Homophily & Network Formation

Advanced Social Computing

Department of Computer Science
University of Massachusetts, Lowell
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Hadi Amiri
hadi@cs.uml.edu

UMASS LOWELL

Announcements

- **HW2 out**
  - Due date: 2/12, 3:30 PM

Lecture Topics

- Homophily
  - Selection
  - Social Influence
- Affiliation Networks
- Network Formation

Homophily

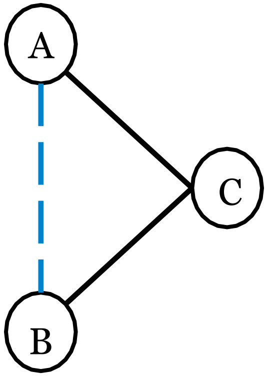
- The principle that we tend to be similar to our friends!
  - your friends are generally similar to you in terms of your characteristics!
    - Immutable characteristics
      - race, ethnicity, country of birth, etc., (determined at birth).
    - Mutable characteristics
      - location, occupations, affluence, interests, beliefs, opinions, etc (change through time).
- Factors that exist outside the nodes and edges of a network (surrounding contexts)

Homophily- Cnt.

- Links in social networks tend to connect people who are *similar* to one another
  - Formation of links in networks!

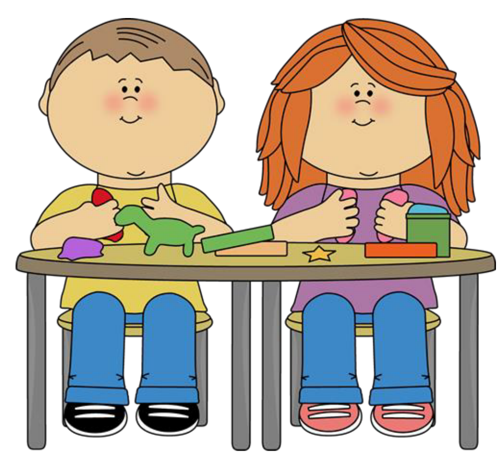
Homophily- Cnt.

- Formation of a new link (friendship):
  - **Case 1: Triadic Closure**
    - Two people will connect through a common friend!
    - Link is added for reasons that are intrinsic to the network itself.
    - We don't need to look beyond the network to understand where the links came from.



Homophily- Cnt.

- Formation of a new link (friendship):
  - **Case 2: Homophily**
    - Two people attend the same school / work for the same company!
    - The link is added for contextual reasons that are byond the network.



Homophily- Cnt.

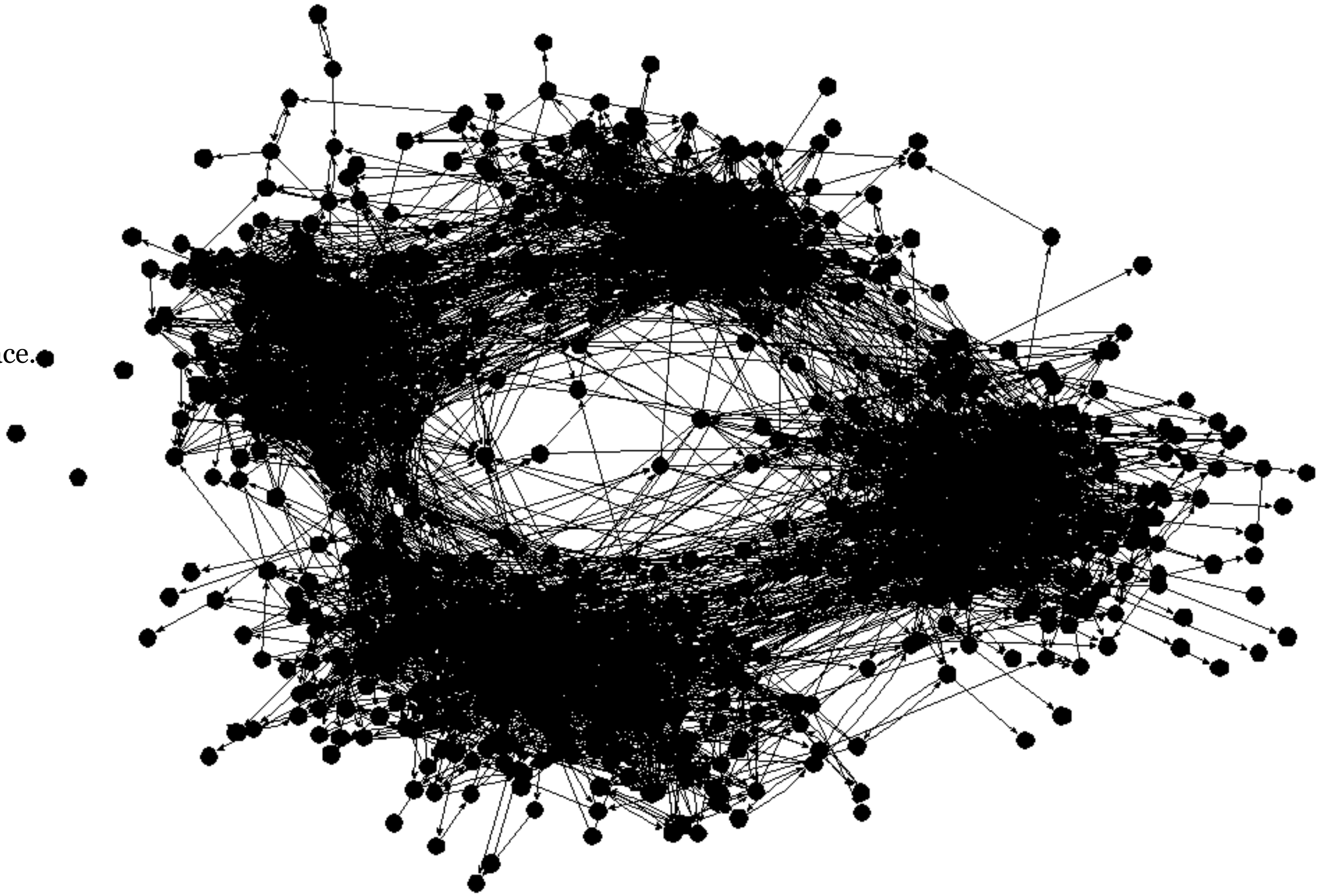
- Social net among students in a middle and high school.

Two context features:

a. Race

b. School

Color the nodes based on race.



Homophily- Cnt.

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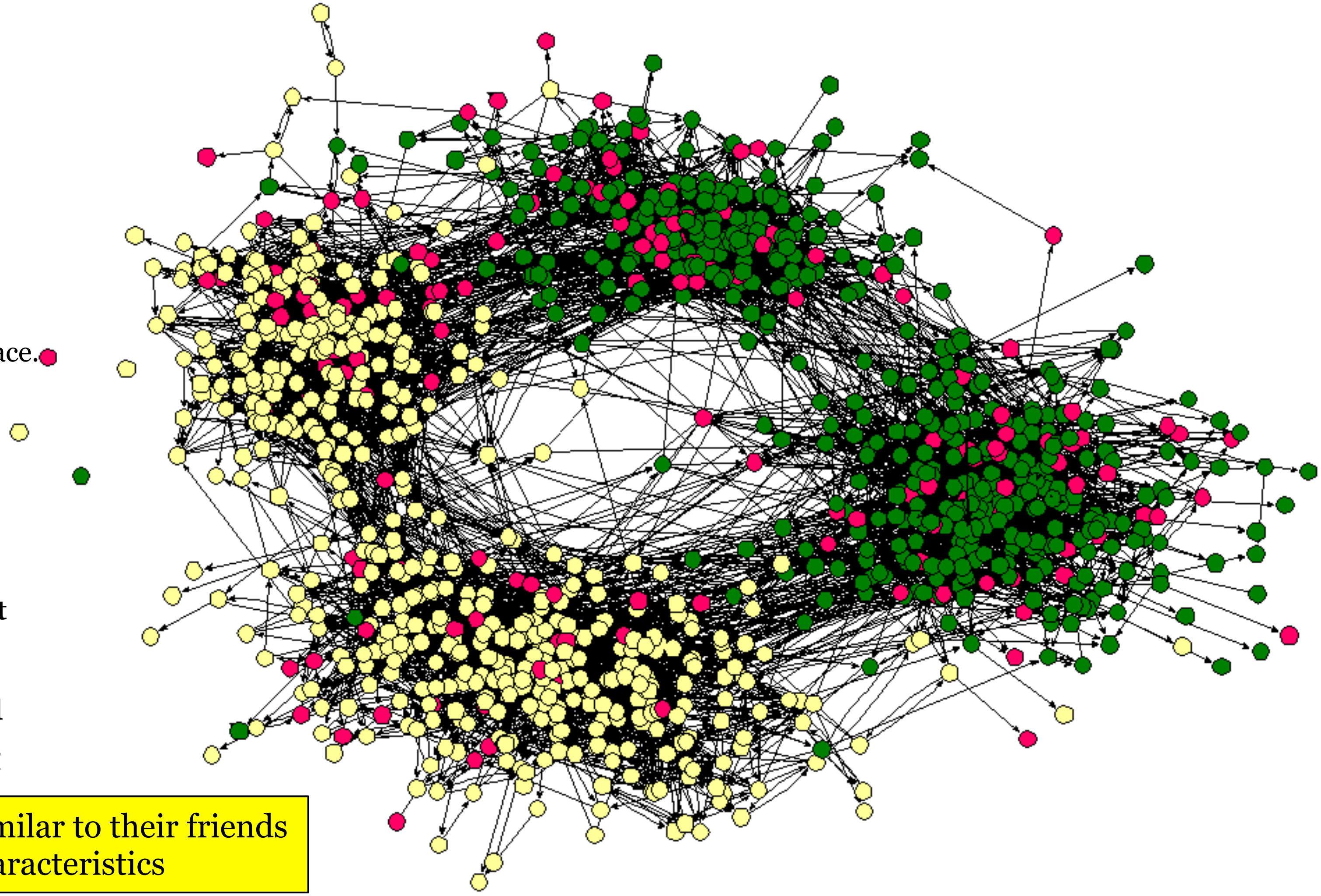


The network exhibits homophily with respect to:

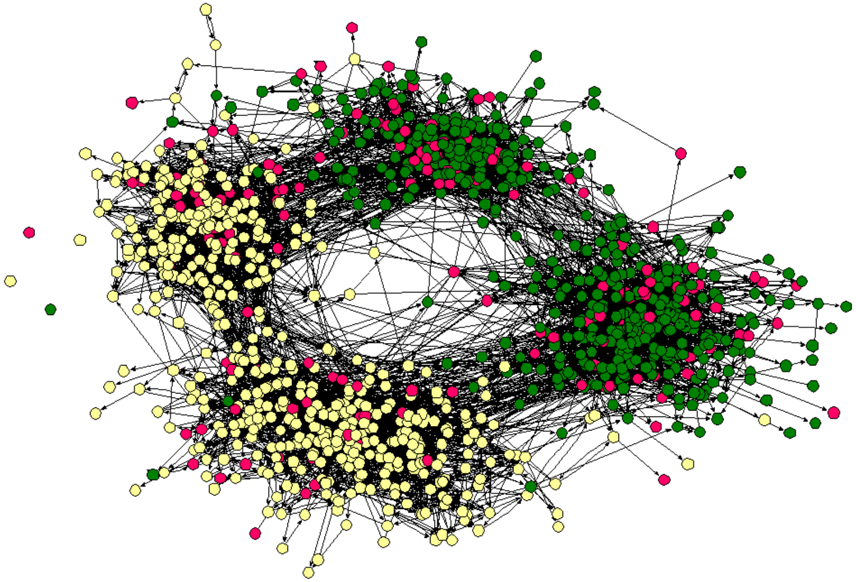
Race (left to right), and

School (top to bottom)!

Students tend to be similar to their friends in terms of specific characteristics

Homophily- Cnt.

- Which factors are more dominant for link formation?
  - **Hard to say!**
  - Most links arise from a combination of several factors
    - network intrinsic effects, and
    - contextual effects.



Homophily vs. Triadic Closure

- Triadic closure
  - intrinsic factor:
    - A and B have a common friend C
    - A and B have increased opportunities to meet
- Homophily
  - contextual factor:
    - A and B are likely to be similar in a number of beyond network dimensions

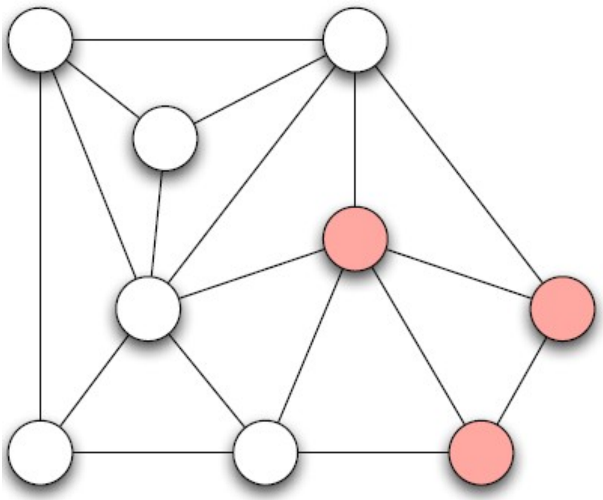
- Both operate concurrently
  - Most links form due to a combination of several factors
  - Difficult to attribute any individual link to a single factor

Measuring Homophily

- Given a particular factor (like race, or age), how can we test if a network exhibits homophily according to this factor?

Measuring Homophily- Cnt.

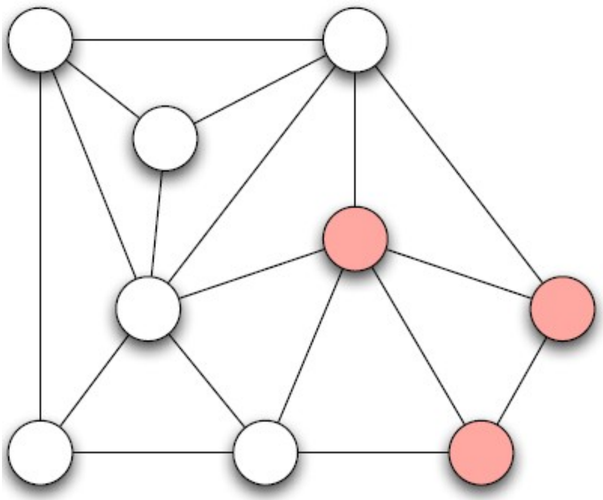
- What does it mean to: “test if this network exhibits homophily according to gender?"



Network of 3 girls and 6 boys!

Measuring Homophily- Cnt.

- Test if this network exhibits homophily according to gender?
- Extreme sense:
  - Edges btw boys
  - Edges btw girls
  - But no cross-gender edges

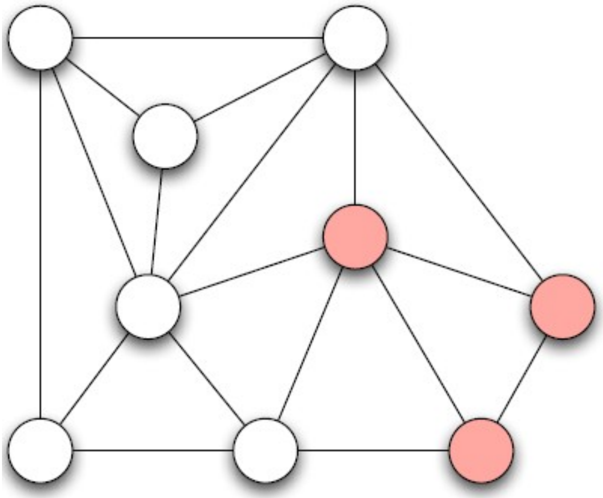


Network of 3 girls and 6 boys!

Boys tend to be friends with boys,
Girls tend to be friends with girls

Measuring Homophily- Cnt.

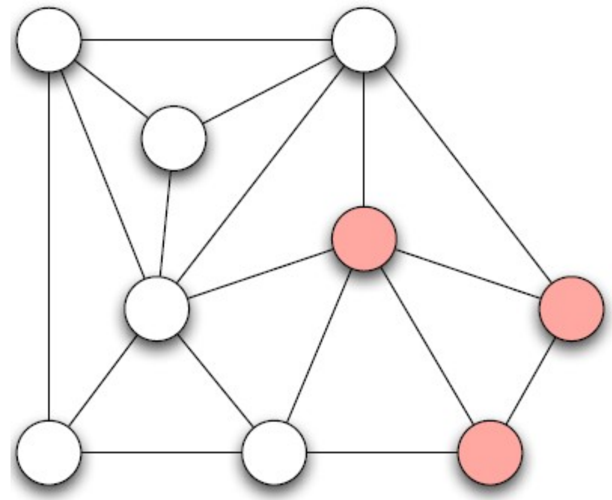
- What does it mean for a network *not* to exhibit homophily by gender?



Network of 3 girls and 6 boys!

Measuring Homophily- Cnt.

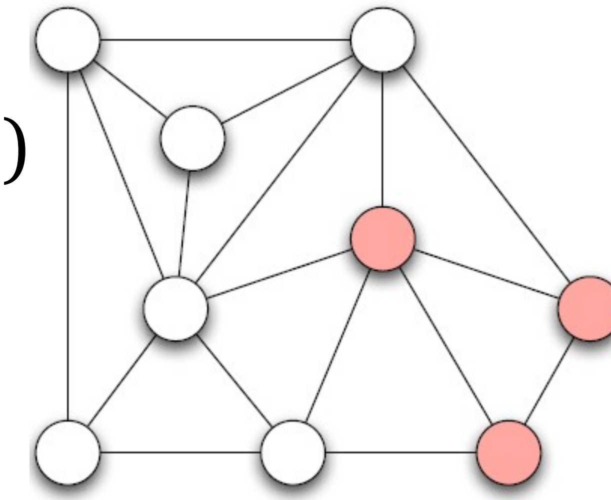
- What does it mean for a network *not* to exhibit homophily by gender?
  - The number of cross-gender edges is not very different from when we randomly assign each node a gender
    - according to the gender balance in the network



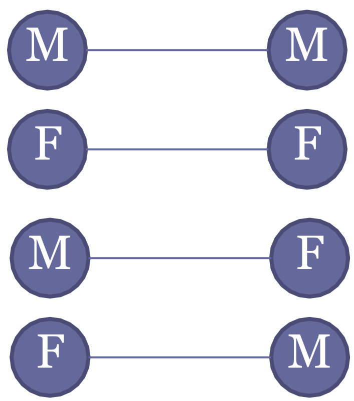
Network of 3 girls and 6 boys!

Measuring Homophily- Cnt.

- p: probability of males (2/3)
- q=1-p: probability of females (1/3)
- For a given edge:
  - if we independently assign each node M with prob p and F with prob q, then



Network of 3 girls and 6 boys!



Homophily

Prob(m and m) = p*p

Prob(f and f) = q*q

Cross-gender

Prob(m and f) = 2*p*q

5/18 < 2pq=4/9 ✓

If the fraction of cross-gender edges is **significantly less than** 2pq, then there is evidence for homophily!

The probability of cross-gender edge when each node is randomly assigned a gender (according to the gender balance in the original network)

Measuring Homophily- Cnt.

- Does this network exhibit homophily wrt to gender?

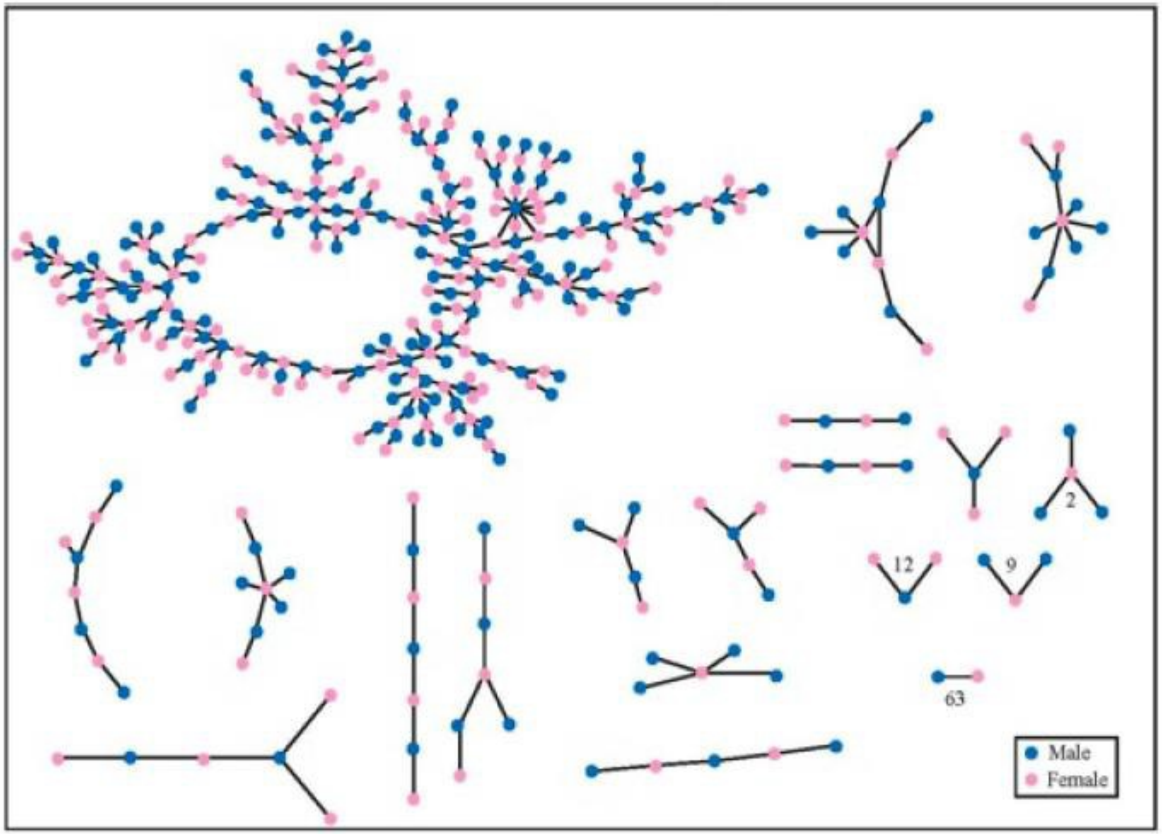


Figure 2.7: A network in which the nodes are students in a large American high school, and an edge joins two who had a romantic relationship at some point during the 18-month period in which the study was conducted [49].

Mechanisms Underlying Homophily

- Homophily has two mechanisms for link formation:
  - Selection
    - Selecting friends with similar characteristics
      - Individual characteristics drive the formation of links
  - Social Influence (socialization)
    - Modify behaviors to make them close to behaviors of friends
      - Existing links influence the individual characteristics of the nodes

Mechanisms Underlying Homophily- Cnt.

- Often times, both Selection and Social Influence apply and interact with each other
  - Teenager behavior:
    - Teenagers seek out social circles composed of people like them, and peer pressure causes them to conform to behavioral patterns within their social circles.
  - Drug use:
    - If drug use exhibits homophily in a network,
      - people showing a greater likelihood to use drugs when their friends do,
    - We can target certain people and influences them to stop using drugs.

Mechanisms Underlying Homophily- Cnt.

- When Homophily is observed, is it more because of Selection or Social Influence?
  - **Selection: Have they selected people who were already like them?**
  - **Social Influence: Have people adapted their behaviors to become more like their friends?**
- More on this later!

Summary

- Homophily links nodes with similar characteristics
- Measuring Homophily
  - compare with random network (generated according to the node characteristics in the original network)
- Selection and social influence determine the formation of links
- Surrounding contexts, forces that exist outside of networks

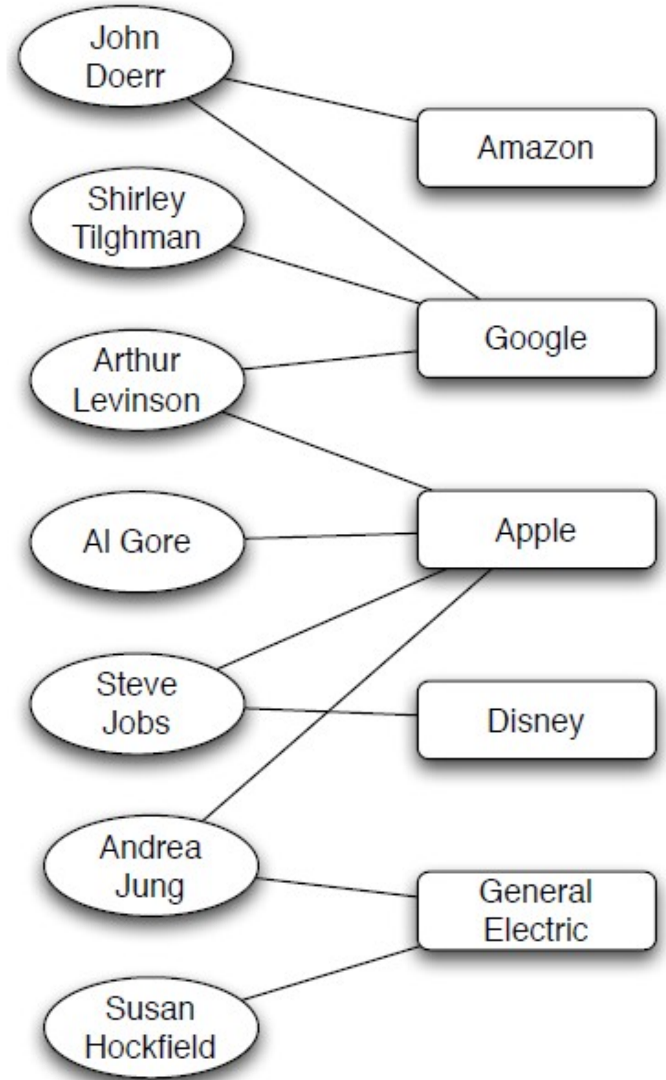
Affiliation Networks

- Network that contains both original nodes & surrounding contexts such as activities a person takes part in:
  - E.g. being part of a particular company / neighborhood, frequenting a particular place, hobby or interest, etc.

- Refer to activities as foci: focal points of social interaction

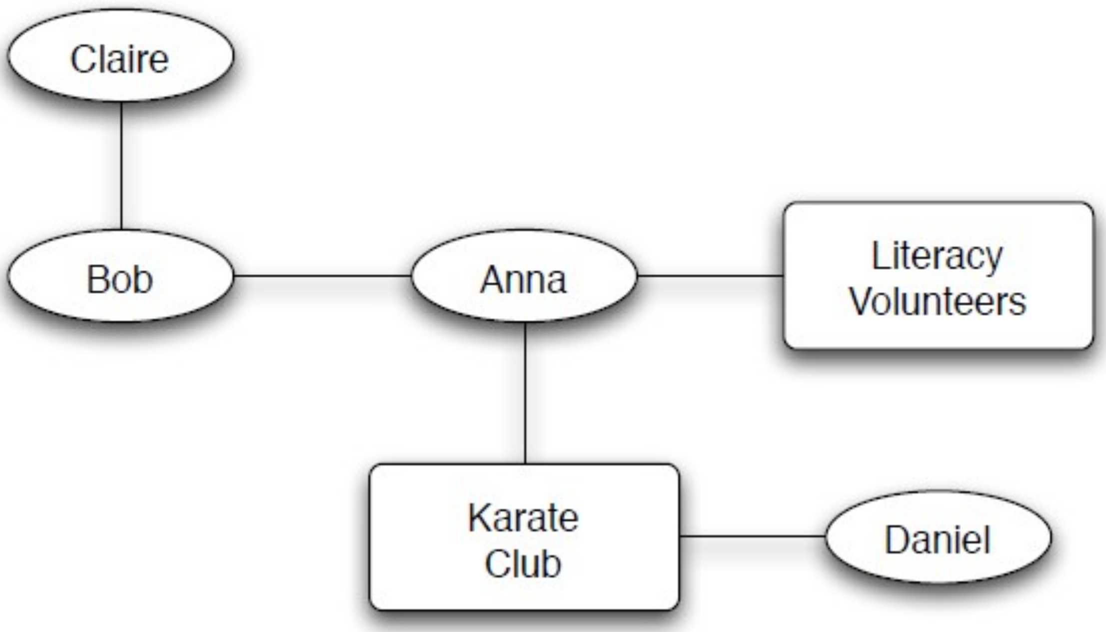
Affiliation Networks- Cnt.

- Bipartite Graph



Social-Affiliation Network- Cnt.

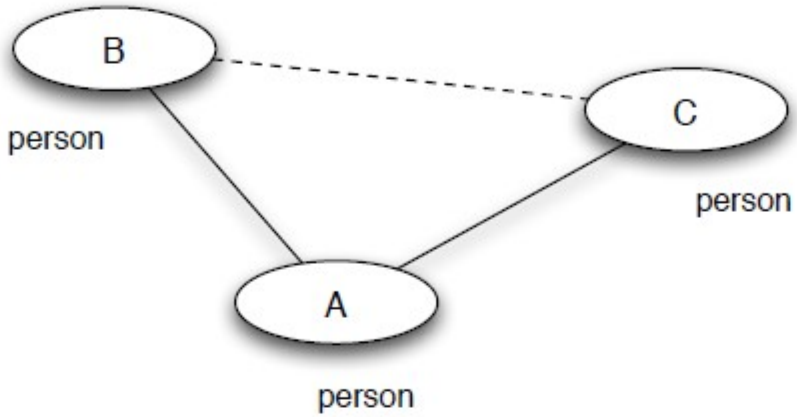
- Social-affiliation network contains:
  - a social network of people, and
  - an affiliation network btw people and foci



Social-Affiliation Network- Cnt.

- Different mechanisms for link formation as types of closure processes!

- **Triadic Closure**:
  A, B, and C represent people



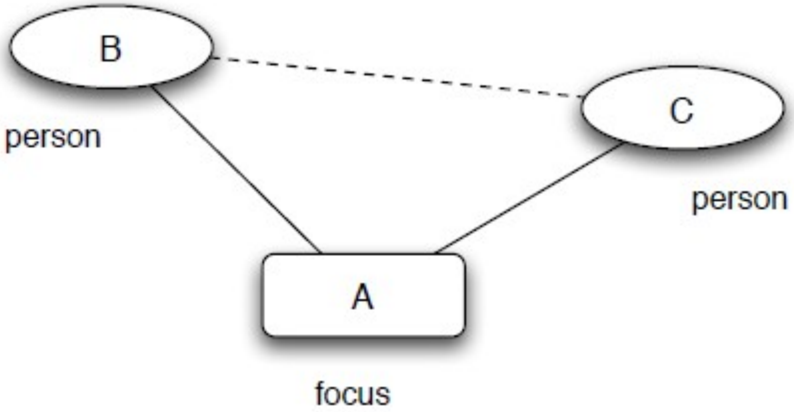
(a) *Triadic closure*

Social-Affiliation Network- Cnt.

- Different mechanisms for link formation as types of closure processes!

- **Focal Closure**:
B and C people, A focus

- **Selection**: B links to similar C (common focus)



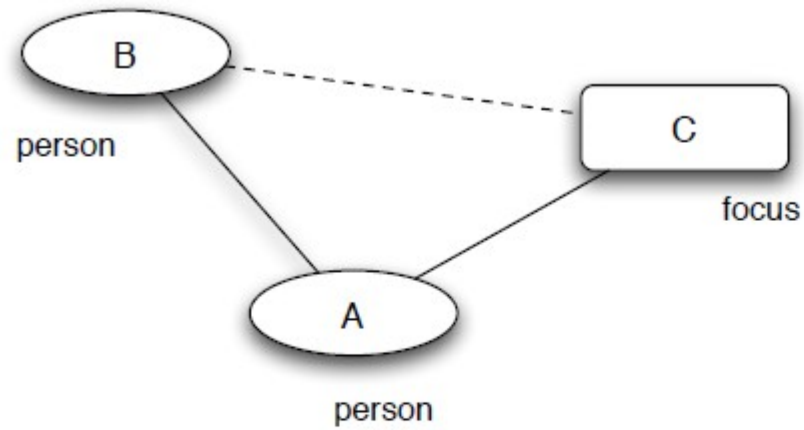
(b) *Focal closure*

Social-Affiliation Network- Cnt.

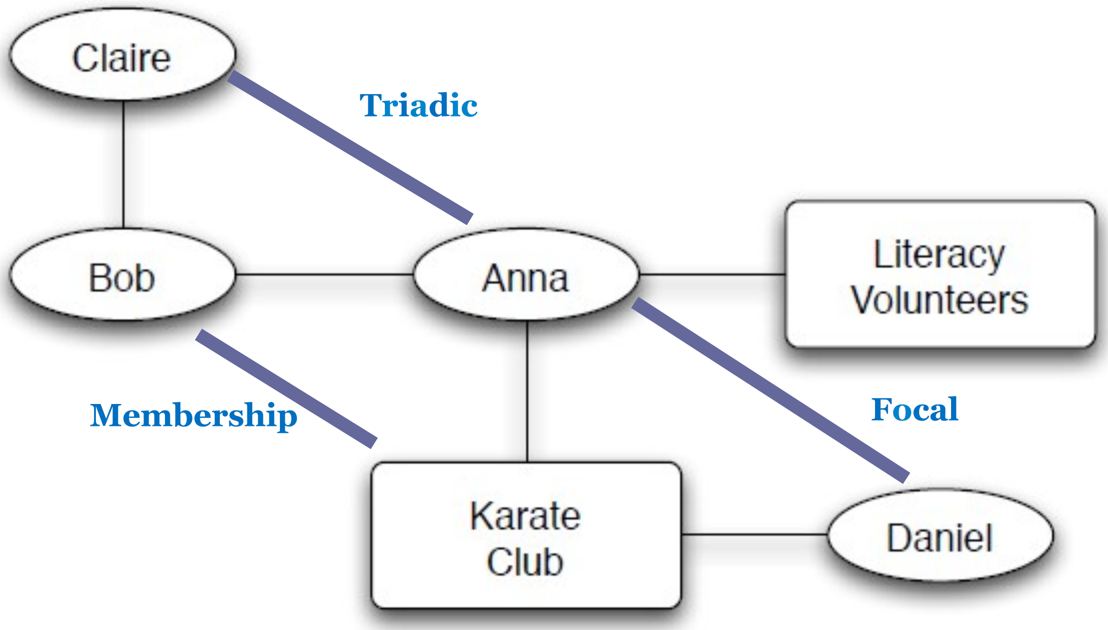
- Different mechanisms for link formation as types of closure processes!

- **Membership Closure**: A and B people, C focus

- **Social influence**: B links to C influenced by A



Social-Affiliation Network- Cnt.



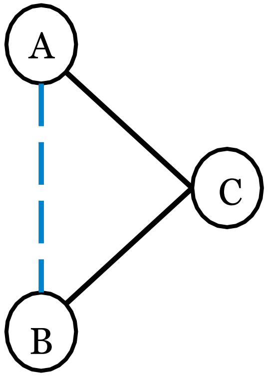
Tracking Link Formation

- Three mechanisms that lead to link formation
  - triadic closure
  - focal closure
  - membership closure

- How can we track link formation in large scale datasets based on e.g. triadic closure?

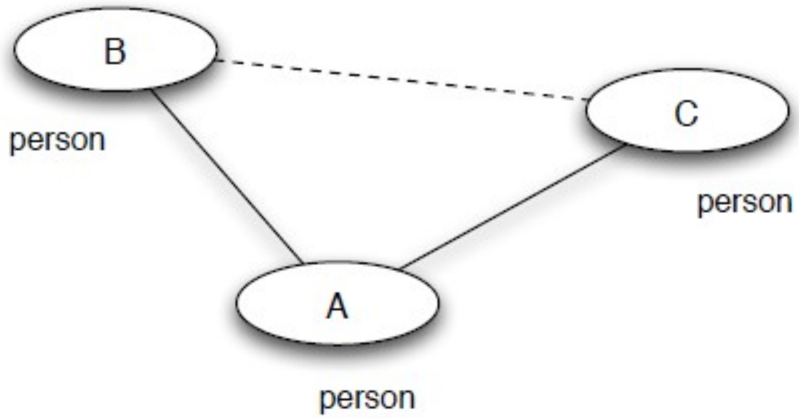
Tracking Link Formation- Cnt.

- Potential solution:
  - Compute link formation probability btw two nodes, if they already have a neighbor in common!
    - What if the nodes have *k* neighbors in common?



Tracking Triadic Closure

- The probability that 2 people form a link as a function of the number of **neighbors** they have in common.



(a) *Triadic closure*

- Q: How to properly design and conduct such experiments?

Tracking Triadic Closure- Cnt.

Algorithm

----

1) Take 2 snapshots of network at different times: **S(1)**, **S(2)**.

2) For each ***k***, find all pairs of nodes in **S(1)** that are not directly connected but have ***k*** common friends.

3) Compute ***T(k)*** as the fraction of these pairs connected in **S(2)**.

estimate for the probability that a link will form btw 2 people with *k* common friends.

4) Plot ***T(k)*** as a function of ***k***

T(0) is the rate of link formation when it does not close a triangle

Tracking Triadic Closure- Cnt.

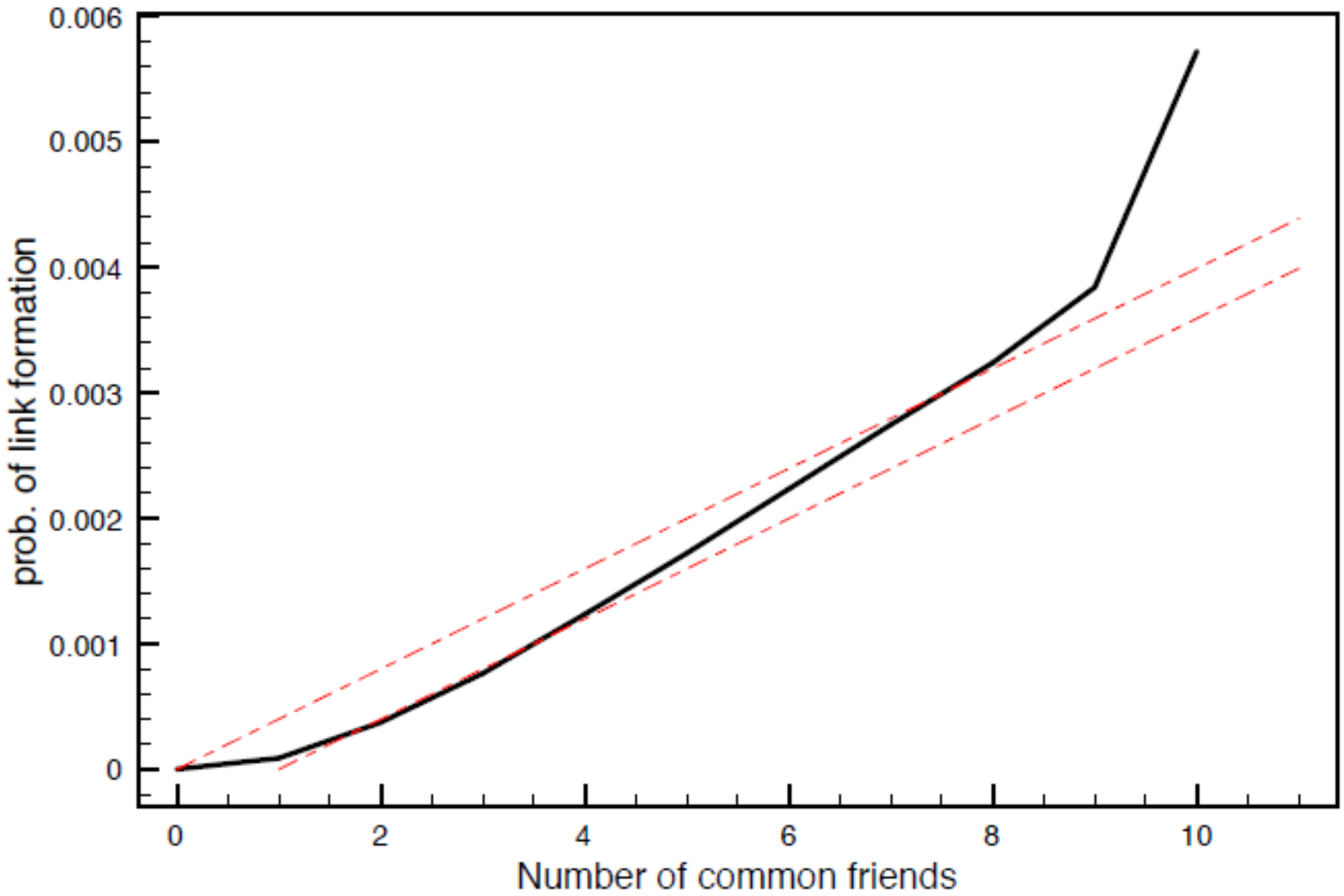
- E-mail communication among students
  - who-talks-to-whom network
- 22,000 students
- One-year period
- observations in each snapshot were one day apart (averaged over multiple snapshots)
  - Shows the average probability that 2 people form a link per day, as a function of the number of common friends they have

Tracking Triadic Closure- Cnt.

- Baseline
  - Assume that each common friend that 2 people have, gives them an independent probability *p* of forming a link
    - 2 people have *k* friends in common => the probability they fail to form a link is:
      - $(1 - p)^k$
    - probability that they form a link is

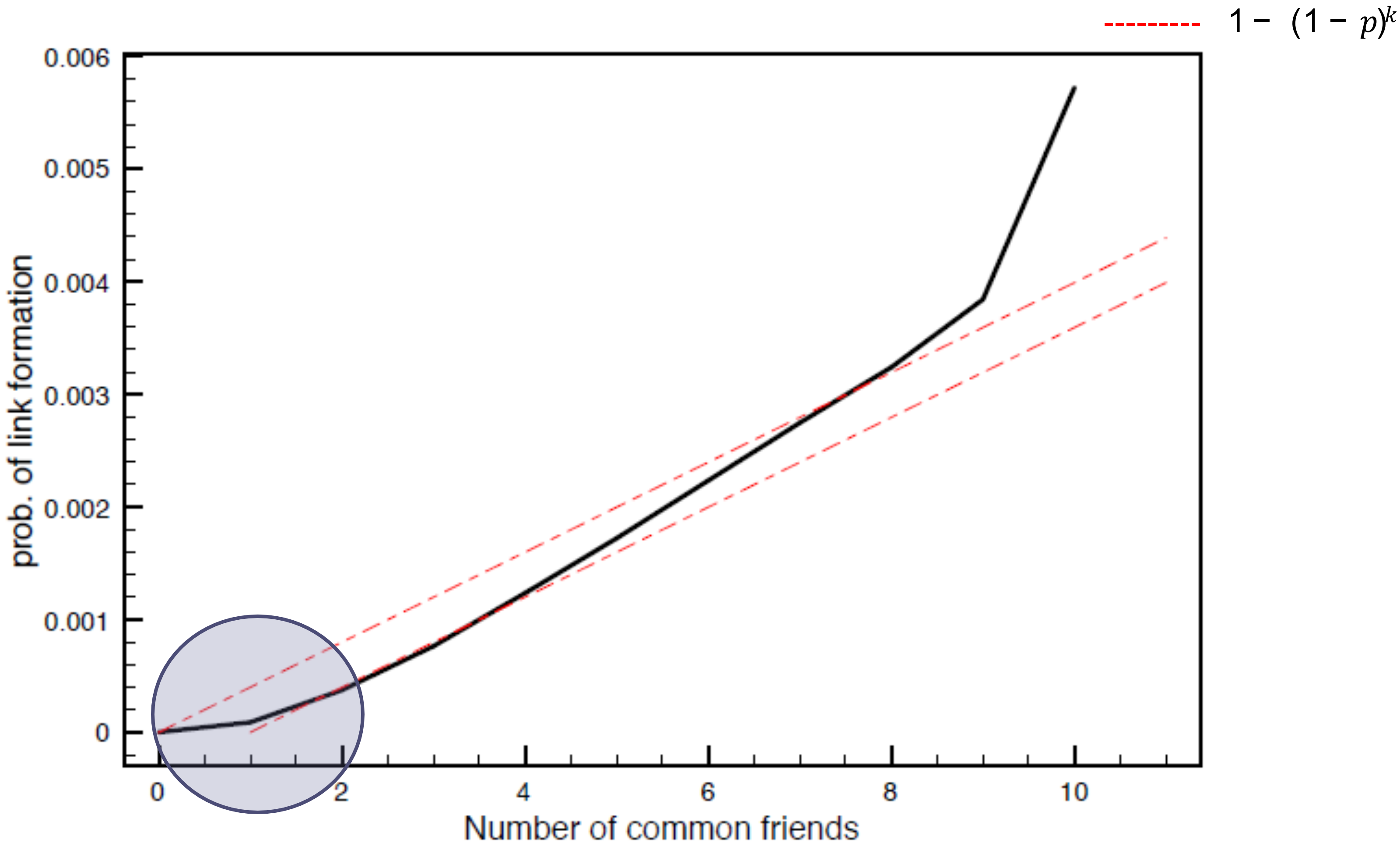
$$T_{baseline}(k) = 1 - (1 - p)^k$$

Tracking Triadic Closure- Cnt.



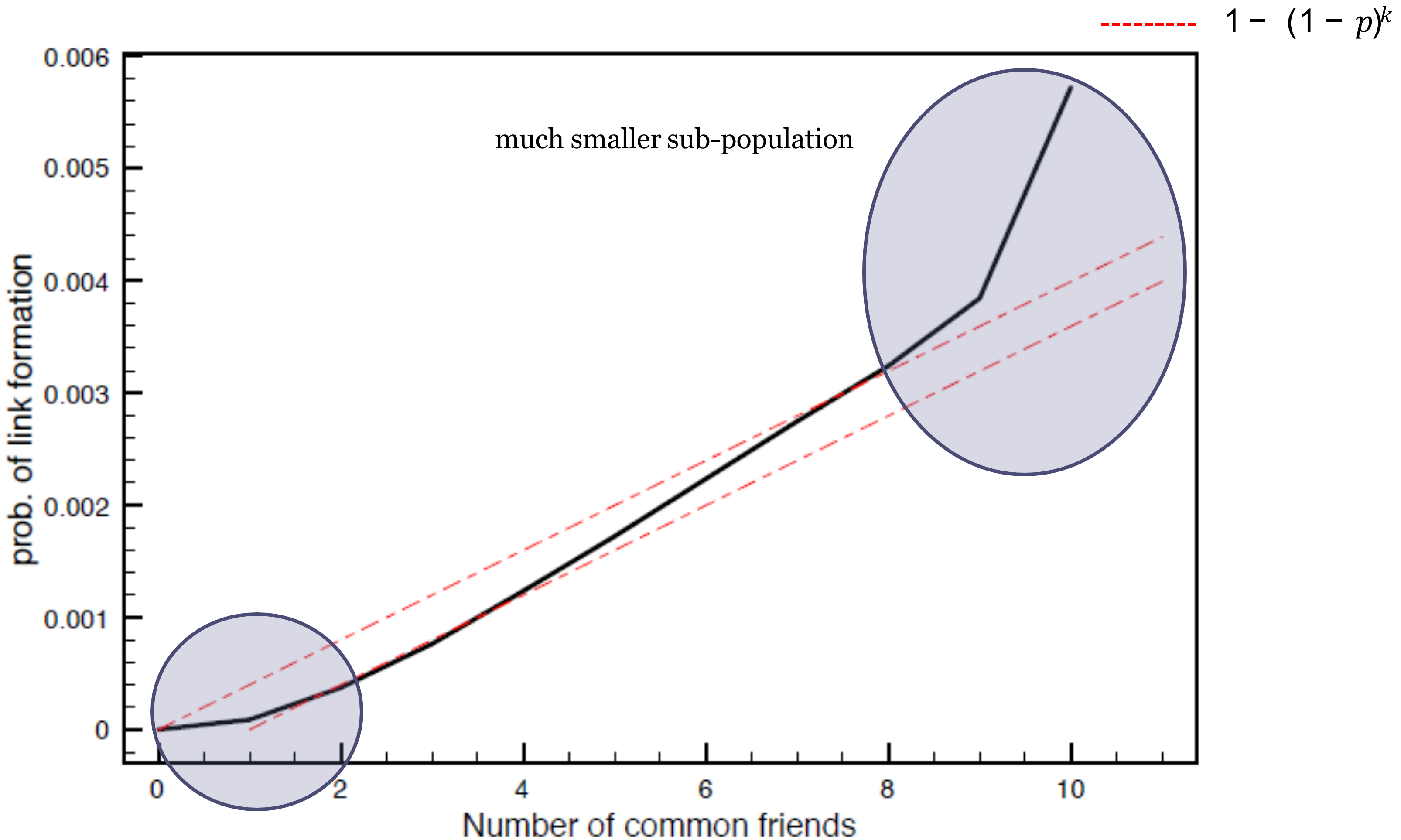
$1 - (1 - p)^k$

Tracking Triadic Closure- Cnt.



Having 2 common friends produces significantly more than twice the effect on link formation compared to having a single common friend!

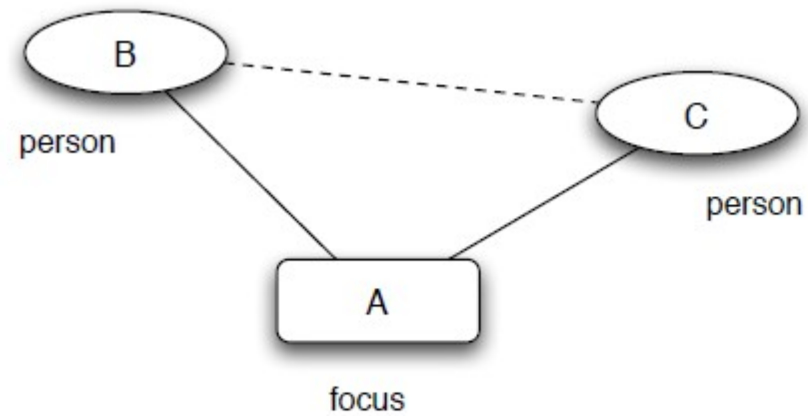
Tracking Triadic Closure- Cnt.



Having 2 common friends produces significantly more than twice the effect on link formation compared to having a single common friend!

Tracking Focal Closure

- The probability that 2 people form a link as a function of the number of **foci** they have in common.

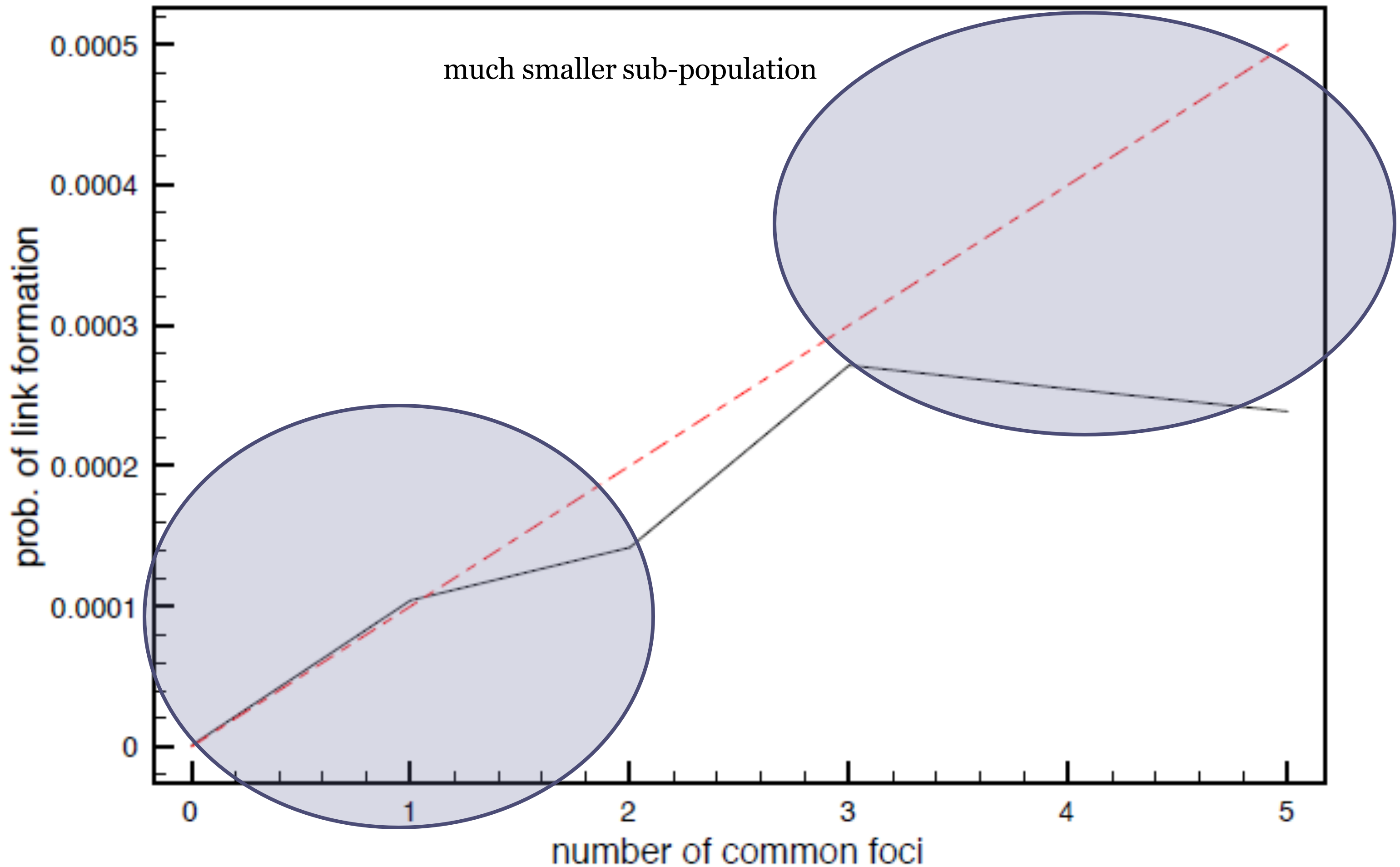


(b) *Focal closure*

Tracking Focal Closure- Cnt.

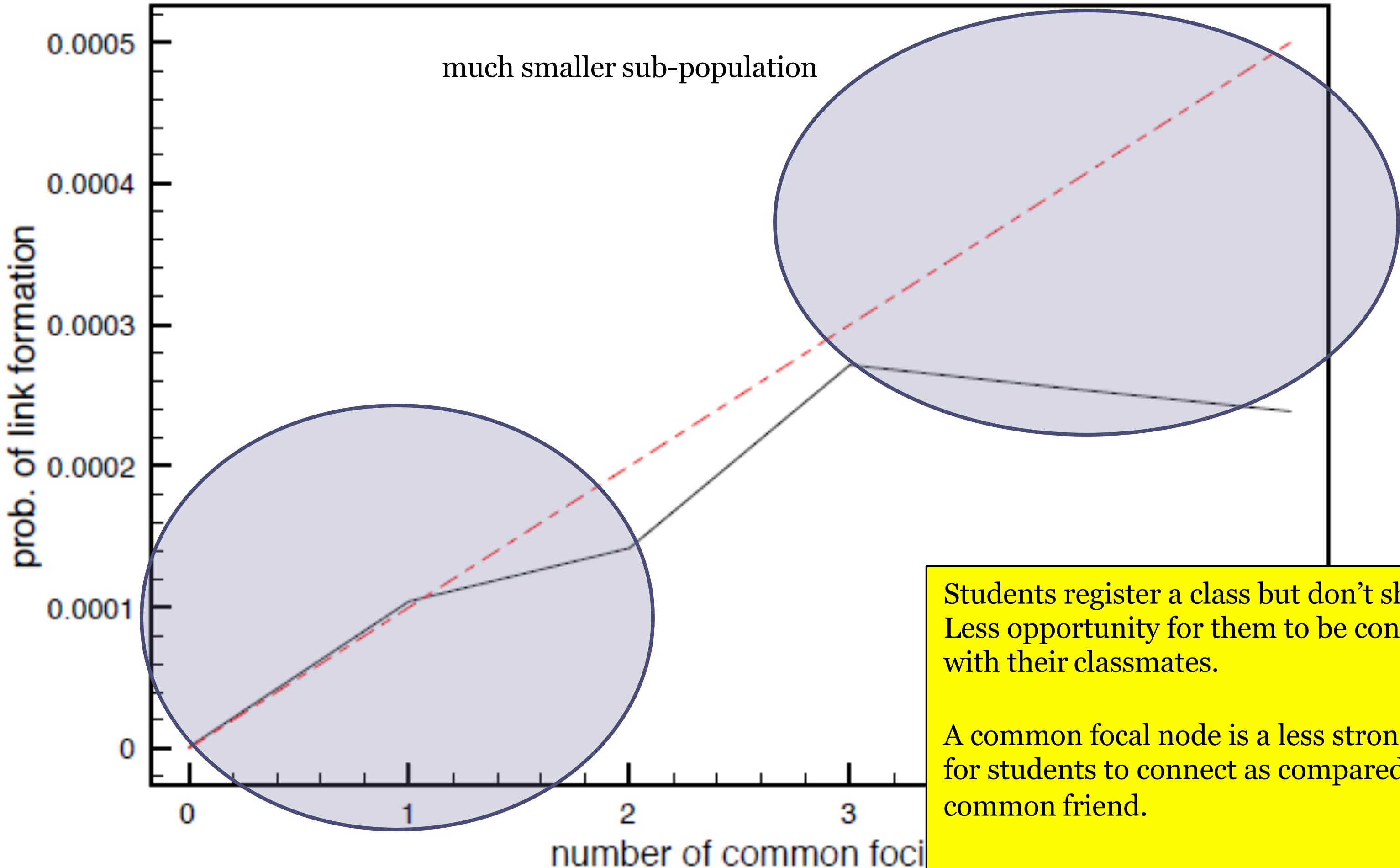
- Supplement university e-mail dataset with information about the class schedules!
  - each class is a focus, and
  - students shared a focus if they had taken a class together.

Tracking Focal Closure- Cnt.



P(k=2) < 2* P(k=1)

Tracking Focal Closure- Cnt.



P(k=2) < 2* P(k=1)

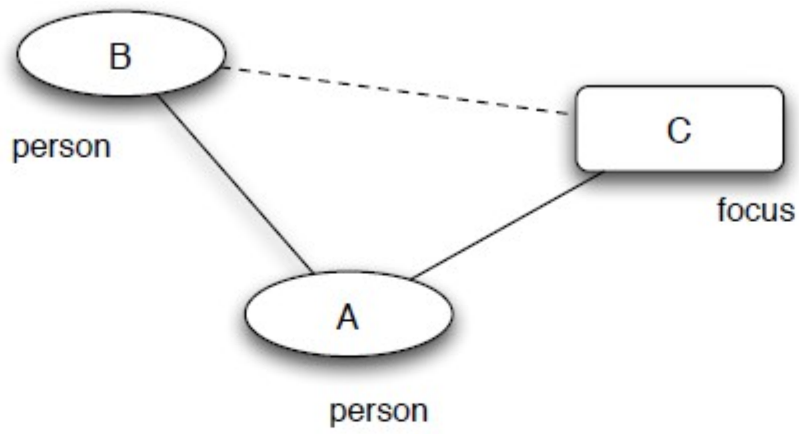
Students register a class but don't show up : Less opportunity for them to be connected with their classmates.

A common focal node is a less strong reason for students to connect as compared to a common friend.

Nature of the focal nodes: limited number classes as compared to number of students.

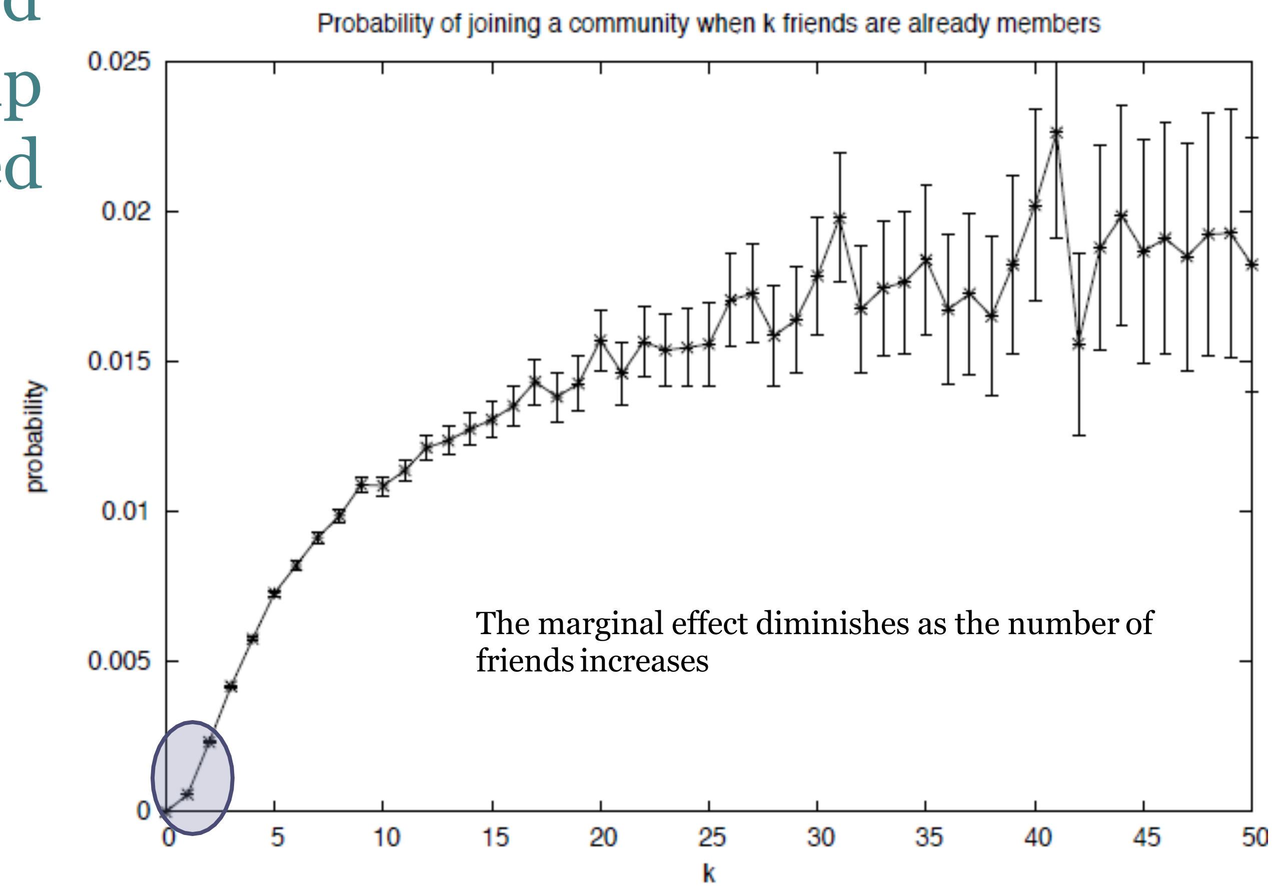
Tracking Membership Closure

- The probability that a person becomes involved with a particular **focus** as a function of the number of friends who are already involved in it?



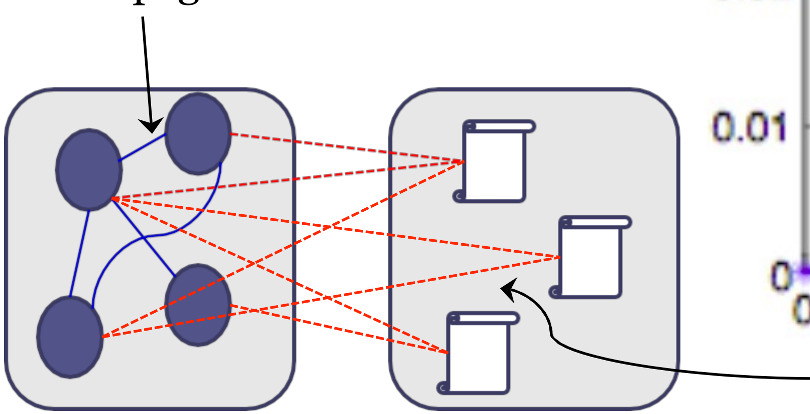
Tracking Membership Closure- Cnt.

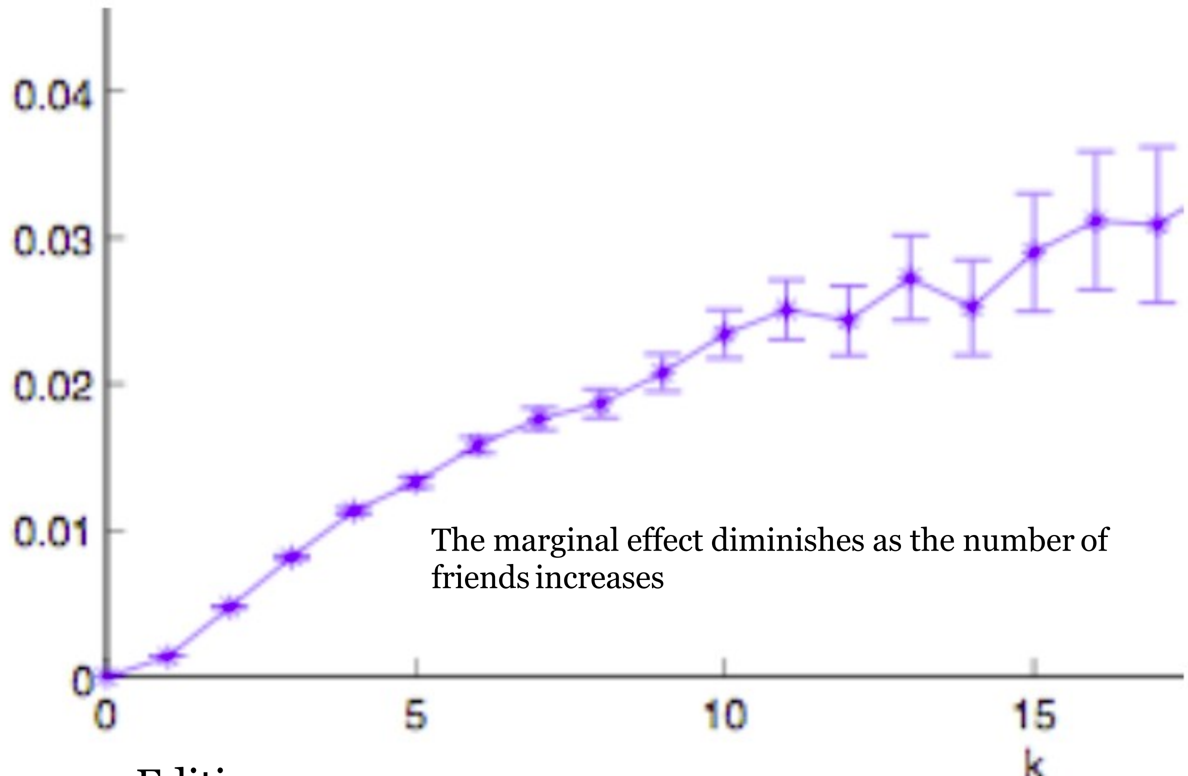
- Blogging site LiveJournal
  - social network (friendship links)
  - foci correspond to membership in user-defined communities



Tracking Membership Closure- Cnt.

- Wikipedia Editors
  - social network (link → writing on user talk page)
  - foci correspond to Wikipedia pages
    - Link → editing a page!

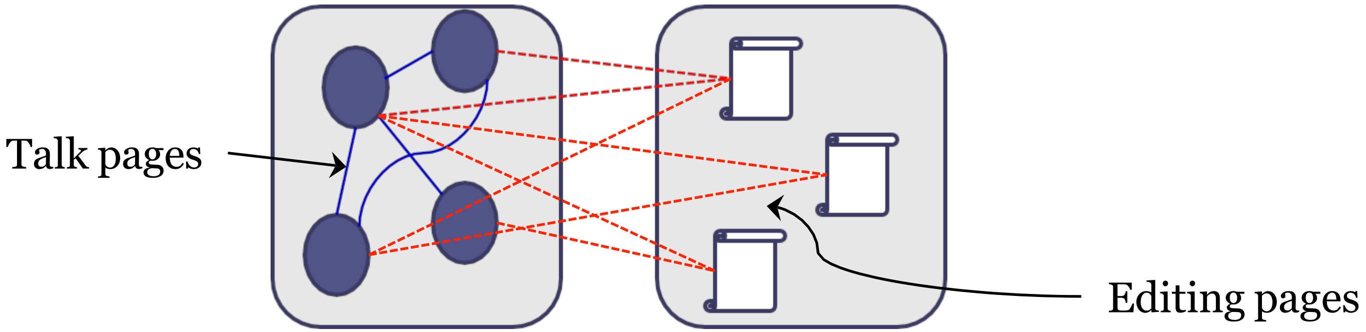




Selection and Social Influence

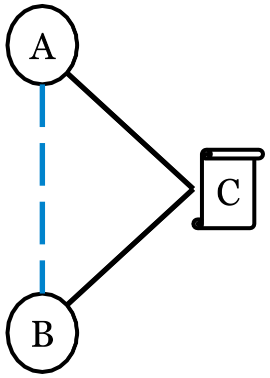
- Interplay btw Selection and Social Influence in producing homophily
  - Similarity btw two Wikipedia editors:

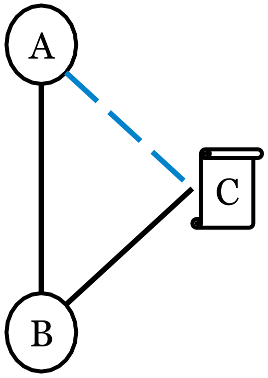
$$\frac{\text{number of articles edited by } \textit{both } A \text{ and } B}{\text{number of articles edited by } \textit{at least one of } A \text{ or } B},$$



Selection and Social Influence- Cnt.

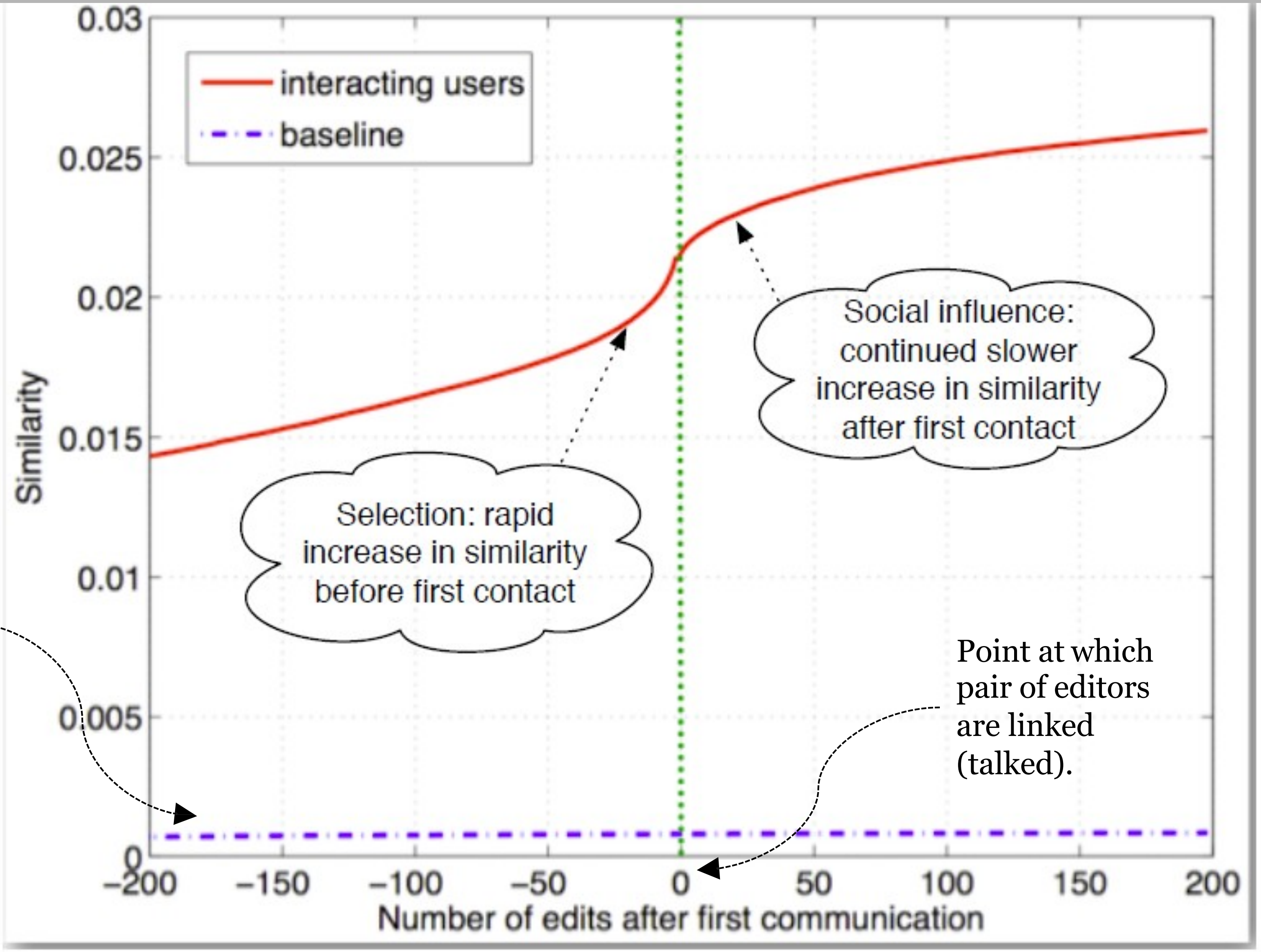
- Does **homophily** (**similarity**) arise because
  - editors are forming connections with those who have edited the same articles (**selection**), or
  - is it because editors are led to edit articles by those they talk to (**social influence**)?





Selection and Social Influence- Cnt.

average similarity relative to the time of first interaction, over all pairs of editors who have ever talked



Record similarity over time for each pair of editors A and B who have ever talked.

Plot the average similarity over all pairs.

similarity of non-interacting pair of editors

homophily is clearly present:
pairs of editors who have talked are significantly more similar than those who never talked.

Point at which pair of editors are linked (talked).

Feedback effects between similarity and social influence in online communities. Crandall, et al., SIGKDD 2008.

Reading

- Ch.04 Networks in Their Surrounding Context [NCM]
- Empirical analysis of an evolving social network. Kossinets, G. and Watts, D.J. Science 2006.
- Group formation in large social networks: membership, growth, and evolution. Backstrom, L., et al. SIGKDD'06.
- Feedback effects between similarity and social influence in online communities. Crandall, D., et al. SIGKDD'08.