Strong and Weak Ties

Advanced Social Computing

Department of Computer Science
University of Massachusetts, Lowell
Spring 2020

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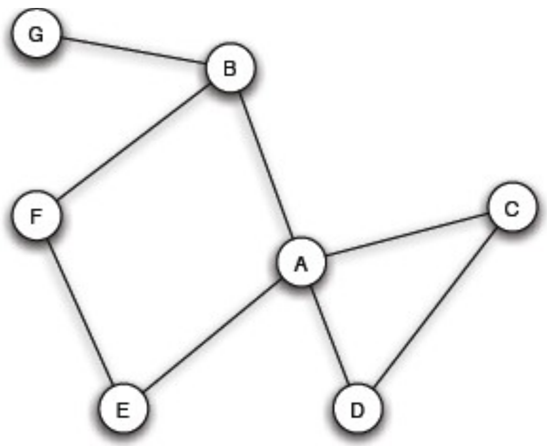
Announcements

- **HW1 out:**
  - Due date: 2/5, 3:30 PM

Lecture Topics

- Triadic Closure
  - Clustering Coefficient
  - Bridges and Local Bridges
  - Tie Strength
  - Strong Triadic Closure
  - Local Bridges and Weak Ties
  - The Strength of Weak Ties
- Tie Strength in Real-World Nets
  - Neighborhood Overlap
  - Analysis on Facebook and Twitter
- Structural Holes

Triadic Closure

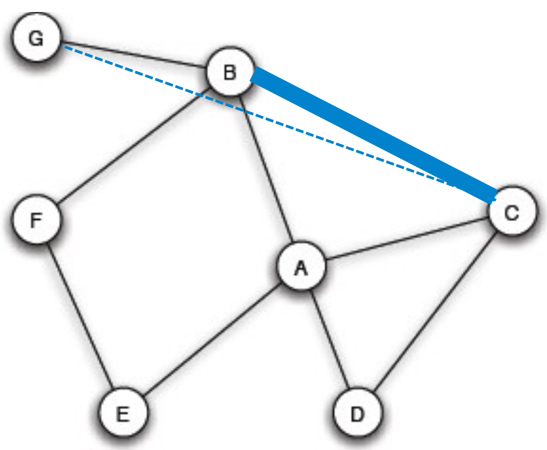


In this friendship net, C-B is more likely to form or C-G?

Triadic Closure

- If two people in a network have a friend in common, then there is an increased likelihood they will become friends themselves.

nodes neighbor connected

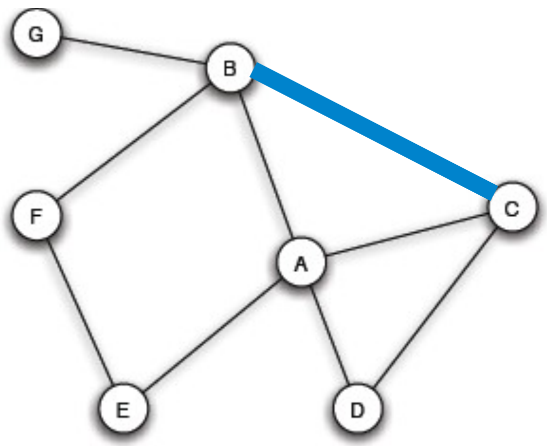


Georg Simmel, 1900s

In this friendship net, C-B is more likely to form or C-G?

Triadic Closure- Cnt.

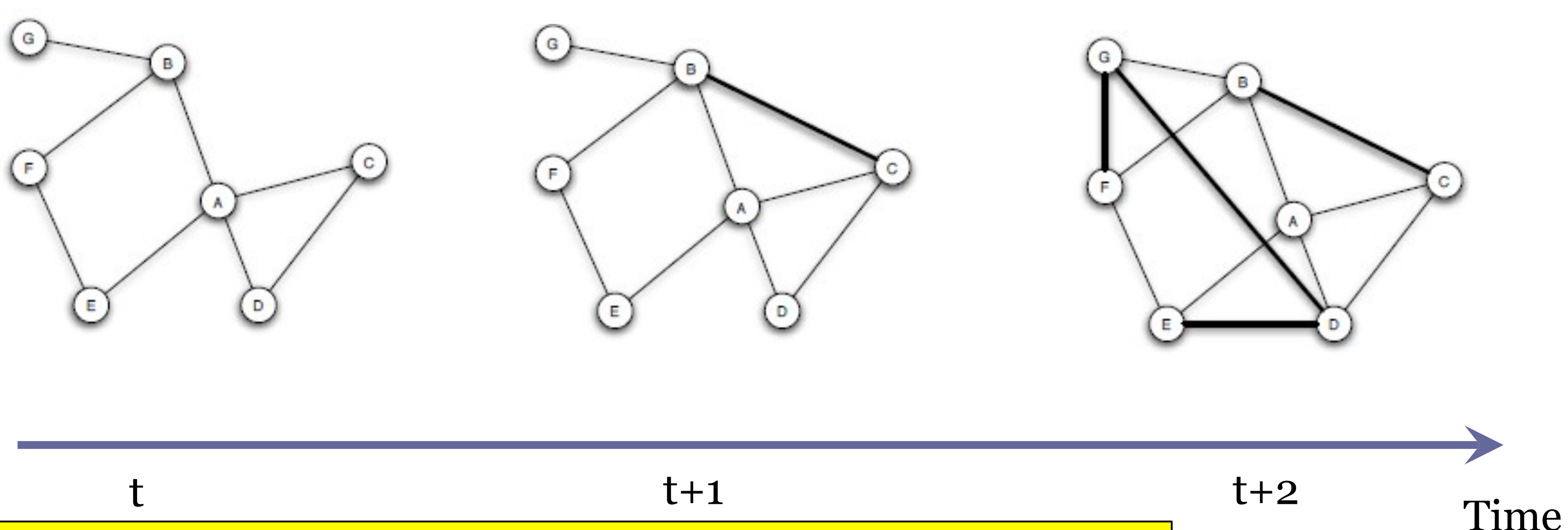
- The term "triadic closure" comes from the fact that the B-C edge has the effect of "closing" the third side of this triangle.



In this friendship net, C-B is more likely to form or C-G?

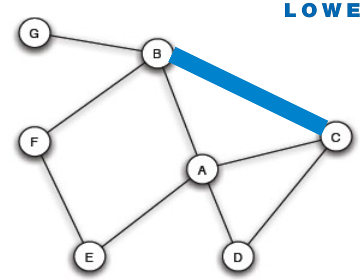
Triadic Closure- Cnt.

- Watching a network for a longer period of time:
  - Multiple edges form!
    - Some form through triadic closure while others (such as D-G) form even though the two endpoints have no neighbors in common.



For other network dynamics see: The Law Prof Twittersphere 2019. https://t.co/fIxPOudwWL

Triadic Closure- Cnt.



- Reasons for Triadic Closure:
  - Opportunity:
    - B and C have a common friend A -> there is an increased chance they will end up knowing each other.
  - Trust:
    - B and C are friends with A -> gives them a basis for trusting each other that an arbitrary pair of unconnected people might lack.
  - Incentives:
    - A may have to bring B and C together (social psychology).

Clustering Coefficient

- A measure to capture the **prevalence of Triadic Closure**

- Clustering Coefficient (CF)
  - CF of a node *A* is defined as the probability that two randomly selected friends of A are friends with each other.

Clustering Coefficient- Cnt.

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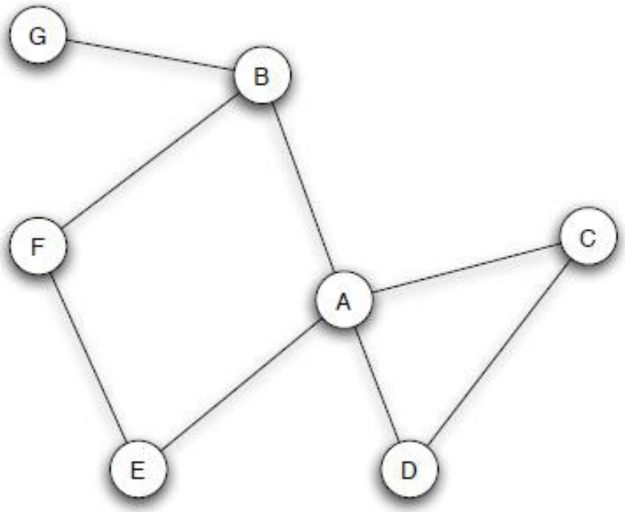
$$CF(A) = \frac{\textit{Number of connections btw A's friends}}{\textit{Possible Number of connections btw A's friends}}$$



Clustering Coefficient- Cnt.

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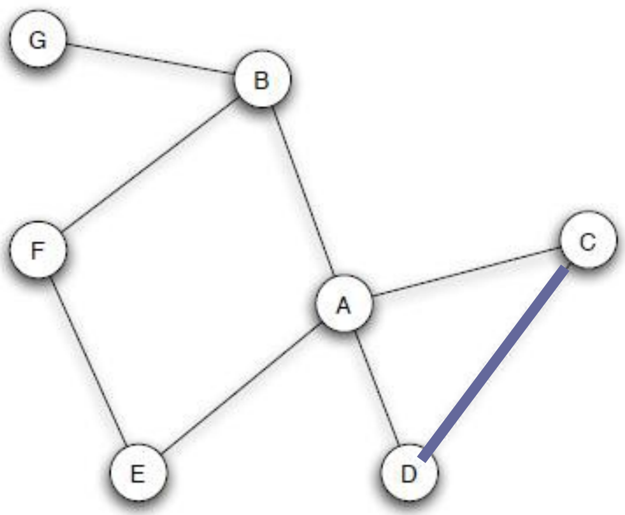
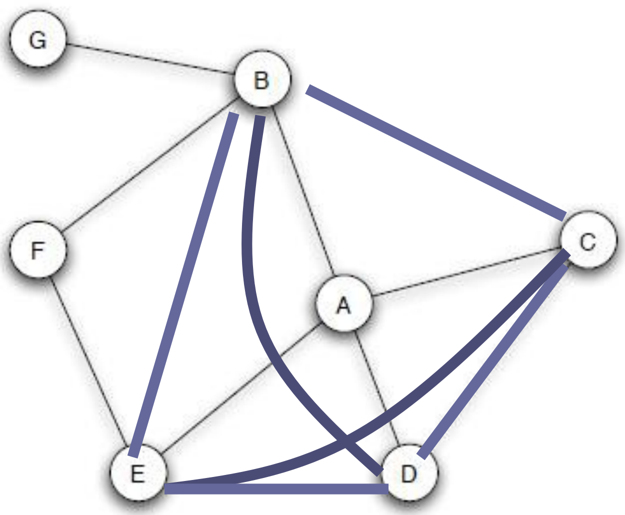
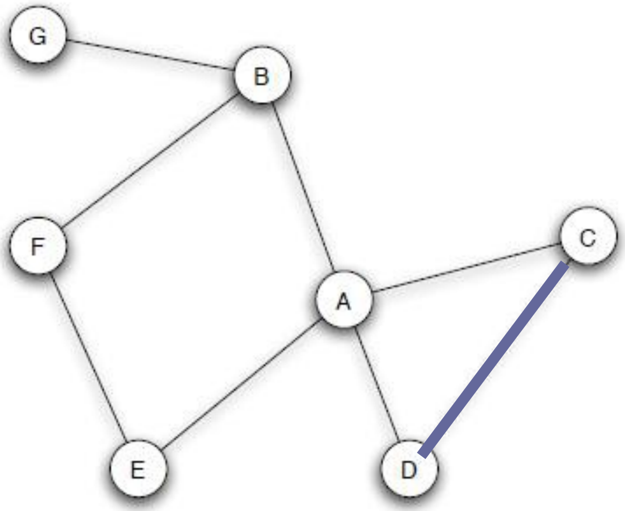


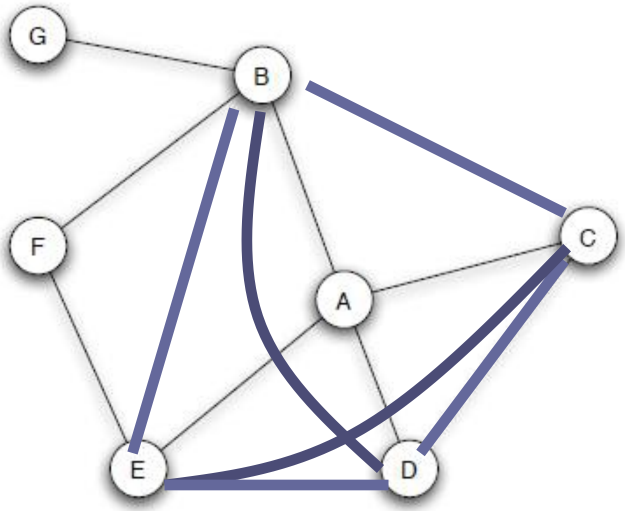


Clustering Coefficient- Cnt.

- Range btw?
  - [0-1]

$$CF(A) = \frac{\textit{Number of connections btw A's friends}}{\textit{Possible Number of connections btw A's friends}}$$





Clustering Coefficient- Cnt.

- Relation btw *triadic closure* & *clustering coefficient*
  - the more strongly triadic closure is operating in the neighborhood of a node, the higher its CF will be.

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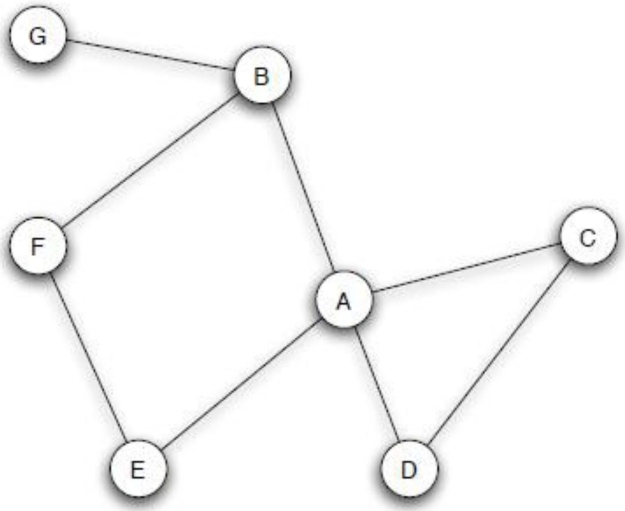
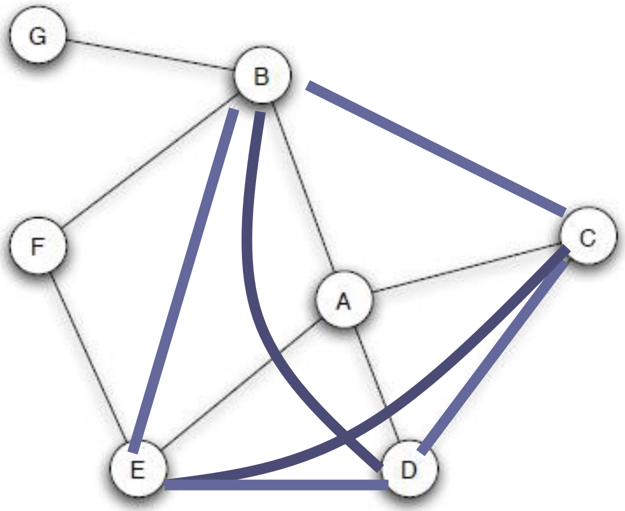




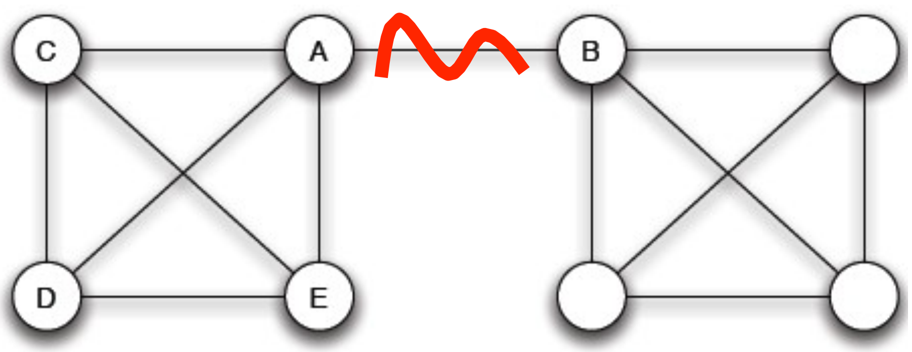
Clustering Coefficient- Cnt.

- Empirical study by Bearman and Moody (2004):
  - Teenage girls who have a low clustering coefficient in their network of friends are significantly more likely to contemplate suicide than those whose clustering coefficient is high!

Source: Suicide and friendships among American adolescents. Bearman and Moody. American journal of public health . 2004.

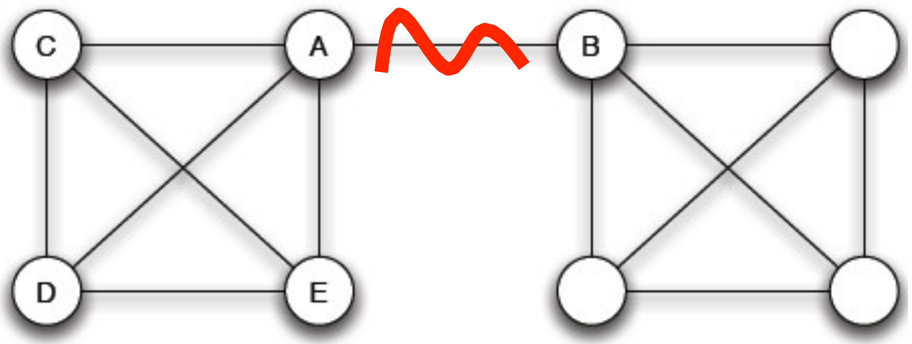
Bridges and Local Bridges

- Structural Notion!
- The edge (A,B) is a bridge if **deleting** it put A and B into **two different connected components**.



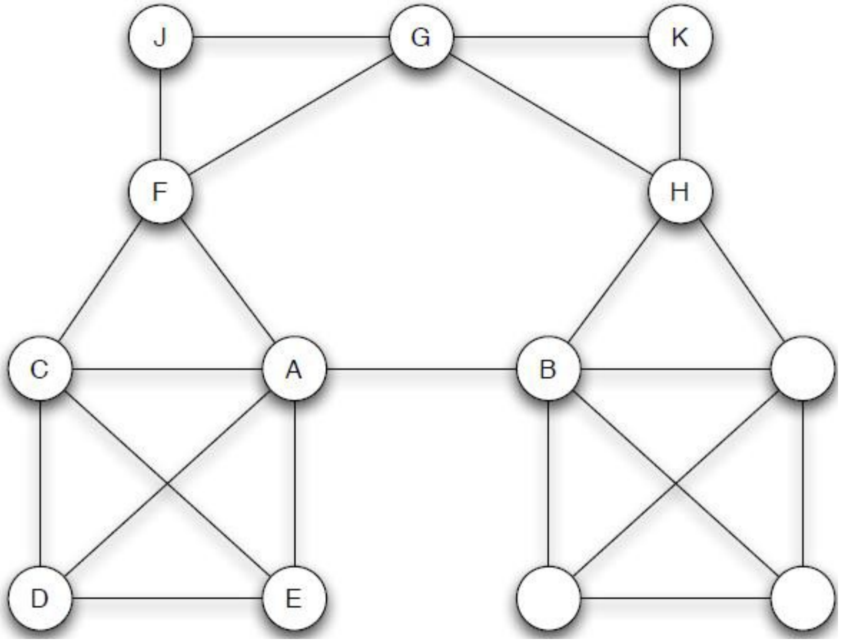
Bridges and Local Bridges- Cnt.

- Important points about Bridges:
  - A Bridge is the only route btw its endpoints!
  - Bridges provide access to parts of the network that are unreachable by other means!



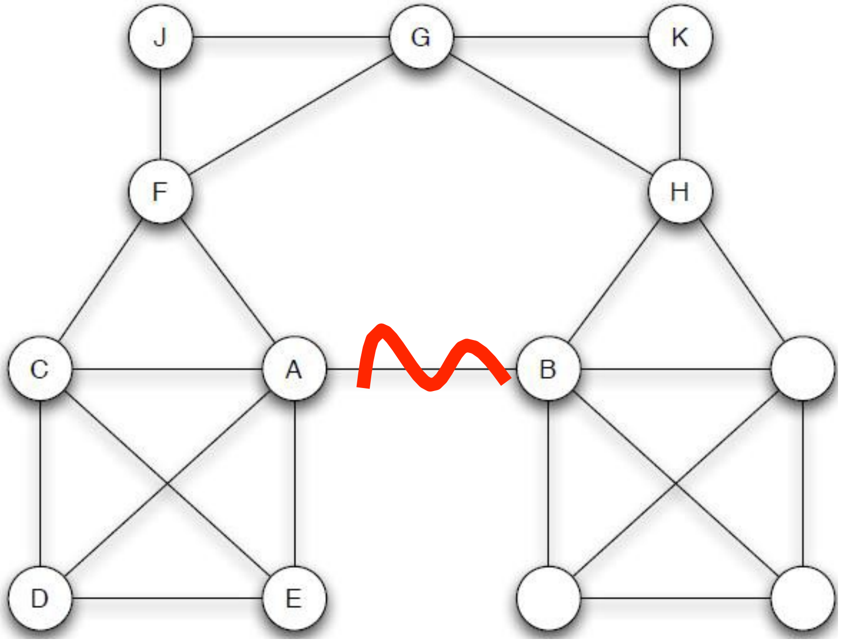
Bridges and Local Bridges- Cnt.

- Aren't bridges rare in real-world networks?
  - Consider the availability of a giant component in real-world nets!
  - There could be others paths that connect two nodes!
    - **A**-**B**, **A**-F-G-H-**B**, etc.



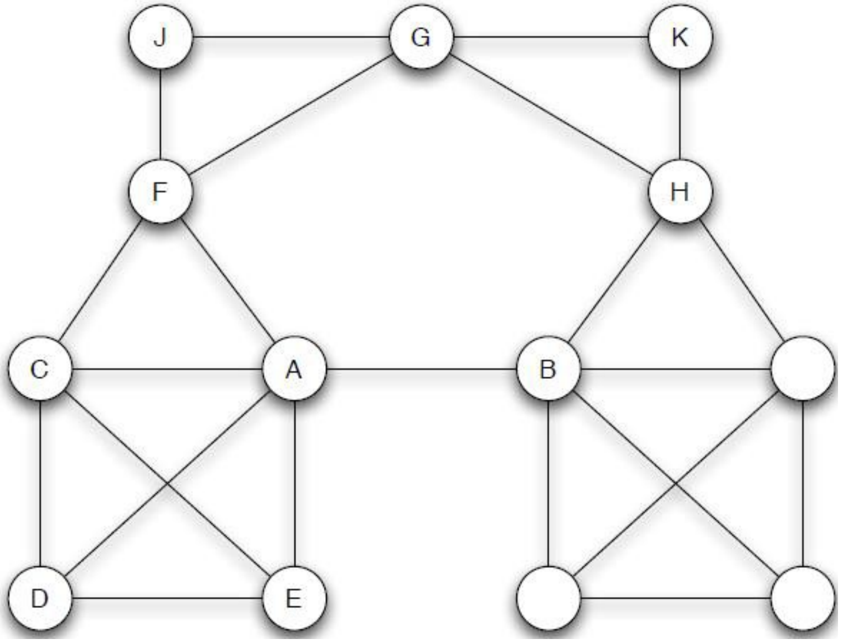
Bridges and Local Bridges- Cnt.

- Local Bridges:
  - The edge (A,B) is a local bridge if A and B have **no friends in common**!
    - In other words, if deleting the edge would increase the distance btw A and B to a value strictly more than 2.



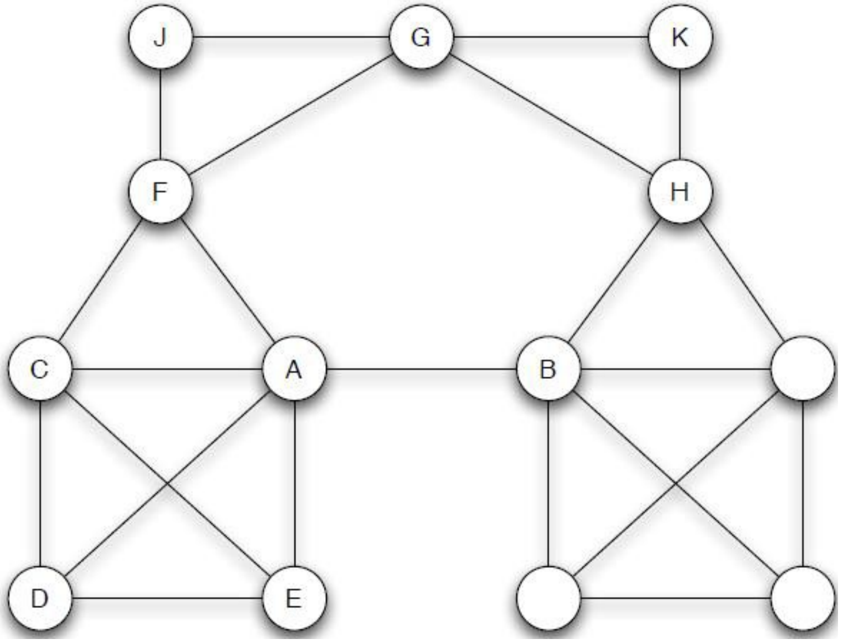
Bridges and Local Bridges- Cnt.

- Beside (A,B), is there any other local bridge in this net?



Bridges and Local Bridges- Cnt.

- Beside (A,B), is there any other local bridge in this net?
  - Local bridges never form the side of any triangle in the net!
  - Local Bridge→ **edge not in a triangle**!



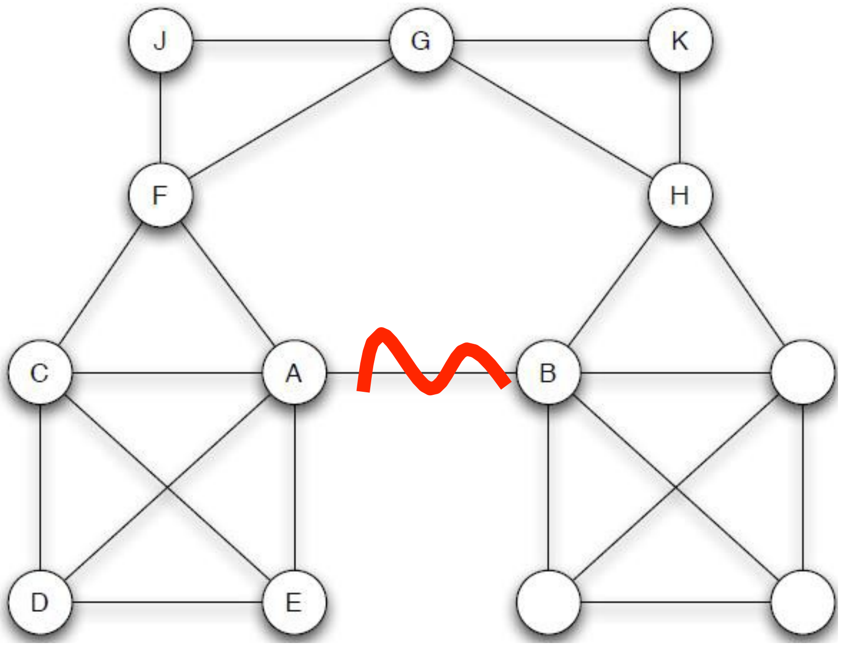
Bridges and Local Bridges- Cnt.

Length of the shortest path btw two nodes

- Span of a Local Bridge:
  - Span of a local bridge is the distance btw its endpoints if the edge were deleted.
  - Span(A-B)=4

Local bridges with large span play roughly the same role as bridges:

Provide their endpoints with access to parts of the net that they would otherwise be far away from.



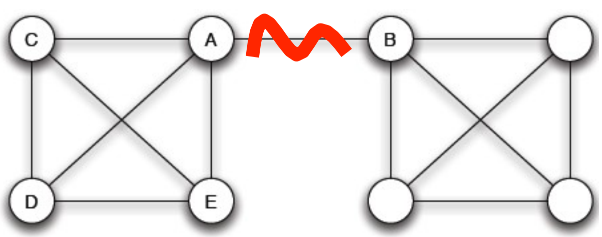
Bridges and Local Bridges- Cnt.

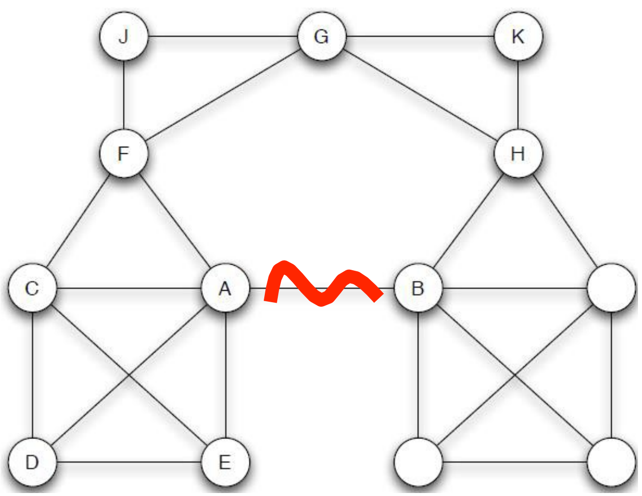
- Granovetter's Experiment
  - 1960s
  - Question: "How people find out about new jobs?"
    - People find the info through personal contacts
    - But: contacts were often *acquaintances* (weak ties) rather than *close friends* (strong ties)!
  - This is surprising as one would expect close friends to help you more than acquaintances!
  - Why are acquaintances most helpful?

Source: Changing jobs : channels of mobility information in a suburban population, Mark S Granovetter. PhD Thesis. 1970

Bridges and Local Bridges- Cnt.

- Why Acquaintances are more important (in Granovetter's Experiment)?
  - A, C, D, and E will all tend to be exposed to similar sources of info, while A's link to B offers access to info A otherwise wouldn't necessarily hear about.





Tie Strength

- Links in networks have strength: E.g.
  - Friendship nets (close friends vs. acquaintances)
  - Telco nets (amount of time talking on the phone)
- We characterize edges / links as either:
  - Strong (corresponding to friends), or
  - Weak (corresponding to acquaintances)

Tie Strength- FB

- **All Friends:** the largest representation of a person's network is the set of all people they have verified as friends.
- **Reciprocal Communication:** as a measure of a sort of core network, we counted the number of people with whom a person had had reciprocal communications, or an active exchange of information between two parties.
- **One-way Communication:** the total set of people with whom a person has communicated.
- **Maintained Relationships:** to measure engagement, we took the set of people for whom a user had clicked on a News Feed story or visited their profile more than twice.

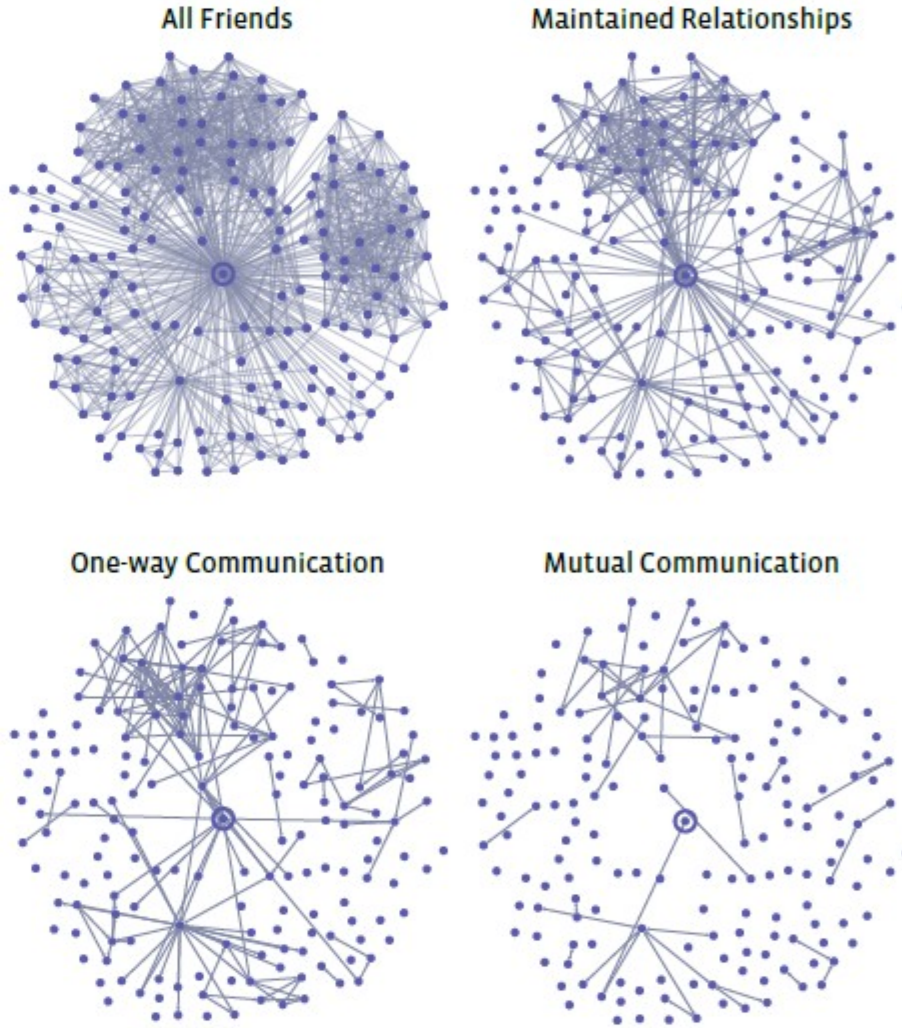
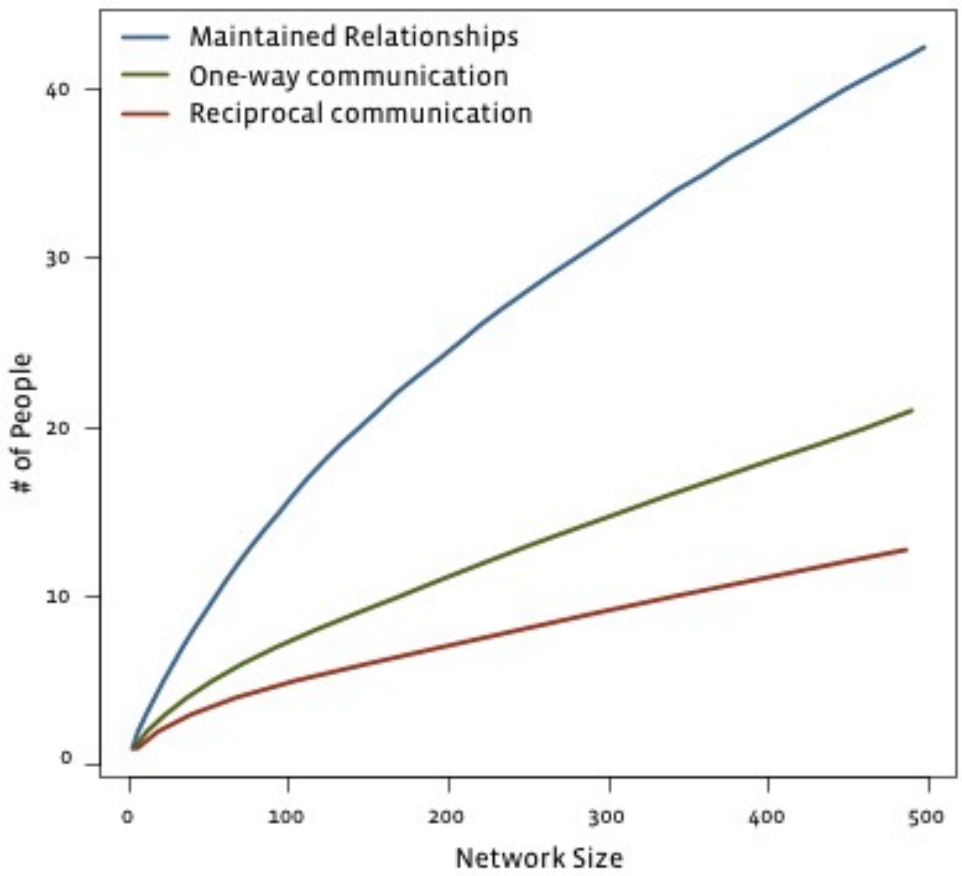


Figure 3.8: Four different views of a Facebook user's network neighborhood

Tie Strength- FB- Cnt.

Number of users with whom a user communicate is generally under 20!

Number of users they follow even passively (e.g. by reading about them) is under 50!

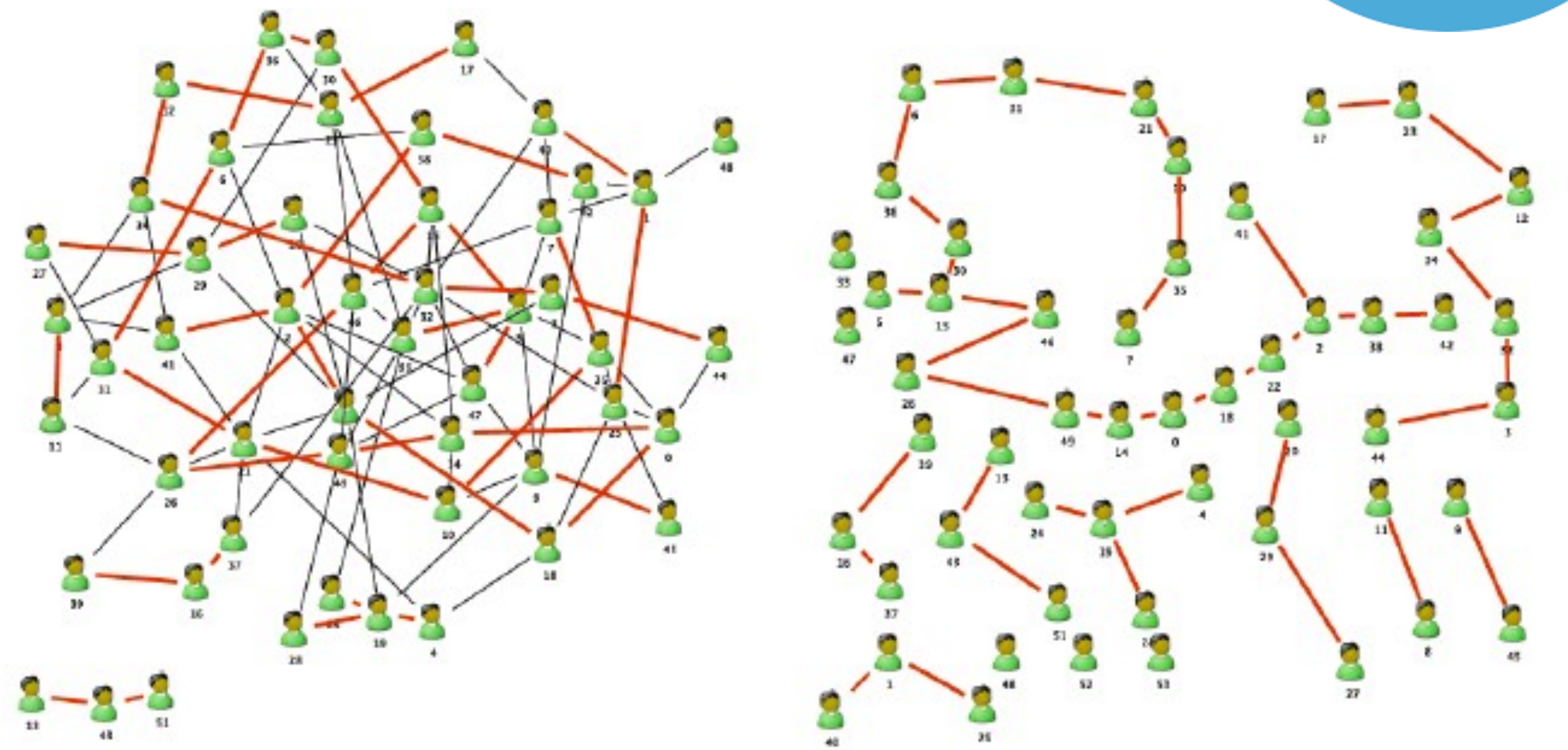


Number of friends on FB

Figure 3.9: The number of links corresponding to maintained relationships, one-way communication, and reciprocal communication as a function of the total neighborhood size for users on Facebook. (Image from [286].)

Source: Maintained Relationships on Facebook. Cameron, 2009. http://on.fb.me/19otPt5

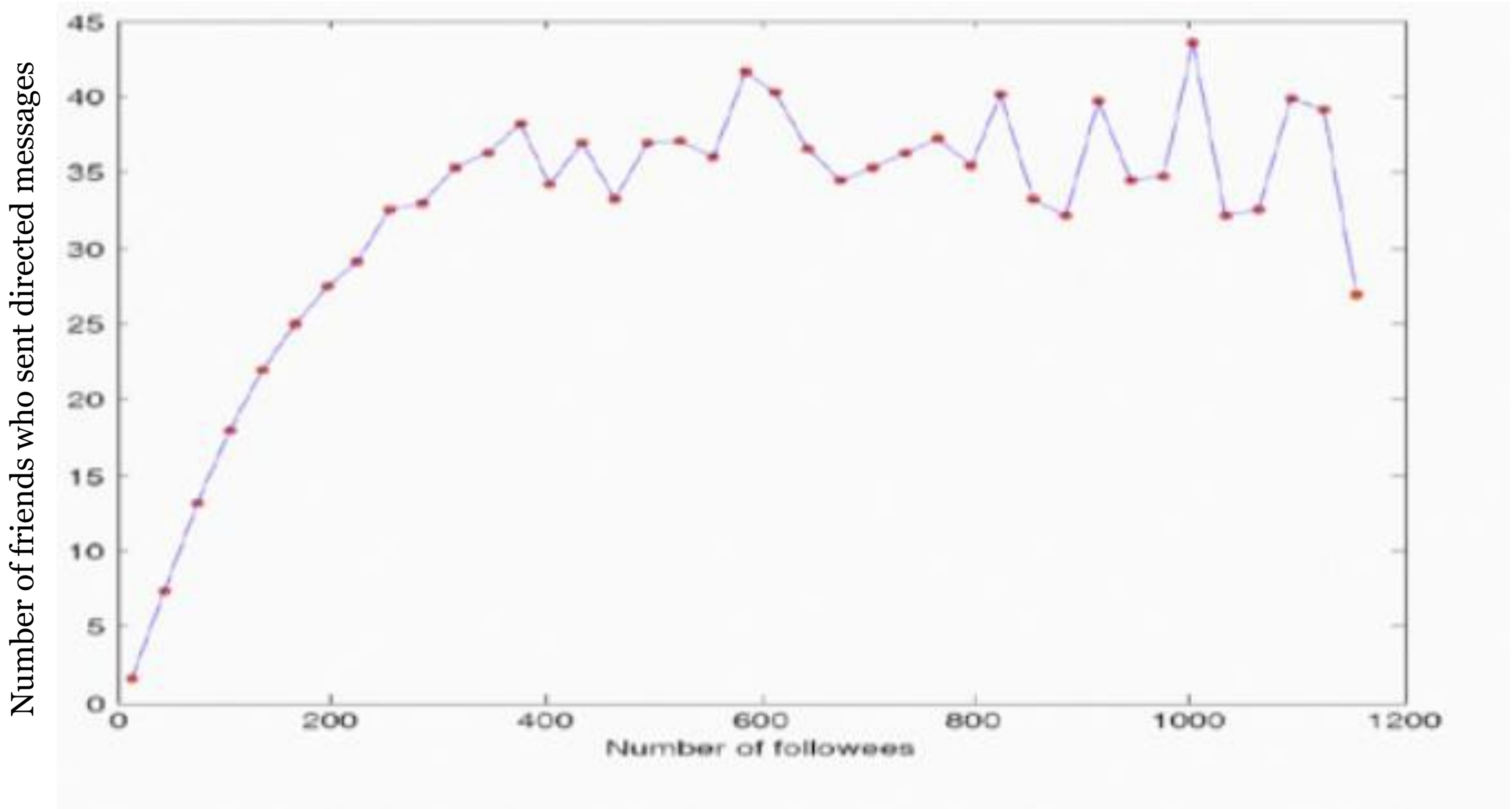
Tie Strength- Twitter



(a) All links are declared followees and the red links are actual friends.

(b) After removing the black links and reorganizing the network look simpler than before. This is the hidden network that matters the most.

Tie Strength- Twitter- Cnt.



Even for users who maintain very large numbers of weak ties on-line, the number of strong ties remains relatively modest, in this case stabilizing at a value below 50 even for users with over 1000 followees.

Tie Strength- Cnt.

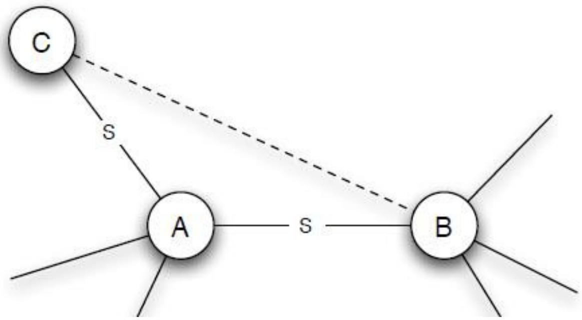
- The relative scarcity of strong ties in environments like Facebook and Twitter

Tie Strength- Cnt.

- The relative scarcity of strong ties in environments like Facebook and Twitter:
  - Each strong tie requires continuous investment of time and effort to be maintained
  - Even people who devote a lot of energy to building strong ties will eventually reach a limit, imposed simply by the hours available in a day, on the number of ties that they can maintain in this way.
  - This is while the formation of weak ties is governed by much milder constraints and such ties don't need to be maintained continuously!

Strong Triadic Closure

- Strong Triadic Closure Property
  - If A has **strong** links to B and C, then there must be a link, either weak or strong, btw B and C!



Strong Triadic Closure- Cnt.

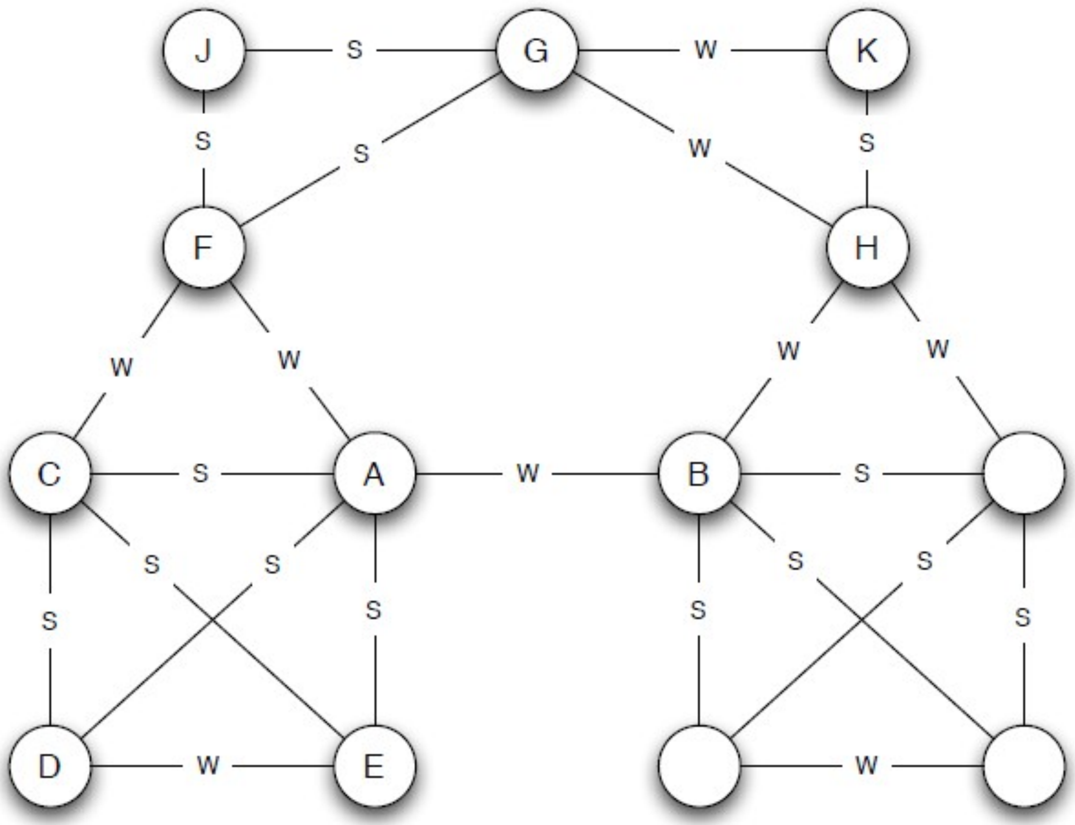
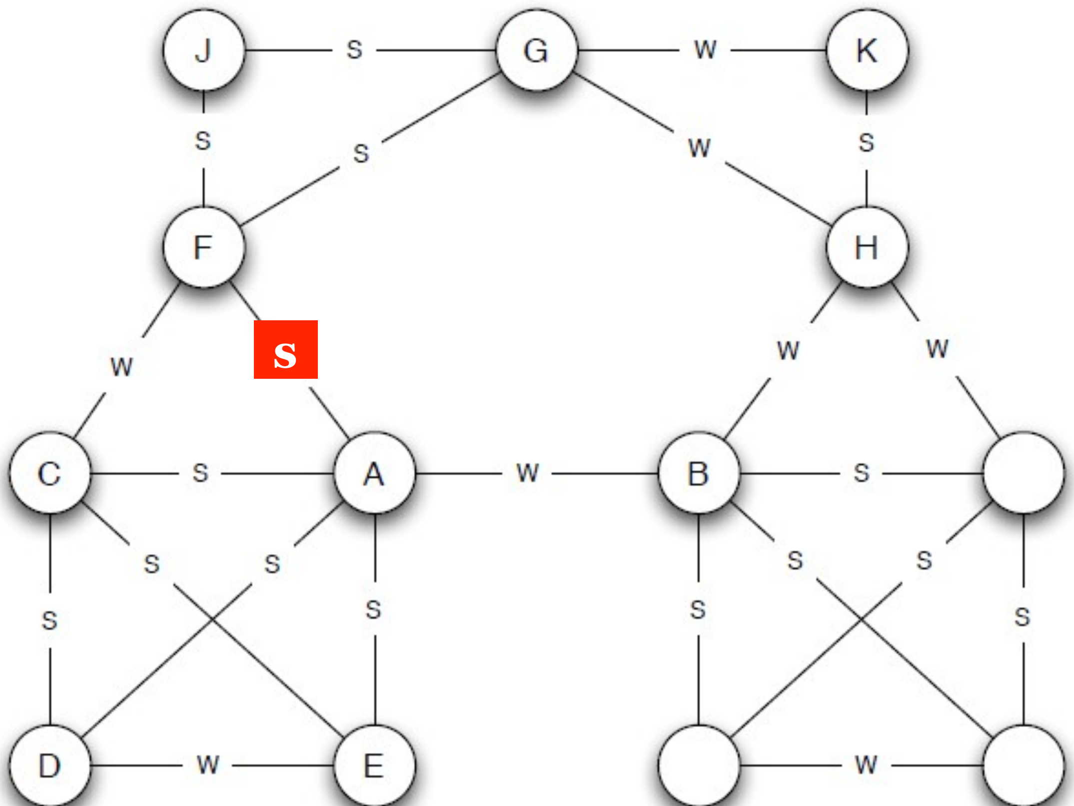


Figure 3.5: Each edge of the social network from Figure 3.4 is labeled here as either a *strong tie* (S) or a *weak tie* (W), to indicate the strength of the relationship. The labeling in the figure satisfies the Strong Triadic Closure Property at each node: if the node has strong ties to two neighbors, then these neighbors must have at least a weak tie between them.

Strong Triadic Closure- Cnt.



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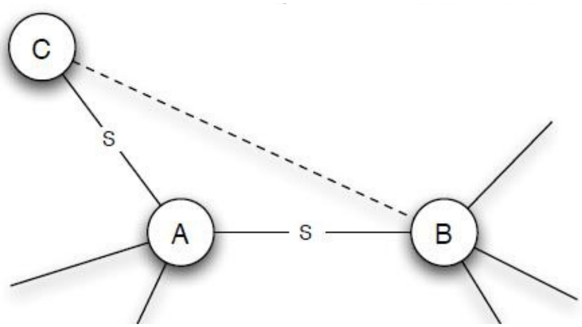
Local Bridges and Weak Ties

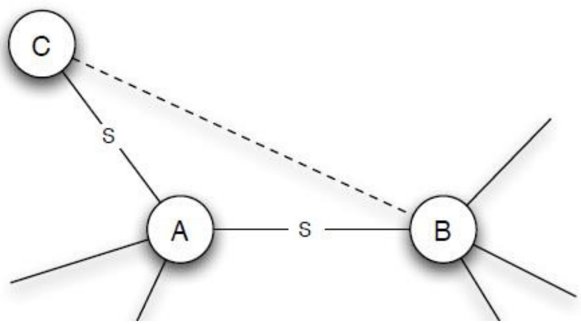
- Relationship btw local bridges and weak ties through strong triadic closure:

- If node A:
  - satisfies **strong triadic closure**, AND
  - is involved in at least **two strong ties**
- Then:
  - any **local bridge** adjacent to A must be a **weak tie**.



Local Bridges and Weak Ties- Cnt.

- If node A satisfies strong triadic closure and is involved in at least two strong ties then any local bridge adjacent to A must be a weak tie.
- Proof by contradiction:
  - A satisfies strong triadic closure & involved in at least 2 strong ties
  - WLOG, suppose A-B is local bridge
  - Strong Triadic Closure says:
    - (B,C) must exist
  - ⊥ local bridge (B,C) can't be part of a triangle!



The Strength of Weak Ties

- The dual role of weak ties - as weak connections but also valuable links - is the surprising strength of weak ties.
  - Weak ties connect us to new sources of information, and their conceptual "span" in the social network (the local bridge property) is directly related to their weakness as social ties.

Summary

- Bridges:
  - if removed their endpoints will be in different connected components.
- Local bridges:
  - edges not in triangles!
- Two types of edges:
  - Strong and weak ties
- Strong triadic closure:
  - Two strong ties imply a third strong/weak tie
- Local bridges are weak ties:
  - Local bridge adjacent to nodes involved in strong triadic closure must be a weak tie.

Tie Strength in Real-World Nets

- Granovetter's theory was untested on real-world large-scale networks!
- They are available now!

Tie Strength in Real-World Nets- Cnt.

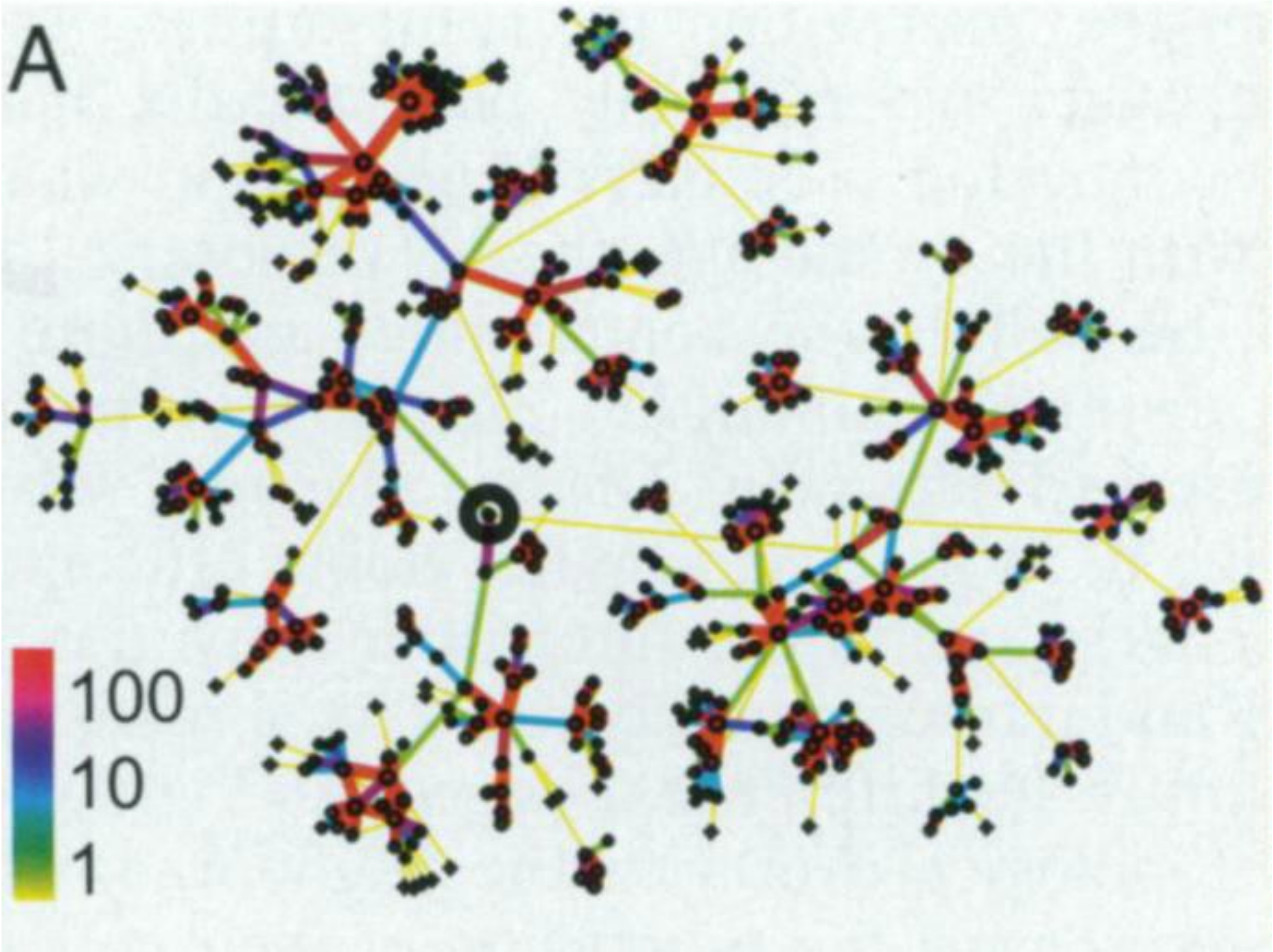
- Onnela et al., (2007) studied who-talks-to-whom net:
  - A node is a user
  - An edge forms btw two users who made phone calls to each other in both directions
  - 20% of the national population (18-week observation period)
  - Mainly used for personal communication

- First Observation: a giant component covering 84% nodes!

Tie Strength in Real-World Nets- Cnt.

All nodes with distance less than six from the selected user (circled)

Real tie strengths: the aggregate call duration in minutes (see color bar).



Tie Strength in Real-World Nets- Cnt.

- Relaxing the definitions (get numerical quantity):
  - Strength
    - Determined by the total number of minutes spent on phone calls between two nodes.
  - Local Bridges
    - Define *neighborhood overlap* for each edge!

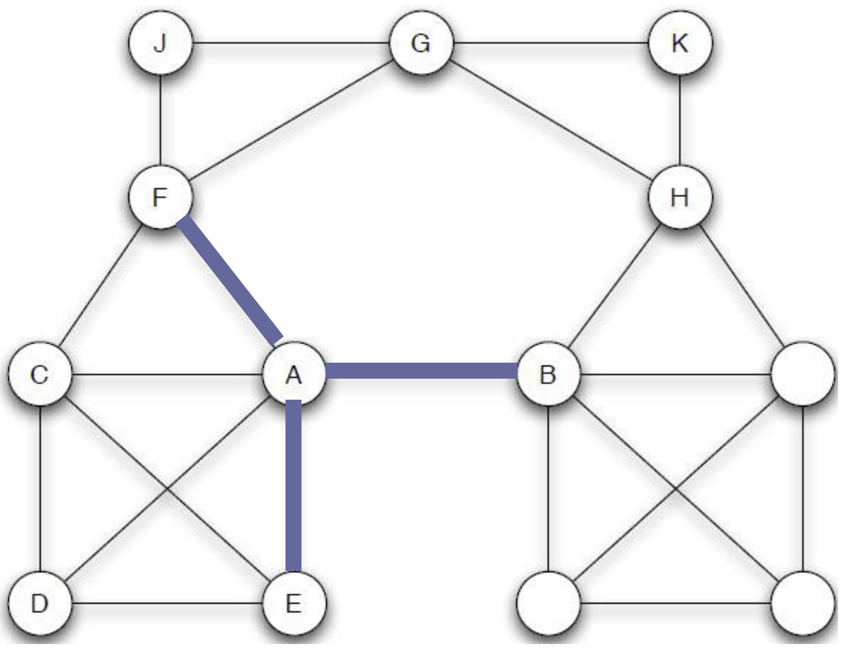
Source: Structure and tie strengths in mobile communication networks. Onnela, et al. National Academy of Sciences. 2007.

Tie Strength in Real-World Nets- Cnt.

- Neighborhood overlap of an edge connecting nodes A and B:

$$\frac{\text{number of nodes who are neighbors of } \textit{both } A \text{ and } B}{\text{number of nodes who are neighbors of } \textit{at least one of } A \text{ or } B\text{'}}$$

Don't count A and B here!

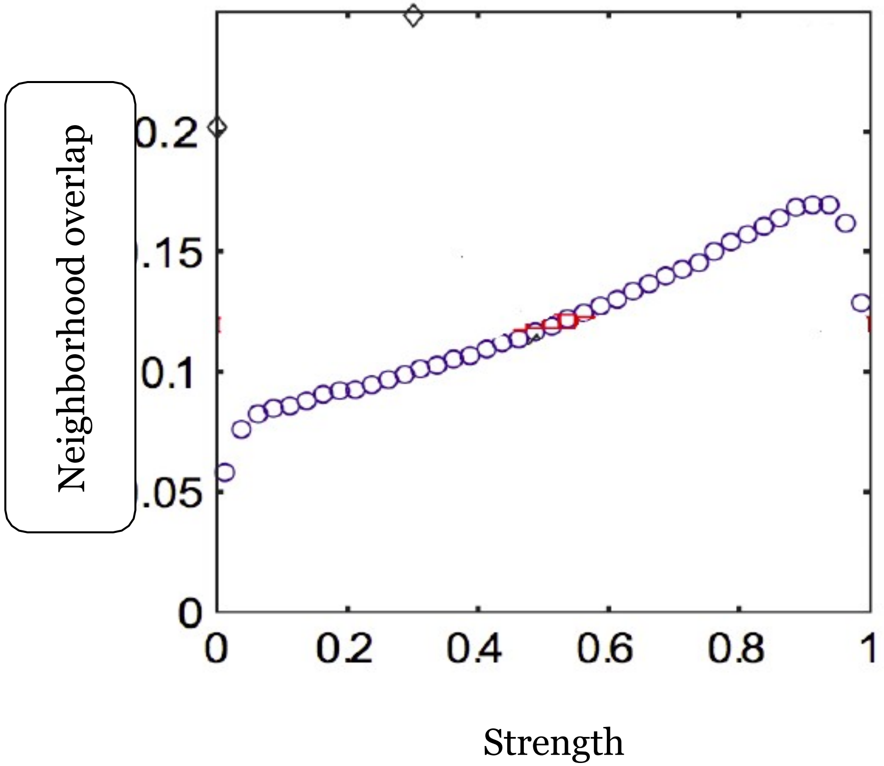


Nodes	Neighborhood overlap
A-E	2/4
A-G	1/8
A-B	0/8 (**Overlap = 0** for local bridges)

Edges with very small neighborhood overlap can be considered as "almost" local bridges

Question 1.- Cnt.

- How the neighborhood overlap of an edge relates to its tie strength?
  - Neighborhood overlap should grow as tie strength grows.



Question 2.- Cnt.

- How weak ties serve to link different communities?

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- Indirect Analysis:
  - **Delete edges** from the network one at a time, starting with the **strongest ties first**!
    - The giant component shrank steadily (its size decreases gradually).

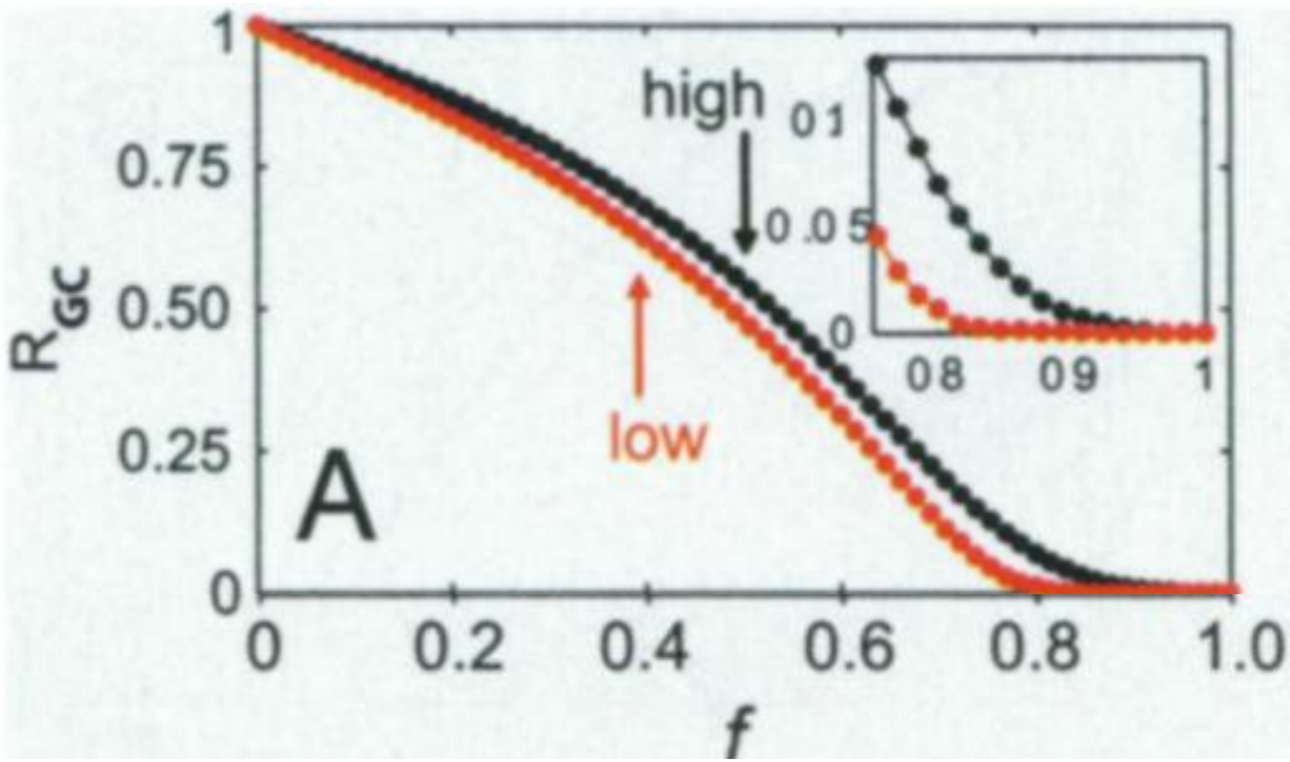
Question 2.- Cnt.

- How weak ties serve to link different communities?

- Indirect Analysis:
  - **Delete edges** from the network one at a time, starting with the **weakest ties first**!
    - The giant component shrank rapidly (its size decreases rapidly).

Question 2.- Cnt.

Size of the largest component



The fraction of removed links

----- black curves: removing first the high-strength ties

----- red curves: removing first the low-strength ties

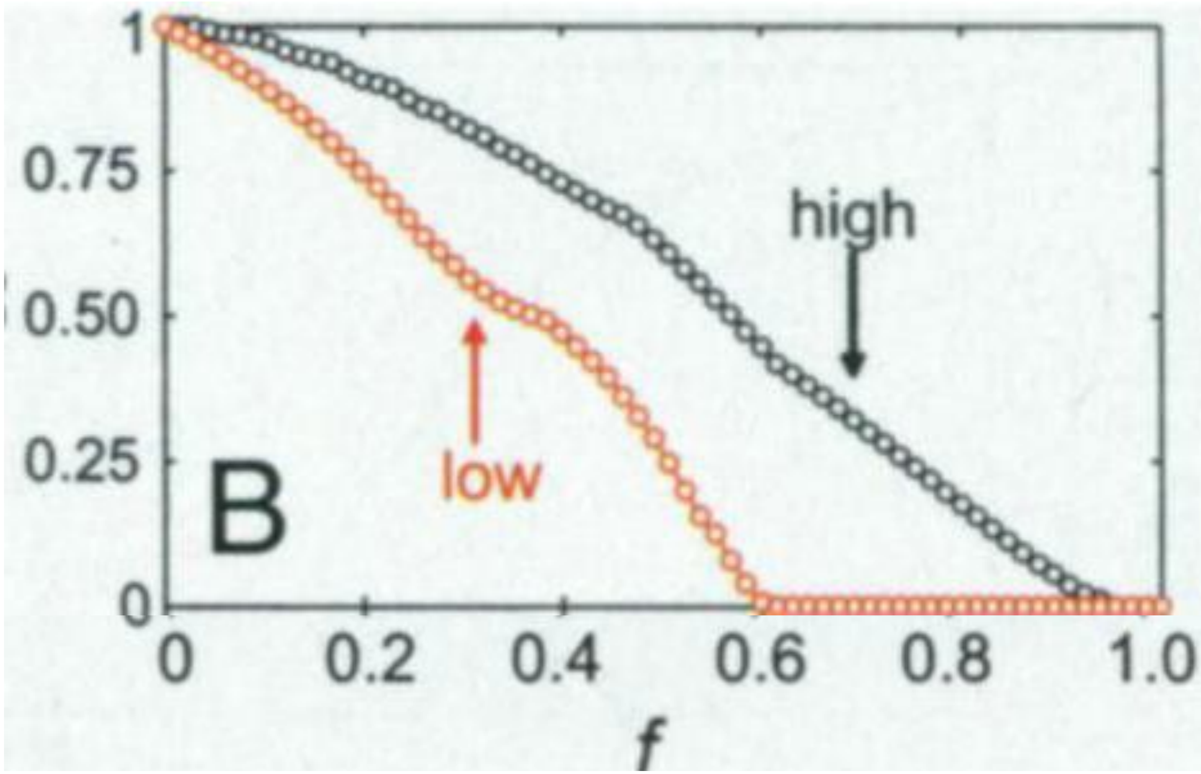
The removal of high weight links leads to the network's gradual shrinkage.

The removal of the low weight links leads to a breakdown of the network.

Source: Structure and tie strengths in mobile communication networks. Onnela, et al. National Academy of Sciences. 2007.

Question 2.- Cnt.

Size of the largest component



The fraction of removed links

----- black curves: removing first the high-overlap ties

----- red curves: removing first the low-overlap ties

The removal of high overlap links leads to the network's gradual shrinkage.

The removal of the low overlap links leads to a breakdown of the network.

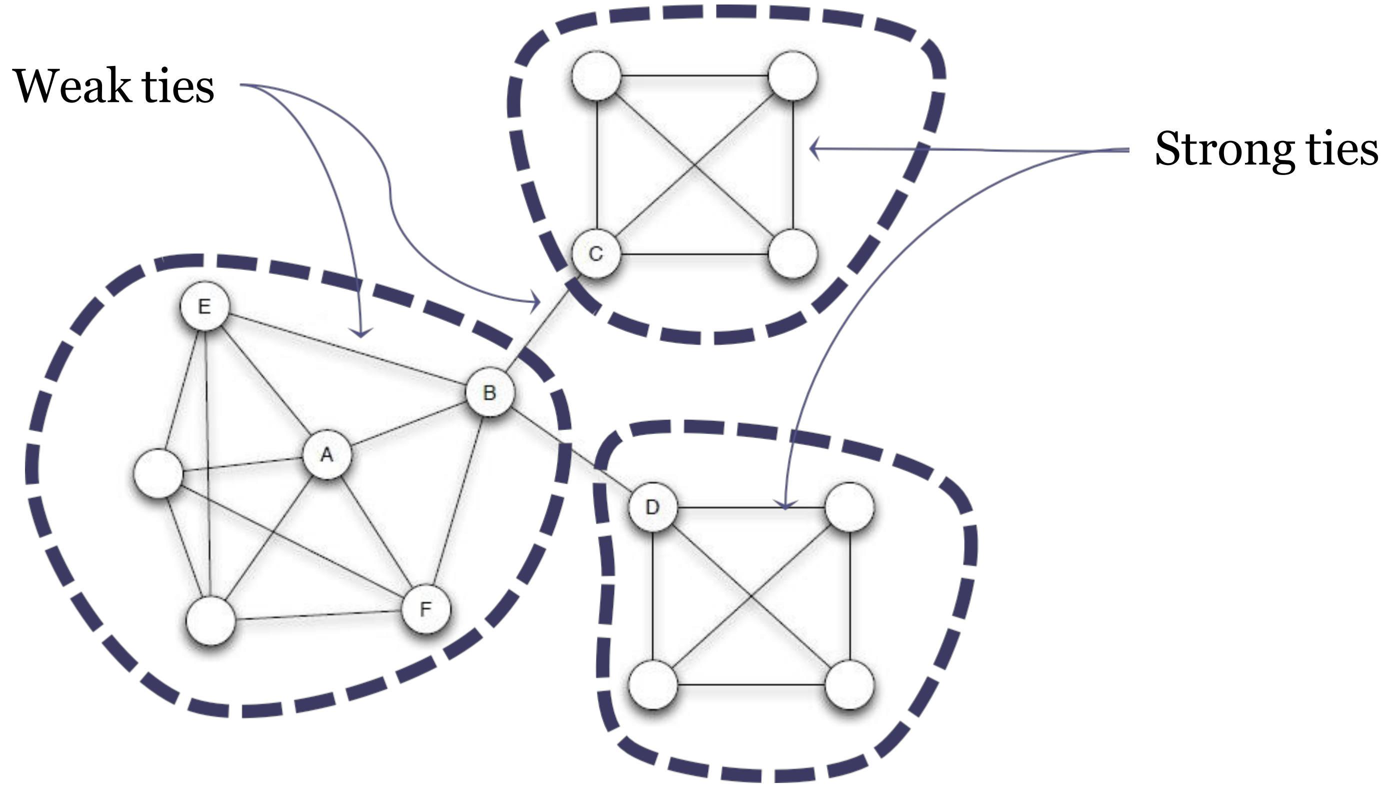
Source: Structure and tie strengths in mobile communication networks. Onnela, et al. National Academy of Sciences. 2007.

Question 2.- Cnt.

- Results are consistent with the expectation that
  - weak ties provide the more crucial connective structure for holding together disparate communities!

Structural Holes

- A structural view of social networks: tightly-knit groups connected by weak ties



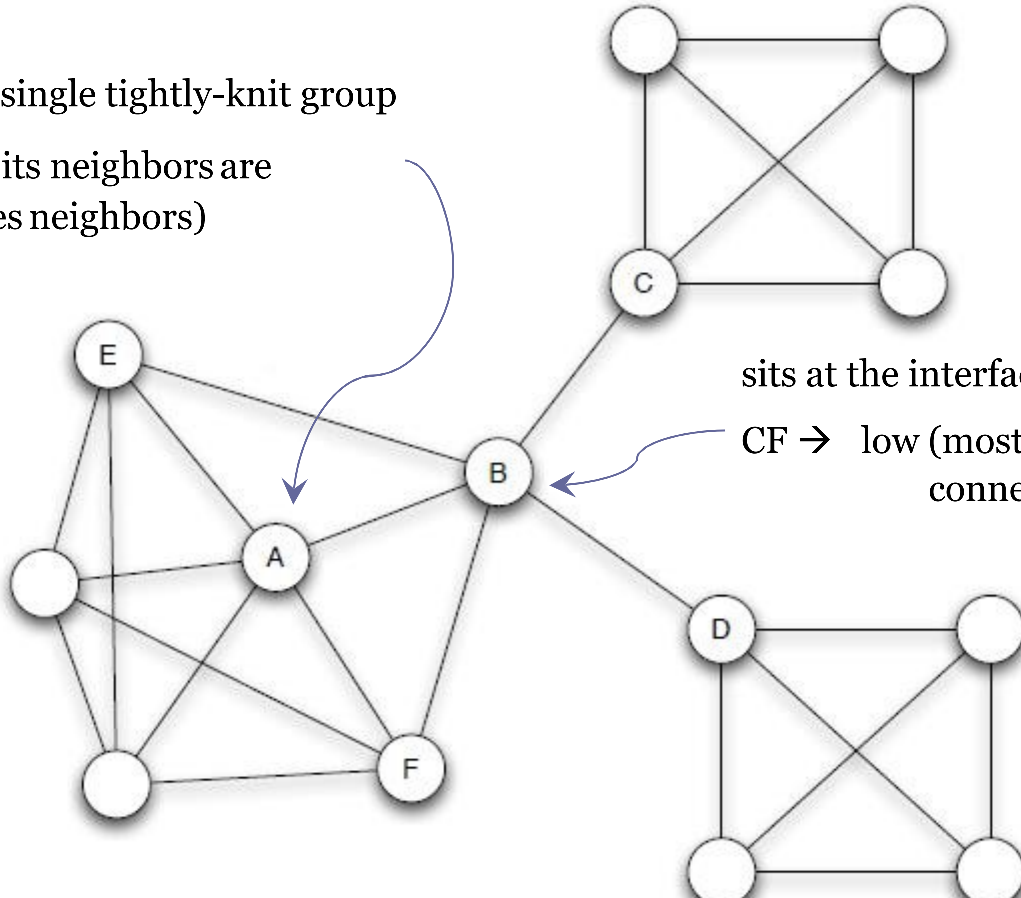
Structural Holes

- Roles that different nodes play in this structure:
  - some nodes are positioned at the interface between multiple groups, while
  - others are positioned in the middle of a single group.

Structural Holes- Cnt.

sits at the center of a single tightly-knit group

CF → high (most of its neighbors are themselves neighbors)



sits at the interface between several groups

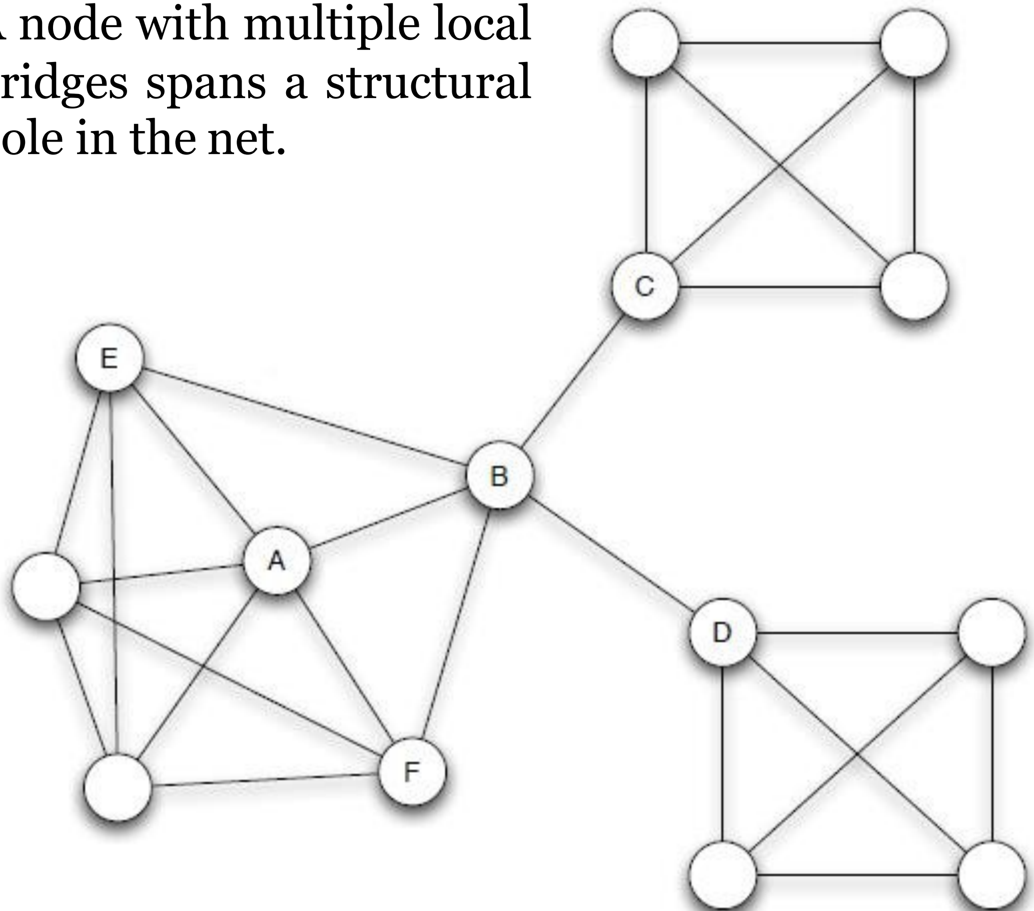
CF → low (most of its neighbors are not connected to each other)

Empirical studies shows that an individual's success within a company is highly correlated to his/her access to local bridges!

Structural Holes- Cnt.

Structural hole: the "empty space" in the net btw 2 sets of nodes that don't interact closely!

A node with multiple local bridges spans a structural hole in the net.



B has early access to info!

B is a gatekeeper and controls the ways in which groups learn about info. It has power!

B may try to prevent triangles from forming around the local bridges it is part of!

How long these local bridges last before triadic closure produces short-cuts around them?

Reading

- Ch.03 Strong and Weak Ties [NCM]
- Structure and tie strengths in mobile communication networks. Onnela, et al. National Academy of Sciences. 2007.