Social and Technological Network Analysis

Lecture 2: Weak Ties and Community Detection

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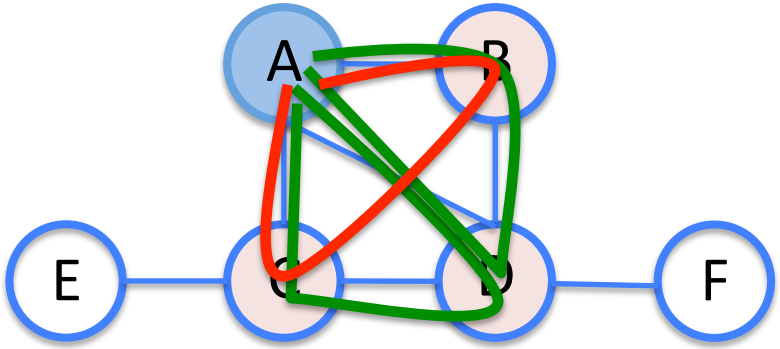
In This Lecture

- We will introduce the concept of weak ties and illustrate their importance
- From weak ties we will discuss some basic community detection methods

Again on Clustering Coefficient

- We have introduced the clustering coefficient. This indicates:
  - The number of triangles including node A.
  - How connected the friends of A are.
- **Triadic closure**: if C and B are connected to A there is an increased likelihood that they will be connected in future.



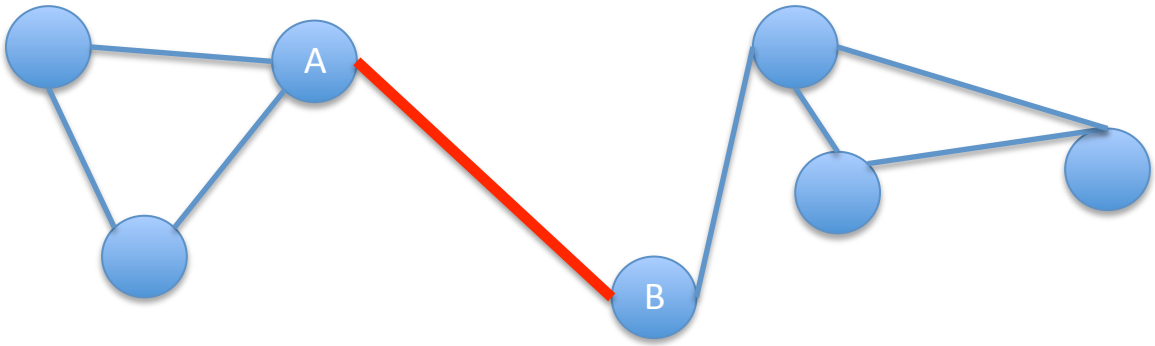
[Granovetter'74]

- Granovetter interviewed people about how they discovered their jobs
  - Most people did so through personal contacts
  - Often the personal contacts described as acquaintances and not close friends

- Basic intuition on this is: close friends are part of triad closures and would know what you know and would know others who would know what you know
- We will explain this more formally…

Bridges

- Edge between A and B is a **bridge** if, when deleted, it would make A and B lie in 2 different components



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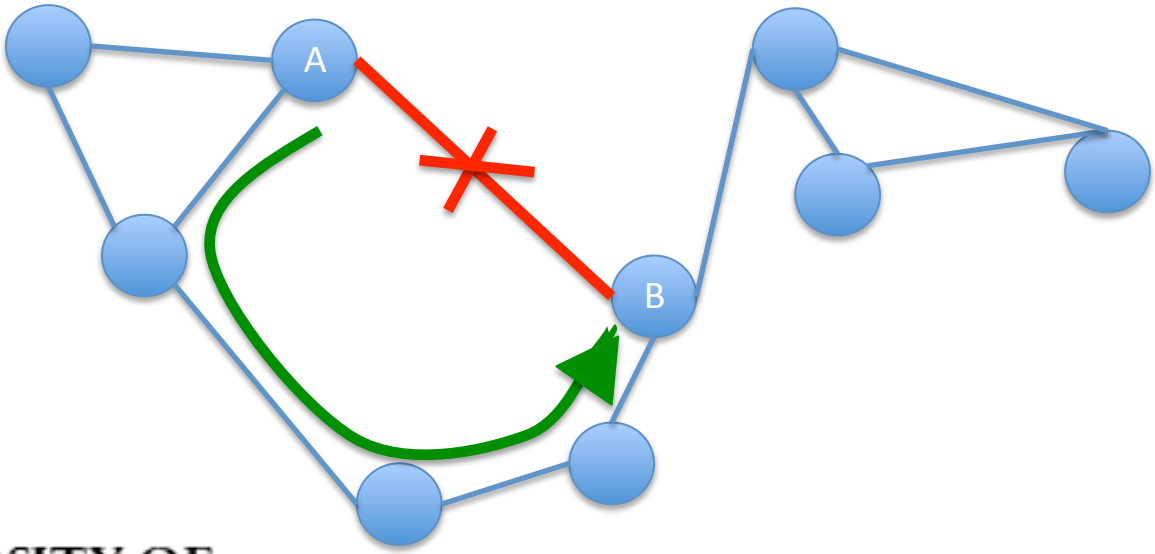
Local Bridges

- An edge is a local bridge if its endpoints have no friends in common
  - If deleting the edge would increase the distance of the endpoints to a value more than 2.



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Strong Triadic Closure Property (STPC)

- Links between nodes have different "value": **strong and weak ties**
  - E.g: Friendship vs acquaintances

- **Strong Triadic Closure Property (Granovetter)**: If a node has two strong links (to B and C) then a link (strong or weak) must exist between B and C.

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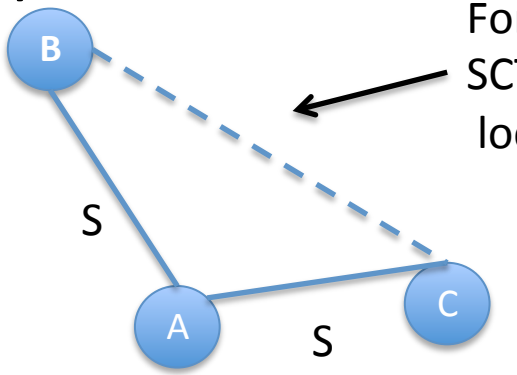
Local Bridges and Weak Ties

- If node A satisfies the SCTP and is involved in at least two strong ties then any local bridge it is involved in must be a weak tie. (Proof by contradiction)



For AC and AB to be a strong link
SCTP says BC must exist but
local bridge definition says it must not

- **Local bridges must be weak ties**

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Real Data Validation

- Granovetter's theory remained not validated for years for large social networks due to the lack of data.
- [Onnela et al '07] tested it over a large cell-phone network (4 millions users):
  - Edge between two users if they called each other within the 18 months period.
  - Data exhibits a giant component (84%).
  - *Edge weight: time spent in conversation.*

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Onnela et al. 2007

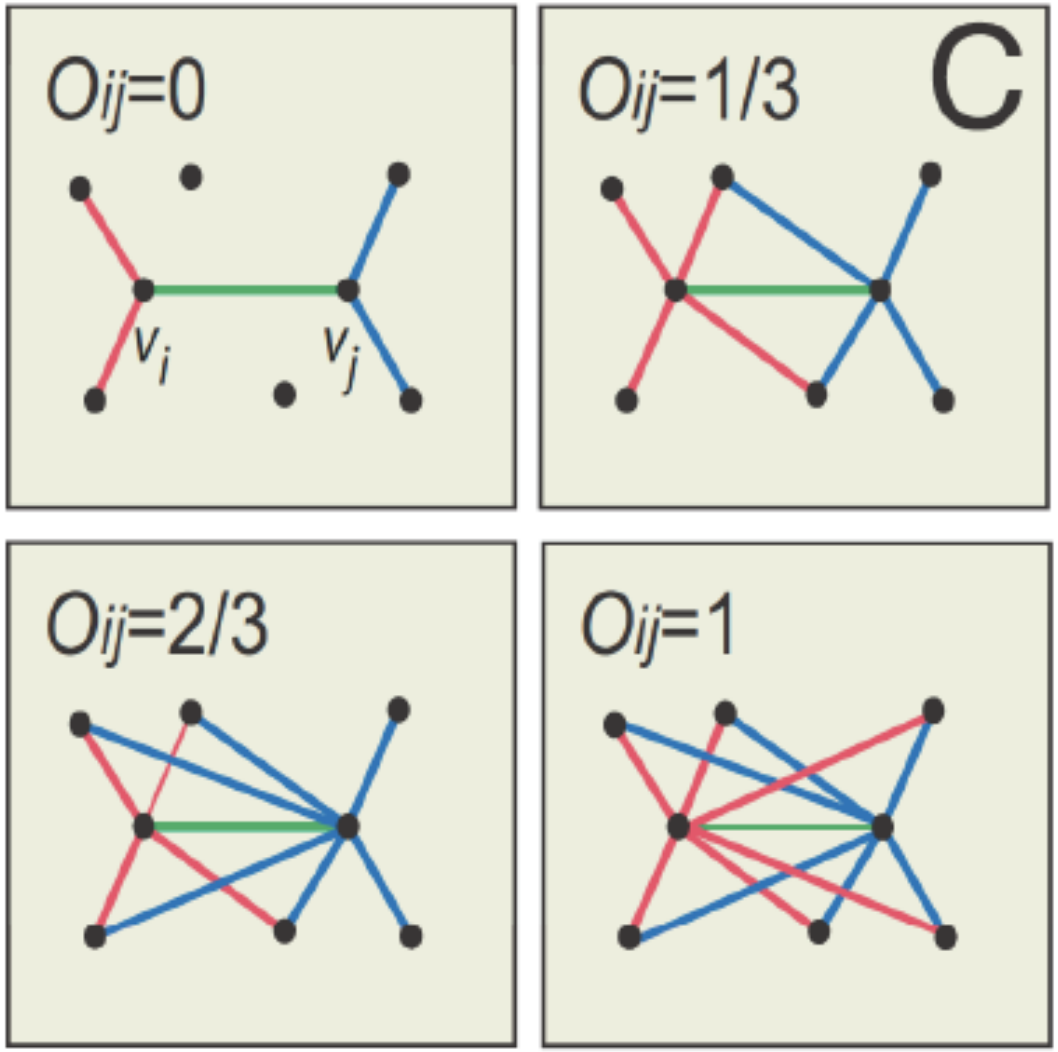
- Extending the definition of local bridge
- Given:

- **Neighbourhood overlap:**

$$\frac{\text{Number of nodes who are neighbours of both A \& B}}{\text{Number of nodes who are neighbours of at least A or B}}$$

- When the numerator is 0 the quantity is 0.
  - Numerator is 0 when AB is a local bridge
- The definition finds "almost local bridges" (~0)

Neighbourhood overlap



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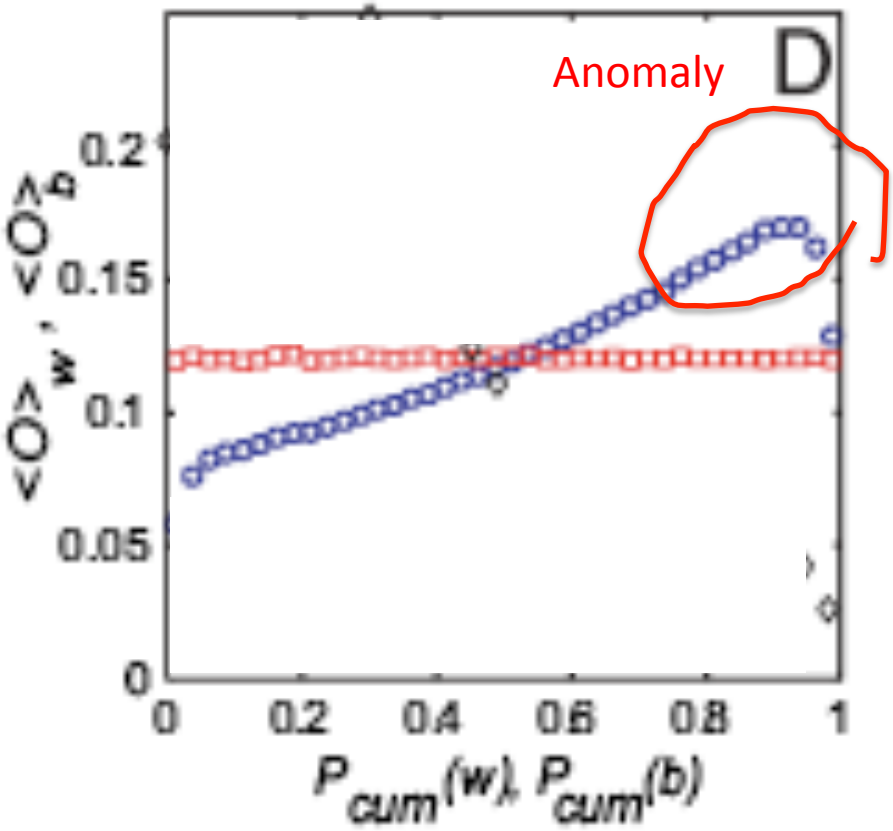
Relationship of Overlap with Tie Strength

- Red: random shuffled weights over links.
- Blue: real ones. Correlation with tie strength.



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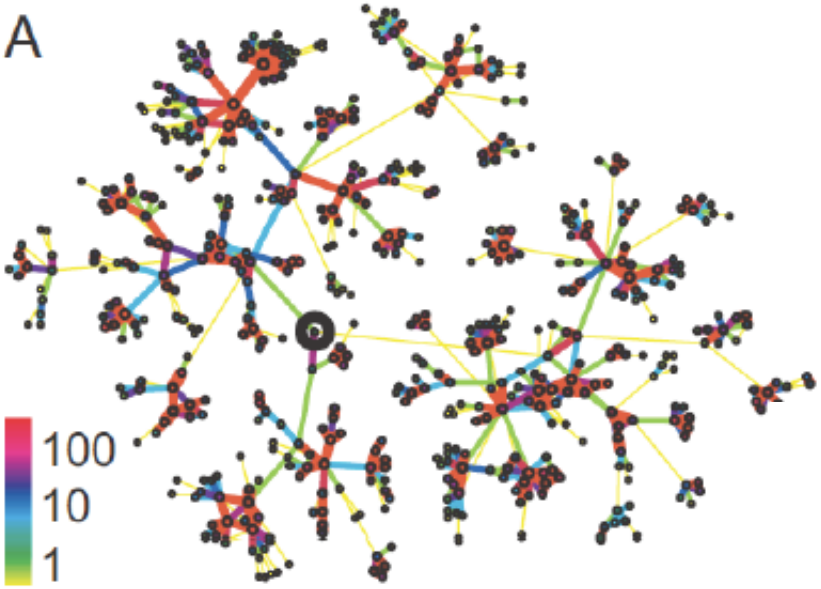
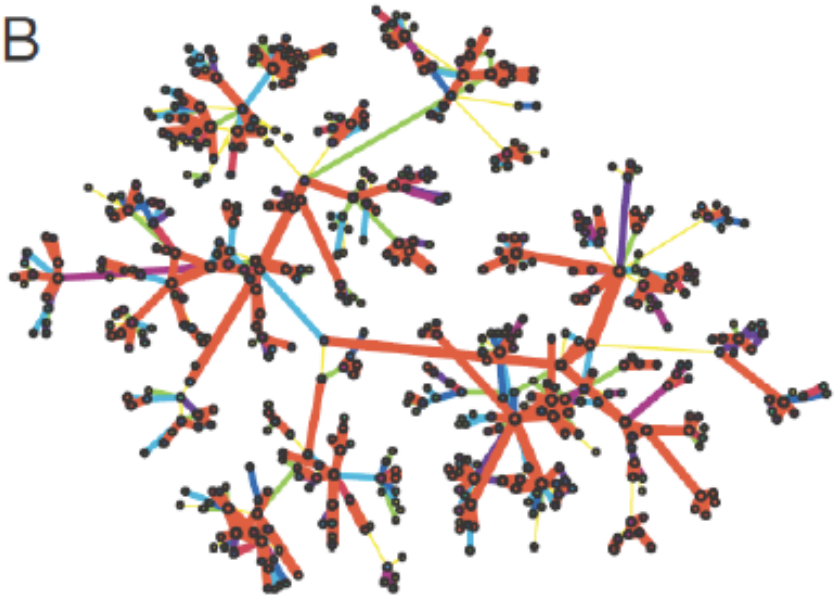
Real tie weights in a portion of the graph (around a random node)



A= Real

B= Randomly shuffled



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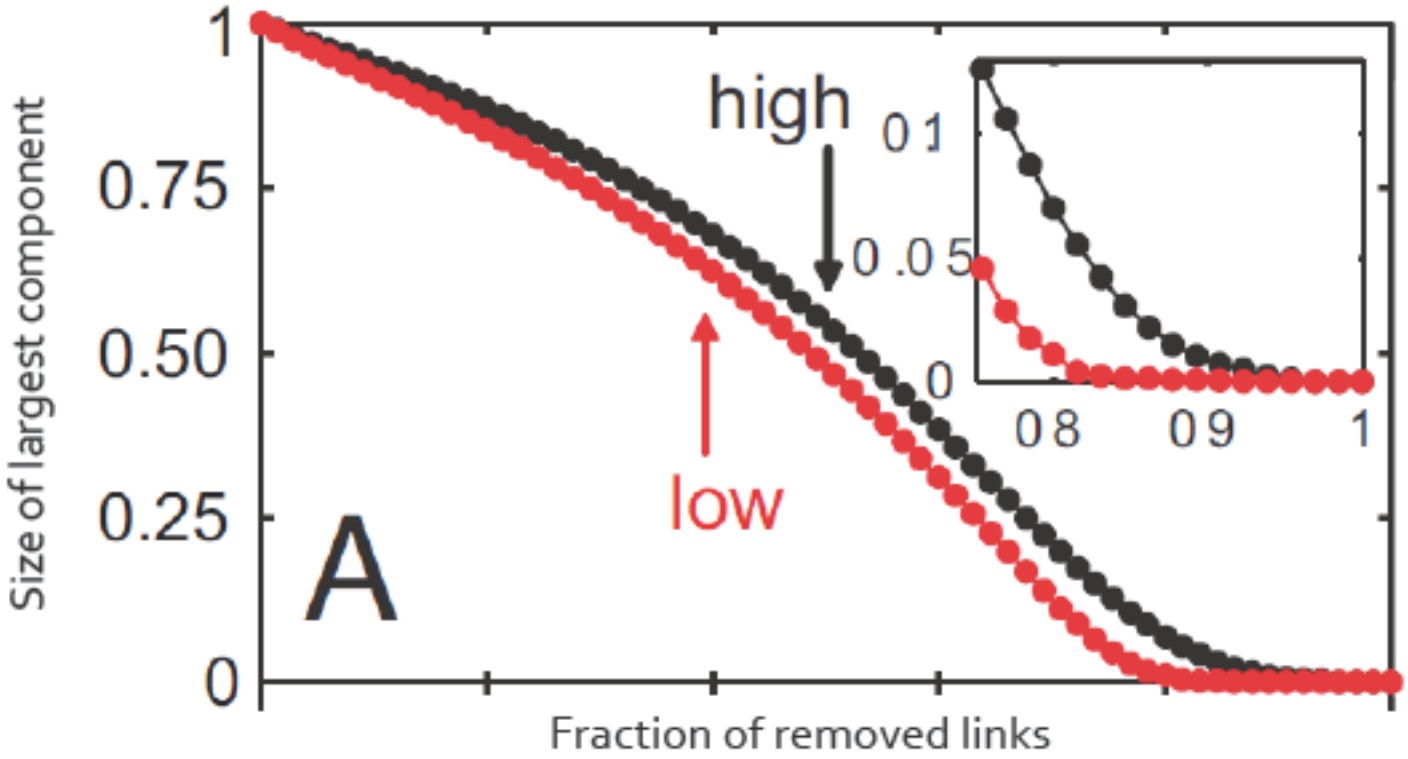
Effect of edge removal



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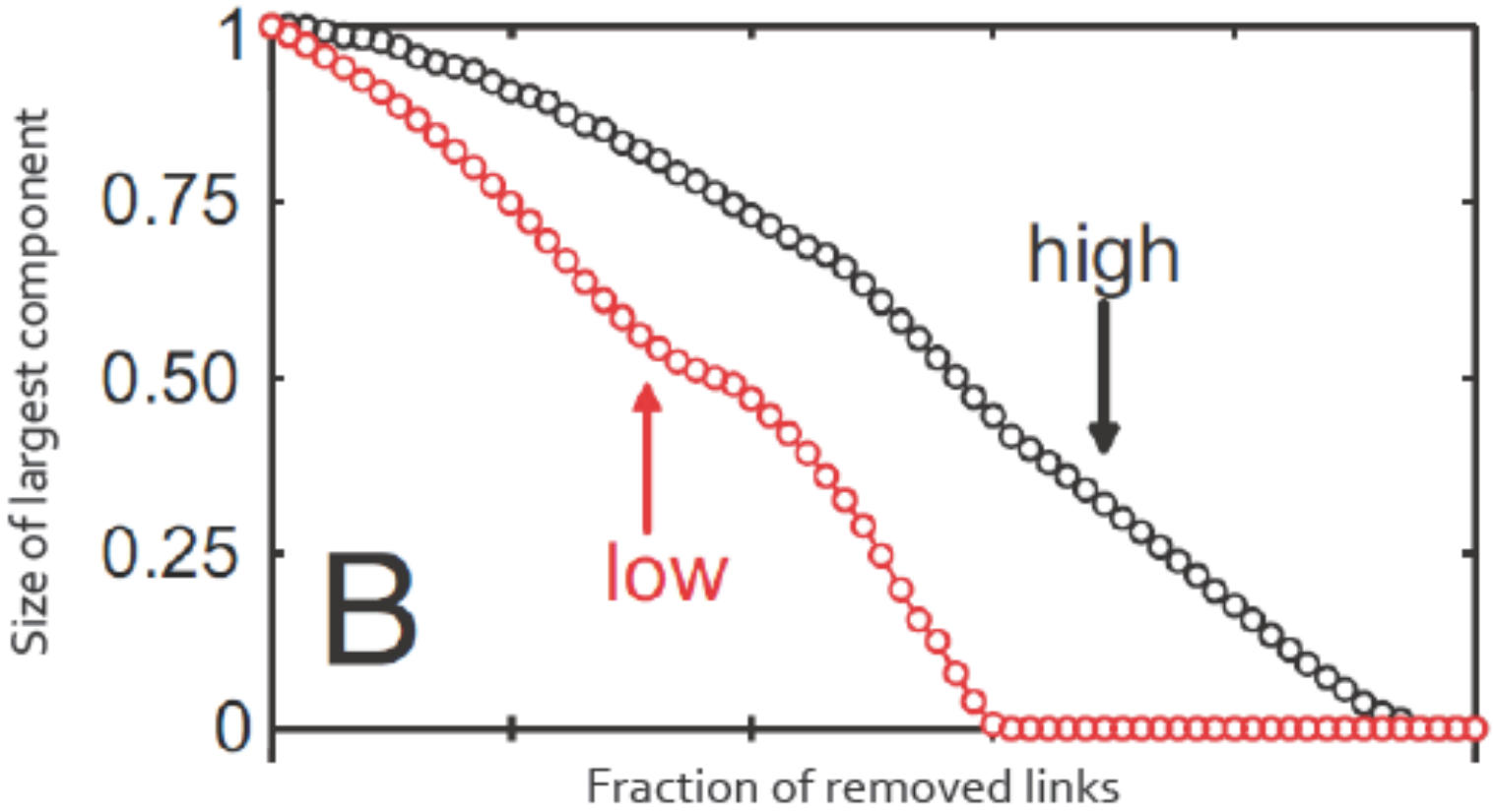
Overlap based link removal



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Weak ties matter!

- We have just seen that weak ties matter and if they are removed, they lead to a breakdown in the network.

- If strong ties are removed they lead to a smooth degrading of the network

Facebook Example

- Facebook data analysis of one month of data
- Four networks:
  - Declared friendship
  - Reciprocal communication (messages)
  - One way communication
  - Maintained relationship: clicking on content on news feed from other friend or visiting profile more than once.

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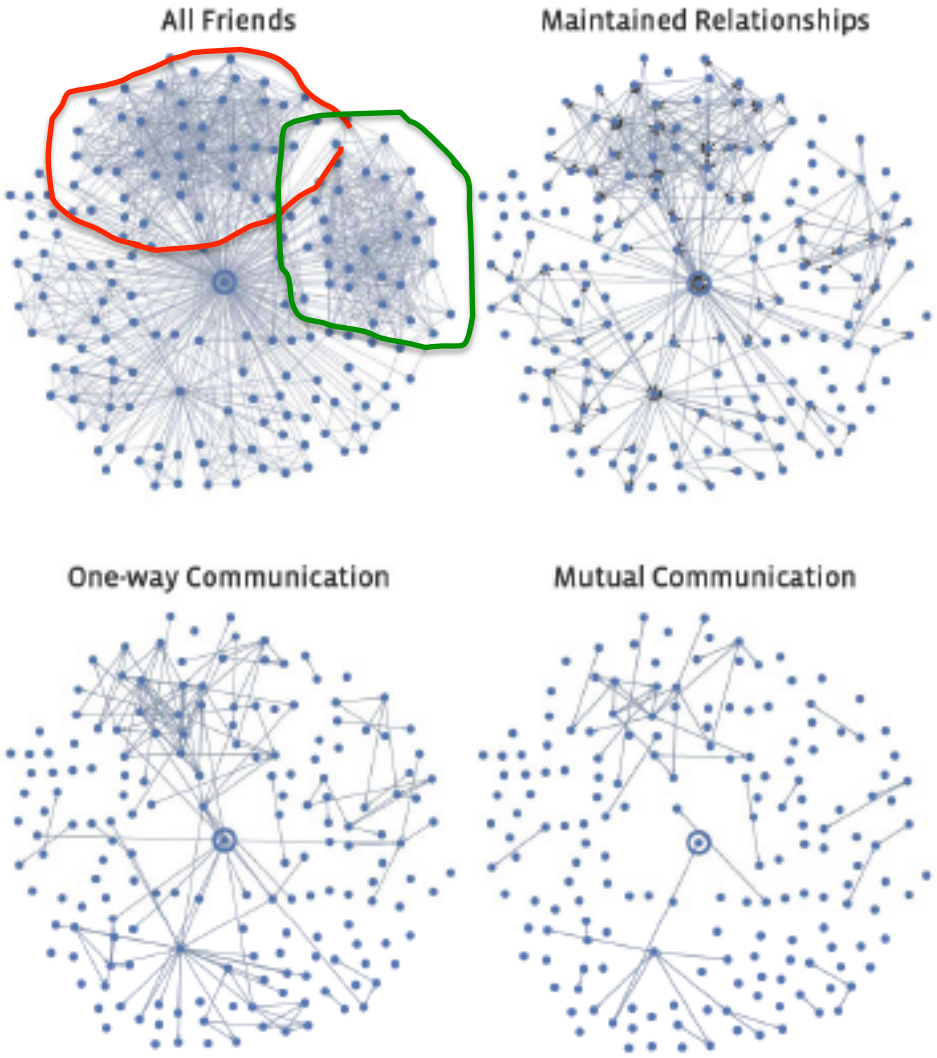
What does it look like? (one random user)



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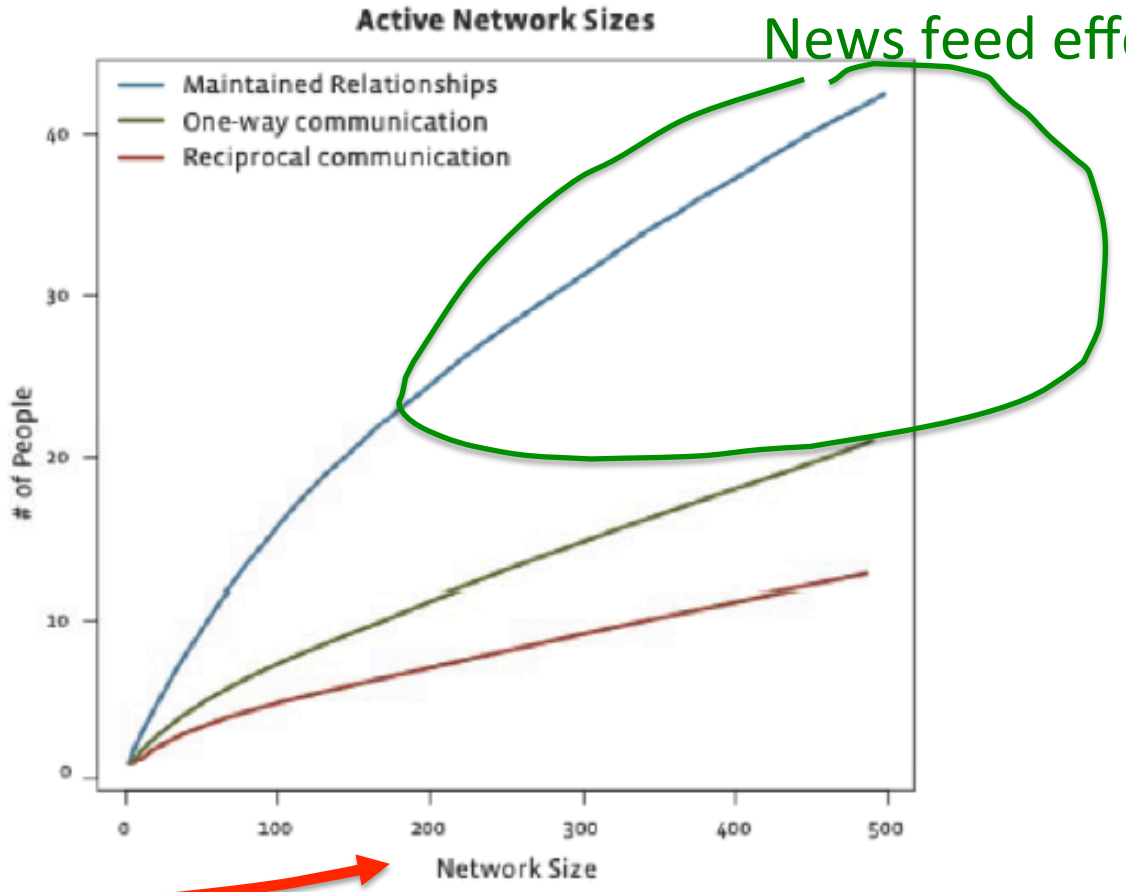
Active Network Size: number of links



News feed effect

Declared friends

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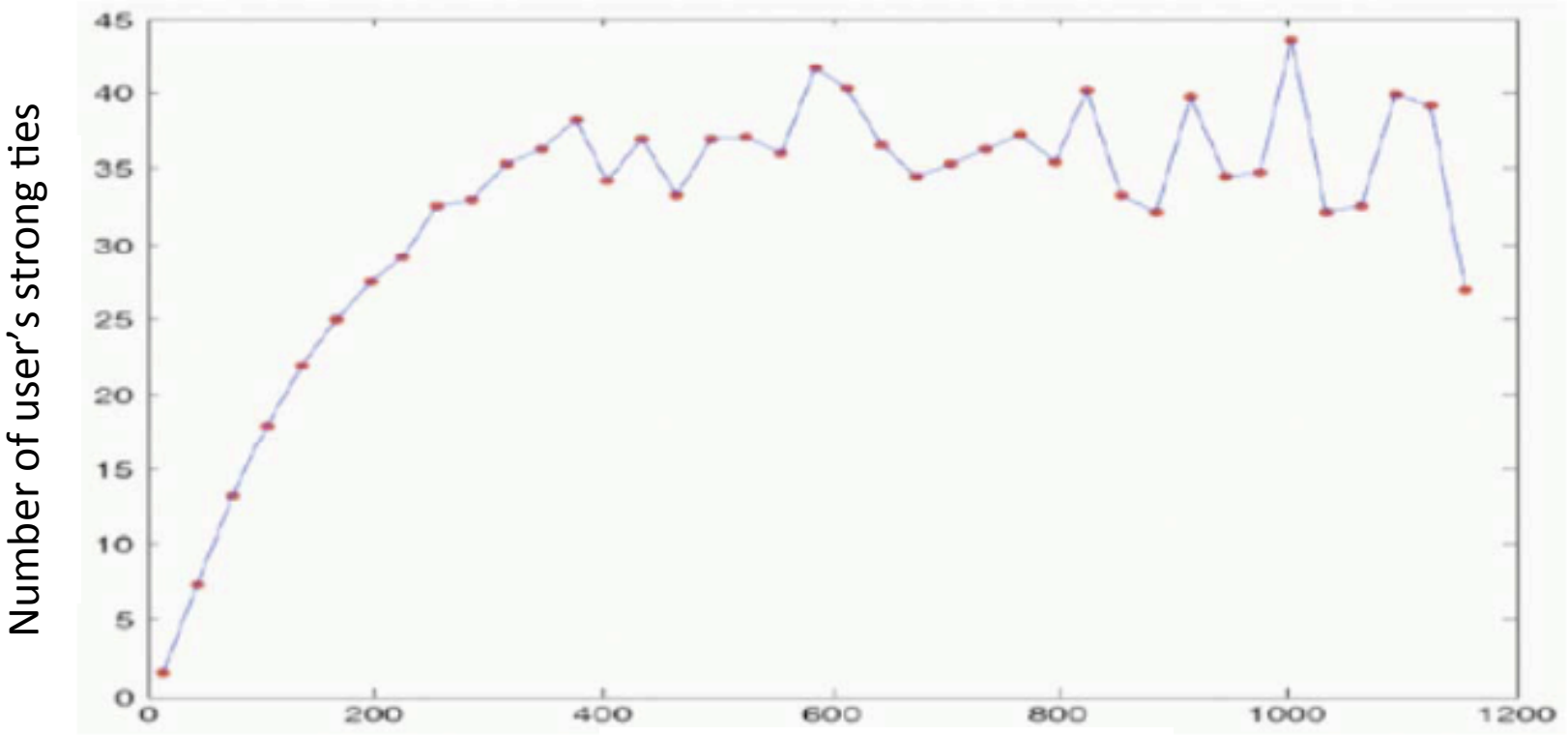
Twitter Analysis

- Huberman at al. have analyzed strong and weak ties in Twitter.
- The "followers" graph in Twitter is directed
  - Someone can follow someone else who does not follow him
- Messages of 140 chars can be posted
- Messages can be addressed to specific users (although they stay readable to all)
- **Weak ties**: users followed
- **Strong ties**: users to whom the user sent at least 2 messages in the observation period

Twitter



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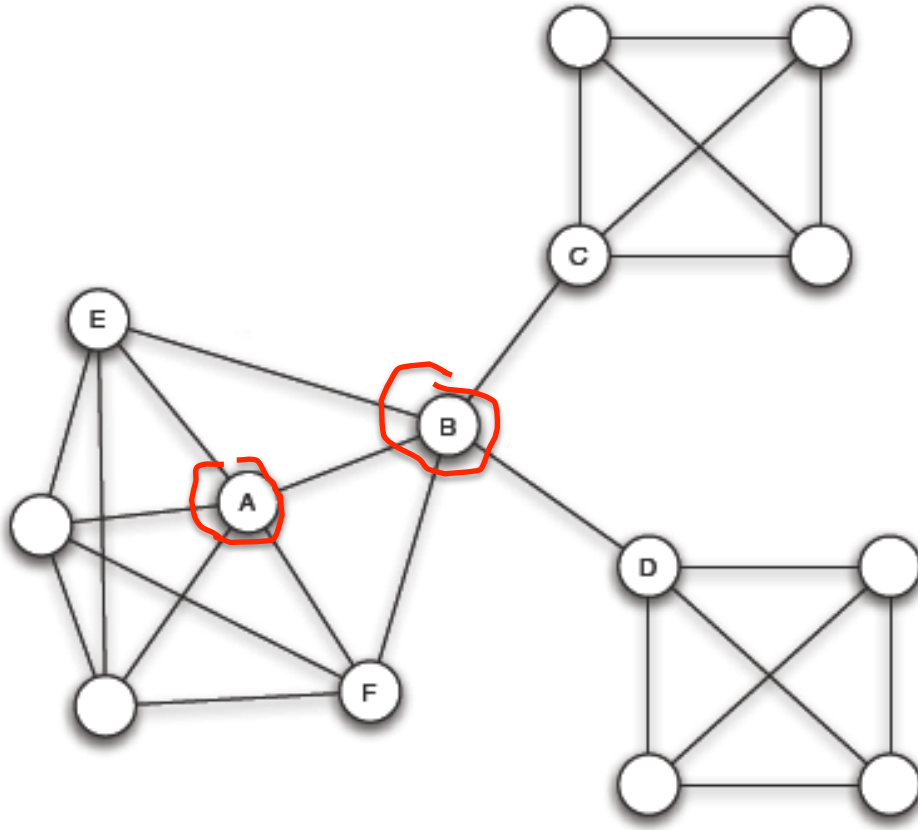
Number of strong ties stays below ~50

Embeddedness

- Emdeddedness of an edge: number of common neighbours of the 2 end points.
- A-B value is 2
- A has high clust. coeff.
- B *spans a structural hole*
- Local bridges have

Embeddedness of 0



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Weak ties and Communities

- Weak ties seem to bridge groups of tightly coupled nodes (communities)
- How do we find these communities?

Why do we want to find partitions/communities?

- Clustering web clients with similar interest or geographically near can improve performance
- Customers with similar interests could be clustered to help recommendation systems
- Clusters in large graphs can be used to create data structures to efficient storage of graph data to handle queries or path searches
- Detect artificial improvements of PageRank
- Study the relationship/mediation among nodes
  - Hierarchical organization study

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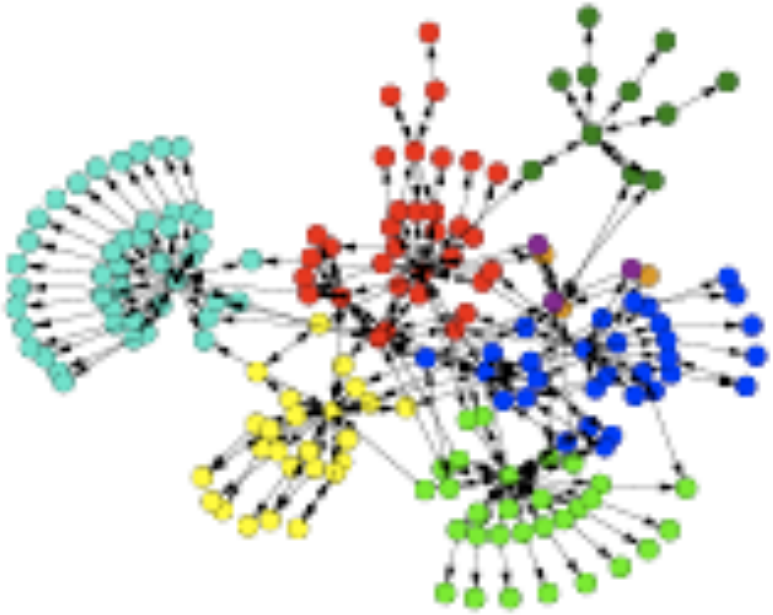
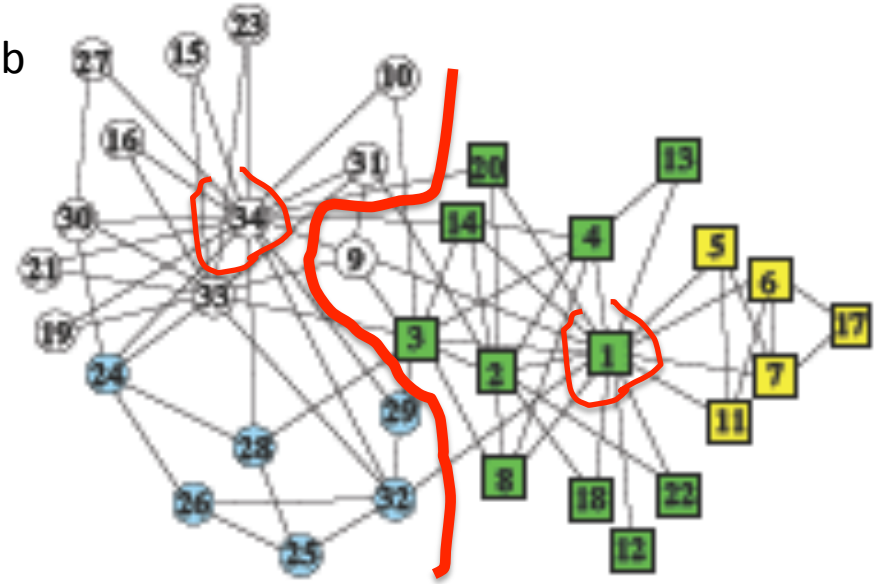
Example

Zachary's Karate club: 34 members of a club over 3 years. Edges: interaction outside the club





WWW: pages and hyperlinks
Identification of clusters can improve pageranking

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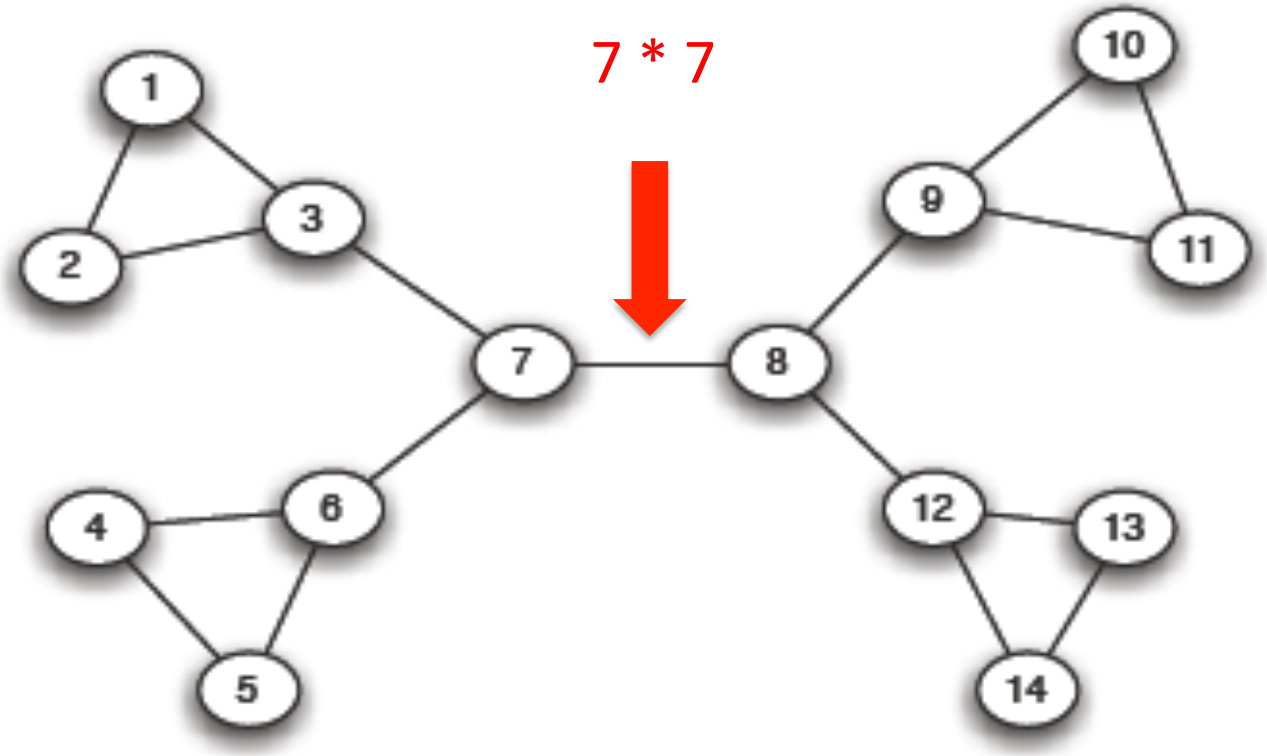
Remove weak ties

- Local bridges connect weakly interacting parts of the network
- What if we have many bridges: which do we remove first? Or there might be no bridges.

- Note: **Without those bridges paths between nodes would be longer**

Edge Betweenness

- Edge Betweenness: the number of shortest paths between pairs of nodes that run along the edge.



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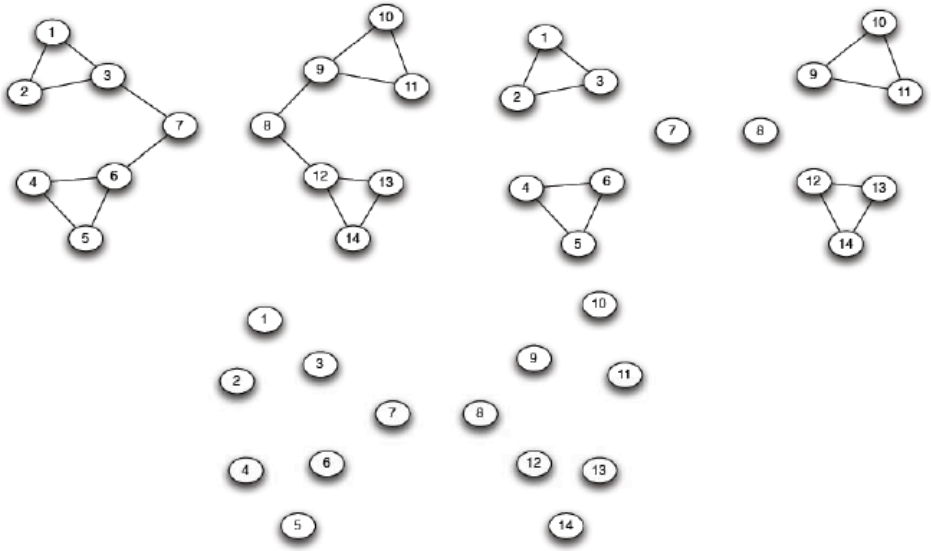
Algorithm of Girvan-Newmann (PNAS 2002)

- Calculate the betweenness of all edges
- Cut the edge with highest betweenness
- Recalculate edge betweenness



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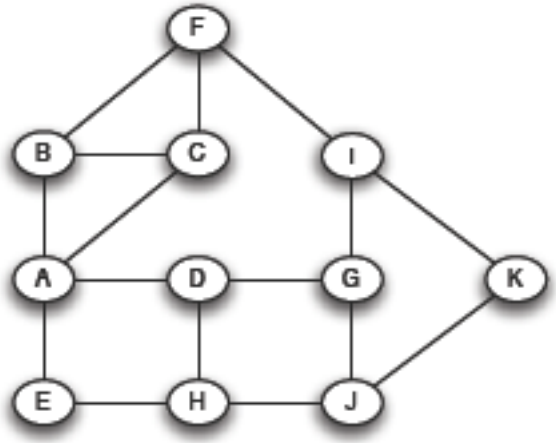
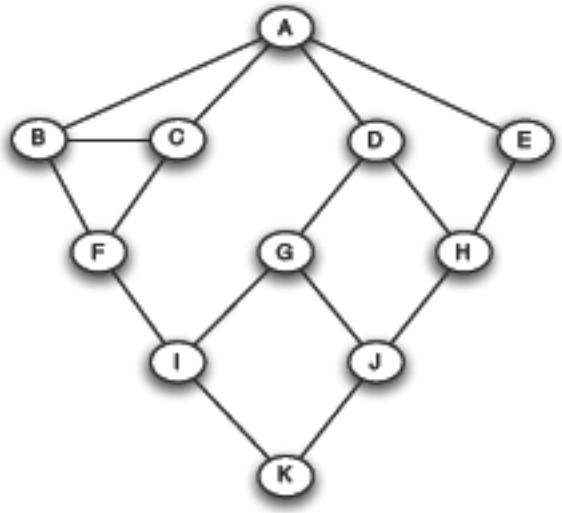
How is the betweenness computed?

- Calculate the shortest paths from node A
  - BFS search from A.
  - Determine number of shortest paths from A to each node.





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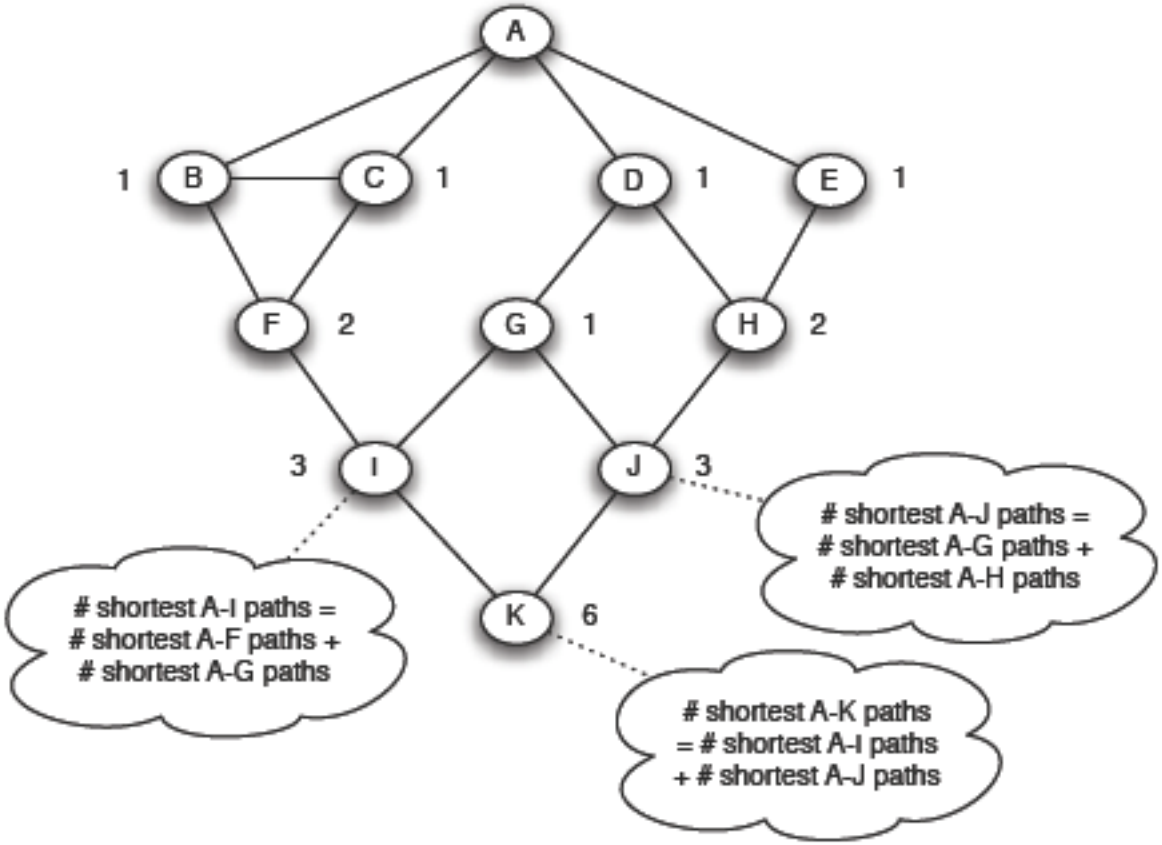
Calculating number of shortest paths



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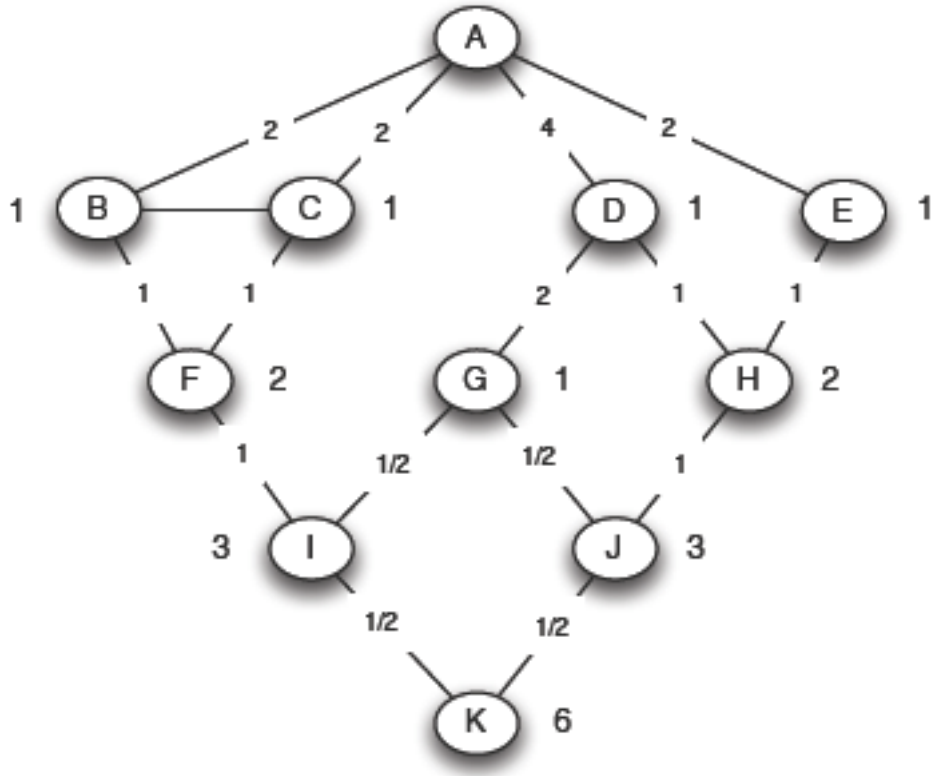
Calculating flows



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Calculating Edge Betweenness

- Build one of these graphs for each node in the graph
- Sum the values on the edges on each graph to obtain the edge betweenness

Community Detection

- How do we know when to stop?

- When X communities have been detected?
- When the level of cohesion inside a community has reached Y?

- There is no prescriptive way for every case
- There are also many other ways of detecting communities

References

- Kleinberg's book: Chapter 3.

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- **Social networks that matter: Twitter under the microscope.** Bernardo A. Huberman, Daniel M. Romero, and Fang Wu. First Monday, 14(1), January 2009.
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