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Homophily & Network Formation

CMSC 498J: Social Media Computing

Department of Computer Science
University of Maryland
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Lecture Topics

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

Homophily

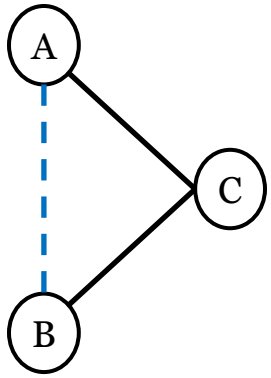
- The principle that we tend to be similar to our friends!
  - your friends are generally similar to you in terms of your characteristics!
- Immutable
  - race, ethnicity, country of birth, etc (determined at birth).
- Mutable
  - location, occupations, affluence, interests, beliefs, opinions, etc (change 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!

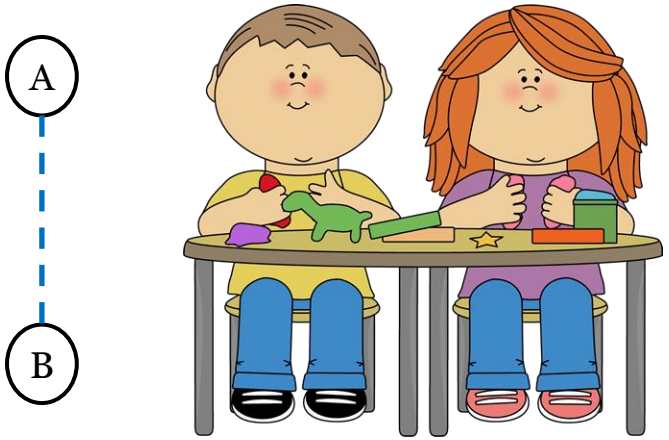
Homophily- Cnt.

- 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.



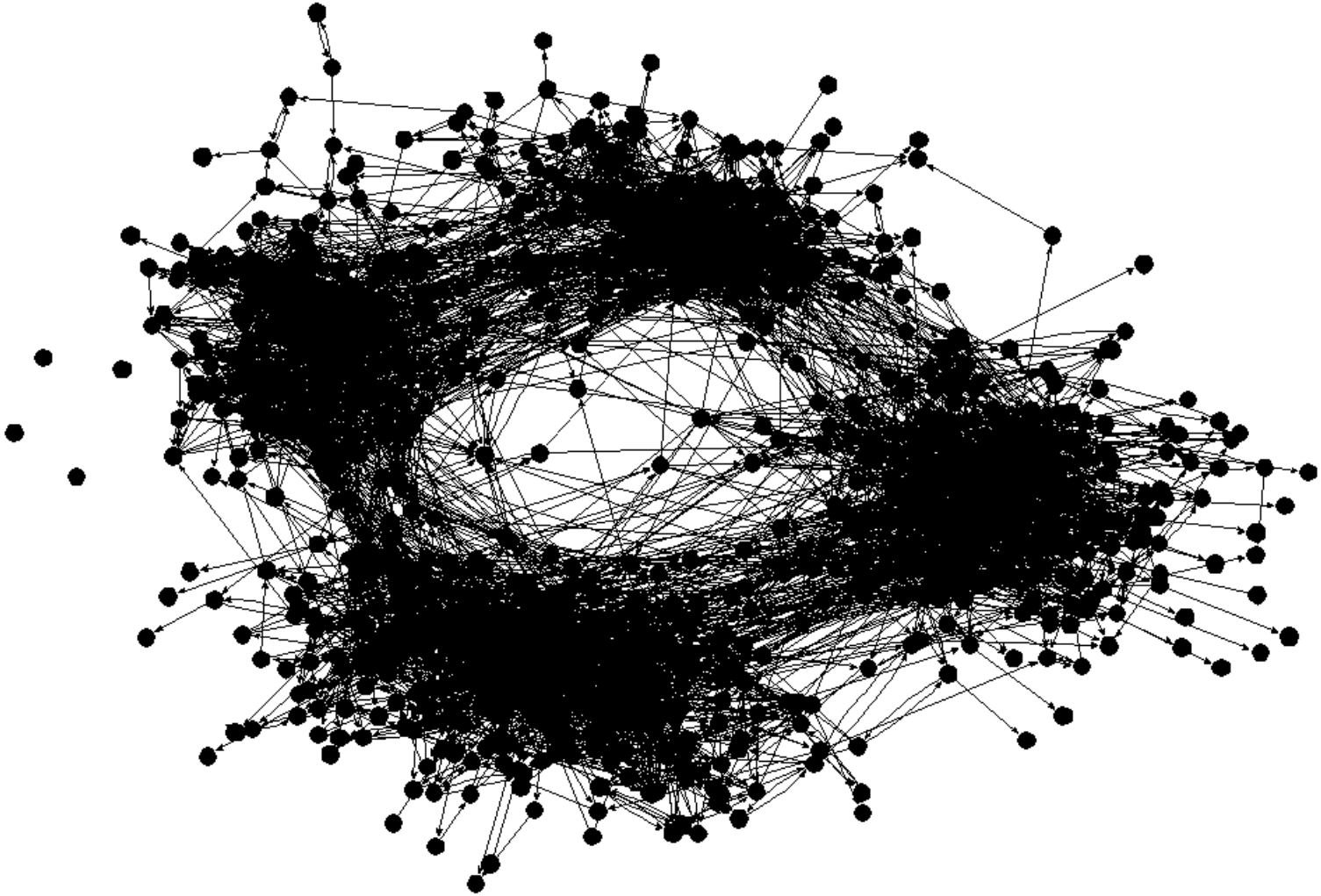
Homophily- Cnt.

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



Homophily- Cnt.

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



Homophily- Cnt.

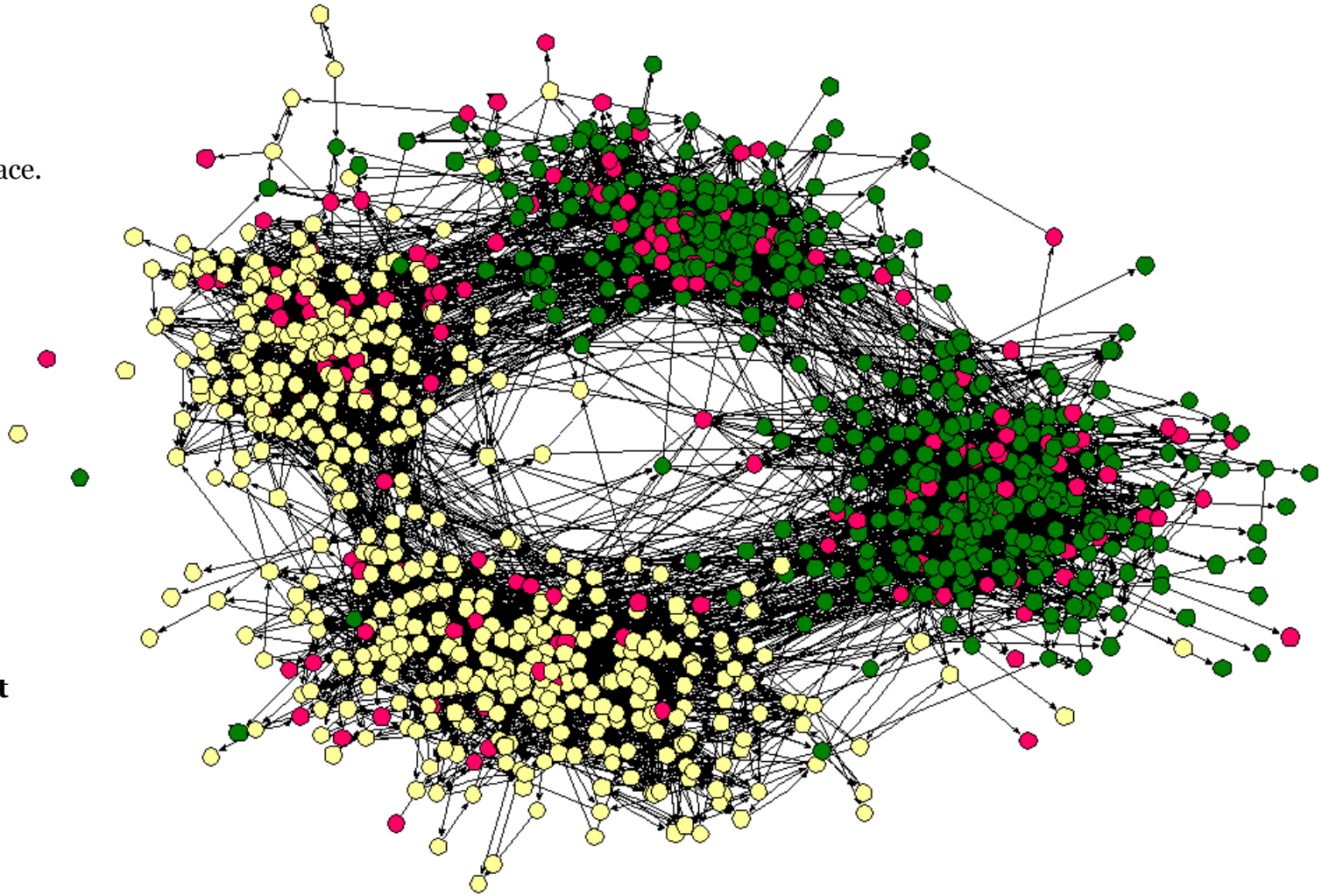
- Social net among students in a middle and high school.

Color the nodes based on race.

Two context features:

a. Race

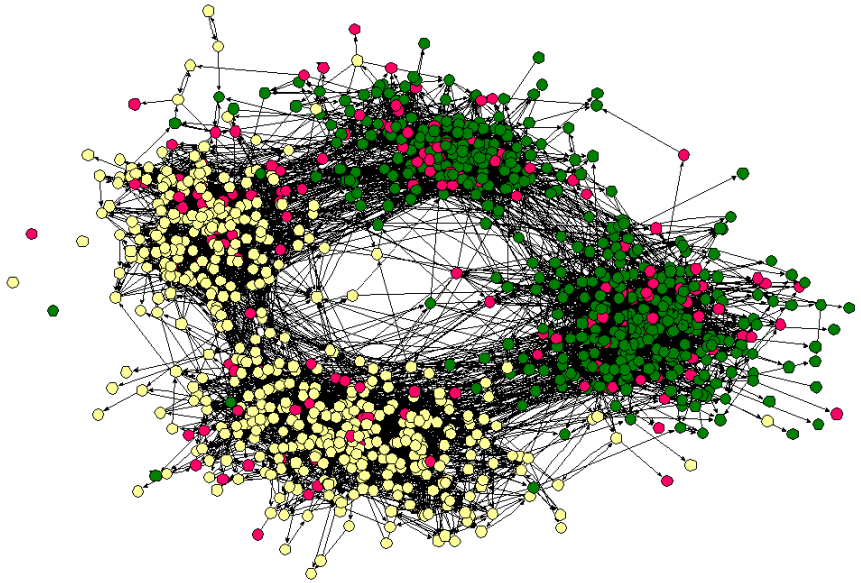
b. School



The network exhibits homophily with respect to Race and School!

Homophily- Cnt.

- Which factors are more dominant for link formation?
  - Difficult to attribute link formation to a single factor!
  - Most links arise from a combination of several factors
    - network intrinsic effects, and
    - contextual effects.



Homophily vs. Triadic Closure

- Both operate concurrently

- 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

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

Measuring Homophily

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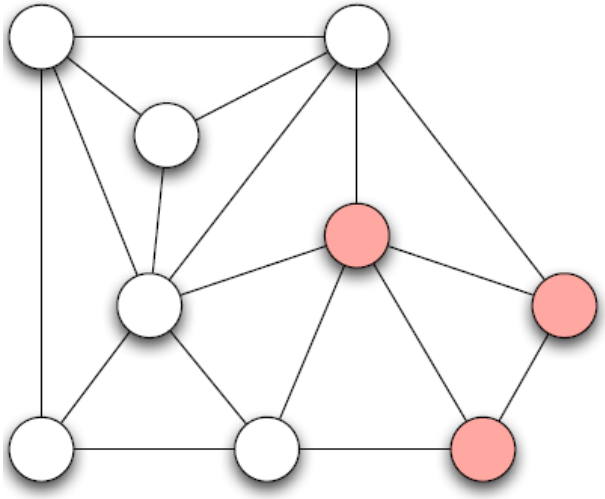
- Given a particular factor (like race, or age), how can we test if a network exhibits homophily according to this factor?

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

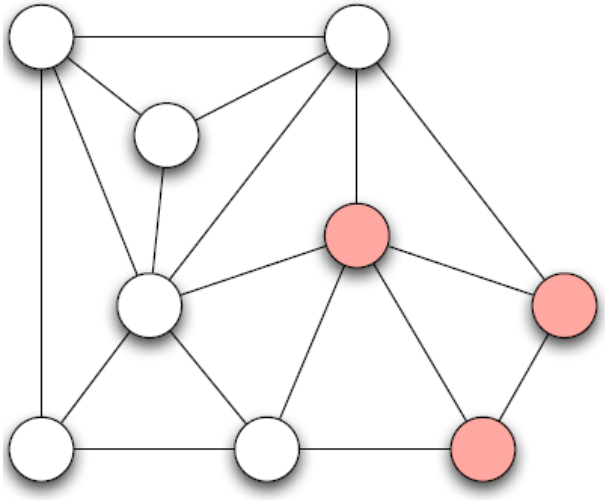


Network of 3 girls and 6 boys!

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

Measuring Homophily- Cnt.

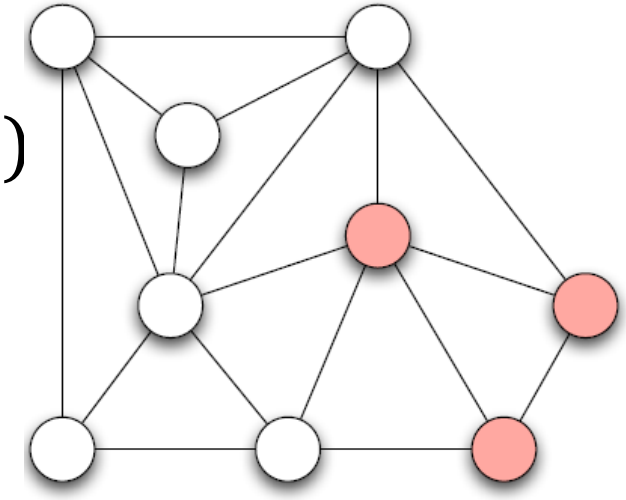
- What would it mean for a network *not* to exhibit homophily by gender?
  - The number of cross-gender edges is not very different from when we randomly assign each node a gender
    - according to the gender balance in the network



Network of 3 girls and 6 boys!

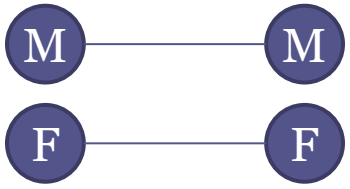
Measuring Homophily- Cnt.

- 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!

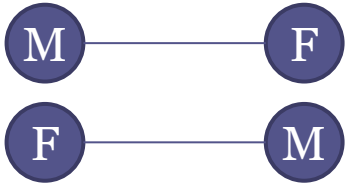
Homophily



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?

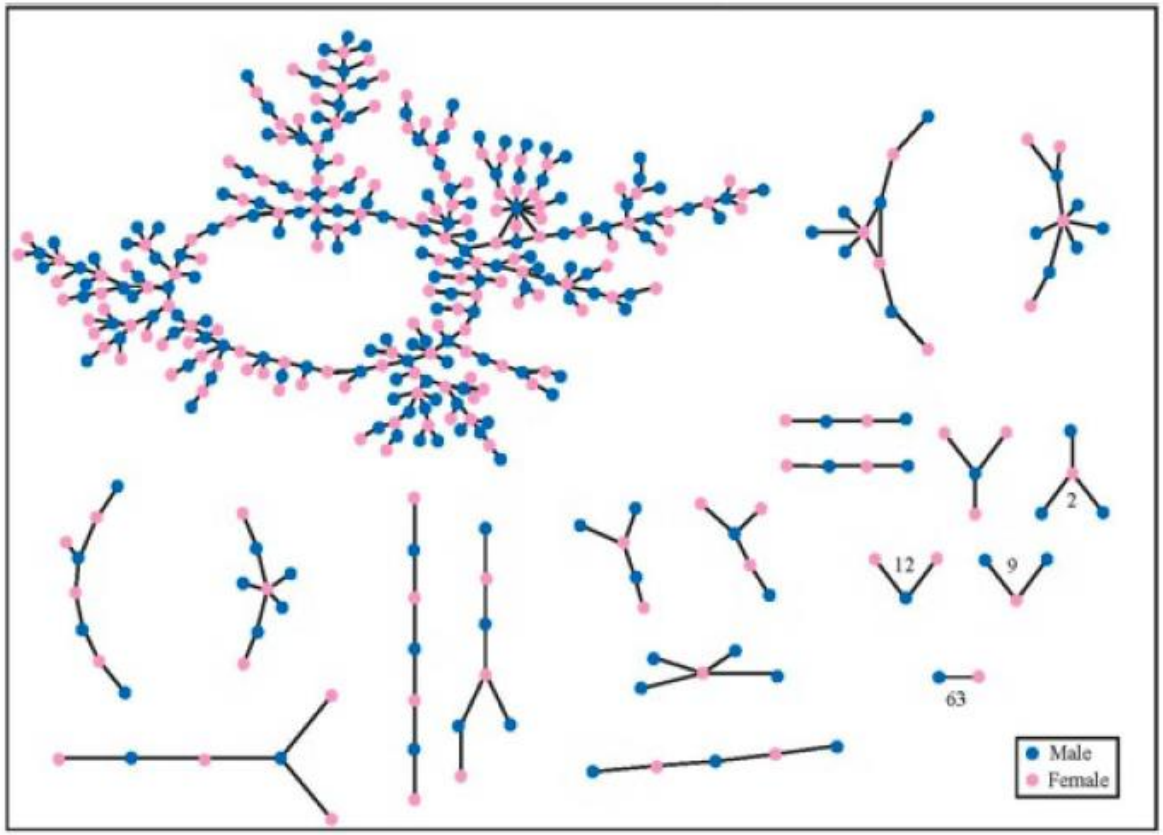


Figure 2.7: A network in which the nodes are students in a large American high school, and an edge joins two who had a romantic relationship at some point during the 18-month period in which the study was conducted [49].

Mechanisms Underlying Homophily

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

Mechanisms Underlying Homophily- Cnt.

- Most of the 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 displays homophily across a network, people showing a greater likelihood to use drugs when their friends do, we can study the effects of a program that targets certain people and influences them to stop using drugs.

Mechanisms Underlying Homophily- Cnt.

- When Homophily is observed, *Selection* or *Social Influence* is more strongly at work?
  - Have people adapted their behaviors to become more like their friends, or have they selected people who were already like them?
- Conduct Longitudinal Studies
  - Tracked the network for a period of time and monitor the effect of each mechanism.
- More on this later!

Summary

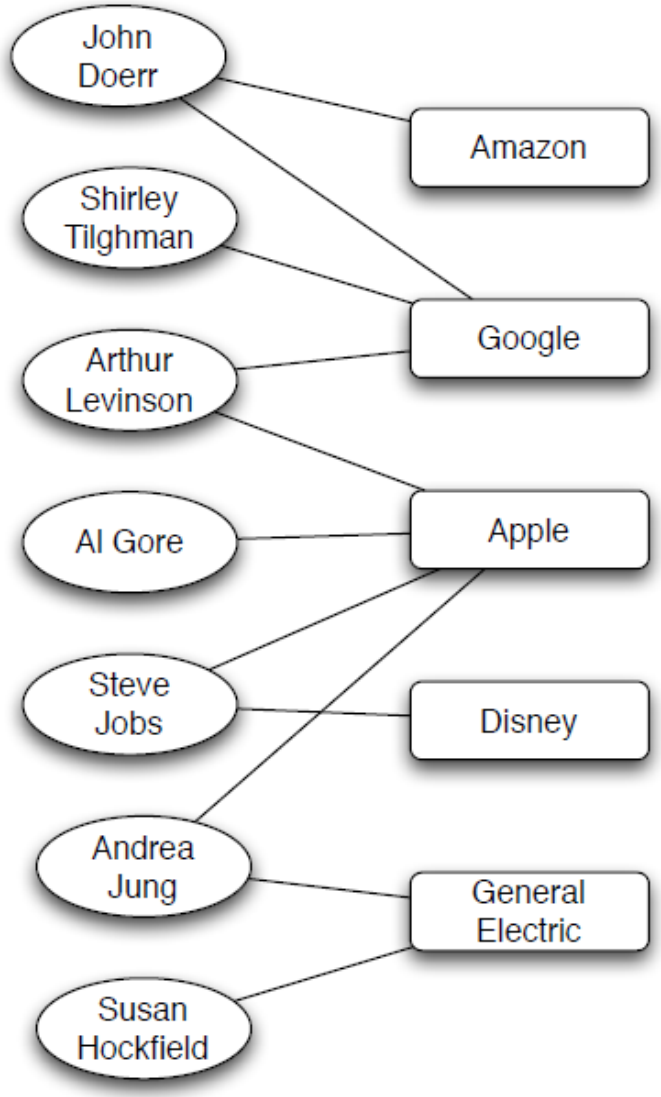
- Homophily links nodes with similar characteristics
- Measuring Homophily
  - compare with random network (generated according to the node characteristics in the original network)
- Selection and social influence determine the formation of links
- Characteristics represent surrounding contexts of networks
  - Exist outside the network
    - Caveat: Most of such forces go largely unrecorded in everyday life!

Affiliation Networks

- Putting surrounding contexts into networks
- Network that contains both original nodes & contexts
- Represent the set of activities a person takes part in
  - 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

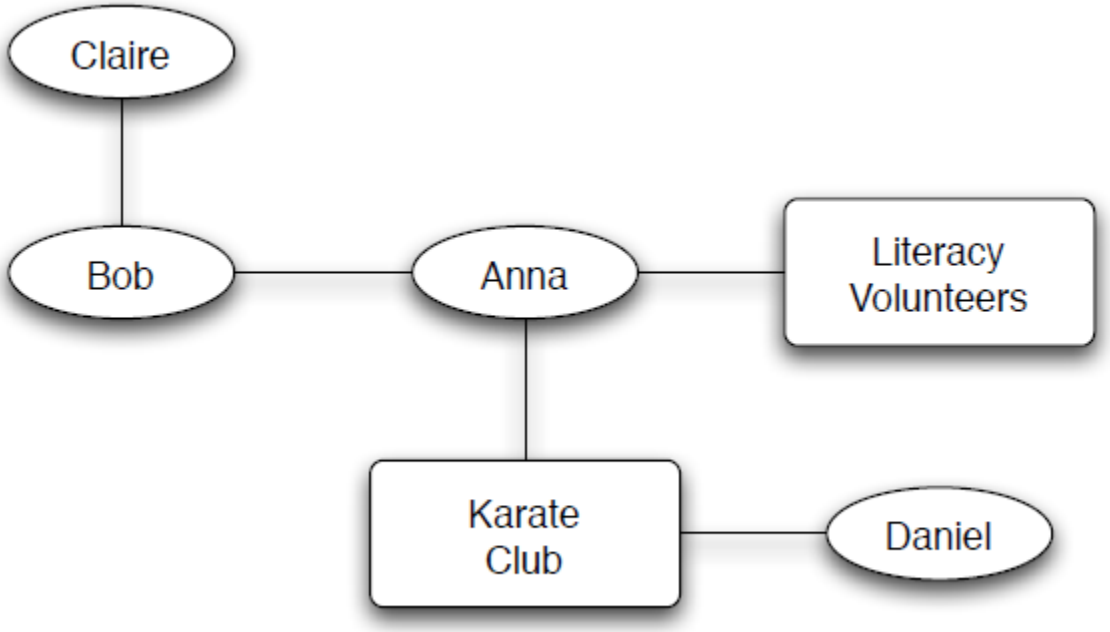


Social-Affiliation Network

- Both Social and Affiliation networks evolve over time
  - new links are formed in social nets
  - people become associated with new foci in affiliation nets
- Co-evolution reflects interplay between selection and social influence
  - If 2 people participate in a shared focus, they are provided with an opportunity to become friends (Selection)
  - If 2 people are friends, they can share their foci (Social Influence)

Social-Affiliation Network- Cnt.

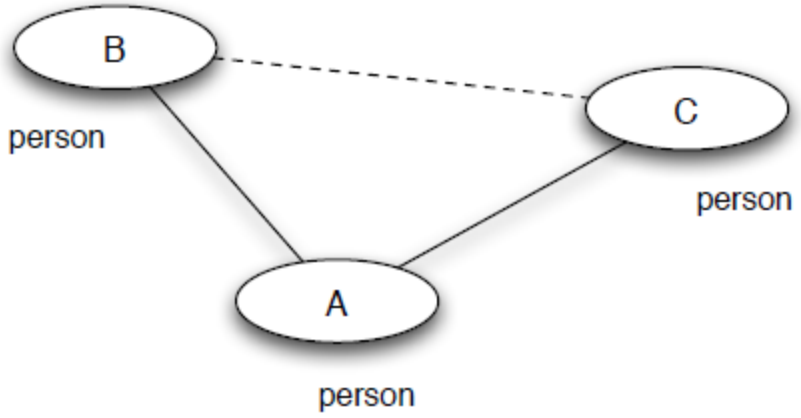
- Social-affiliation network contains:
  - a social network of people, and
  - an affiliation network btw people and foci



Social-Affiliation Network- Cnt.

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

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



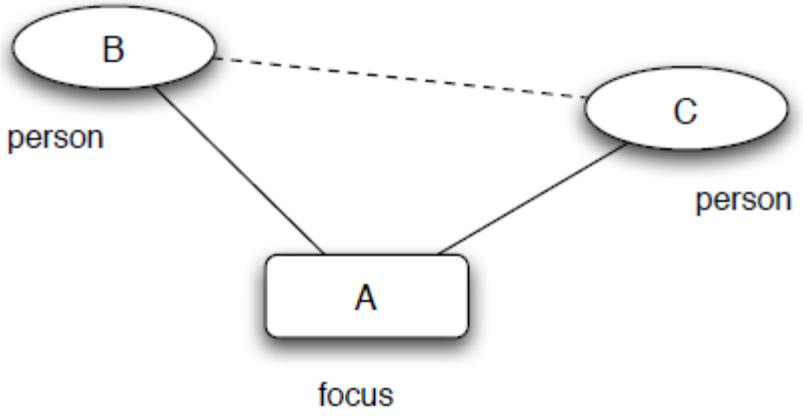
(a) *Triadic closure*

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)



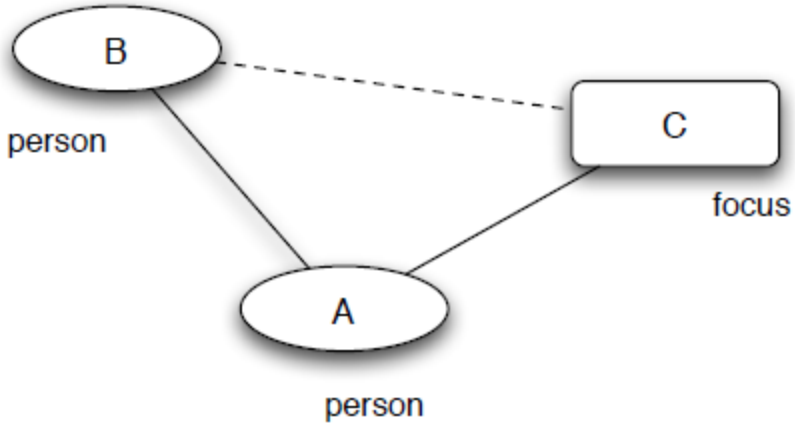
(b) *Focal closure*

Social-Affiliation Network- Cnt.

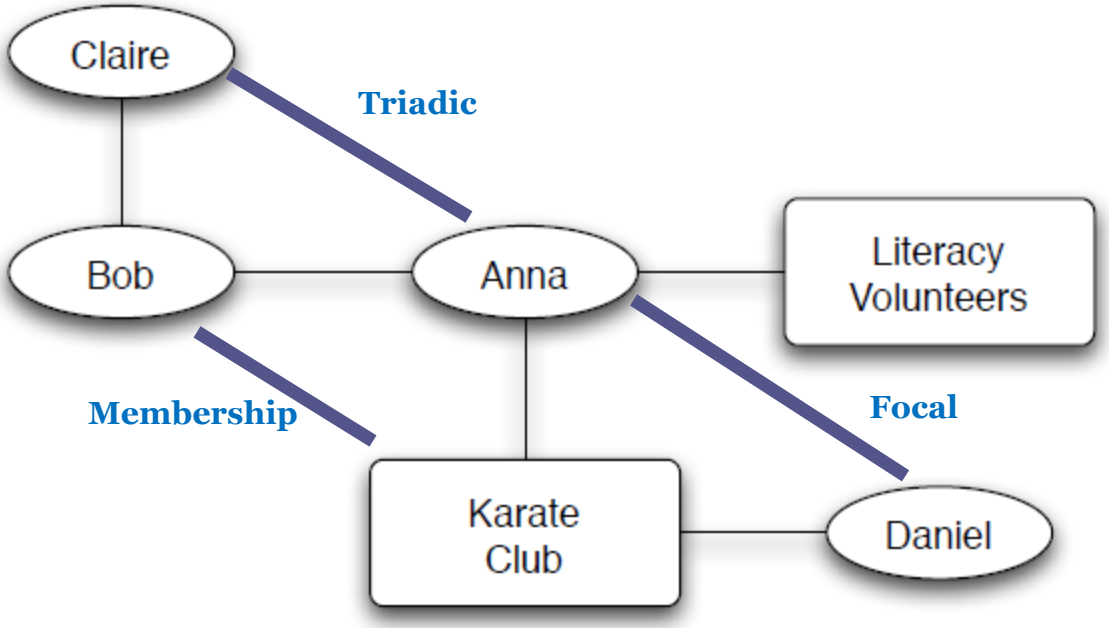
- Different mechanisms for link formation as types of closure processes!

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

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



Social-Affiliation Network- Cnt.



Tracking Link Formation

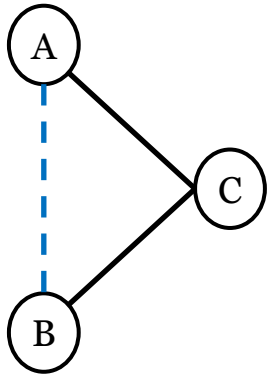
- Caveat: Most of forces responsible for link formation go largely unrecorded in everyday life!
  - it is a challenge to select a large group of people (and social foci), and accurately quantify the relative contributions that these different mechanisms make to the formation of real network links.

Tracking Link Formation- Cnt.

- Three mechanisms that lead to link formation
  - triadic closure
  - focal closure
  - membership closure
- Tracking link formation in large scale datasets based on the above mechanisms

Tracking Link Formation- Cnt.

- But how to conduct such experiments?
  - Compute probability of a link to form btw 2 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.

Tracking Triadic Closure- Cnt.

Algorithm

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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.

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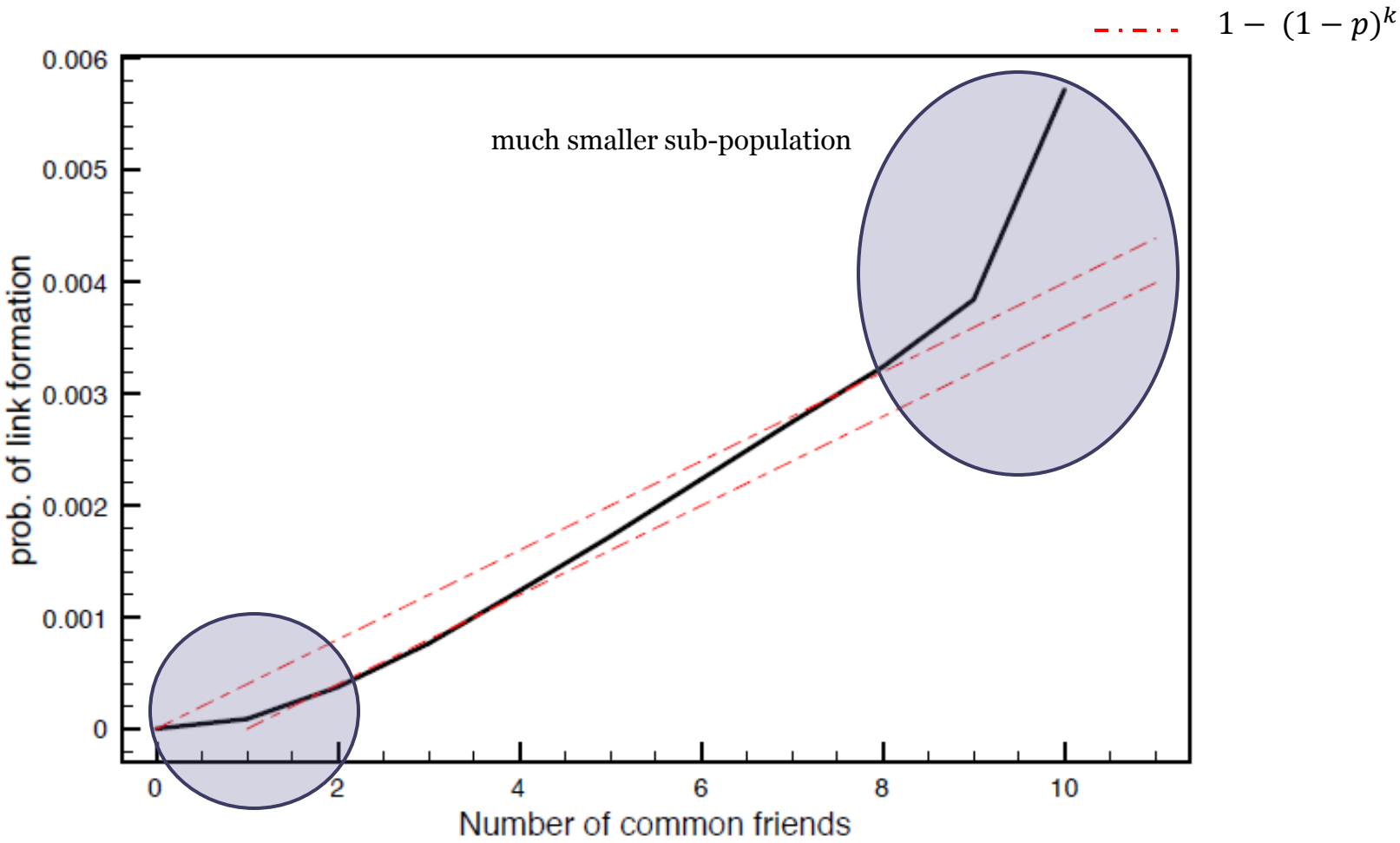
- Baseline
  - Assume that each common friend that 2 people have, gives them an independent probability p of forming a link
    - 2 people have k friends in common => the probability they fail to form a link is:
      - $(1-p)^k$
    - probability that they form a link is
      - $T_{baseline}(k) = 1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

Tracking Triadic Closure- Cnt.



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

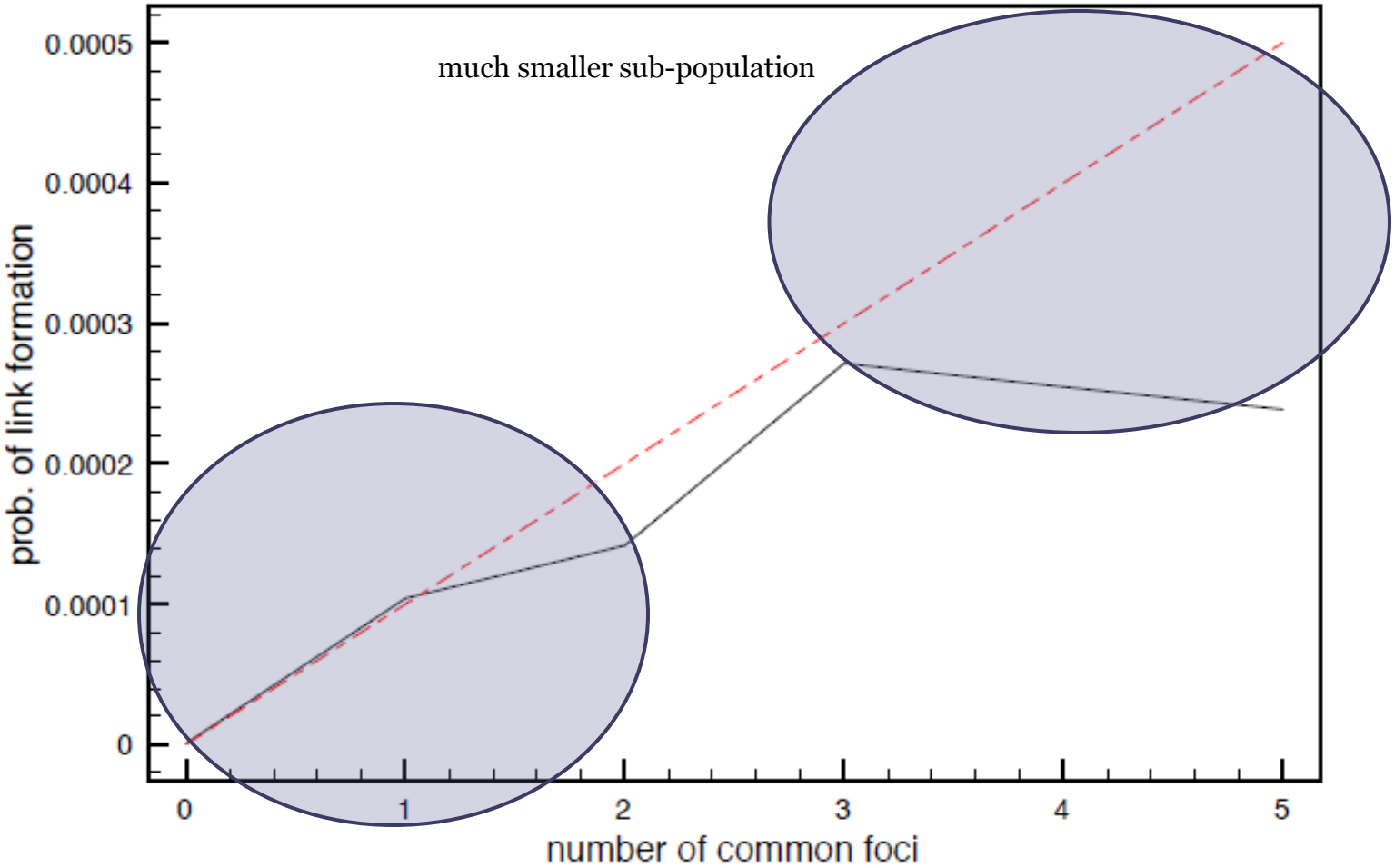
Tracking Focal Closure

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

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.



Having 2 common foci has significantly less effect on link formation compared to having a single foci!

Tracking Membership Closure

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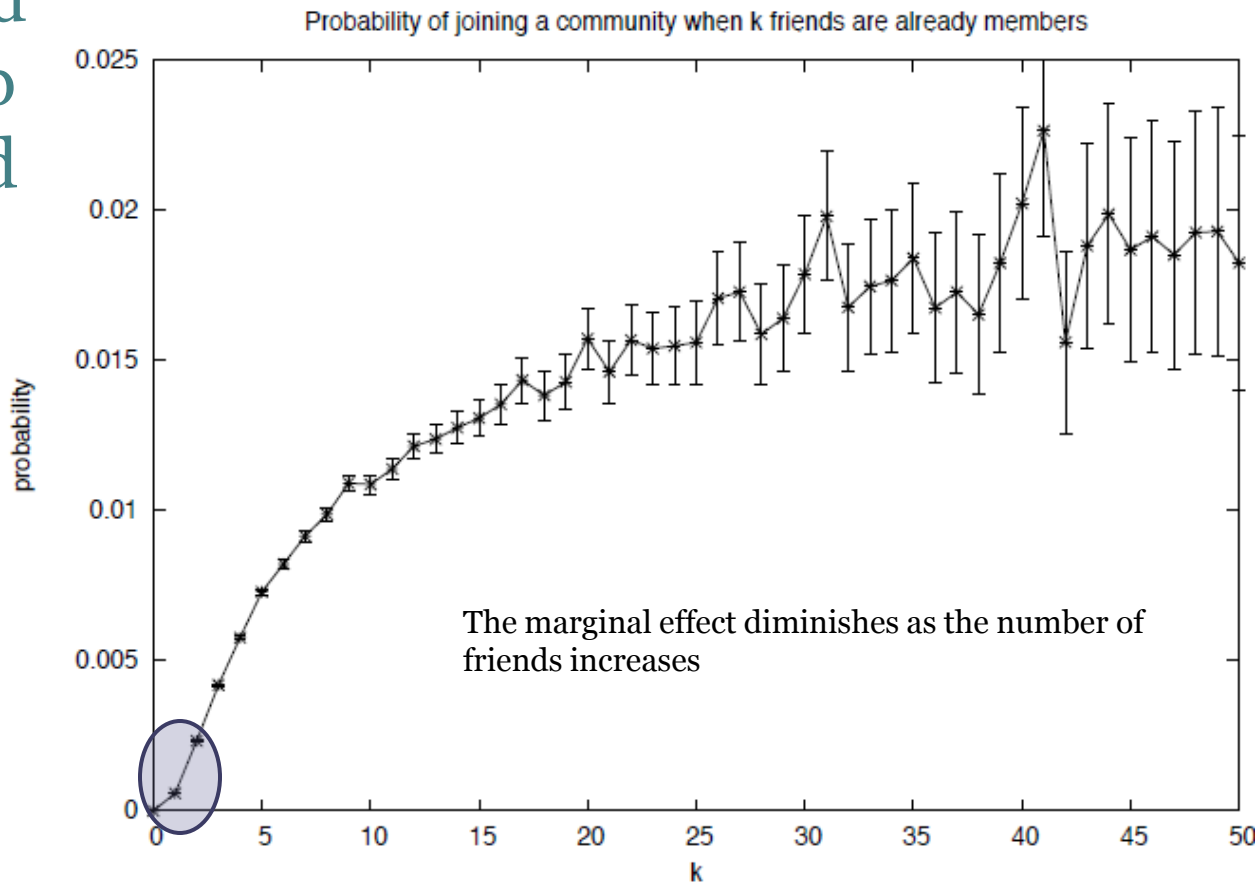
- The probability that a person becomes involved with a particular **focus** as a function of the number of friends who are already involved in it?

Tracking Membership Closure- Cnt.

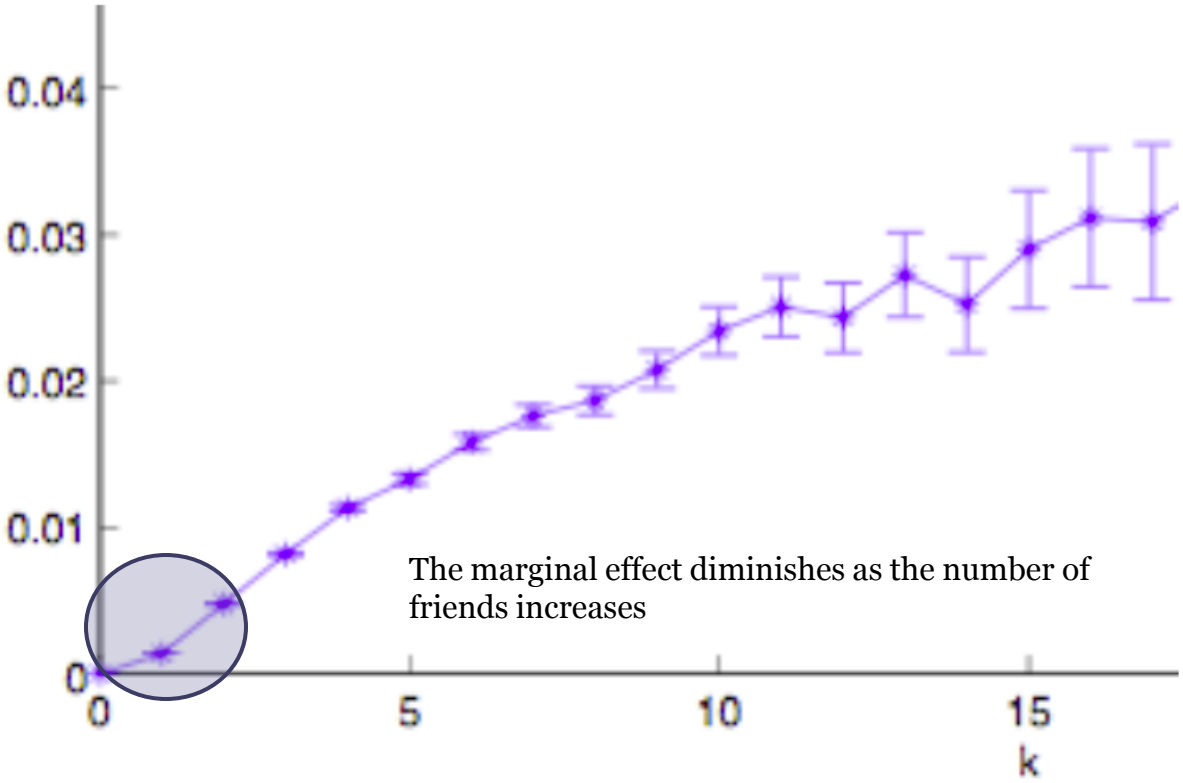
- Blogging site LiveJournal
  - social network (friendship links)
  - foci correspond to membership in user-defined communities



Group formation in large social networks: Membership, growth, and evolution. Backstrom, et al,. SIGKDD 2006.

Tracking Membership Closure- Cnt.

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



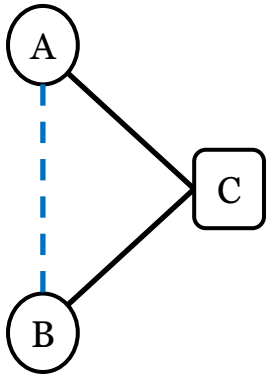
Selection and Social Influence

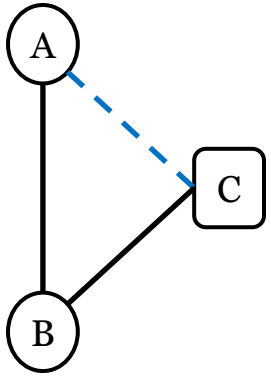
- Interplay btw Selection and Social Influence in producing homophily
  - how do similarities in behavior btw 2 Wikipedia editors relate to their pattern of social interaction over time?
  - Similarity

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

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.

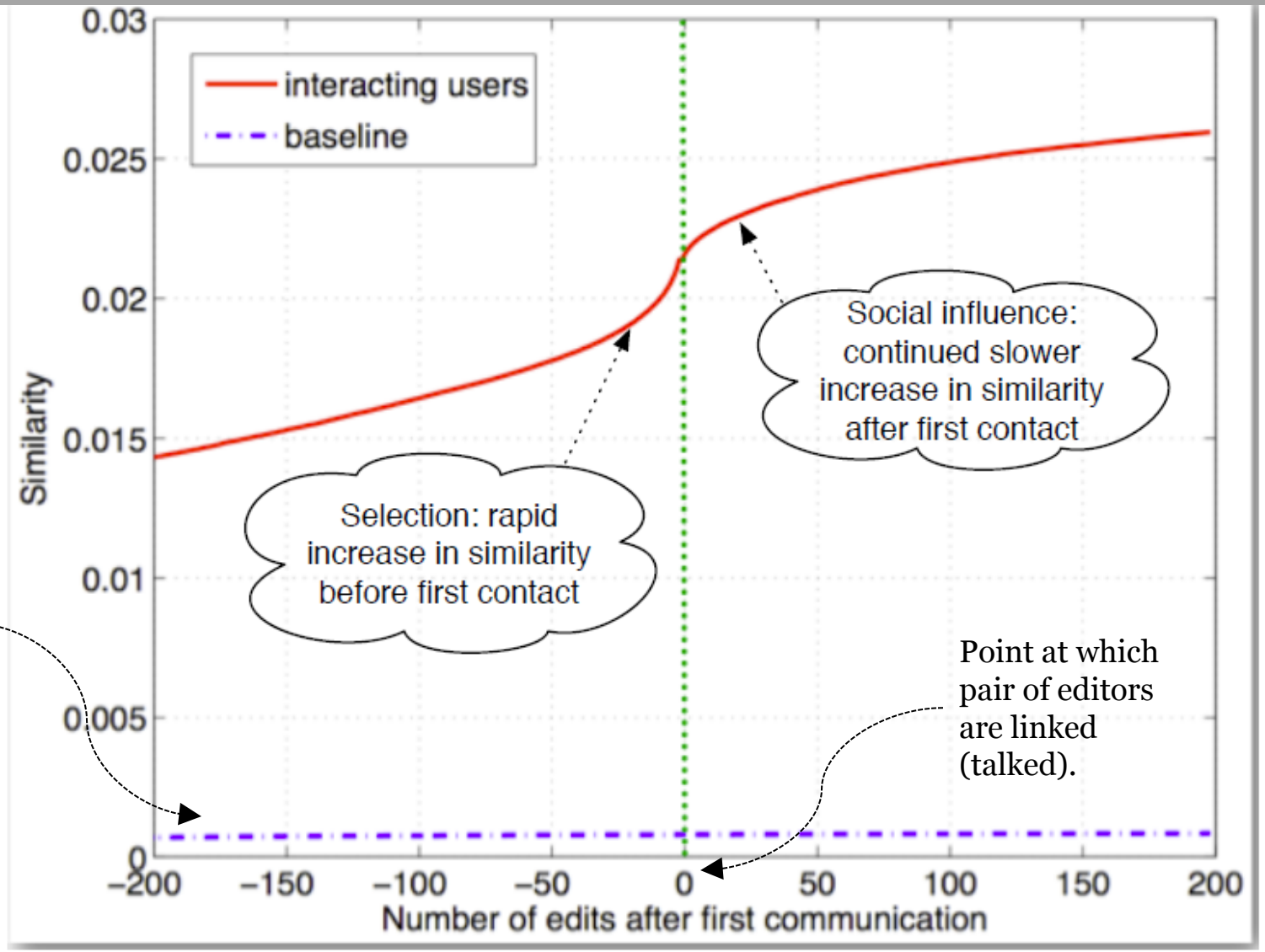
average similarity relative to the time of first interaction, over all pairs of editors who have ever talked

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.



Questions?

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Reading

- Ch.04 Networks in Their Surrounding Context [NCM]