

Tie strength, social capital, betweenness and homophily

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Networks

- Position of a node in a network determines its role/importance
- Structure of a network determines its properties

Today

- Notion of strong ties (close friends) and weak ties (remote acquaintances)
 - How they influence the network and spread of information
- Friendships and their evolution
- “Central” locations

Strong and weak ties

- Survey of job seekers show people often find jobs through social contacts
- More important: people more often find jobs through *acquaintances (weak ties)* than close friends (strong ties)

- Strength of weak ties. Mark S. Granovetter, American journal of Sociology, 1973

Strong and weak ties

- Explanation:
 - A close friend is likely in the same community and has the same information sources
 - Person in a different community is more likely to have “new” information, that you do not already know
- *Weak* ties are more critical: they can act as *bridges* across communities
- Other observation: Job information does not travel far – long paths are not involved

Weak ties in social action

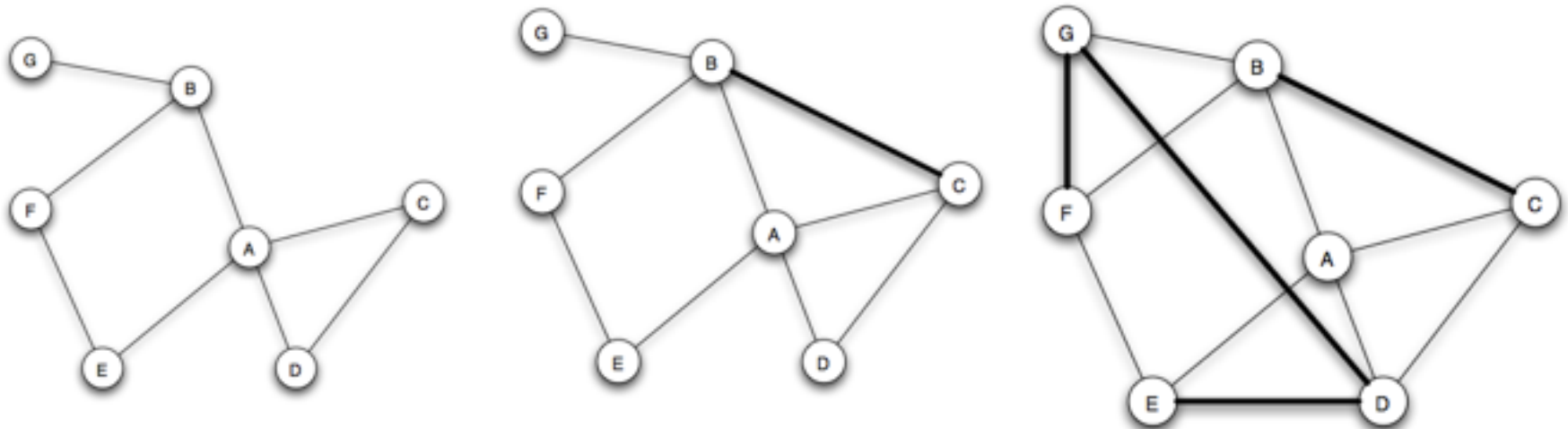
- Psychology: People do not often act on global information (radio, tv) etc
- People are more likely to act when confirmed by friends (creates trust)
- Therefore, people are more likely trust a leader when confirmed by direct familiarity or common friends acting as intermediaries
- A society without *bridges* is fragmented
 - The leader does not reach a large number of people that trust him

Weak ties in social action

- Example (from Granovetter): A small town needs to coordinate action on a social issues
 - If everyone works at different places in nearby industries
 - Then people only know their families. There are no work-acquaintances, etc.
 - Organizing a protest is hard
 - If everyone works at the same large industry
 - Likely there are work-acquaintances (weak ties)
 - Social action works better
- See also:
 - Ted talk: Online social change: Easy to organize, hard to win (can you model and explain this?)

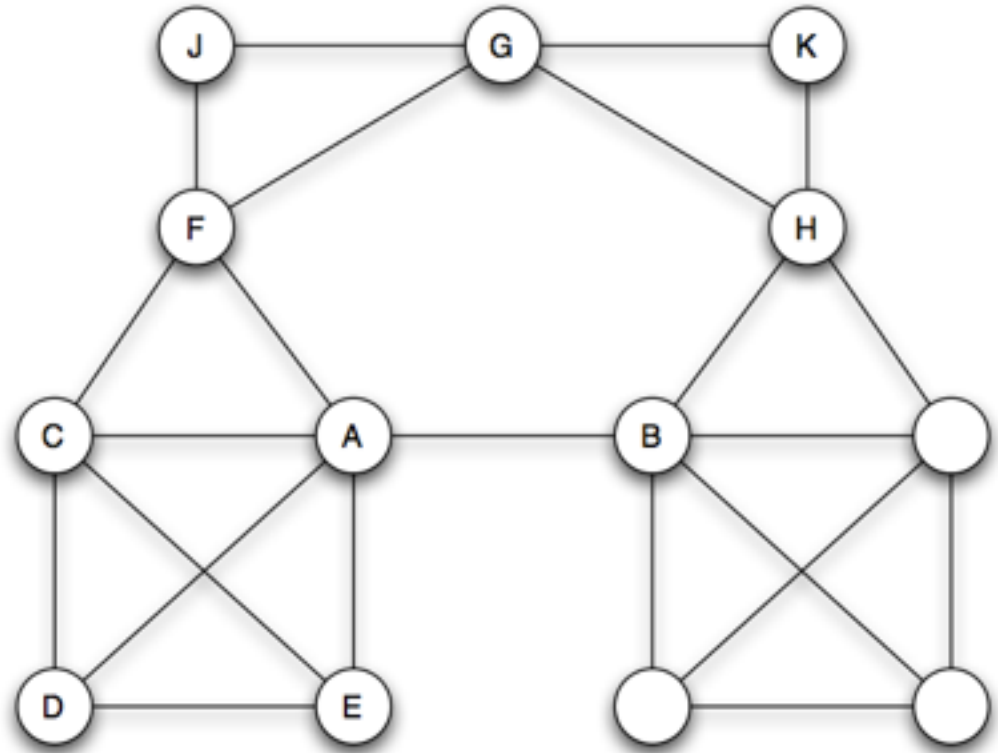
Triadic closure: Friends of Friends

- If two people have a friend in common, they are more likely to become friends
 - *Triadic closure*
- If B & C both know A
 - They are likely to meet, may be for extended time
 - Likely to trust each-other



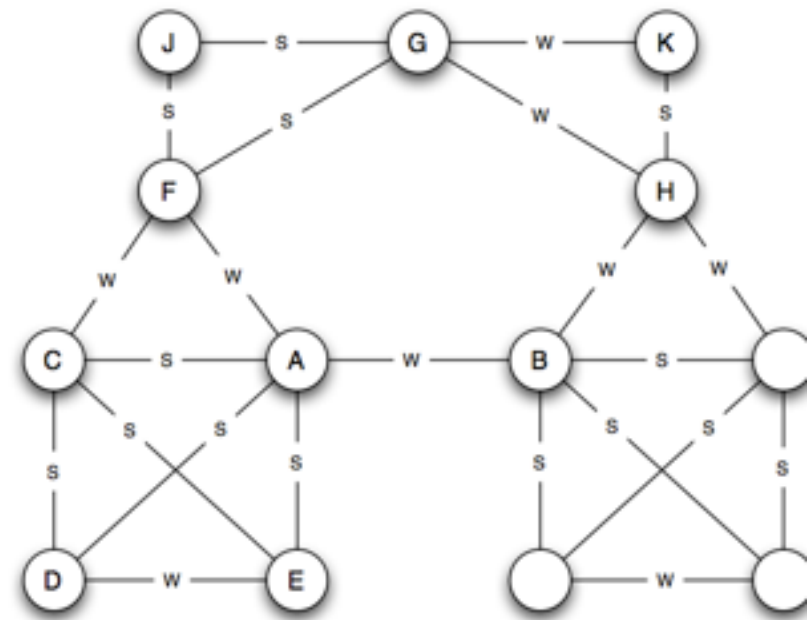
Bridges

- Bridge: Removing a bridge will disconnect network
 - Rare in real networks
- Local bridge (A, B): If A, B have no friends in common
 - Deleting (A, B) will increase distance to $d > 2$
 - d is called the *span* of the bridge (A, B)



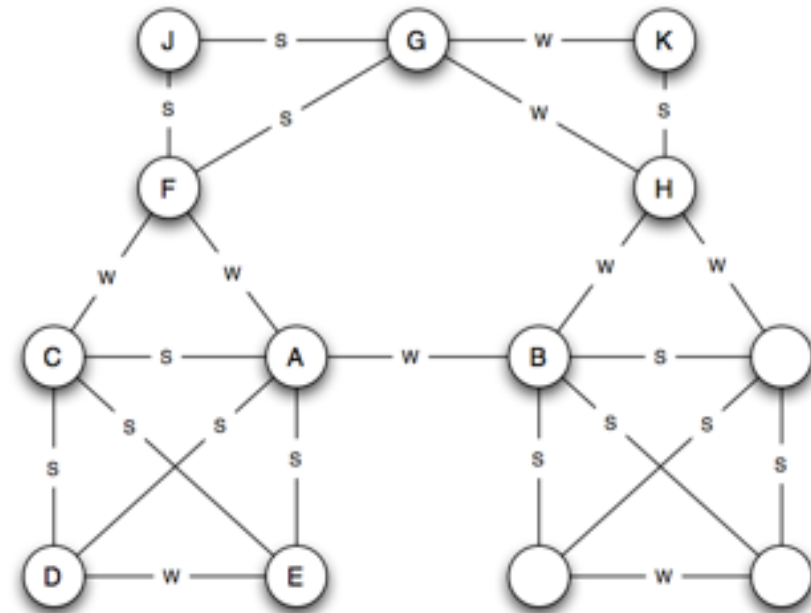
Strong triadic closure

- Suppose we know some ties to be strong, some to be weak
 - For some definition of strong/weak
- Strong triadic closure: If ab and bc are strong, then edge ac exists (may be weak, but it is there)



Strong triadic closure

- Theorem: if a network satisfies strong triadic closure and node A has ≥ 2 strong ties then any bridge involving A must be a weak tie.
- Proof: Easy!
- In real world, triadic closure is reasonably important
 - Many examples
 - People want their friends to be friends (otherwise it is hard to have groups)
 - Absence of triadic closure implies poor relation between friends, stress etc



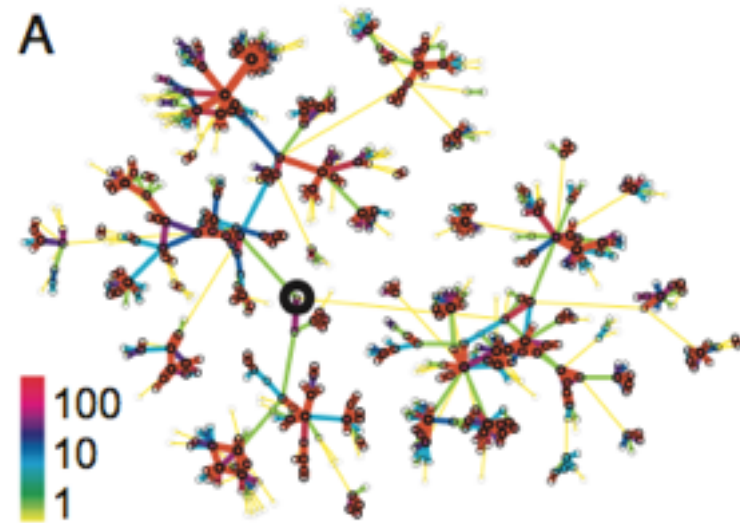
An experiment: Cell phone social net

- Network from phone conversations
- 18 weeks of all mobile calls for ~20% of US population, 90% had a mobile phone
- link: at least 1 reciprocating call.
- tie strength : aggregated duration of calls

- Onella et al. Structure and tie strengths in mobile communication networks. PNAS 2007

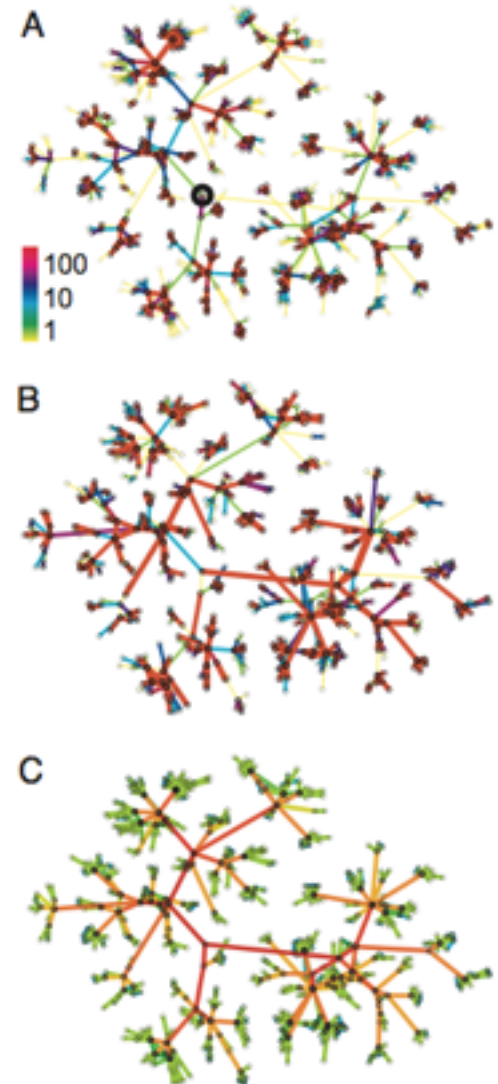
Observations

- Most people talk to few others, few talk to many people
 - Power law-like distribution
 - “Hubs” are relatively rare
- Strong ties are within clusters
- Onella et al. Structure and tie strengths in mobile communication networks. PNAS 2007



Possible network structures

- Efficiency: Inter-cluster ties are strong
 - Eg. Highways, Internet routers, water distribution, etc, to allow large flows (C)
- Dyadic: tie strength depends on individual relationship only
 - Simulated as random(B)
- Strength of weak ties (A)
 - Opposite of c
 - Argument: Social Information does not have a conservation requirement like transport or water



Other observations

- When strong ties are removed, network degrades slowly, but remains largely connected
- When the weak ties are removed, the network quickly and suddenly (phase transition) falls apart. i.e disconnects into chunks
- Experiment: Spread a rumor in this network. Anyone having the rumor is likely to transmit probabilistically: ie. More likely in a longer conversation
 - Observation: In majority of cases, people learn of it through ties of *intermediate strength*.

Neighborhood based tie strength

- $N_r(p)$: neighborhood of r hops centered at p .
Sometimes written as $B_r(p)$

- $N(p) = N_1(p)$

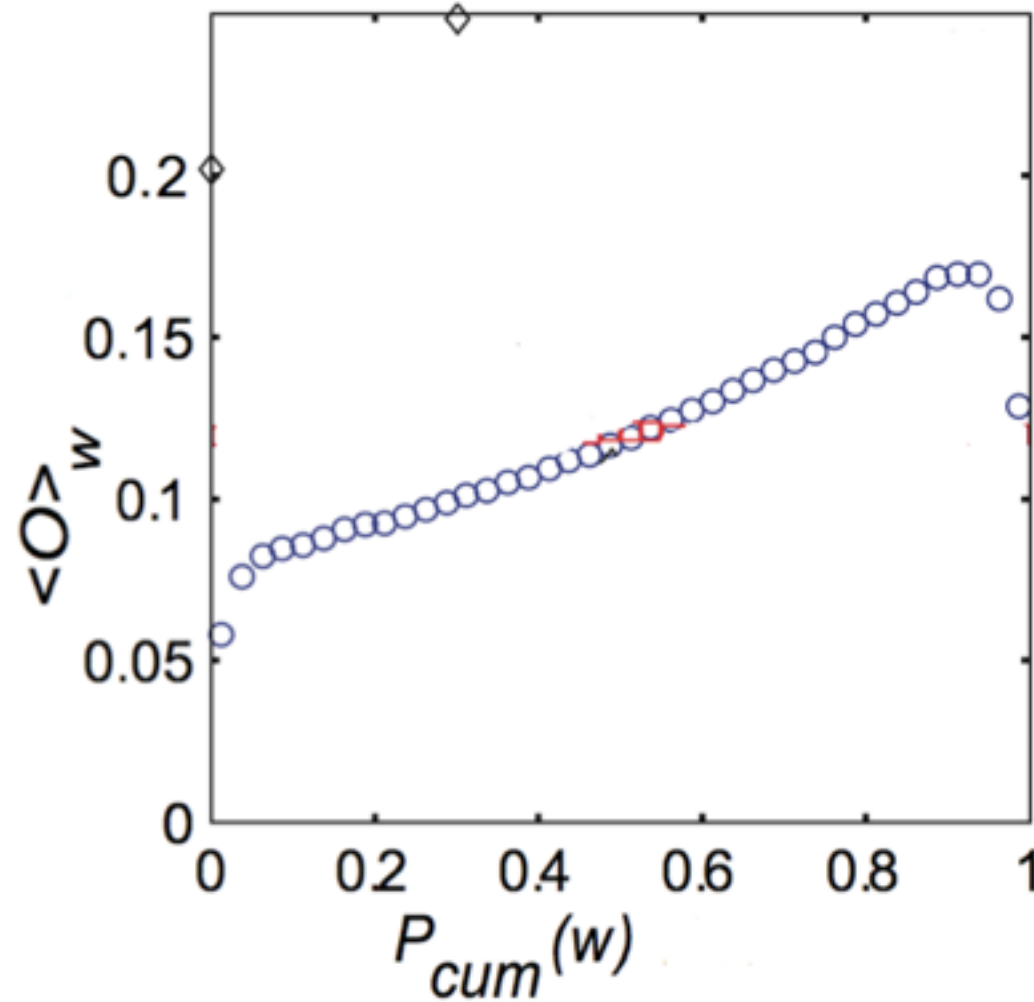
$$\frac{|N(a) \cap N(b)|}{|N(a) \cup N(b)|}$$

- Neighborhood overlap of ab :

$$\frac{|N(a) \cap N(b)|}{|N(a) \cup N(b)|}$$

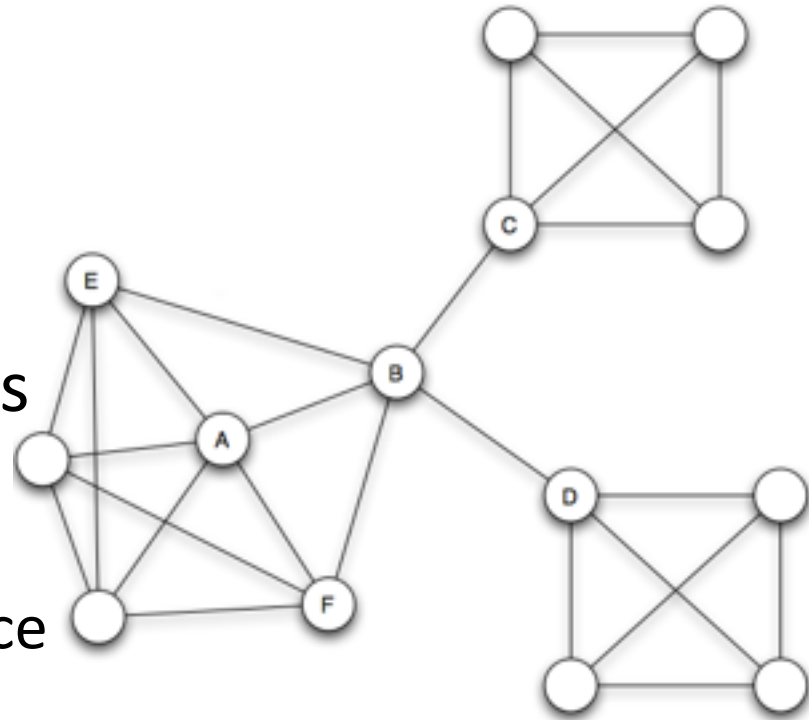
- A more continuous notion of strength
 - And derived from the network
 - Potential experiment : compare with other definitions of strengths
- Zero (or small, depending on definition of N) when ab is a local bridge

Neighborhood overlap Vs phone call duration



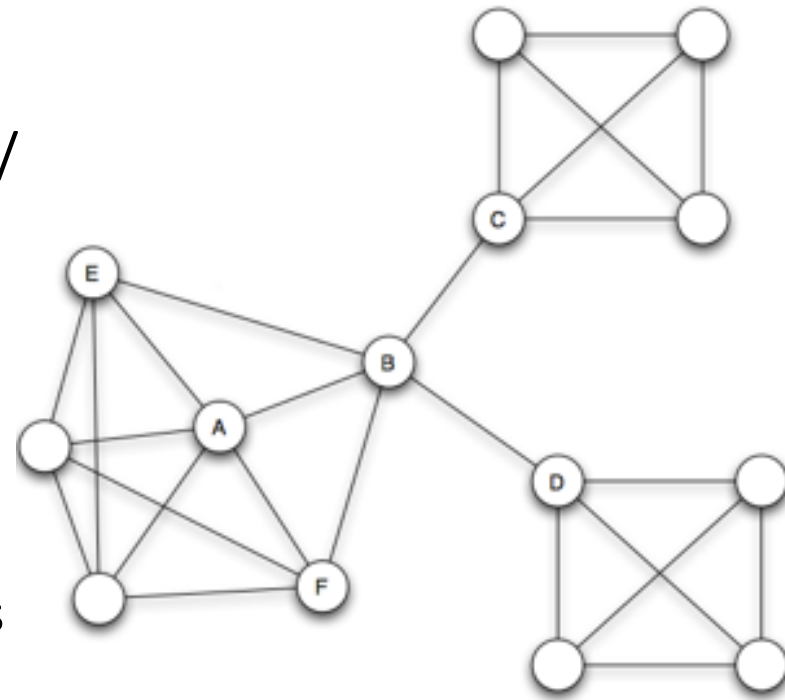
Embeddedness of an edge

- The number of common friends
- Higher embeddedness implies more people monitoring the relation
 - B does not want to cheat A since E will no longer trust B
 - But B can sacrifice relation with C without losing any direct friend



Structural holes

- B has is part of a bridge that spans a gap/ hole in the network
- B has early access to information from other parts of network
- Interesting ideas occur as synthesis of multiple ideas
- B has control over what the group learns from c and d
- B has reason to not allow triangles to form
- On the other hand, B's relations are not so protected by embeddedness
- How people actually behave in such situations is not well understood
 - Tension between closure and *brokerage*



Social capital

- The ability to secure benefits by virtue of membership (and position) in social networks or other social structures
- Sometimes used as a property of a group

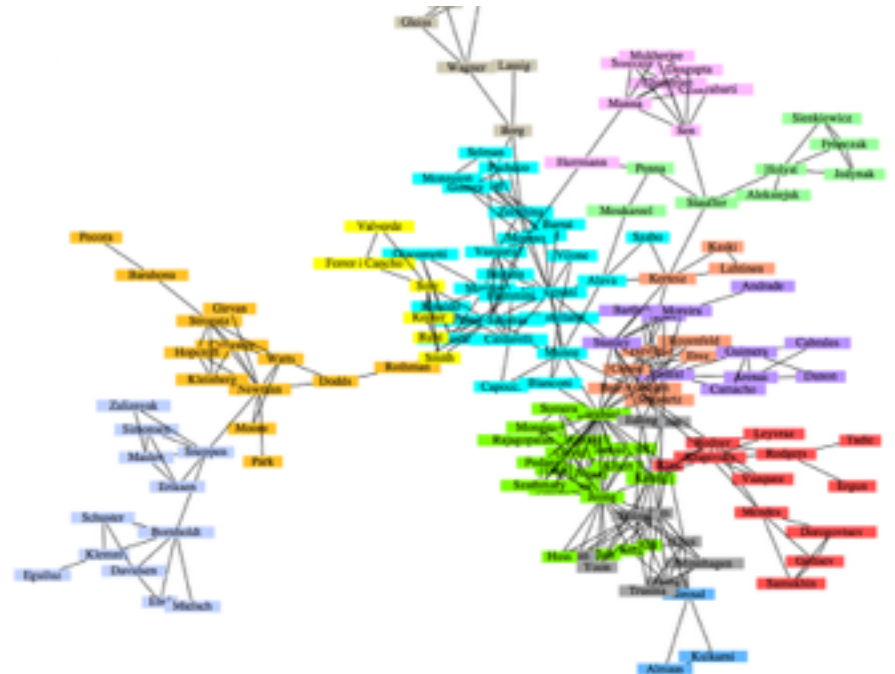
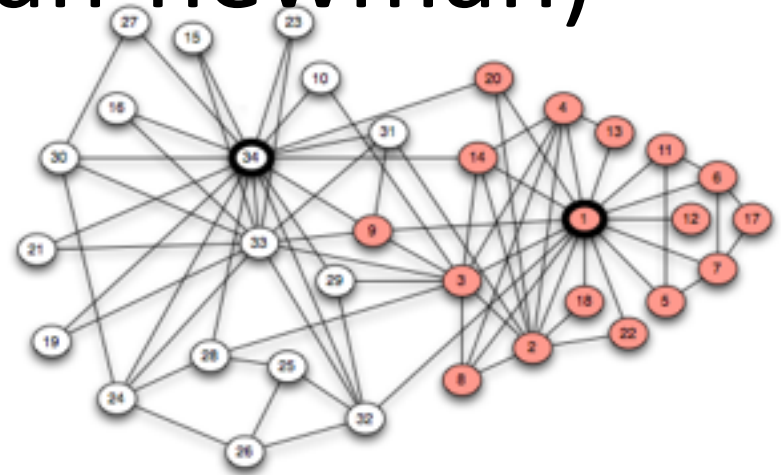
Betweenness & graph partitioning

- We want to split network into tightly knit groups (communities etc)
- Idea: Identify the “bridges” and remove them
- Bridges are “central” to the network
 - They lie on shortest paths
- Betweenness of edge (e) (or vertex (v)):
 - We send 1 unit of traffic between every pair of nodes in the network, and measure what fraction passes through e , assuming the flow is split equally among all shortest paths.

Partitioning (Girvan-newman)

Repeat:

- Find edge e of highest betweenness
- Remove e
- Produces a hierarchic partitioning structure as the graph decomposes into smaller components

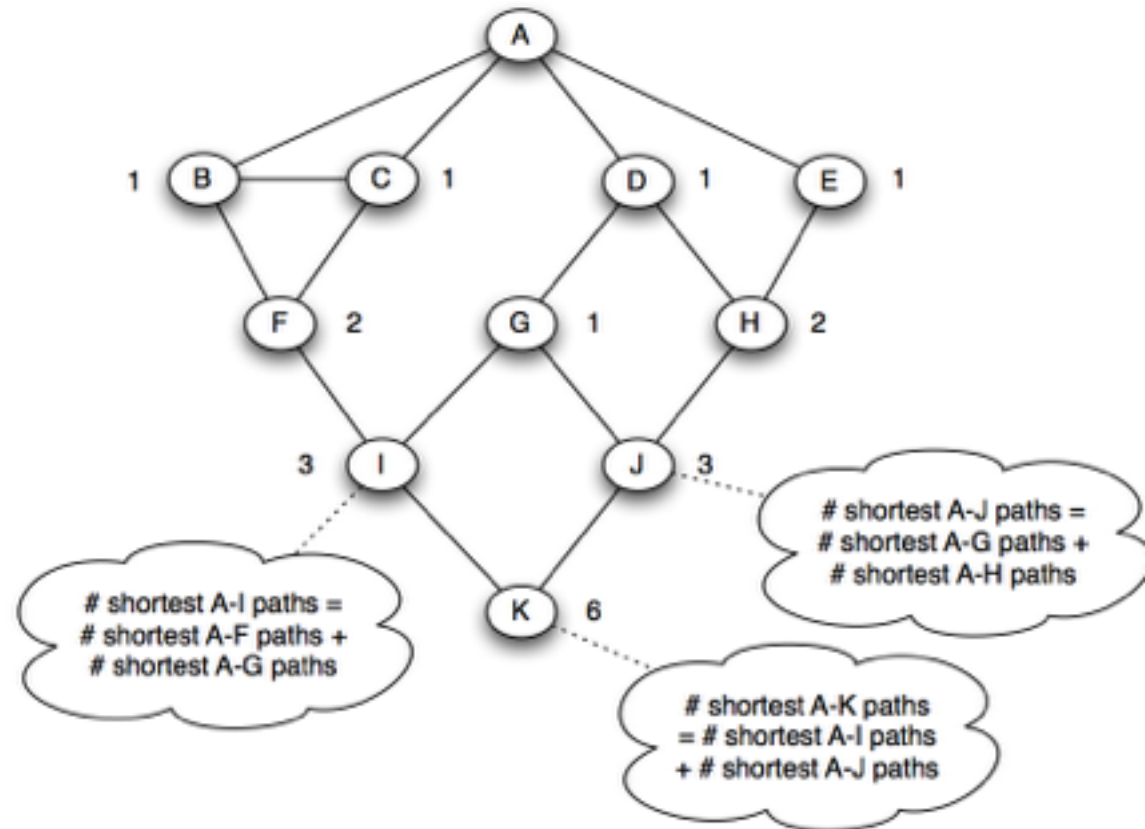


Computing betweenness

- Computing all shortest paths separately is inefficient
- A more efficient way:
- From each node:
 - Step 1: Compute BFS tree
 - Step 2: Find #shortest paths to each node
 - Step 3: Find the flow through each edge

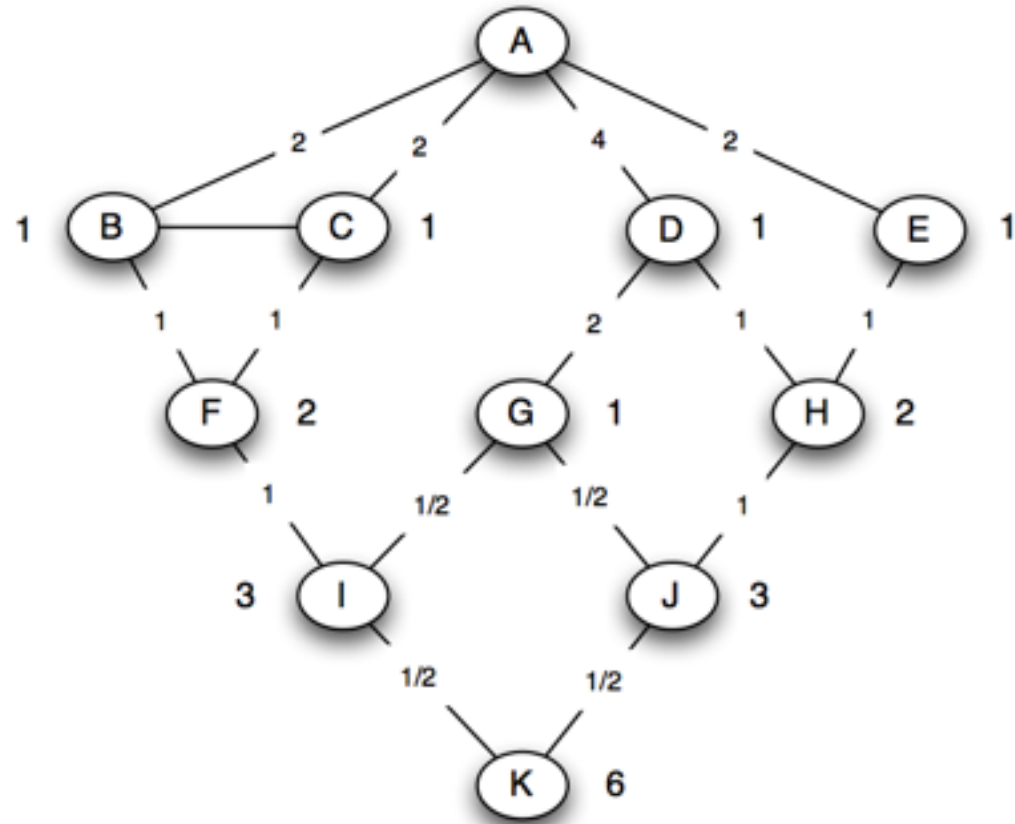
Computing betweenness

- From each node:
 - Step 1: Compute BFS tree layers
 - Step 2: Compute #shortest path to a node as sum of shortest paths to neighbors in previous layer of BFS



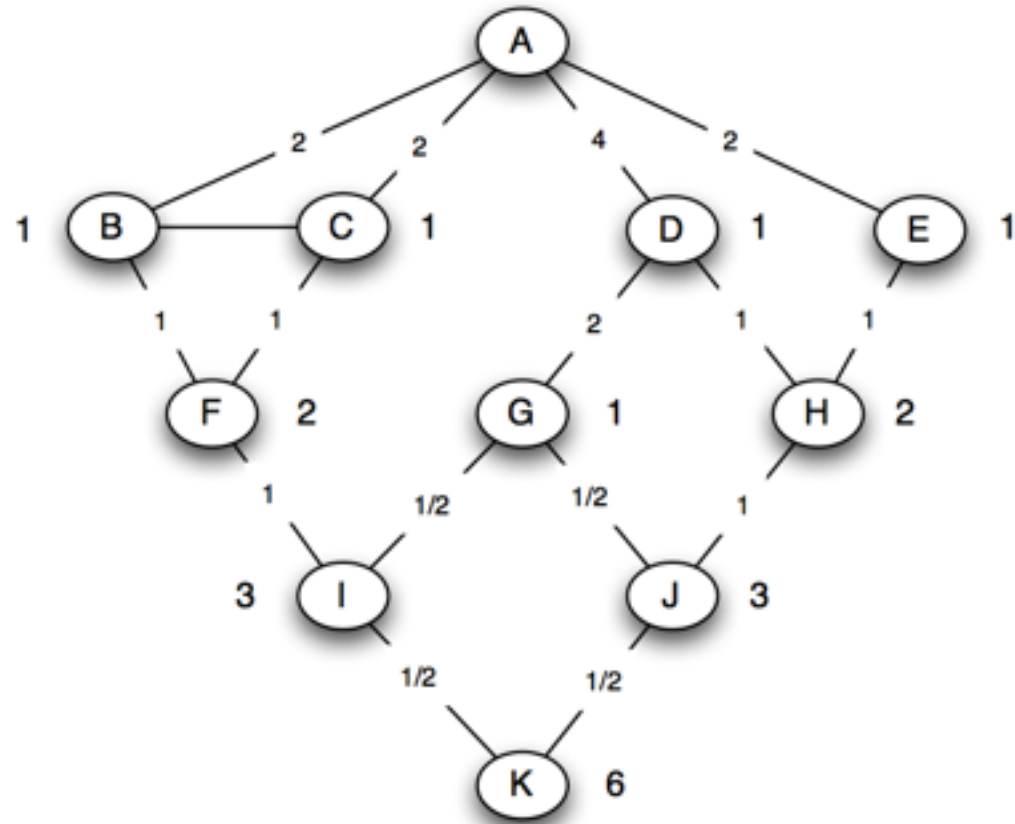
Computing betweenness

- Step 3: Work up from bottom layer: Every node receives 1 unit of flow for itself, plus whatever it needs to handle for nodes lower down



Computing betweenness

- Finally:
 - Do this for all nodes, and add up
- Complexity?



Other Centrality measures

- Degree centrality – nodes with high degree
- Eigen vector centrality (similar to pagerank)
- K-core:
 - A maximal connected subgraph where every vertex has degree k or more in the subgraph

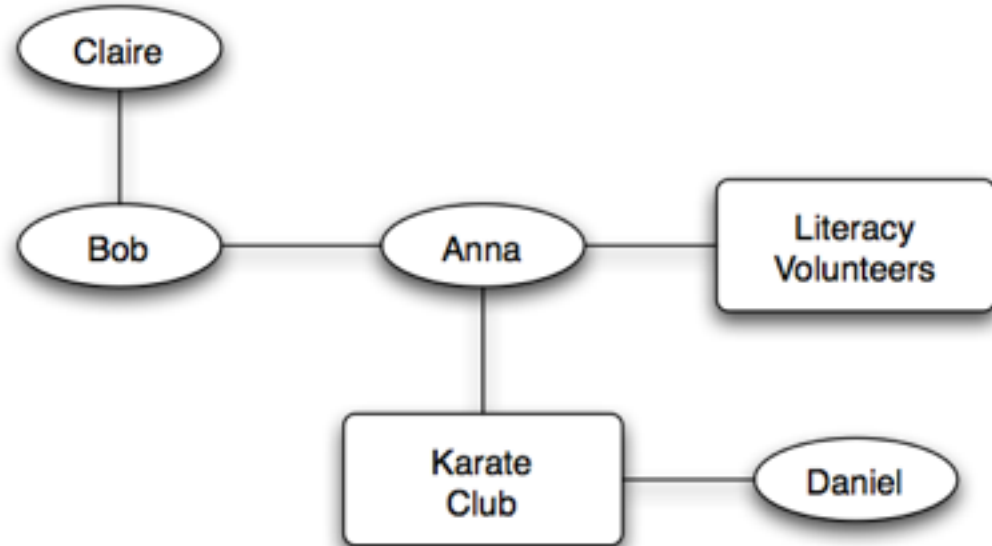
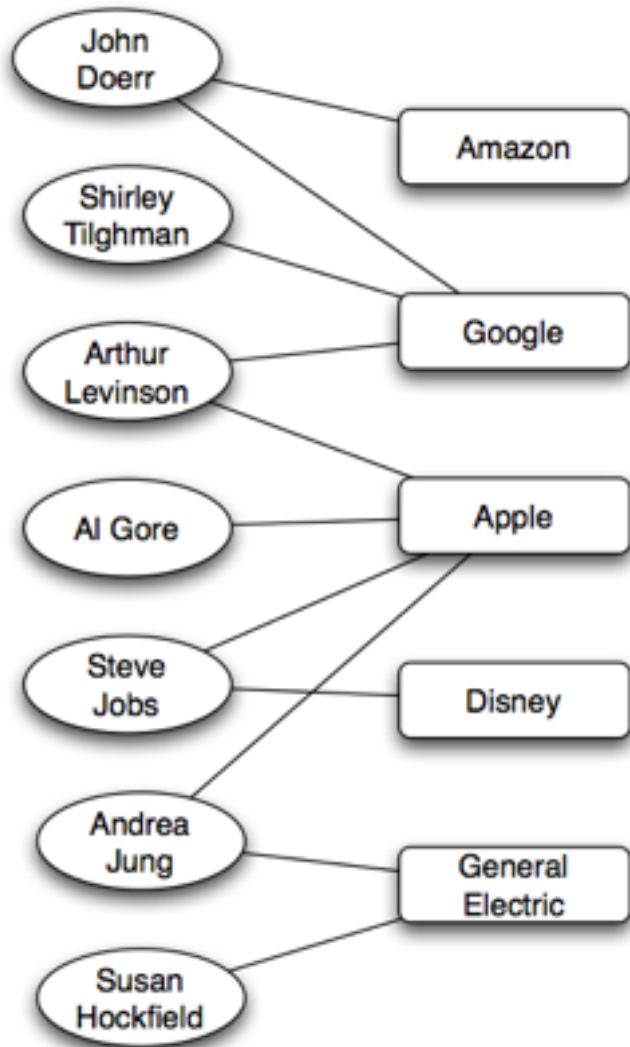
Homophily

- We are similar to our friends
 - Not always explained by things intrinsic to the network like simple triadic closure
- External contexts like Culture, hobbies, interests influence networks
- Suppose the network has 2 types of nodes (eg. Male, female), fractions p and q
 - Expected fraction of cross-gender edges: $2pq$
- A test for homophily:
 - Fraction of cross gender edges $< 2pq$

Homophily: The obesity epidemic

- Christakis and Fowler (See TED talk: hidden influence of social networks)
- Is it that:
 - People are selecting similar people?
 - Other correlated homophilic factors (existing food/cultural habits...) affecting data?
 - Are obese friends influencing the habits causing more people to be obese?
- Authors argue that tracking data over a period of time shows significant evidence of the influence hypothesis
 - It is an epidemic

Social foci: affiliation networks



Triadic closure in affiliation networks

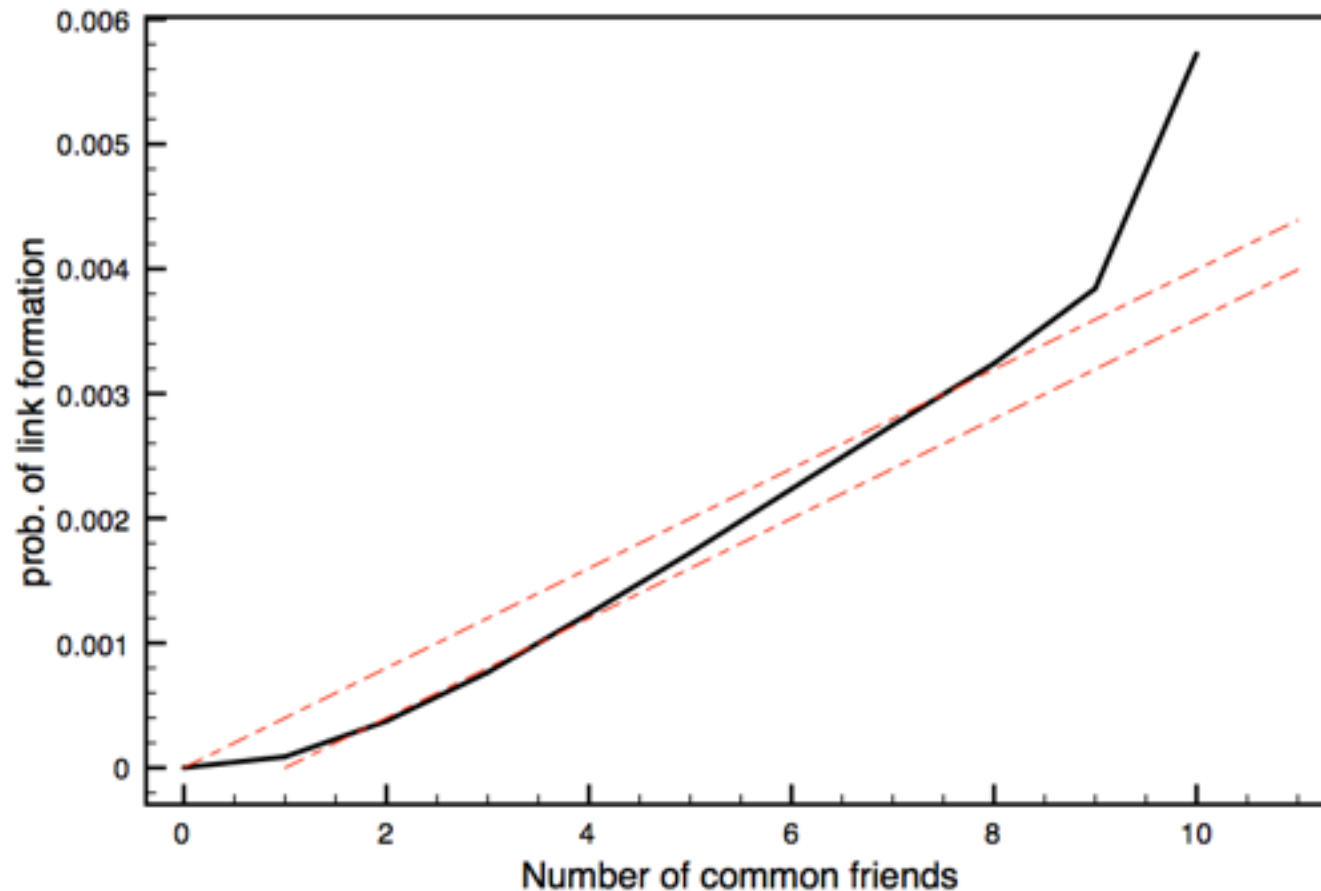
(i) Bob introduces Anna to Claire.

(ii) Karate introduces Anna to Daniel.

(iii) Anna introduces Bob to Karate.

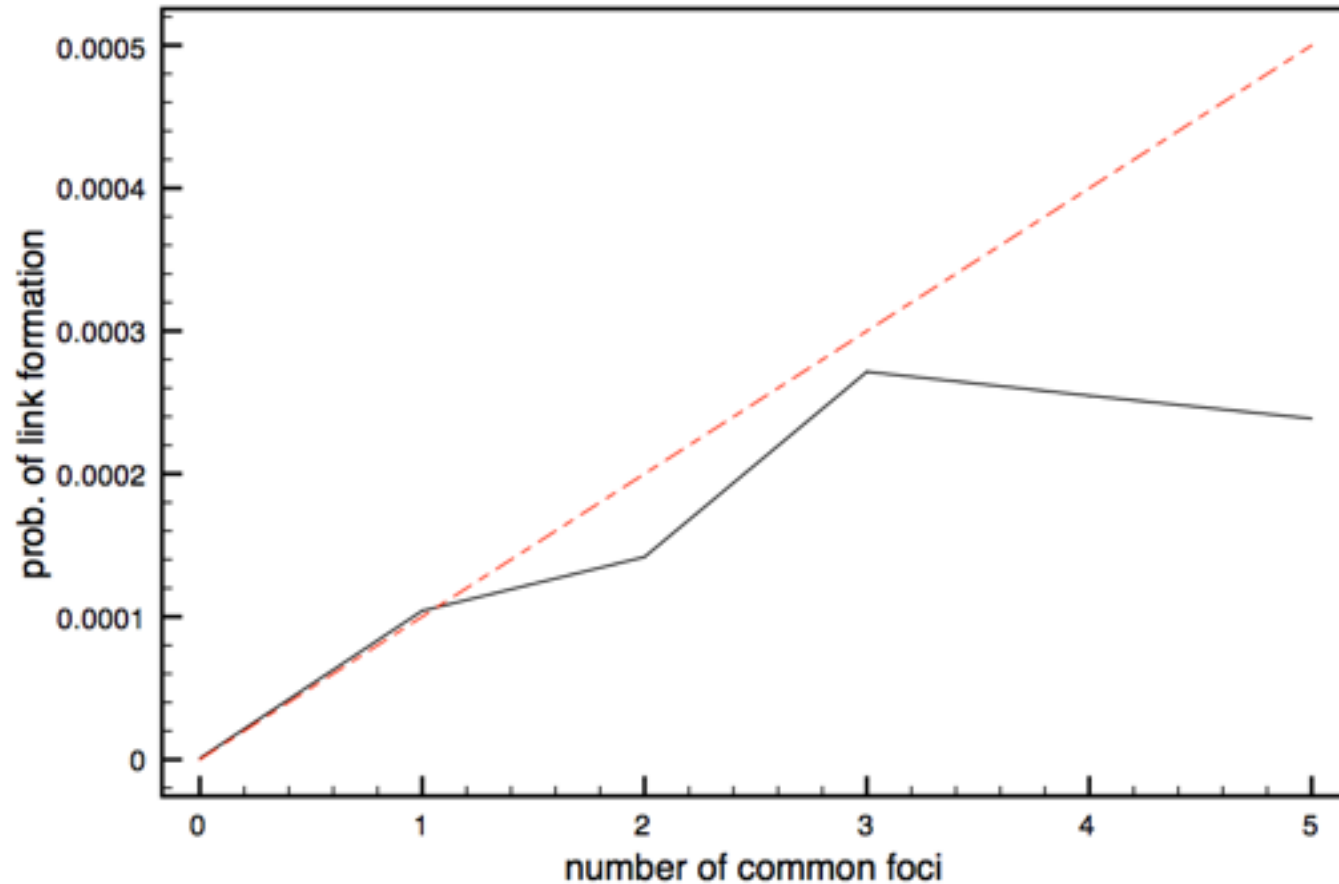
Triadic Closures

- From student email dataset



Focal closure

- Classes as foci



Membership closure

