SAND2011-7230C

Modeling the Spread of Public Opinion on Smart Grid technology and Electric Vehicles through Online Social Networks

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Presentation Outline:

1. Objective
2. Motivation
3. Network Structure
4. Opinion Propagation
   a. "Nowak" Model
   b. Multivariate Linear Model
      - Standard Simulation
      - Strongly Opinionated Individuals
      - Current Work – Group Conformity
5. Future Work

Project Objective

1. Develop a mathematical model which predicts how opinions regarding smart grid technology and consumers' willingness to purchase electric vehicles are spread through an online social network

2. Use this model to optimize smart grid public education approaches

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Why i[illegible]portant?

Most Americans confused about plug-in hybrid, electric vehicles, survey says

By Ami Chopa | March 11, 2011, 4:26 PM PST

Electric Vehicles: A March to Madness?

By Brent Dewar
Published April 01, 2011

Consumer Like Those Electric Cars, They Just Don't Know Who Makes Them

By Edward Niedermeyer on June 30, 2011

"This low level of understanding about the way in which electric powertrain vehicles work will have profound consequences for vehicle sales," said Stephen Popiel, senior vice president of Synovate Motoresearch.

Can EVs Overcome Their Own Hype?

By GreenBiz Staff
Published October 28, 2010

"While considerable interest exists among governments, media and environmentalists in promoting HEVs and BEVs, consumers will ultimately decide whether these vehicles are commercially successful or not," John Humphrey, J.D. Power and Associates senior vice president of automotive operations.

Why the All-Electric Leaf May Not Be Your Greenest Fleet Option

By Matthew Wheeland
Published May 23, 2011

In order for the implementation of smart grid technology to be successful,

Consumer support is *essential* – There are many questions

Are the batteries in electric cars reliable? How does the cold affect the batteries?

Are there health risks associated with this technology?

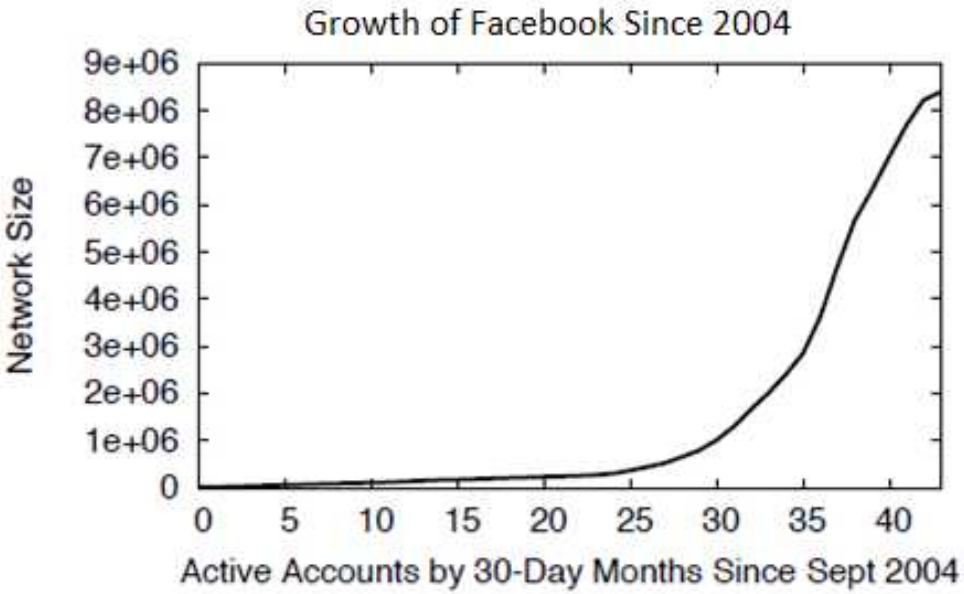
Is my privacy compromised by any of the smart grid technology?

What is the charge time for Plug in Hybrid Electric Vehicles?

What are the economical savings?

What are the differences between on peak and off peak hours? How does this affect carbon emissions?

Why Online Networks?



Wilson

- People spend over 700 billion minutes per month on Facebook

Facebook.com

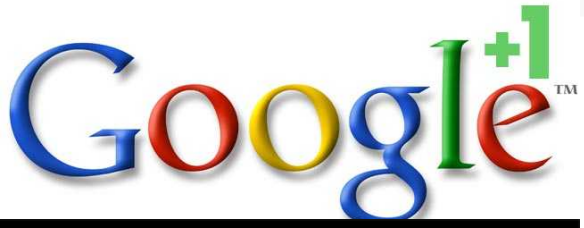
Currently:

- More than 750 million active users
- 41.6% of the US population has a Facebook account
- 50% of Facebook users go on daily
- 20% of the US population goes on Facebook daily

Online Social Networks:

Have added new aspects to the way people communicate

- **Information spreads more quickly**
- **Users are influenced by:**
  - **A greater quantity of people**
  - **People located at large geographical distances away from them**
  - **People who they do not have strong relationships with**



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Online Social Network Analysis

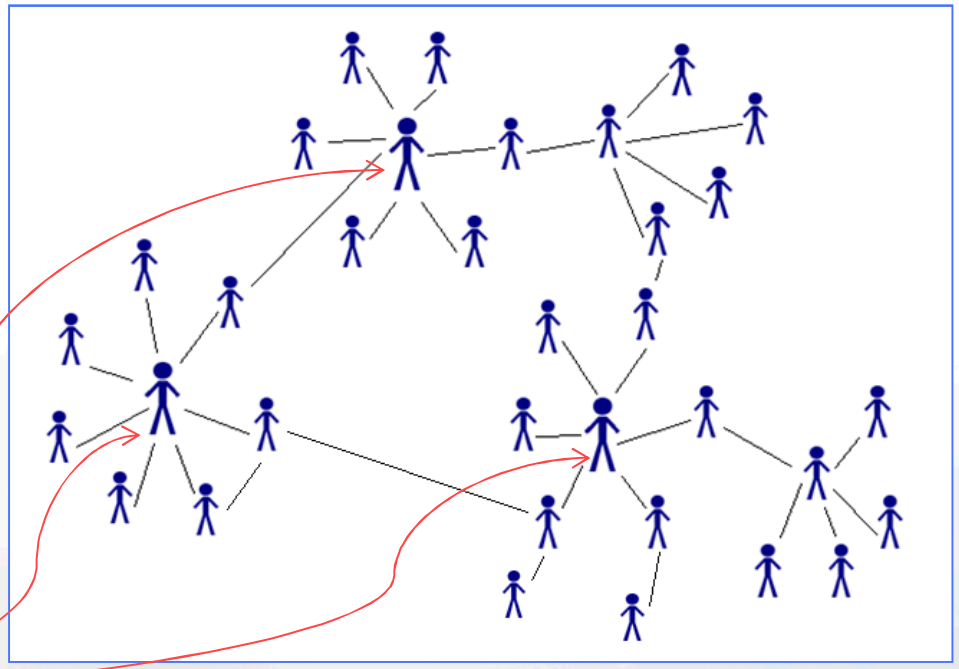
Display *scale free* and *small world* properties

Scale Free Network Characteristics:

- Degree distribution follows a power law

  Degree: The number of connections a node has

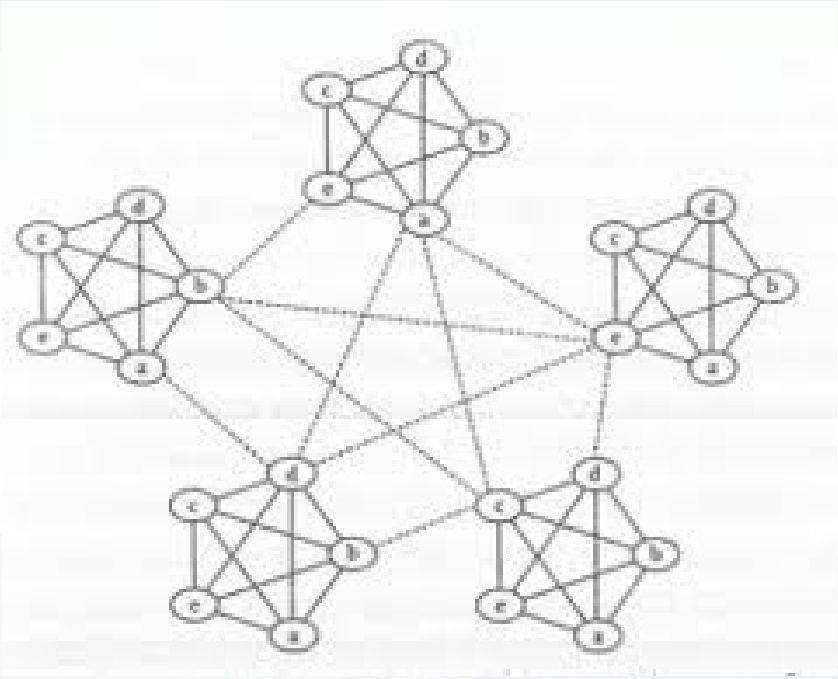
- Existence of "hubs"



Online Social Network Analysis

Small World Network Characteristics:

- High clustering coefficients
- Short characteristic path lengths



$$Clustering\ Coefficient = C = \sum_{i \in N} \frac{T_i}{0.5 * k_i(k_i - 1)}$$

$T_i = Number\ of\ triangles\ with\ vertex\ i$

$k_i = degree\ of\ i$

Scale Free Network Creation

Barabási–Albert (BA) model

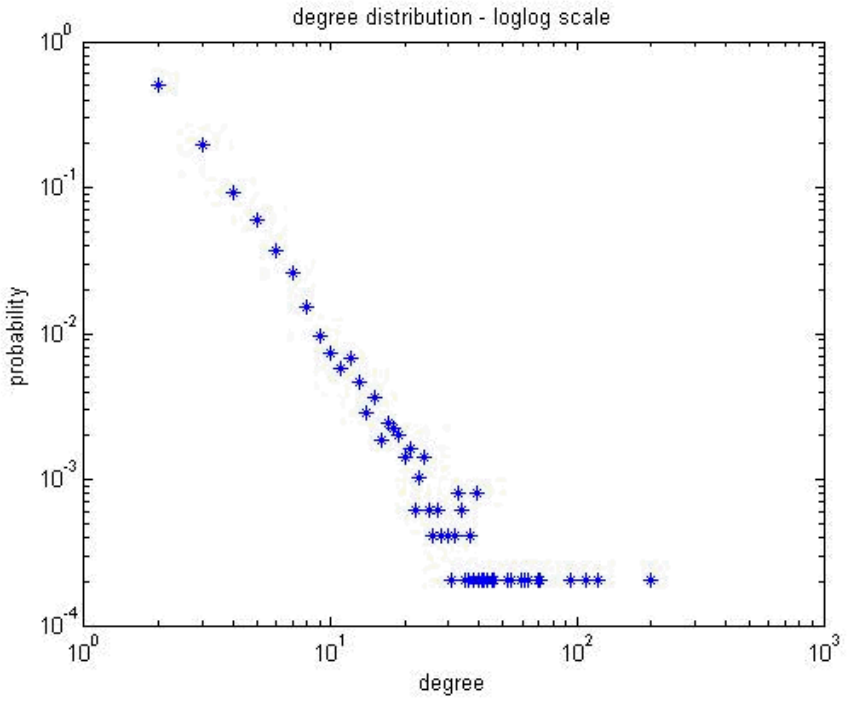
- Start with a small number of nodes
- Every time step add a new node which makes connections a certain number of existing nodes
- The probability of a new node connecting to an existing node i depends on i's degree (Preferential Attachment)

$$P(i) = \frac{k_i}{\sum_j k_j}$$

$$P(k) \sim k^{\alpha}$$

$$k = degree$$

$$-3 \leq \alpha \geq -2$$



$$P(k) = k^{-2.451}$$

$$N = 4900$$

Small World Aspect Addition: Large Clustering Coefficient

Relative Preferential Attachment Model

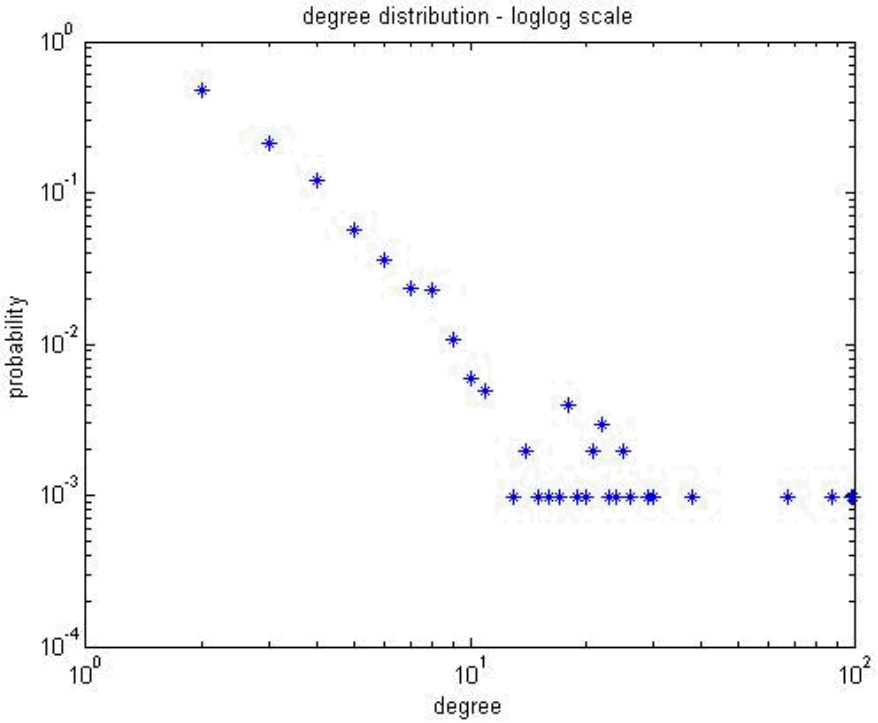
- **Adds an adjustable clustering coefficient to the BA model**

$$P(i) = \frac{k_i}{\sum_j k_j}$$

$$P(i) = (1 - \partial)\frac{k_i}{\sum_j k_j} + \partial\frac{h_i}{\sum_v h_v}$$

$$(0 \leq \partial \leq 1)$$

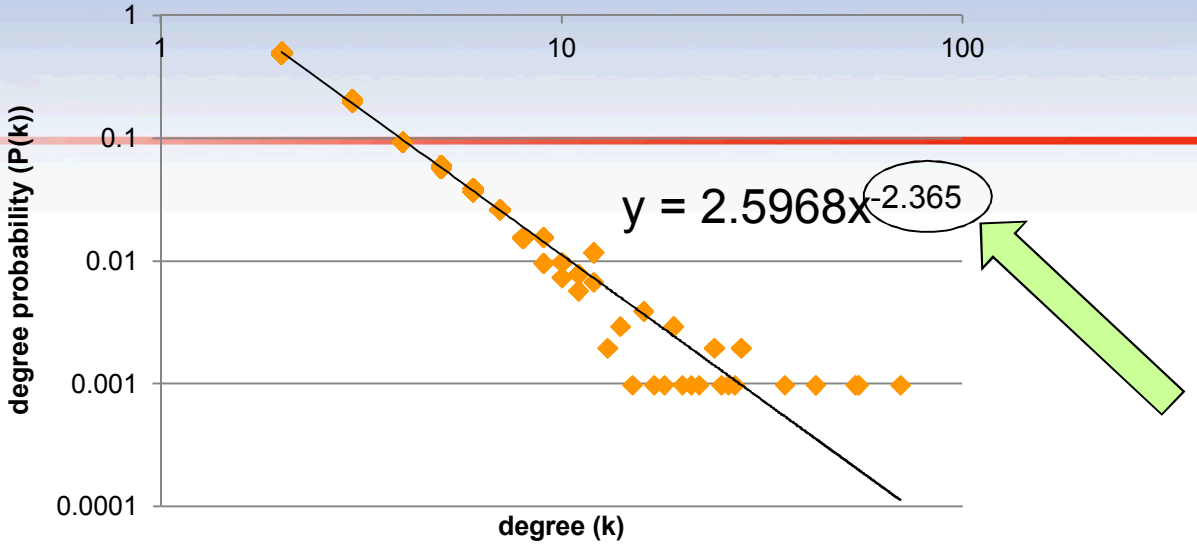
∂: *Controls the amount of clustering*



$$P(k) = k^{-2.343}$$

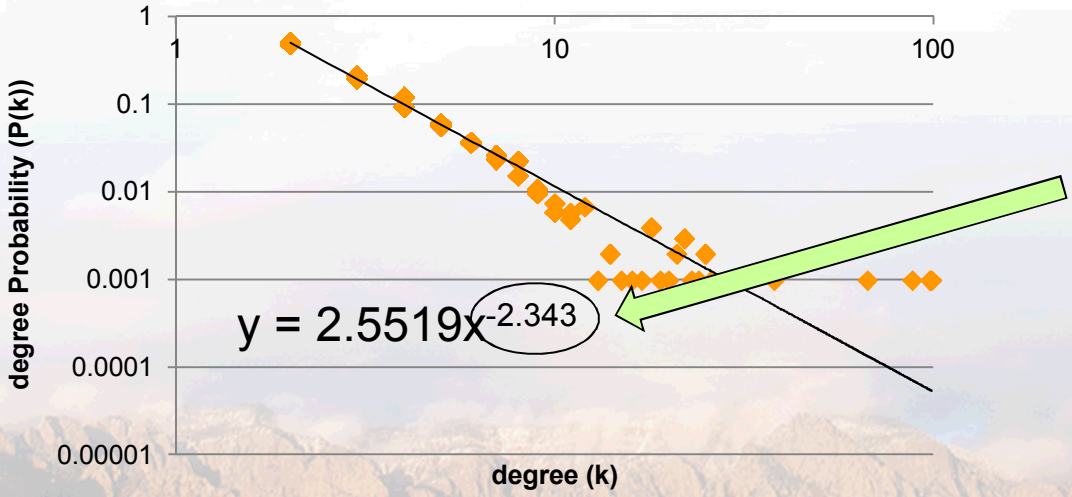
$N = 1024$ $C_{avg} = 0.3962$ $\partial = 0.7$

No Clustering (∂=0)



Power law is conserved

Clustering (∂=0.7)



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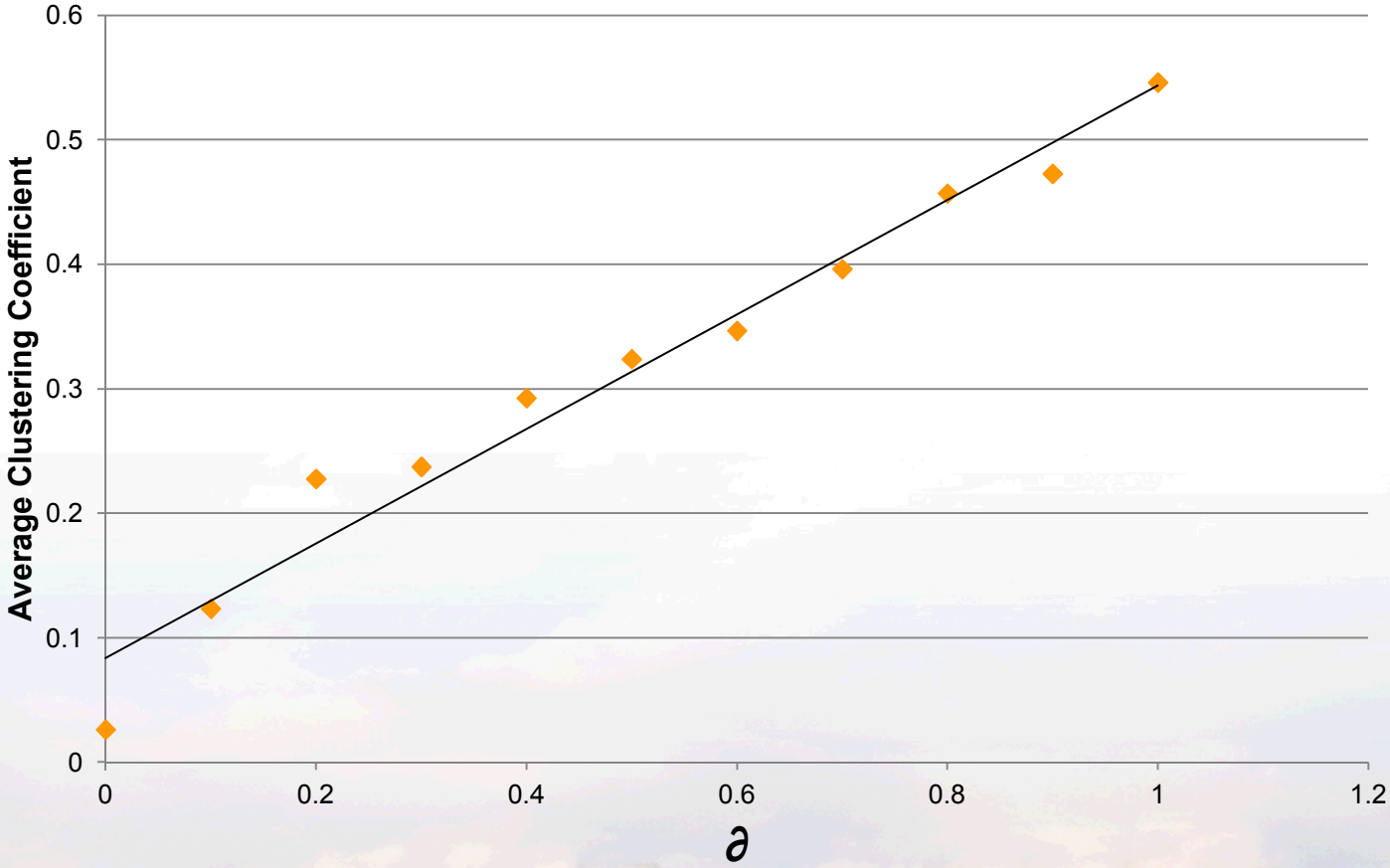
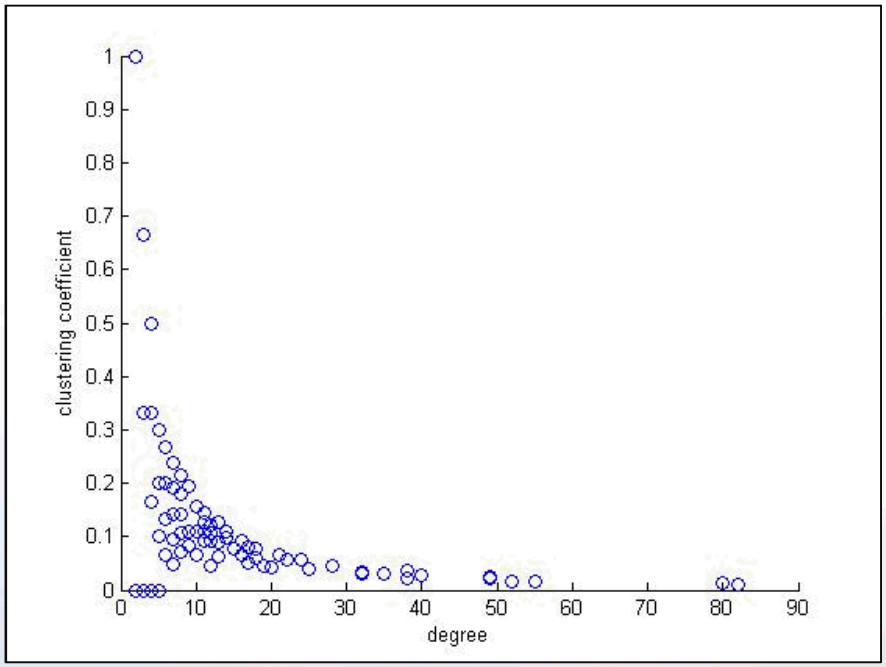
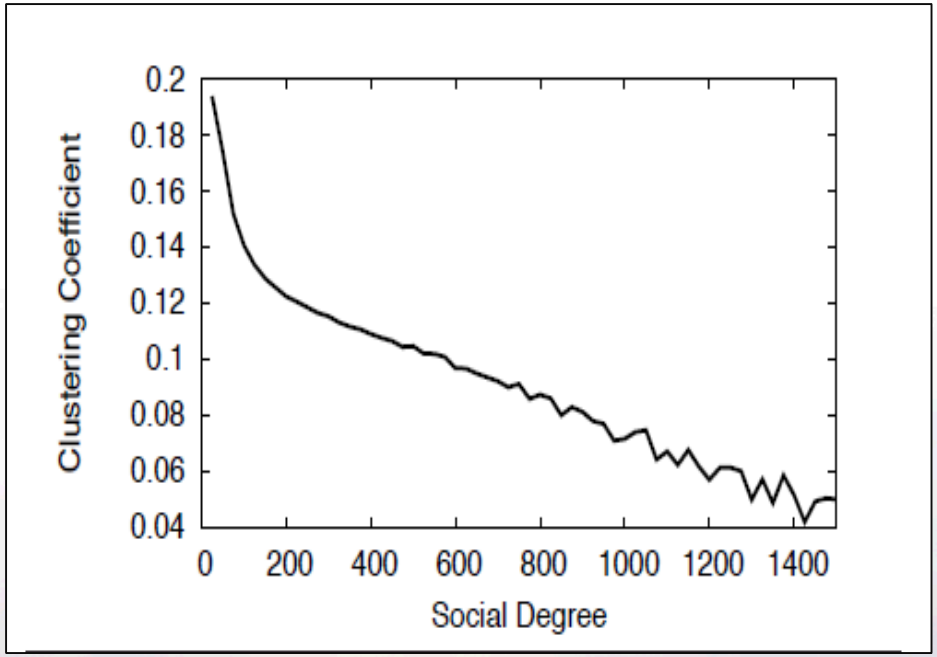
1024 Nodes- Clustering Vs. ∂



Degree Vs. Clustering Coefficient (∂=0.5)



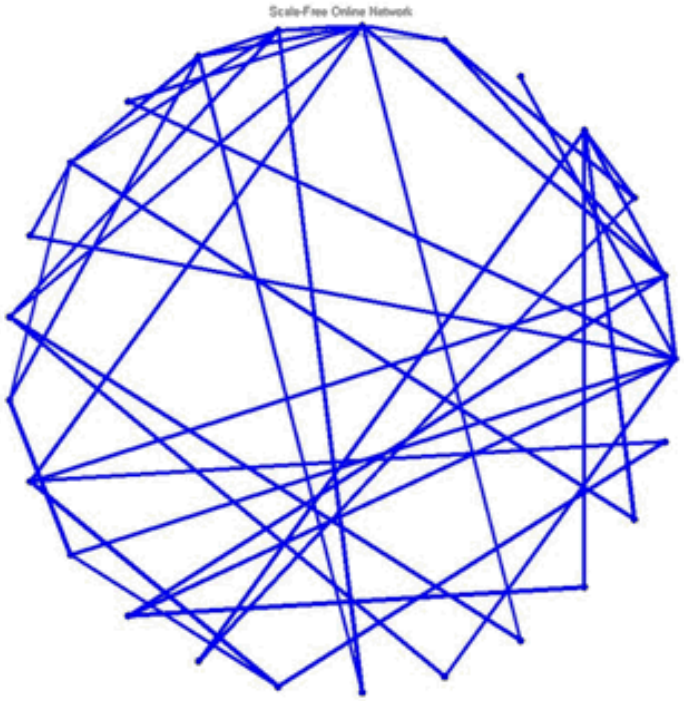
Real Facebook Data Degree Vs. Clustering Coefficient



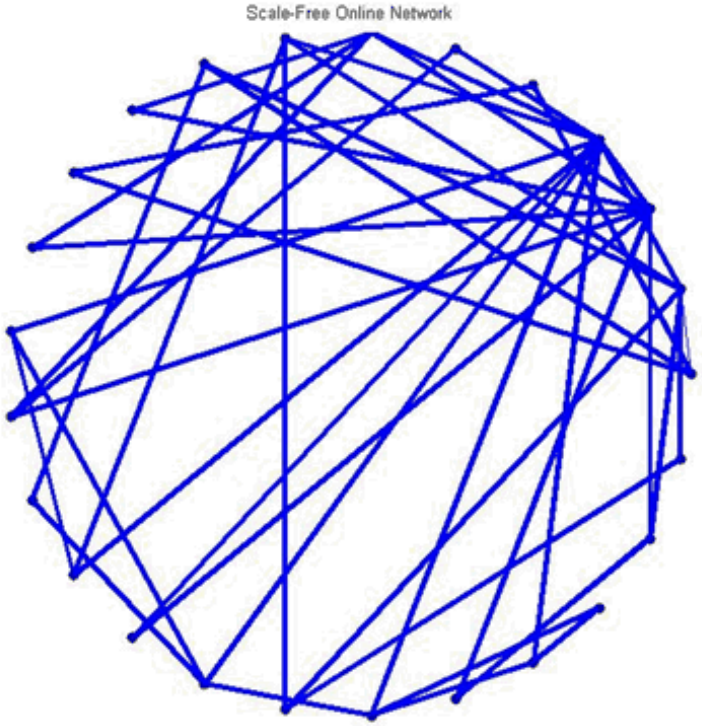
Wilson

25 Node Network

∂=0.1



∂=0.9



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Opinion Propagation – Original Considerations ("Nowak" Model)

- Network: XY Cartesian (not Scale Free)
- Social Impact Model
- Predicts change of attitudes in a population resulting from social impact

$$i_s = N_S^{\frac{1}{2}} \left[\sum \frac{\frac{s_i}{d_i^2}}{N_S} \right]$$

$$i_p = N_O^{\frac{1}{2}} \left[\sum \frac{\frac{p_i}{d_i^2}}{N_O} \right]$$

d_i = distance between the agent i and the neighbor

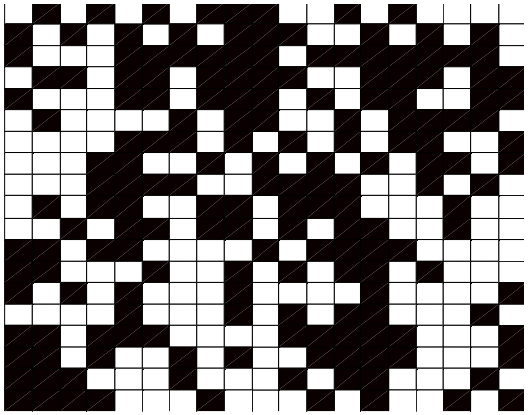
N_O =number of neighbors with different opinion than agent i

N_S =number of neighbors with the same opinion as agent i

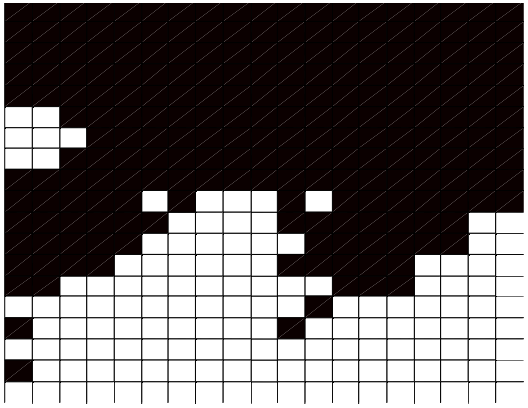
Original algorithm from Nowak, 1990

“Nowak” Model: Results

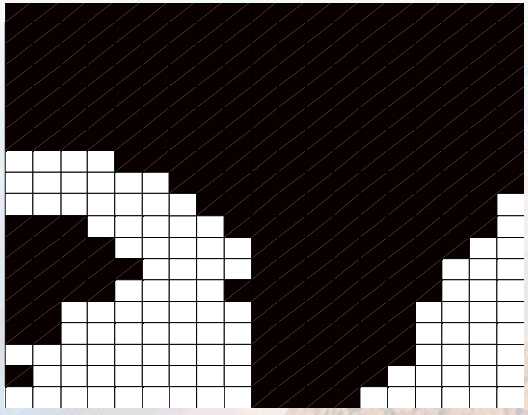
Iteration: 1



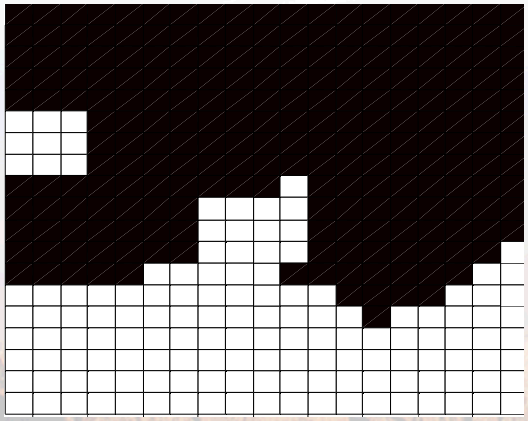
Iteration: 33



Iteration: 66



Iteration: 100



- Iterations: 100
- Number of agents: 400
- XY axis: network laid out in Cartesian coordinates
- White: attitude value “0”
- Black: attitude value “1”

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Multivariate Linear Model

- ***Assumption:*** opinions are likely to be influenced by the attitudes and beliefs of peers
  - Uses a weighted average

Opinion Update

$$O_{ik,t+1} = O_{ik,t} + \frac{1}{2(N-1)} \sum_{i \neq j} W_{ij} (O_{jk,t} - O_{ik,t})$$

Weight Update

$$W_{ij,t+1} = 1 - \frac{|1 - M_{ij}| + |O_{jk,t} - O_{ik,t}|}{2}$$

Parameters:

k = k^{th} attitude or issue

$O_{ik,t}$ = agent i's opinion on k at time t

W_{ij} = social distance between i and j

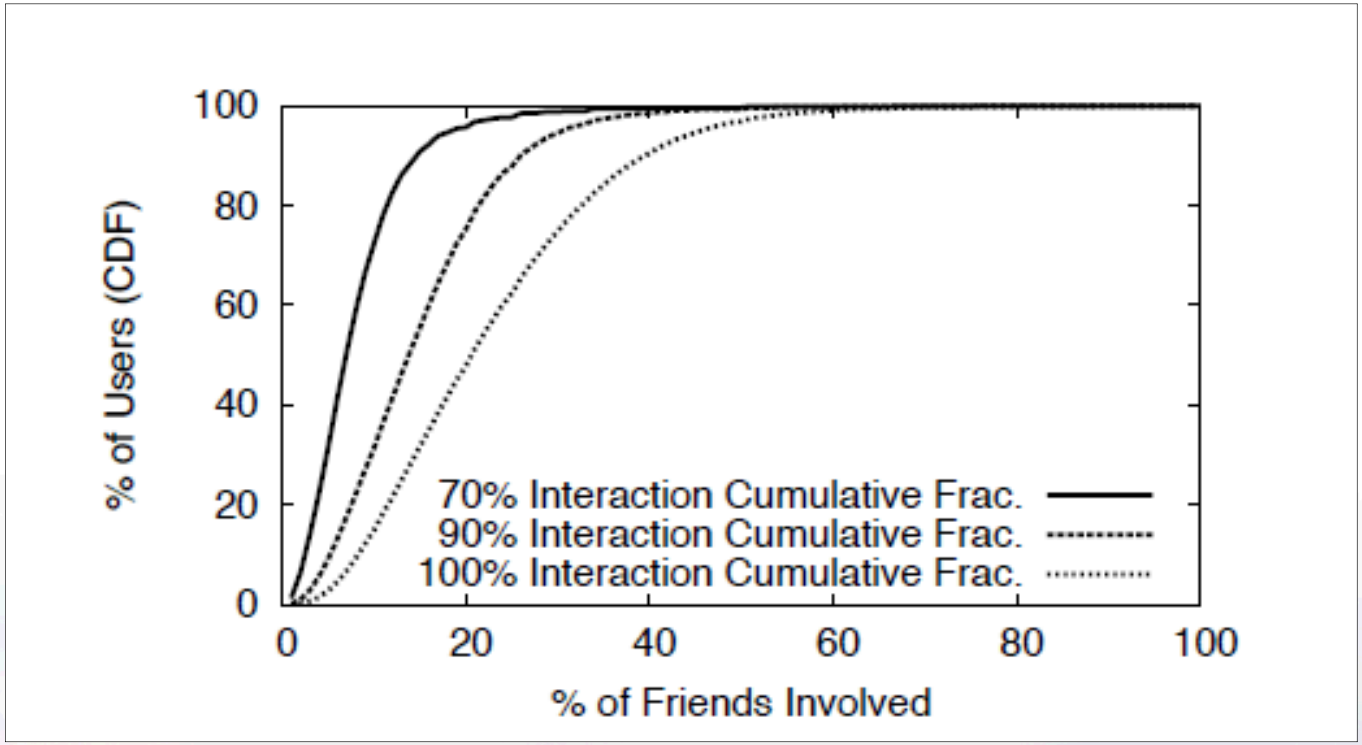
M_{ij} = mutual friend weight

Original algorithm from Macy, Flache 2009

Multivariate Linear Model: Side Note

- Realistic to actual social networks, with the assumption that a given individual can only interact with a small number of people

Facebook - Distribution of Users' Interaction Among Their Friends



Conclusion Drawn: **User will only interact with a small subset of social links, so connections must be weighted**

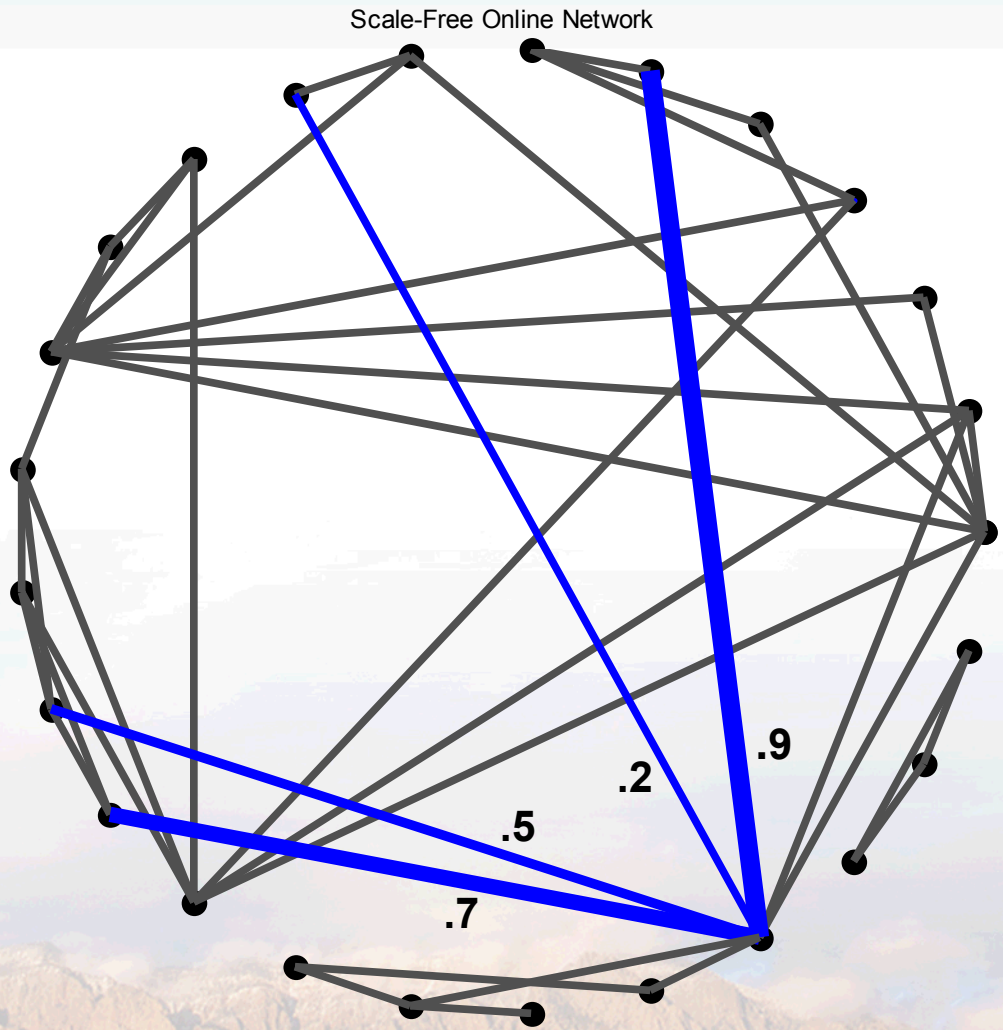
Graph taken from Wilson, 2009

Multivariate Linear Model: Mutual Friend Weight

- Understanding the weight of each connection is crucial towards understanding how two given nodes might influence each other

- We define weight by the number of mutual friends two people have

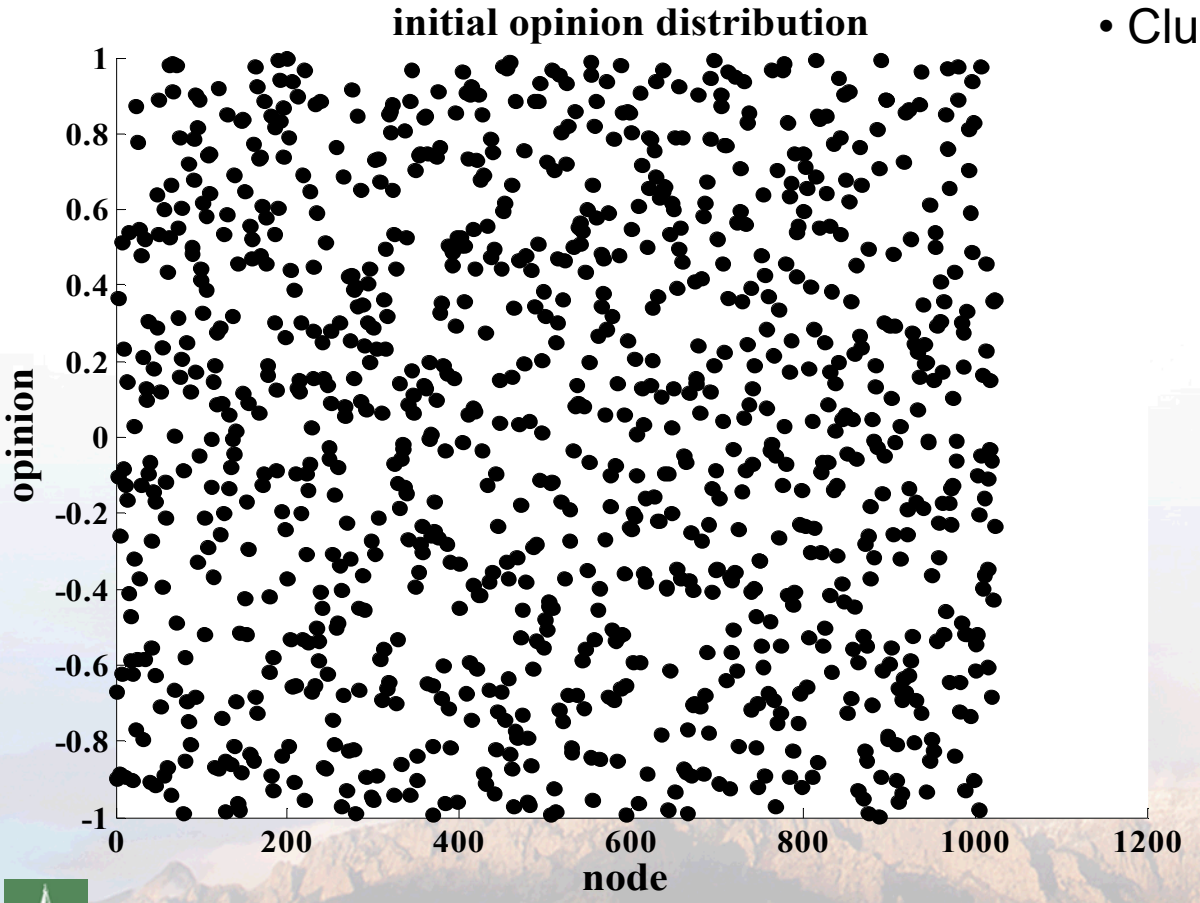
$$W_{ij,t+1} = 1 - \frac{|1 - M_{ij}| + |O_{jk,t} - O_{ik,t}|}{2}$$



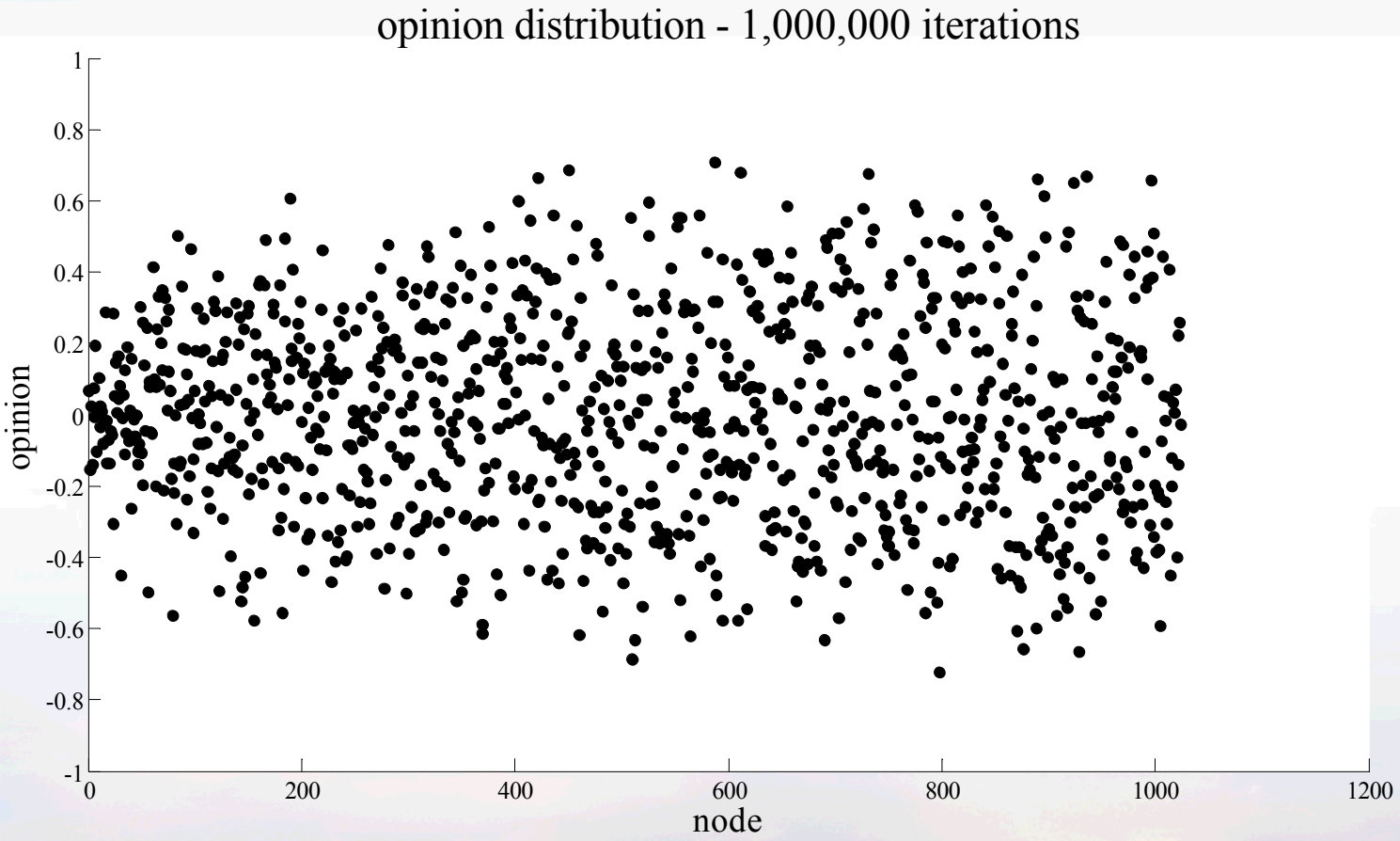
Multivariate Linear Model: Results

Using:

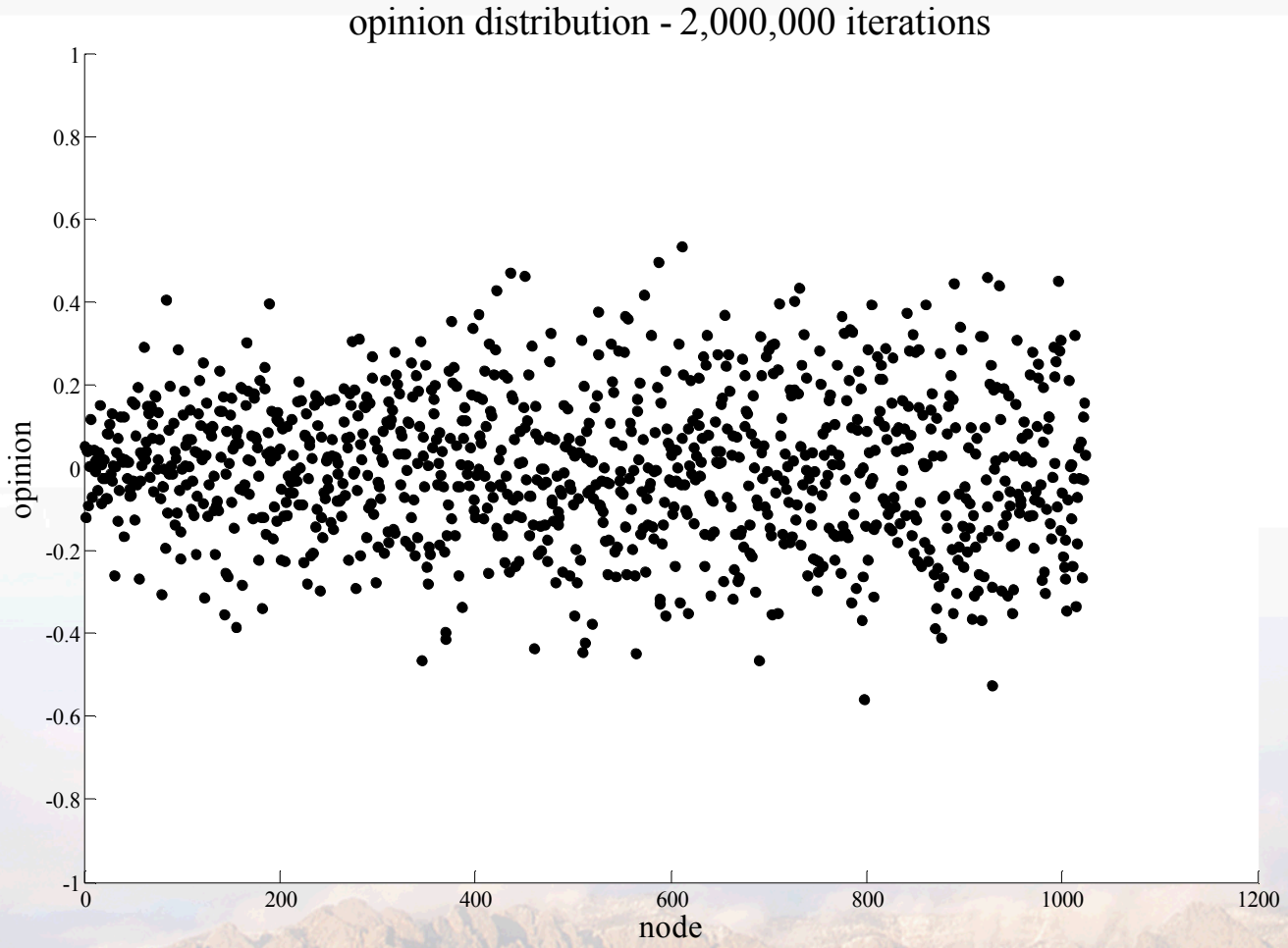
- Scale Free Network – $P(k) \sim k^{-2.02}$
- 1024 Nodes
- Clustering Coefficient = 0.0632



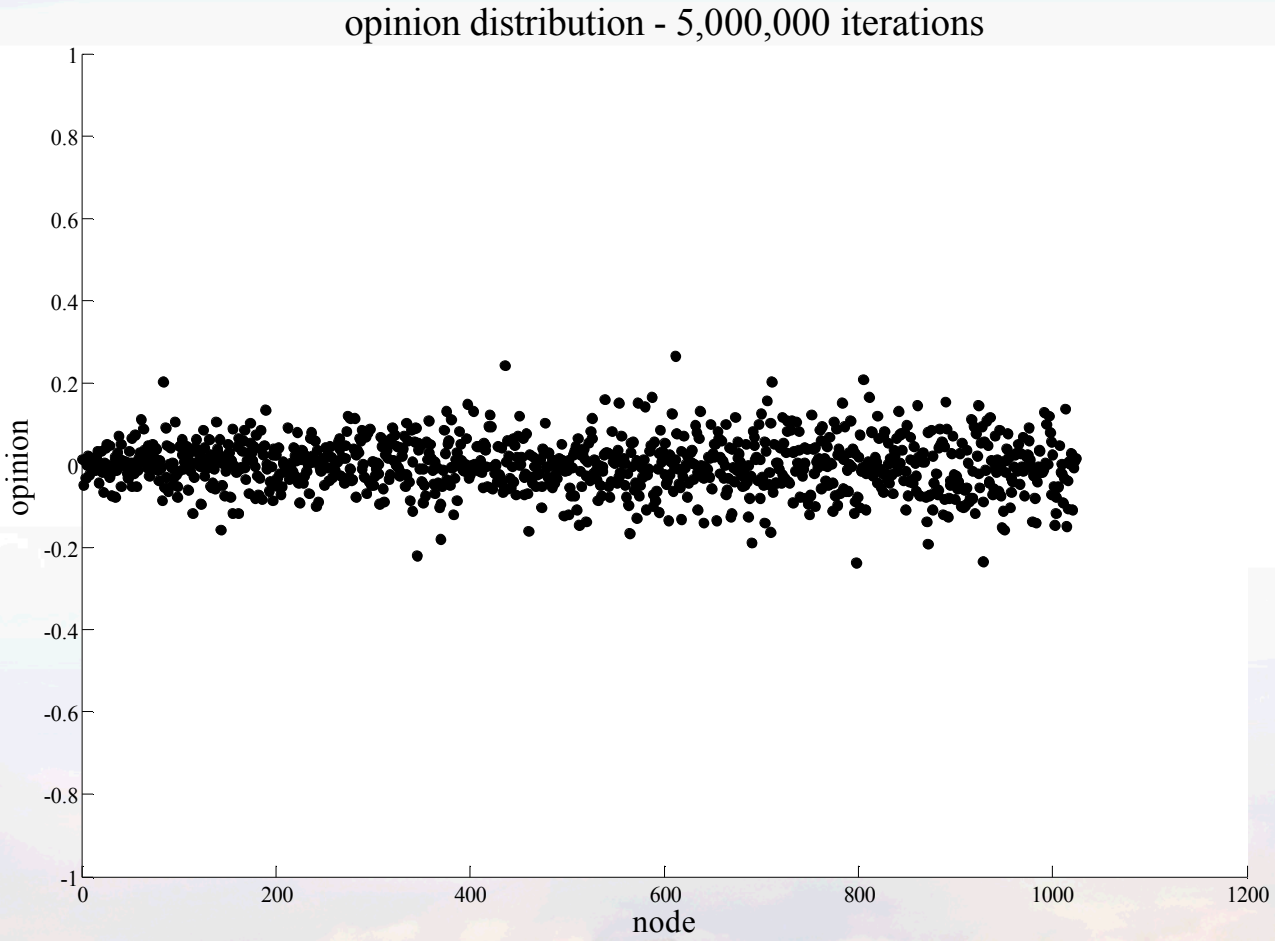
Multivariate Linear Model: Results



Multivariate Linear Model: Results

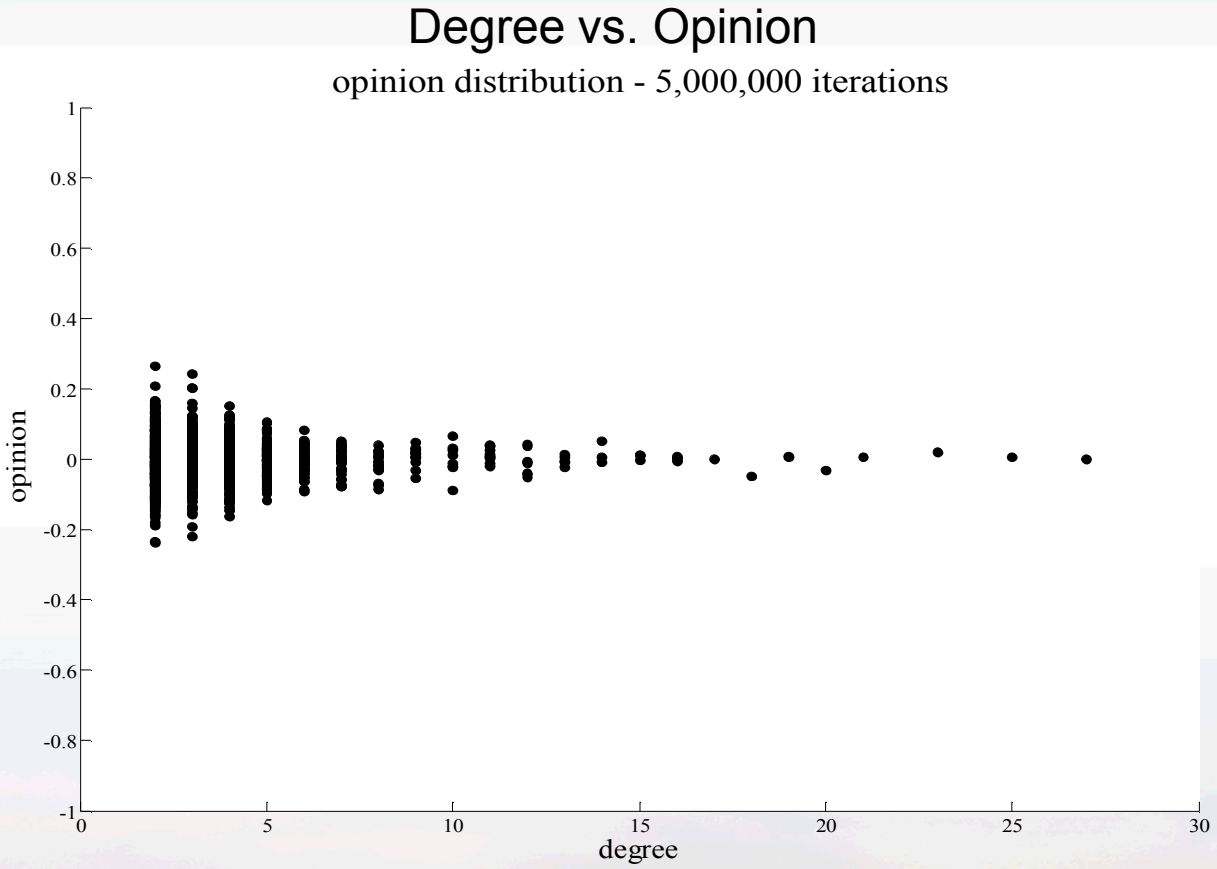


Multivariate Linear Model: Results



Conclusion: Opinion values converge to the mean with the presence of several outliers

Multivariate Linear Model: Why Outliers?



Conclusion: Those high degree nodes tend to agree with the majority in a fewer amount of time steps.

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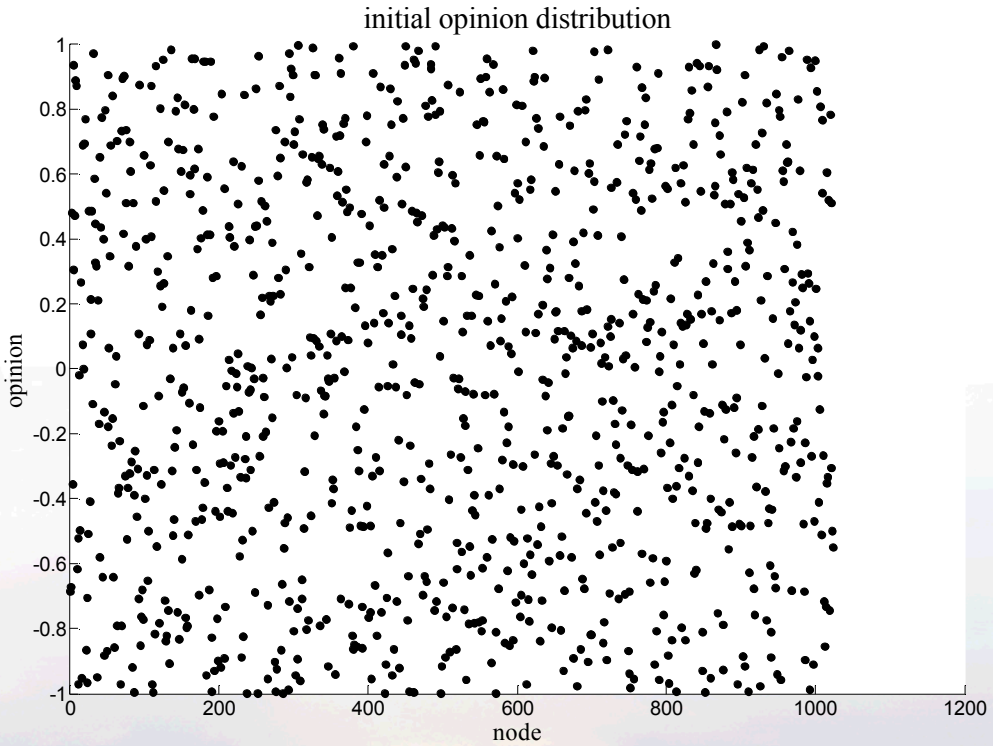
Strongly Opinionated Individuals

Sociological Question: **If a small percentage of the group is strongly opinionated and not influenced by the beliefs of others, how does this affect the group as a whole?**

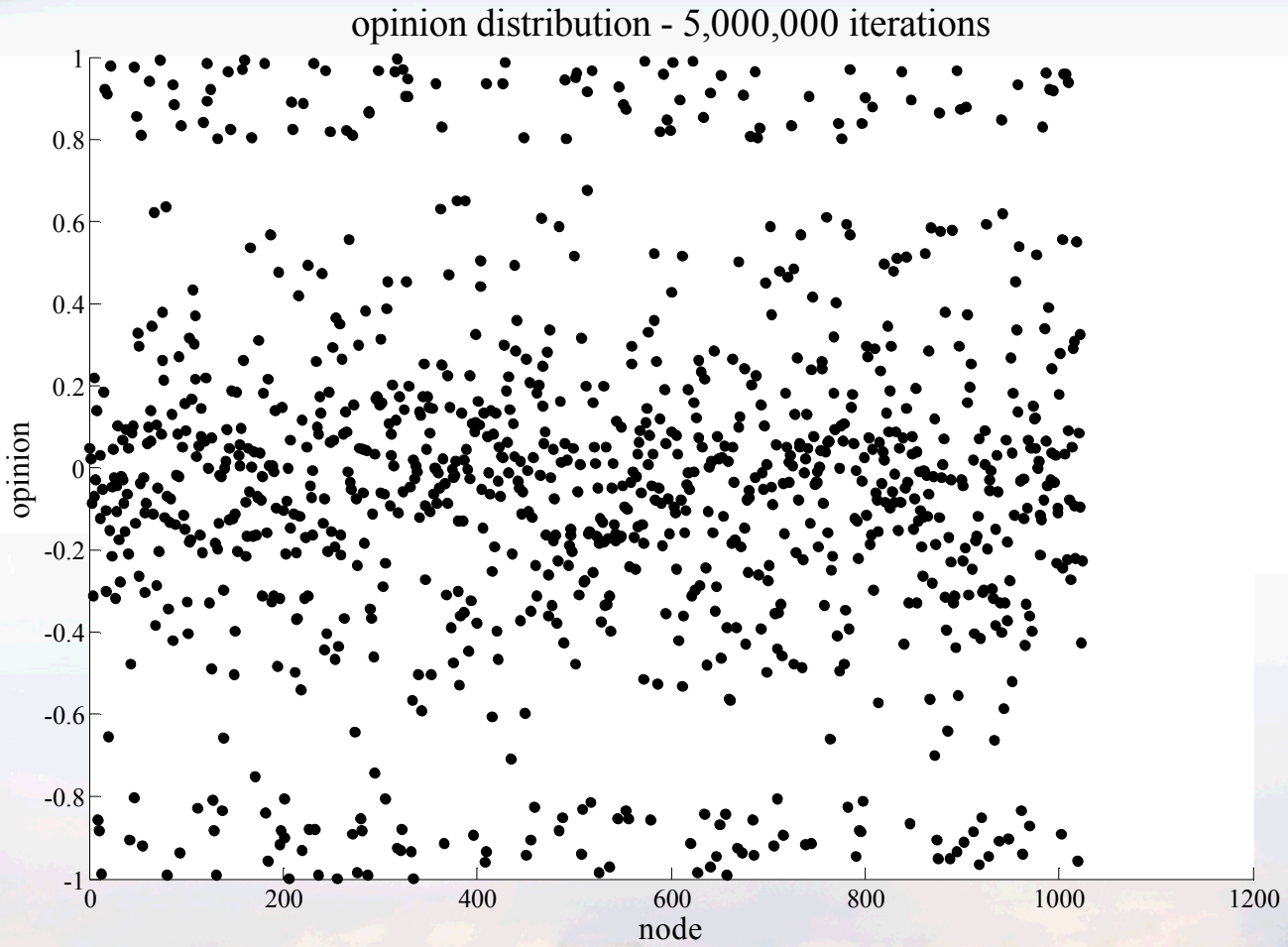
Mathematical Approach:

- Assign some nodes a strong opinion value
- These nodes must maintain that strong opinion value throughout the simulation



1024 Nodes
Threshold Value = .8 or -.8
Number of Susceptible Nodes = 200

Multivariate Linear Model:
Implementation



The effect of several strong opinions on a group as a whole:

It takes longer for a group to agree

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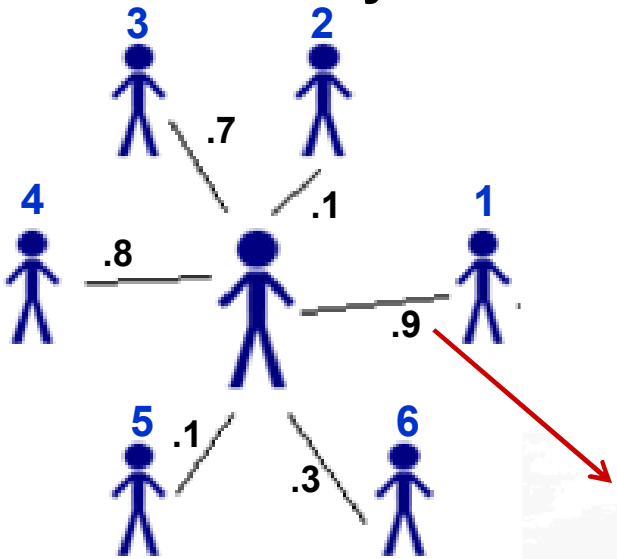
Current Work – Group Conformity

Sociological Question: **How might conformity in a friend group affect polarization in society?**



Mutual Friend Weight "M"

Mathematical Approach:

•Take average opinion value of those higher-weighted connections (those within friend group)

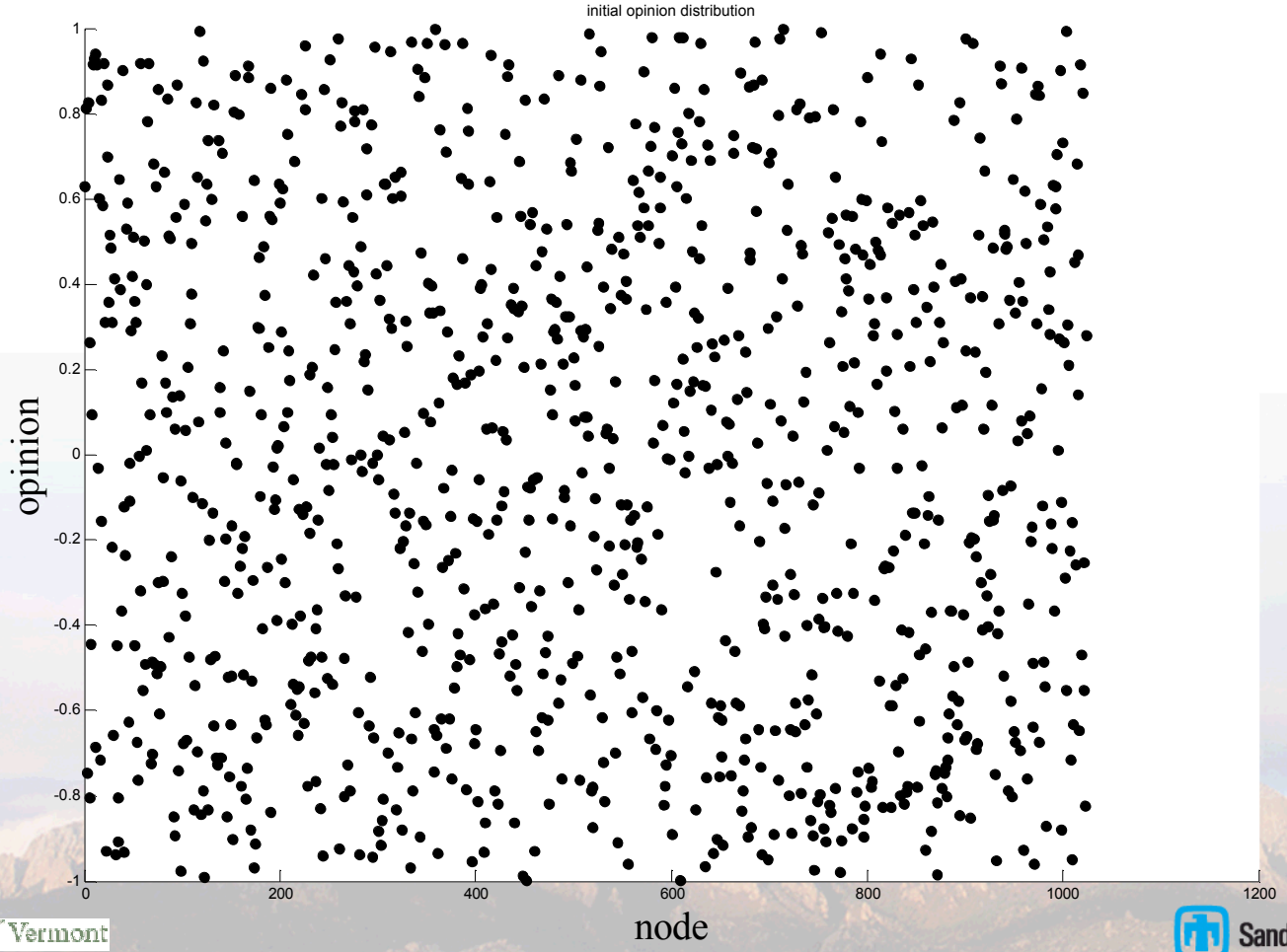
• $O_{avg} = (O_1 + O_3 + O_4)/3$

• If O_{avg} is influential (e.g. > .7 or < -.7)

•Have O_n = value closer to O_{avg}

Multivariate Linear Model:
Group Conformity

Iteration = 1

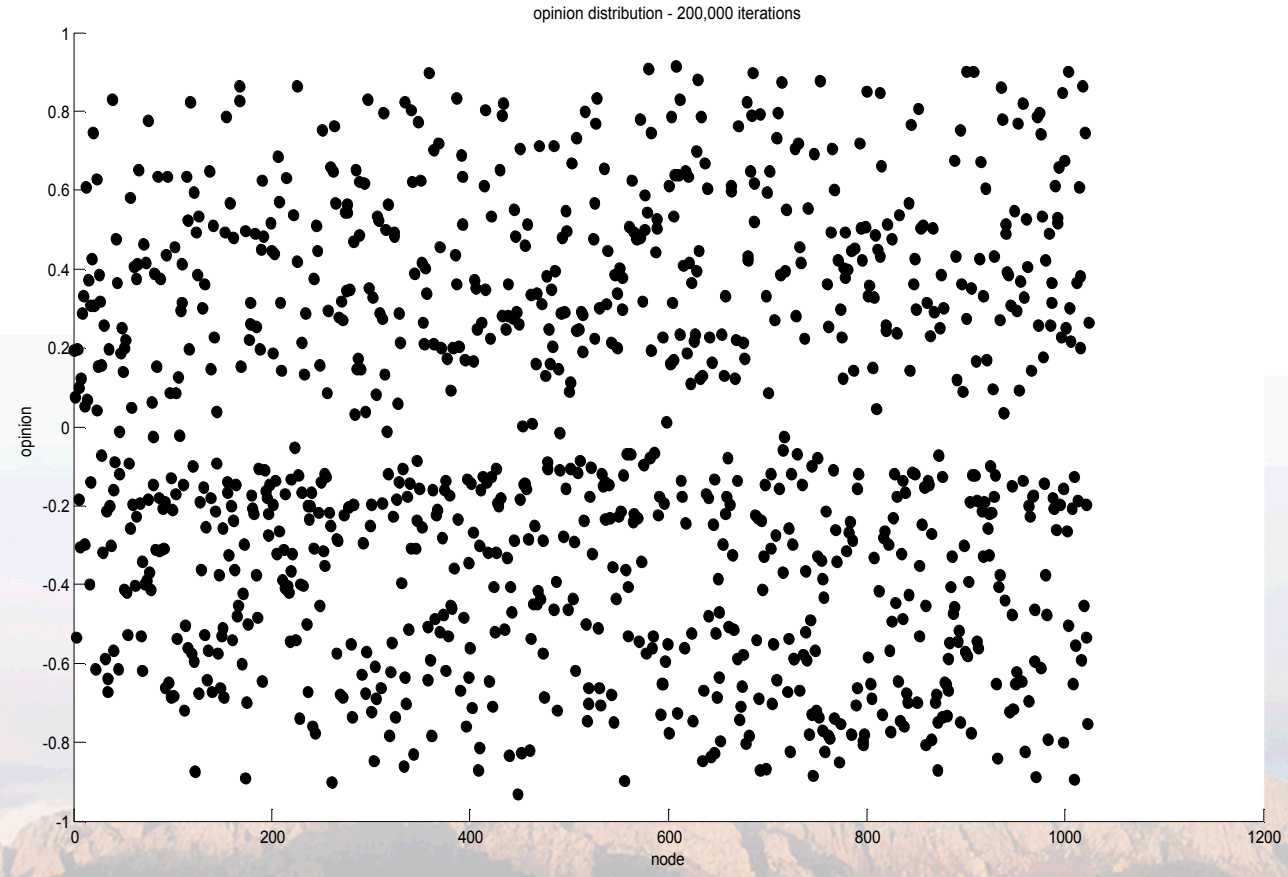


Multivariate Linear Model:
Group Conformity

Iteration = 75,000

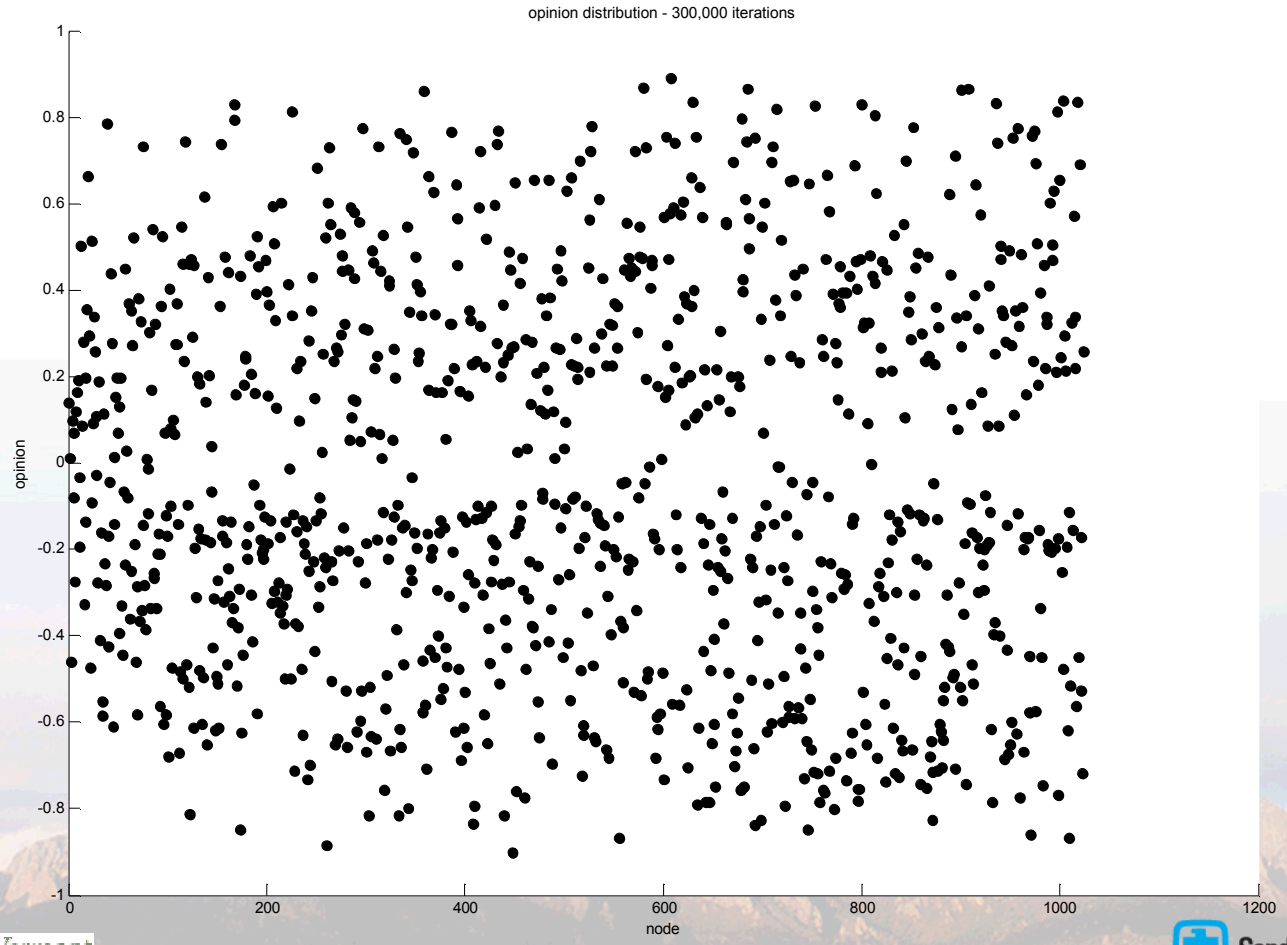
Multivariate Linear Model:
Group Conformity

Iteration = 200,000



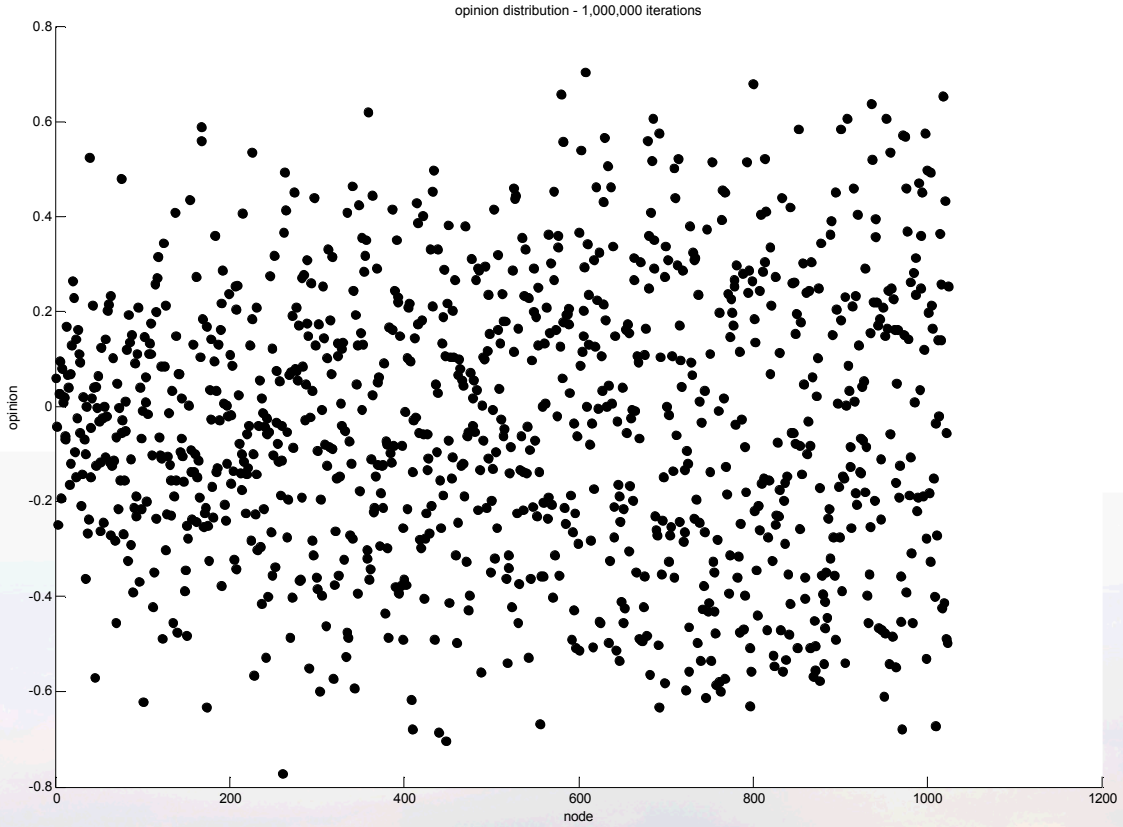
Multivariate Linear Model:
Group Conformity

Iteration = 300,000



Multivariate Linear Model:
Group Conformity

Iteration = 1,000,000



Observations: Opinions seem to polarize at first away from the mean, but the majority eventually overpowers the groups and the opinion values will converge to zero.

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Future Work – Educational Implementations

How does opinion propagation change with implementation of education?

"Forcing Mechanism"

1. Advertisement – influence a *large range* of nodes *randomly*
   - TV Ad
   - SmartGrid display at Ecco Center in Burlington
2. Offer a Class – set a *condition* or *bias* for a random set of nodes
   - Classes currently offered at UVM
3. Computer Game – pick a *cluster* to implement with this
   - Proposed at Champlain College

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