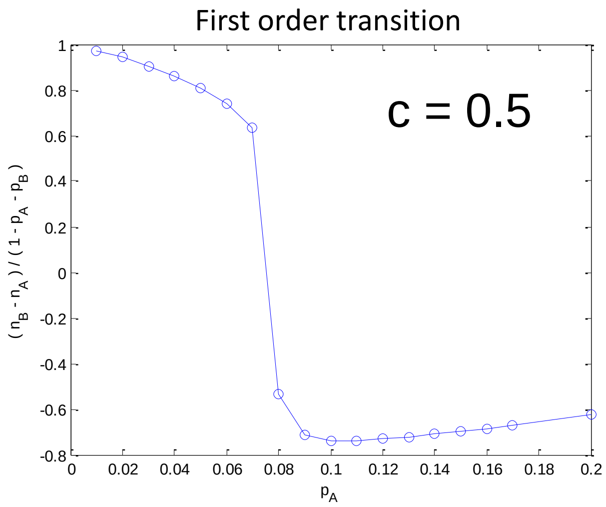


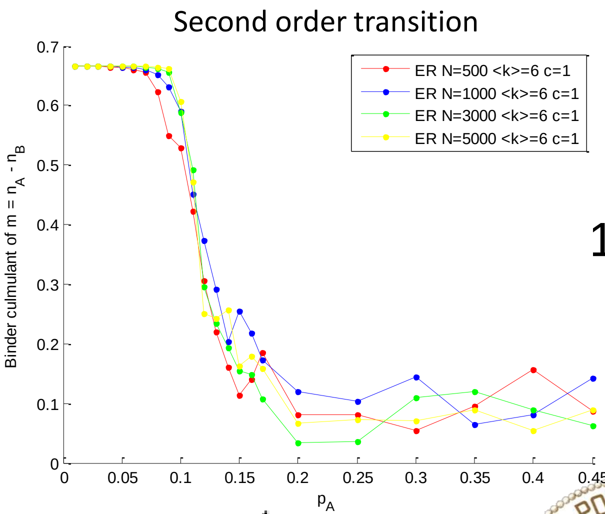


Two-committed Minorities in Finite Size Networks

ER Networks



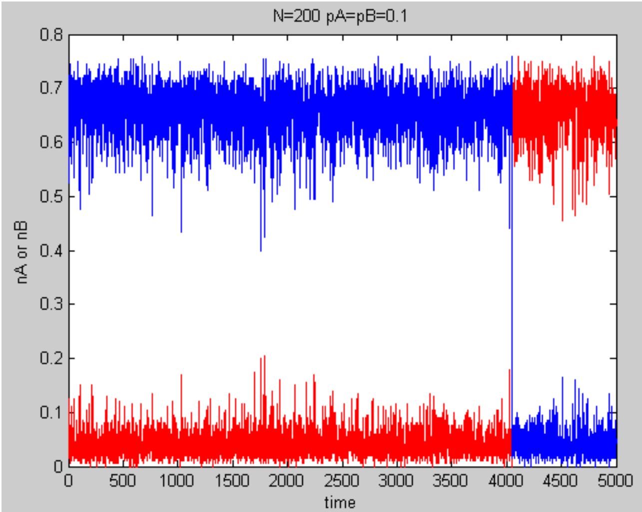


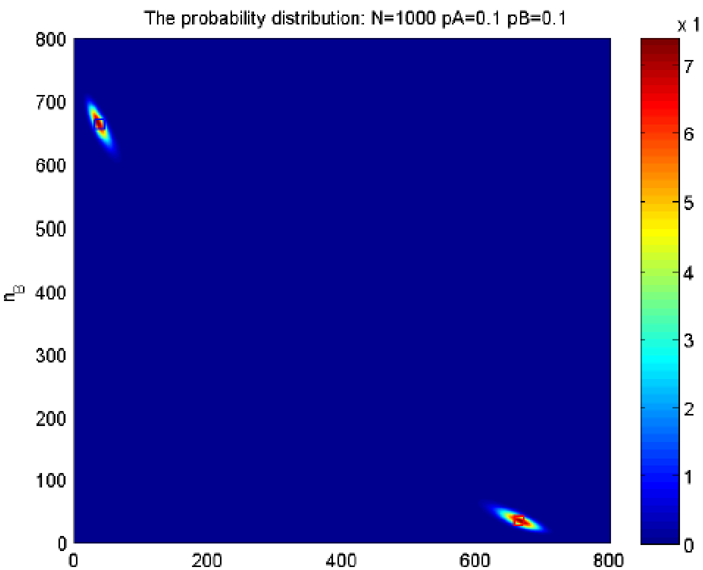


Qualitatively, results do not depend on graph topology

$$B = 1 - \left[\frac{<(m-<m>)^4>}{3<(m-<m>)^2>^2}\right]$$

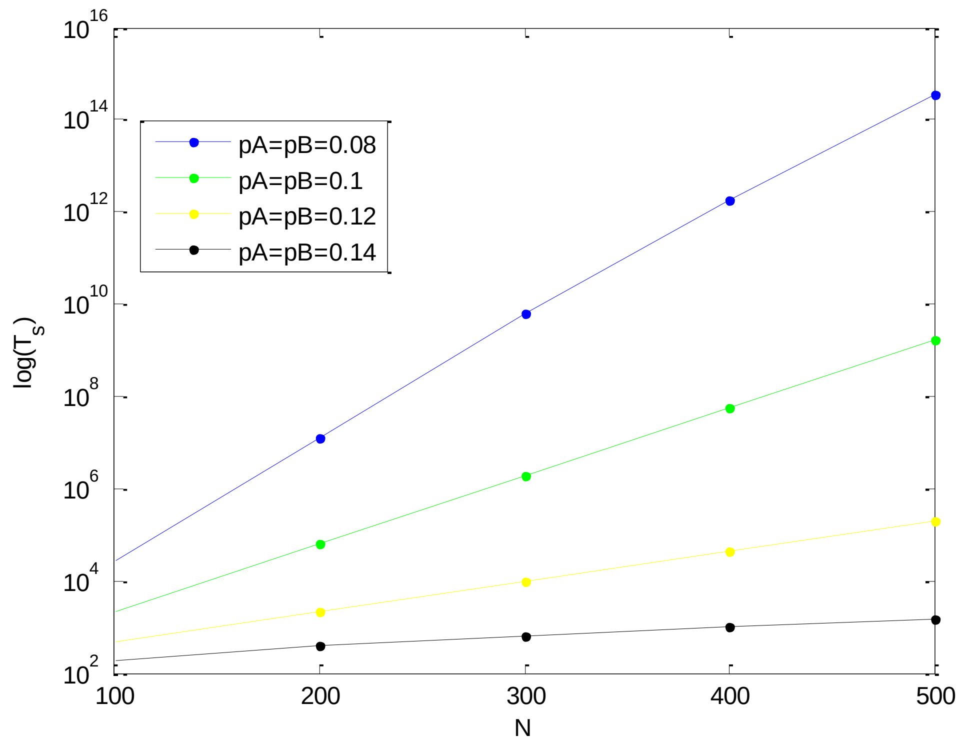
Switching Time with pA=pB





Time Series versus Stationary Distribution

Below p_c, waiting time for switches between A-dominated and B-dominated states scales exponentially with N.



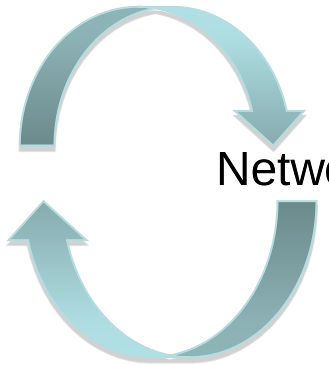
Features of social networks

- Homophily: The tendency of individuals to form social connections to others who are similar to them*.

- Link persistence: The tendency of social connections between similar individuals to last longer than those between dissimilar individuals**.

Co-existence of such structural dynamics along with social influence gives rise to a complex feedback process:

Traits/opinions diffuse and change



Network rewires to maintain homophily

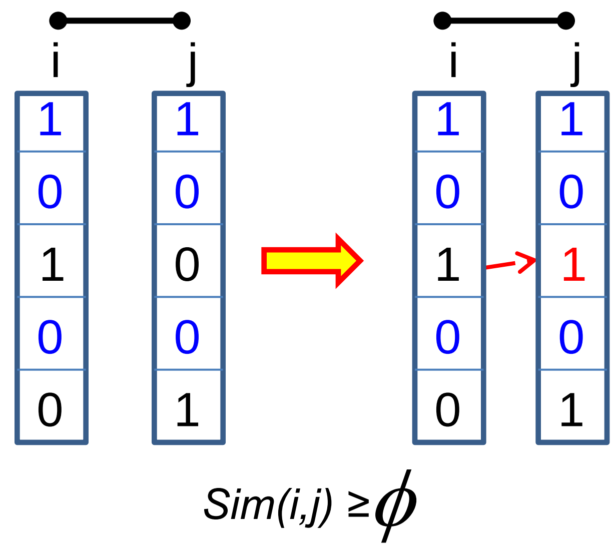
** P. F. Lazarsfeld, R. K. Merton, Freedom and Control in Modern Society,* ***!8:****18 (1954)*

*** R. S. Burt, Social Networks* ***22,*** *1 (2000)*

Network Model: social influence + rewiring

Model parameters:

- Each node has F attributes,
each of which can take q values (opinions)
  - Two nodes i and j are similar if they share similar opinions for at least ϕ attributes.
- Initial network is an Erdos-Renyi network with average degree $\langle k \rangle = 6$.



Model dynamics:

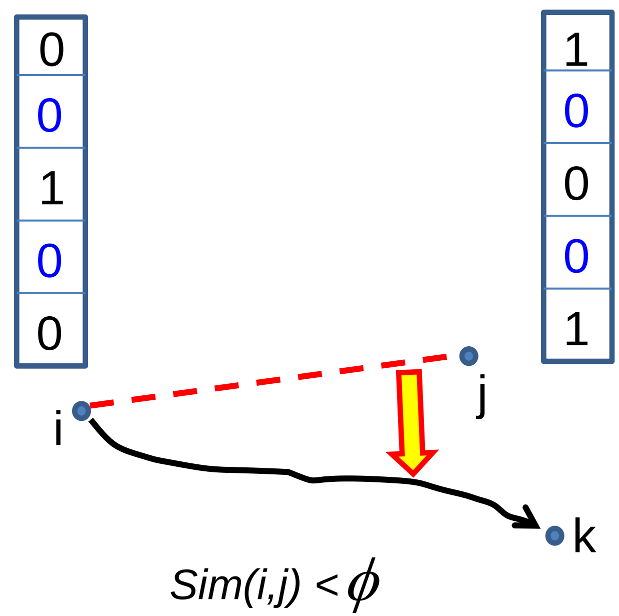
A node i is selected randomly and one of its neighbors j is selected randomly.

If *Sim(i,j)* >= ϕ

j copies the opinion of i, for an attribute on which they are currently dissimilar.

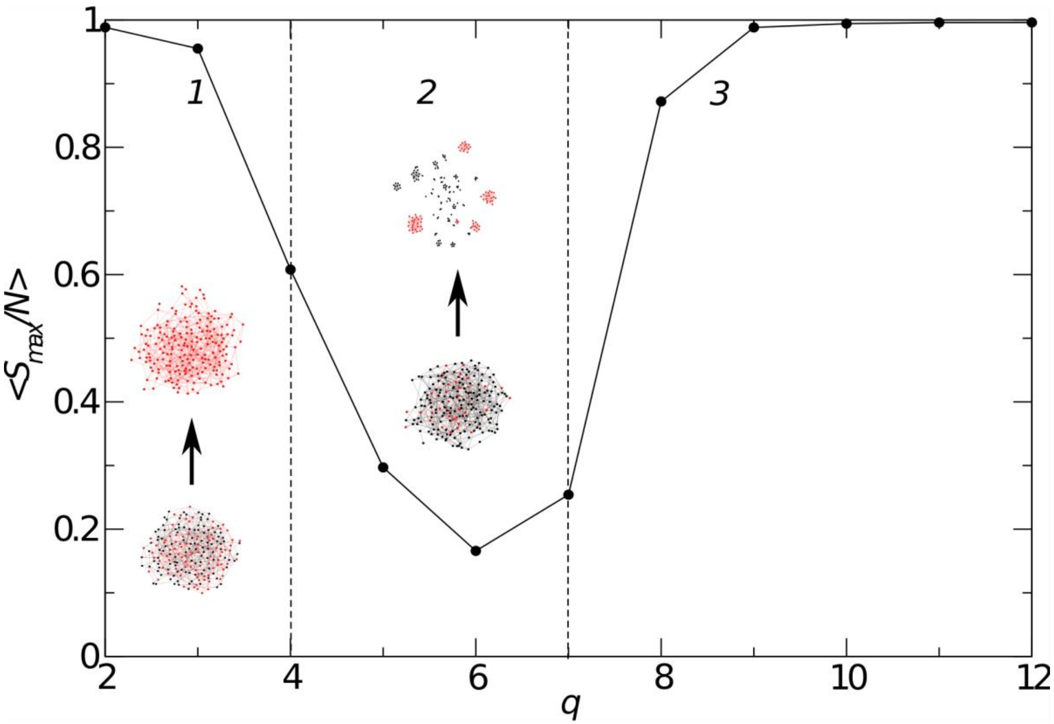
If *Sim(i,j)* < ϕ

i disconnects its link to j, and connects to a randomly chosen node (excluding its current neighbours).



Phase diagram of the model

Fractional size of giant component



N=200, F = 5,

$\phi = 3$

similar phase diagram observed in: *Vazquez et al., PRE 76, 046120 (2007)*

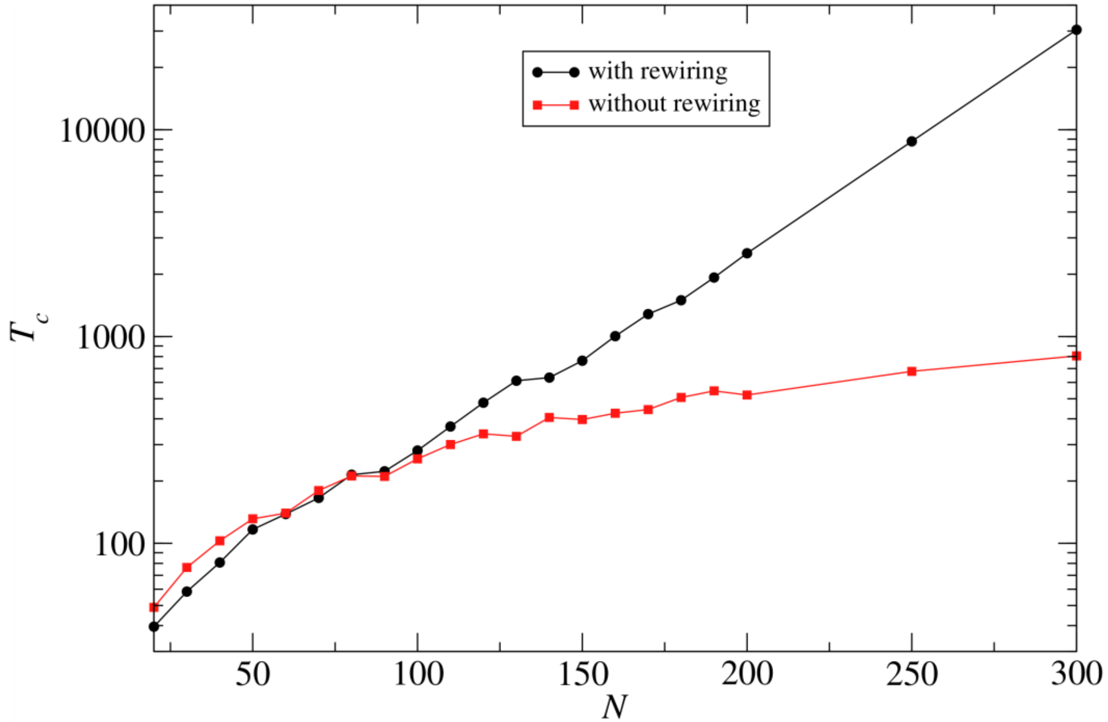
(q = number of traits/opinions per attribute)

Three phases are observed:

- **Region 1** : The largest component is of the order N when rewiring stops and the system reaches consensus on all attributes.
- **Region 2**: The largest component << N when rewiring stops. Consensus is reached independently in each component
- **Region 3**: The largest component ~ N but rewiring continues indefinitely and consensus is never reached.

In the following only phase 1, with F=5, q=2, $\phi = 3$ is presented

How does rewiring affect consensus times?



Without rewiring => Fast consensus $T_c \sim \ln N$

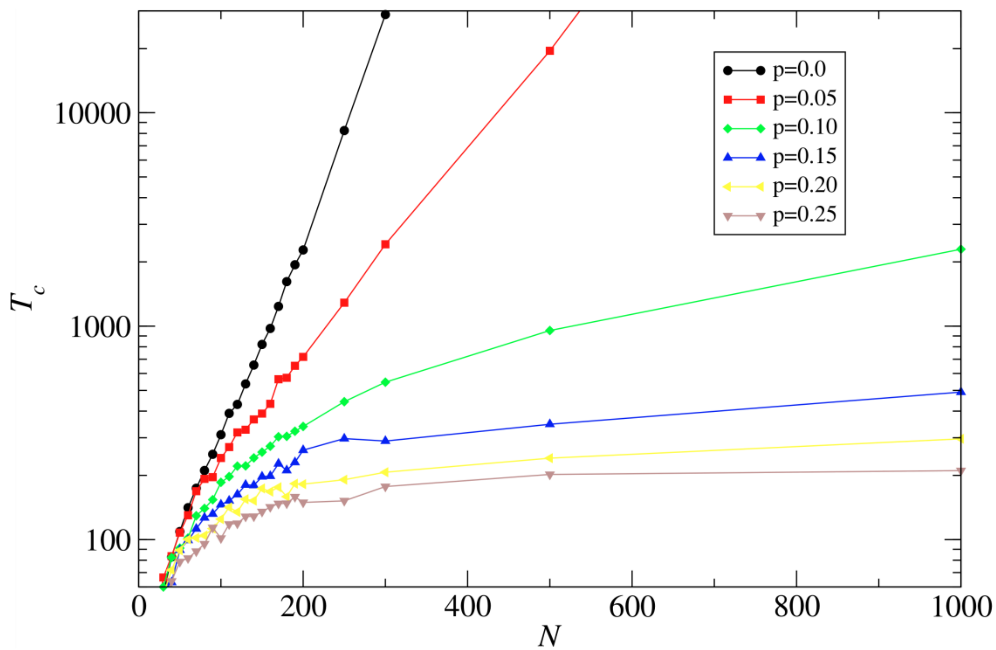
With rewiring => Consensus is slow $T_c \sim \exp(\gamma N) \quad (\gamma \approx 0.2)$

=> Rewiring impedes consensus formation

Q. Suppose we want a particular trait for a particular attribute to be adopted by all nodes, how can we accelerate consensus on this *designated* attribute?

Effect of committed individuals

- Committed individuals (nodes) hold a fixed opinion (1) for the designated attribute.
- All other nodes hold either 1 or 0 for the designated attribute with equal probability
- All nodes hold either 1 or 0 wih equal prob. for attributes beside the designated one.



p denotes the committed fraction

There exists a critical committed fraction

$$p_c \approx 0.1$$

such that for

$$p > p_c : \quad T_c \sim \ln N$$
$$p < p_c : \quad T_c \sim \exp(\gamma N)$$

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Committed agents accelerate consensus provided their fraction is higher than p_c

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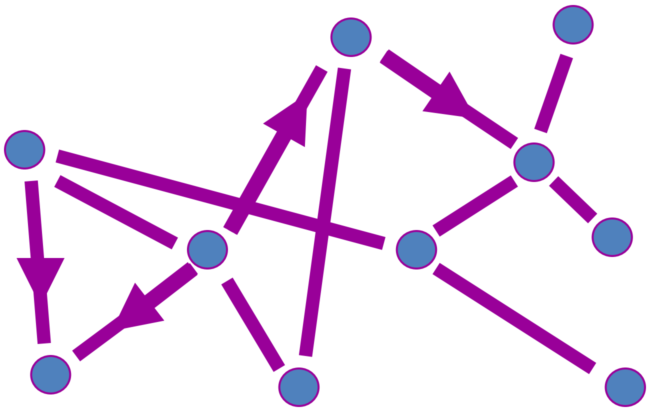
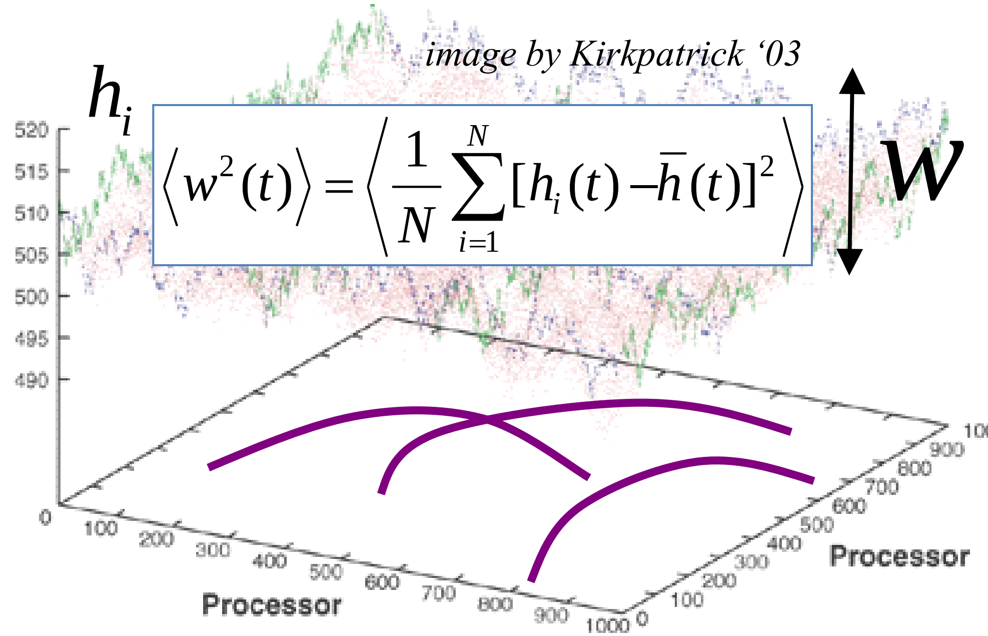
Synchronization and Coordination in Networks



- generalized information processing networks

GK *et al*., '03; Kirkpatrick '03; Kozma *et al*., '04, '05; GK '07



$$\left\langle w^2(t) \right\rangle = \left\langle \frac{1}{N} \sum_{i=1}^{N} [h_i(t) - \bar{h}(t)]^2 \right\rangle$$

$$\partial_t h_i(t) = -\sum_j C_{ij} [h_i(t-\tau_o) - h_j(t-\tau_{ij})] + \eta_i(t)$$

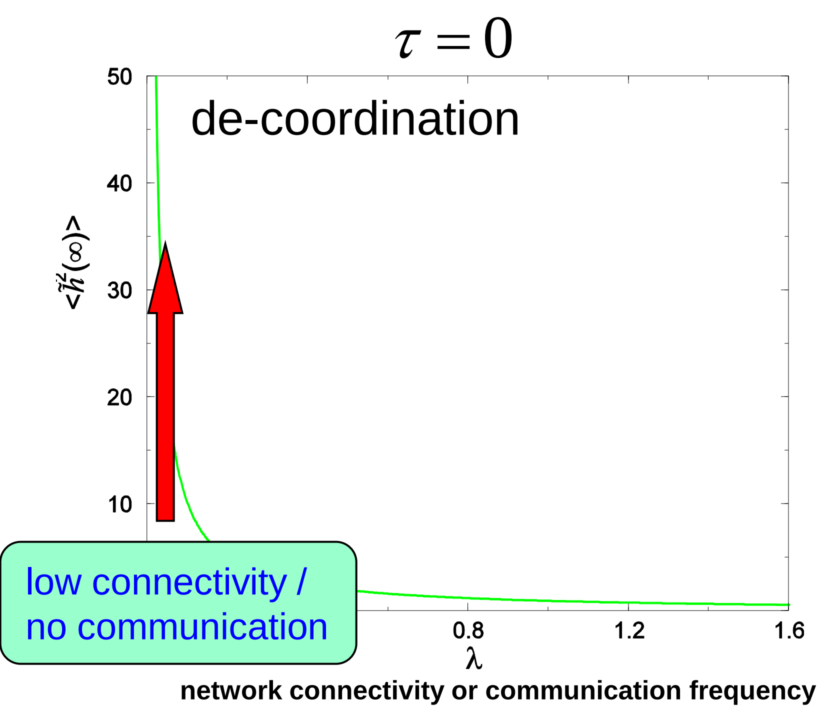
delay — noise

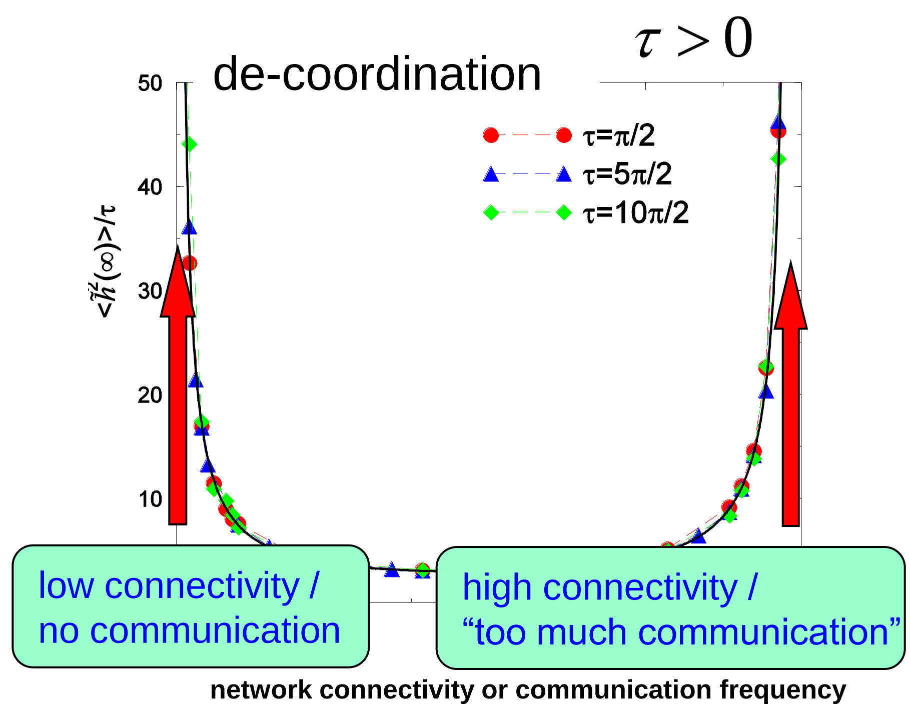
Understand fundamental and inherent instabilities in networks with delayed feedbacks and reactions

Olfati-Saber and Murray IEEE TAC (2004) -- deterministic consensus
Hunt, Korniss, and Szymanski PRL (2010) and Phys. Rev. A (2011)-- stochastic coordination

The Impact of Time Delays in Info-Social Networks

- Individuals constantly react to endogenous and exogenous information: coordination/agreement/consensus/alignment in a social networks
- They react to the information or signal received from their neighbors possibly with some time lag τ (as result of finite transmission, decision, or cognitive delays)
- Applications: autonomous coordination of: unmanned aerial vehicles, microsatellite clusters, sensor and communication networks, flocking, social networks





Hunt et al., Phys. Let. A (2011)

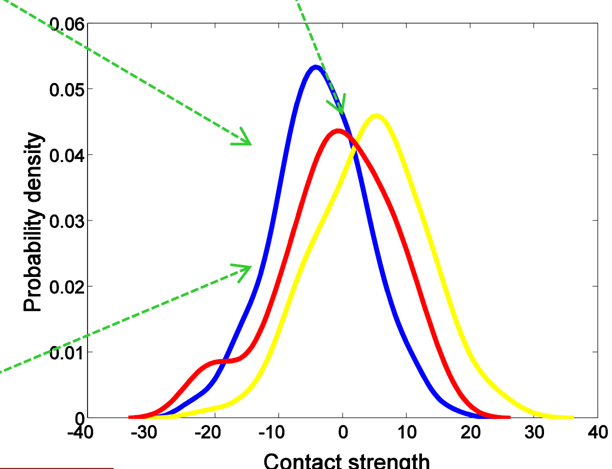
Adjusting Coupling Strength for Synchronizibility: Empirical Evidence

Market traders favor weak ties and high communication in normal condition and strong ties and low communication in pre-crisis time (left part of the slide). This observation agrees with our finding that decreasing coupling restores synchronizibility with too high communication (right part of the slide)

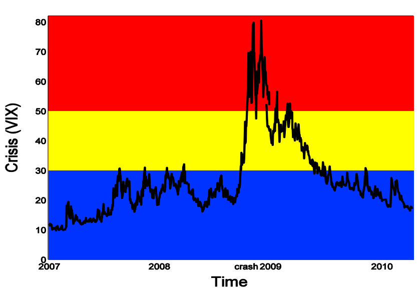
Blue State (baseline, more traffic) Networks favor weak ties Chi Sq <0.000

Yellow State (less traffic) Networks shift to favor strong ties Chi Sq <0.000

Red State Networks shift to favor balance of strong and weak ties Chi Sq <0.000

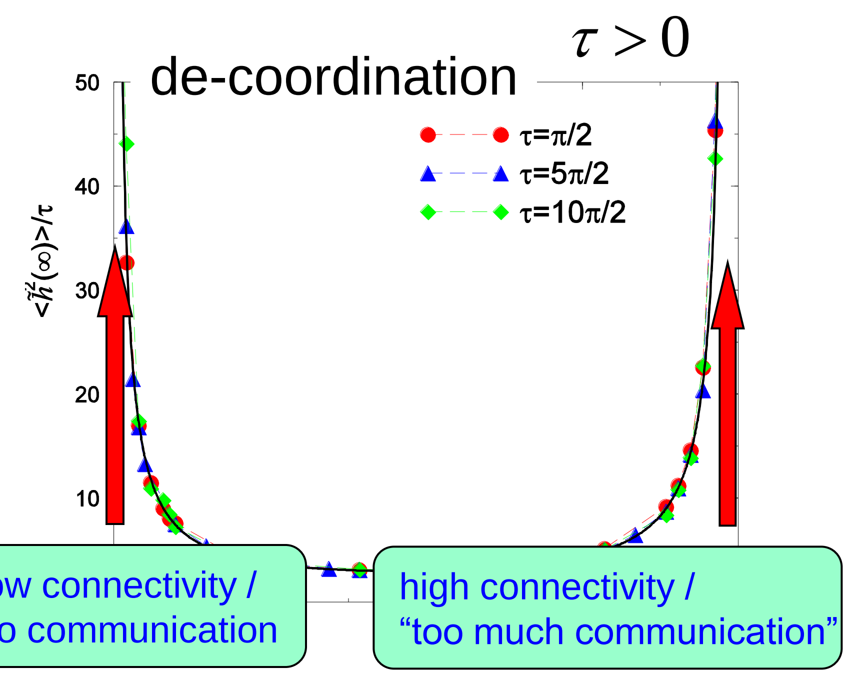


Weaker Ties← 0 → Stronger ties make up the networks



Market states and associated colors

$\lambda_{max}\tau > \pi/2$ → $C_{ij}' = \sigma C_{ij}$ $(\lambda_k' = \sigma\lambda_k)$ → $\lambda'_{max}\tau < \pi/2$



Hunt, Korniss Szymanski, Phys. Rev. Lett. 105, 068701 (2010)

Saavedra at al. Uzzi Synchronicity, Instant Messaging and Performance among Financial Traders, PNAS 2011

Trust in Network Interactions

– Net-Centric Systems may unwittingly bias human-information and human-human interaction. For example,

- –Sequence bias: Causality may be wrongly inferred
- –Trustworthiness of source unknown, assumed, or biased by "surface" features
- –Anchoring effects
- –Information bias: Ease of gathering *more* information may delay decision-making

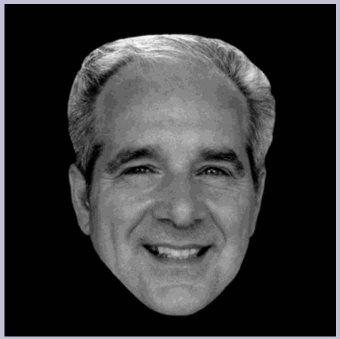
- –Facial appearance appears to exert a constant influence on judgments of trustworthiness
- –These effects hold
  - –Regardless of experience (i.e., positive or negative reciprocity)
  - –Regardless of reputation (trustworthy or not)

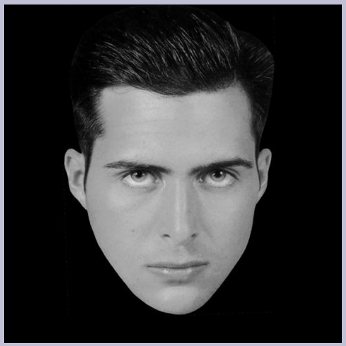
Main Result:

–Regardless of experience or reputation, trustworthy faces are trusted more than untrustworthy ones

Current Hypothesis:

- Accessibility heuristic at work. Certain facial features prime cultural biases in the assessment of trustworthiness
- Positive priming from trustworthy faces provides a continual boost that cannot be overridden by memory-based factors.

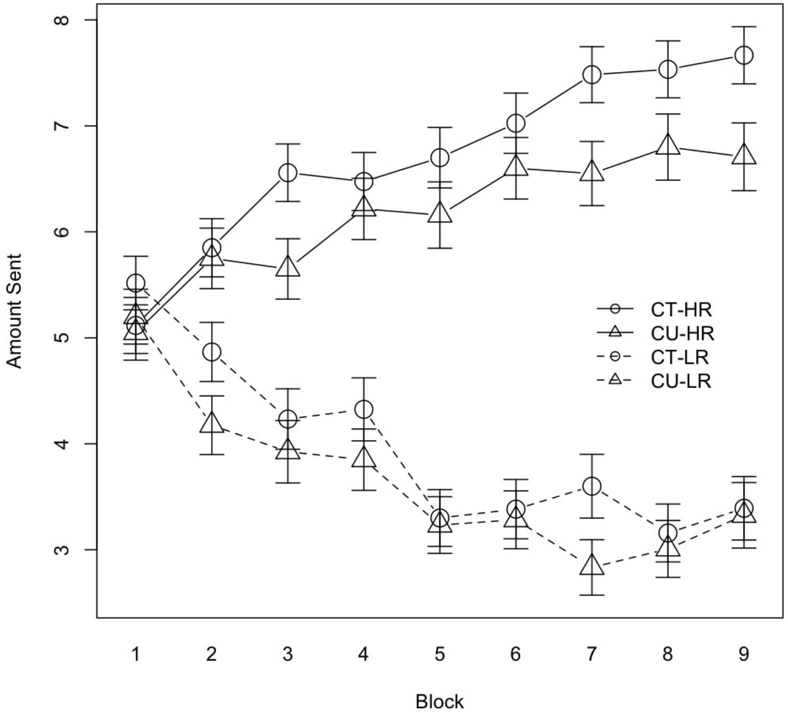




J. Golbeck, UMD (2011)

Appearances may ameliorate the influence of experience (reciprocity) or reputation.

Appearance Bias



Looks count!
Having a trustworthy looking face (CT) is always an advantage compared to having an untrustworthy face (CU)

Is a trustworthy face worth $65 billion?

Con artists often have trustworthy appearances (e.g., Bernie Madoff). In social media we often have a picture of the person we interact with. Exactly how much does looking trustworthy counteract nontrustworthy behaviors?
What can be done to guard against this "appearance bias?"

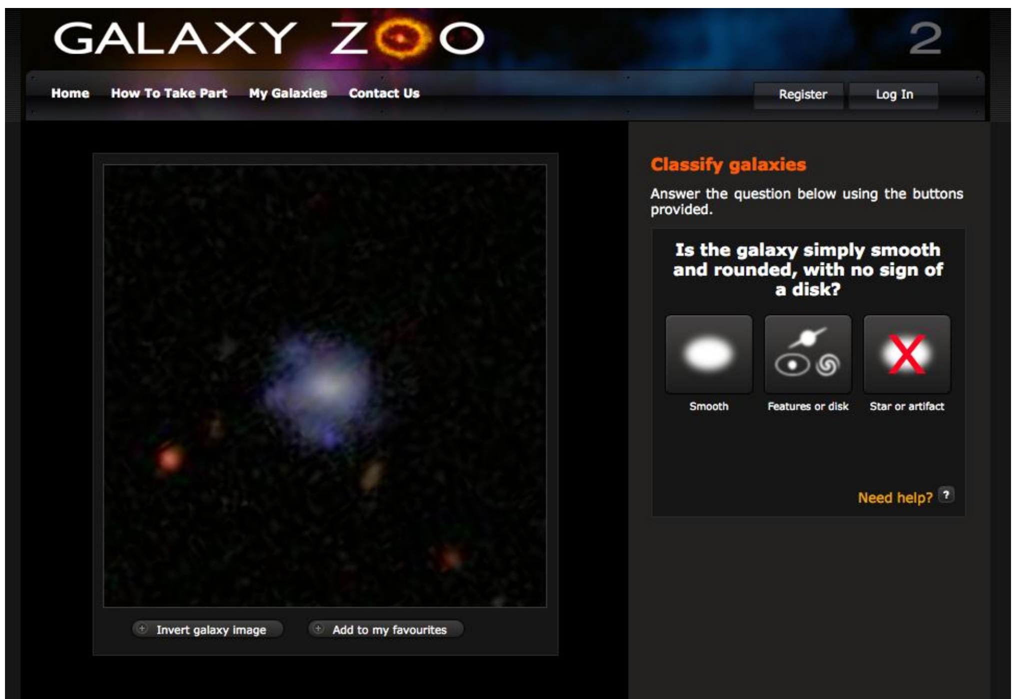
J. Golbeck, UMD (2011)

Participatory Computing and Processing: Science

User of the day
Hi! I'm a cruncher of the HFR team, the most powerful mini-team of l'Alliance Francophone. Contact us if you like crunching and friendship.

Run at RPI, MilkyWay@home has became the largest BOINC computation (among 100's), about 2 Petaflops

Galaxy ZOO uses human minds to discover rare galaxies in the images taken by the Hubble Telescope



An early example of collective problem solving using the Internet and volunteers

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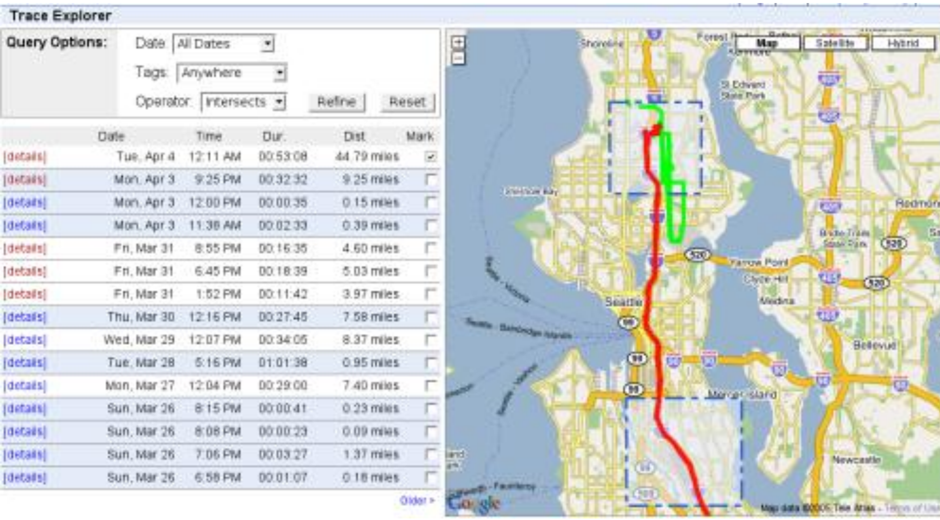
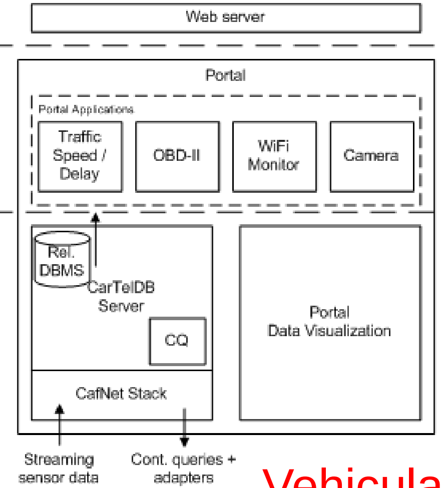
Participatory Computing, Sensing and Processing



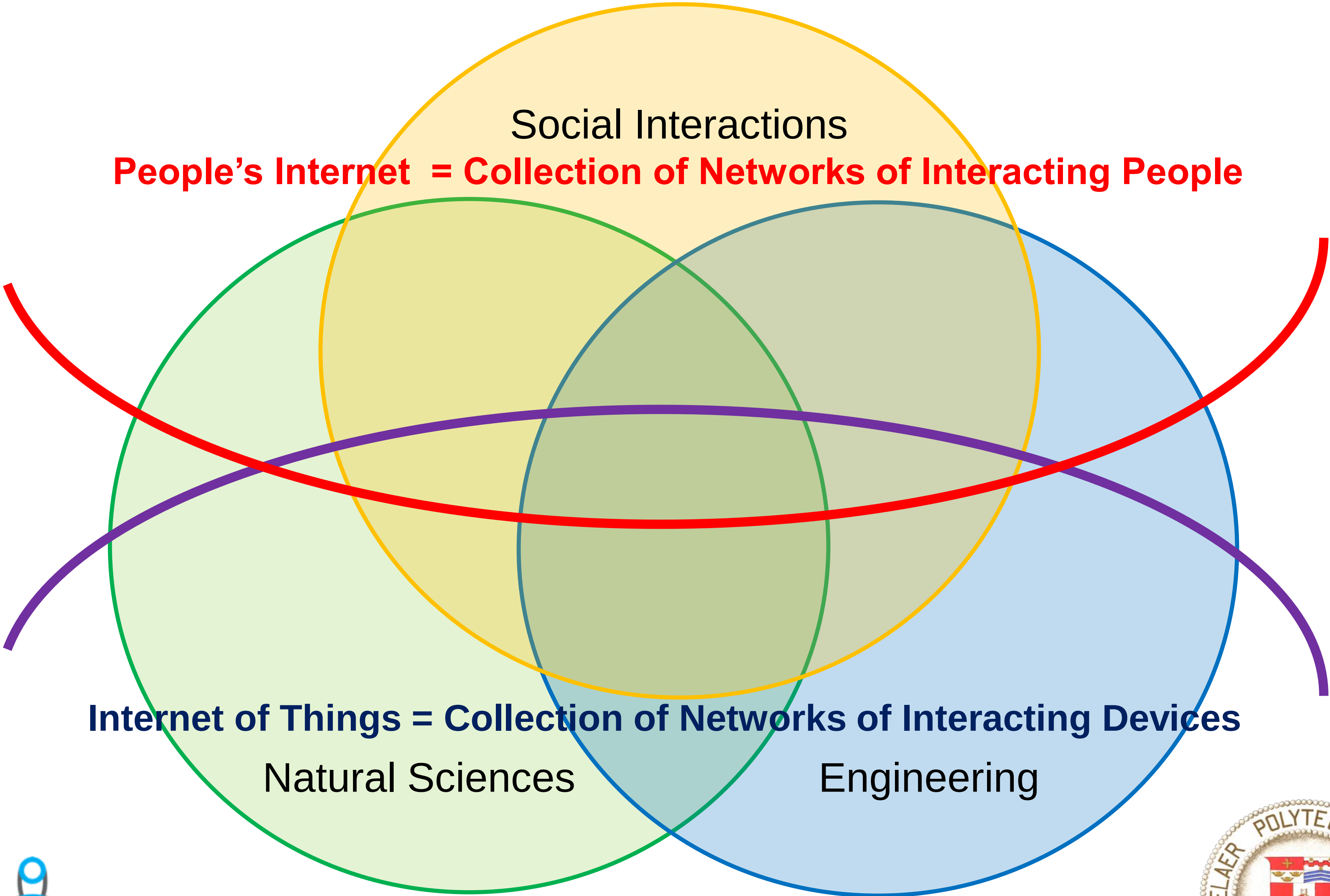


CarTel: a distributed, mobile sensing & computing system using phones and custom-built on-board telematics devices;

Vehicular cyber-physical system

PEIR, the Personal Environmental Impact Report, An online tool allows using mobile phones to explore and share mutual impact of individuals and the environment.

Vision for the Future: People's Internet



Challenges

1. Technological Challenges:
   i. Scale of supporting 7 billion active users will strain bandwidth, memory, processing power, energy needed to run data and processing centers
   ii. Provenance and correctness of data
   iii. Protection against illegal uses, including exploitation
2. Societal Challenges:
   i. Privacy and security
   ii. Ownership, preservation and removal of data
   iii. Assurance of free and equitable access
   iv. Finances: who and in what form will pay?

Thank You !!!

Questions

?

Economic Impact of Information Delay

Gyorgy Korniss, RPI

Posed in 1930's by Michal Kalecki at U. Chicago

David Hunt, RPI

Jierui Xie, RPI

Tahrir Square, February 11, 2011.

Sameet Sreenivasan, RPI

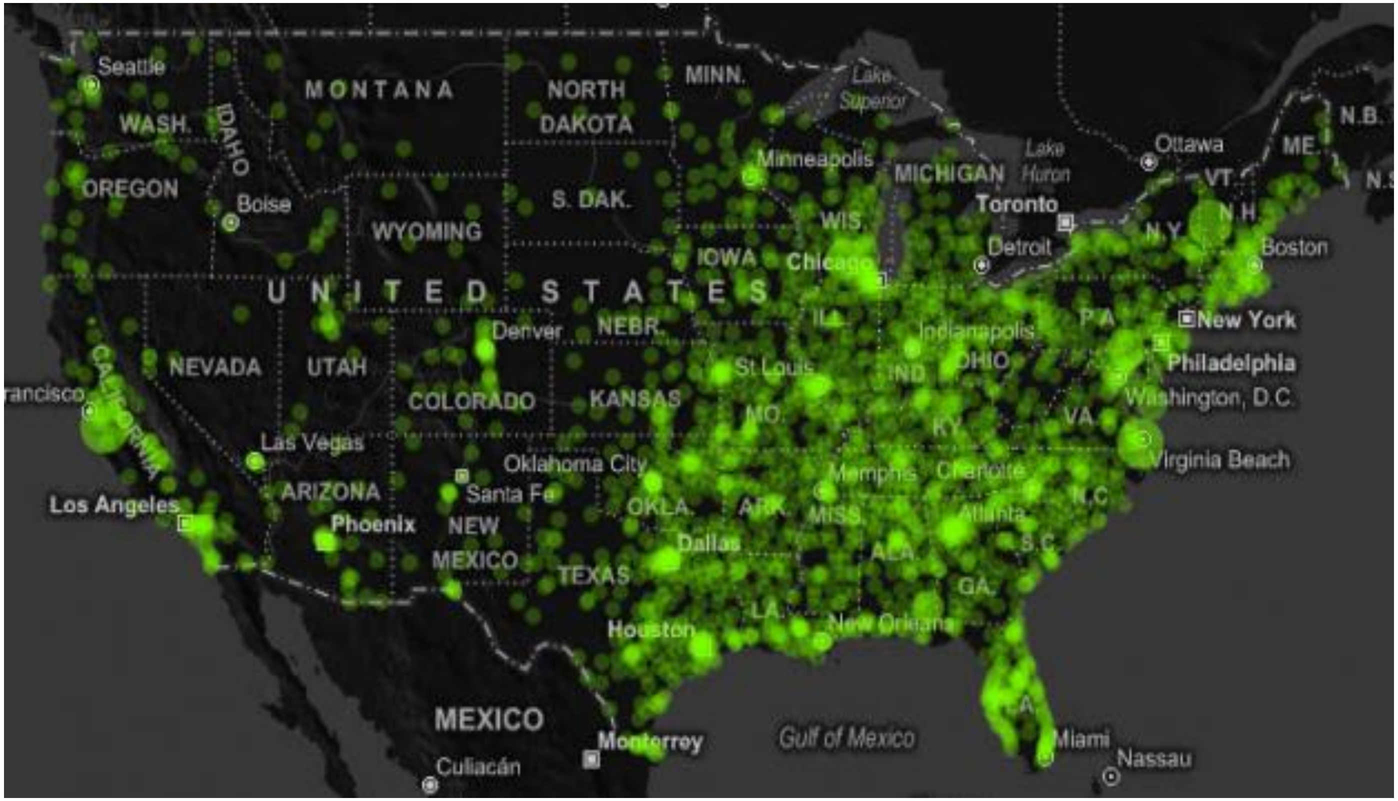
Tipping Point of Committed Minority Influence

Posed in Spring 2011 on streets of Cairo

Monitoring the Growth of Information Campaign Network Across America in Real Time

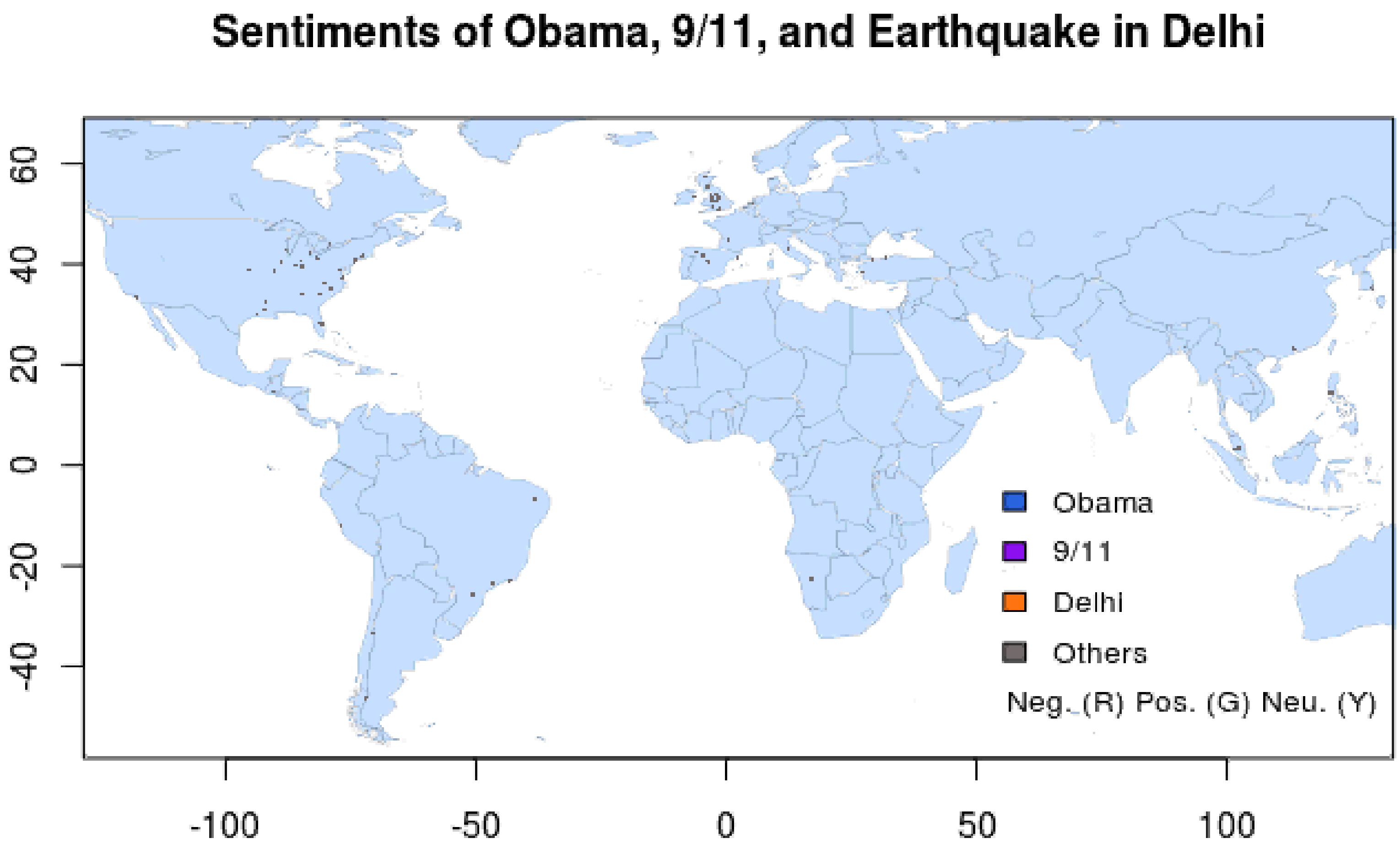
Trends : 911, Halloween, Obama, etc.,

Plot (in real time) the propagation of tweets corresponding to the trends geographically



Study of information campaign **speed**, **geographical coverage**, **penetration**, and **<u>tipping point</u>**.

Presented Data



Date ranges (all in 2011):

Obama : Sept. 7, - Oct. 11; 9/11 : Sept. 09, - Oct. 6; Earthquake: Sept. 07, to Sept. 08