Strong and Weak Ties

CMSC 498J: Social Media Computing

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Lecture Topics

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

Granovetter's Experiment

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

Granovetter's Experiment- Cnt.

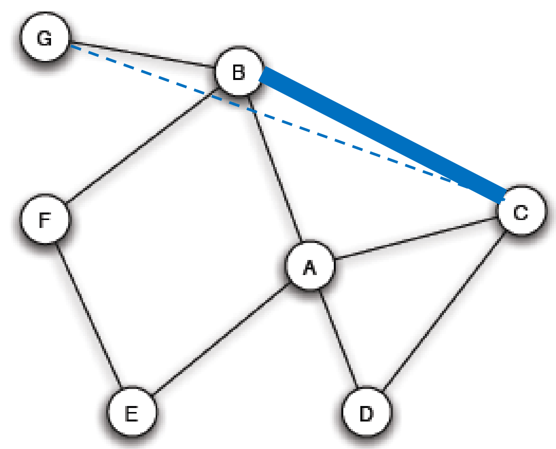
- Granovetter's Answers:
  - Two different perspectives on friendships
    - Interpersonal: friendship between two people is either ***strong*** or ***weak***.
    - Structural: friendships span different portions of the full network
- A way of thinking about the architecture of social networks more generally!

Triadic Closure

nodes neighbor

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

connected



Georg Simmel, 1900s

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

Triadic Closure- Cnt.

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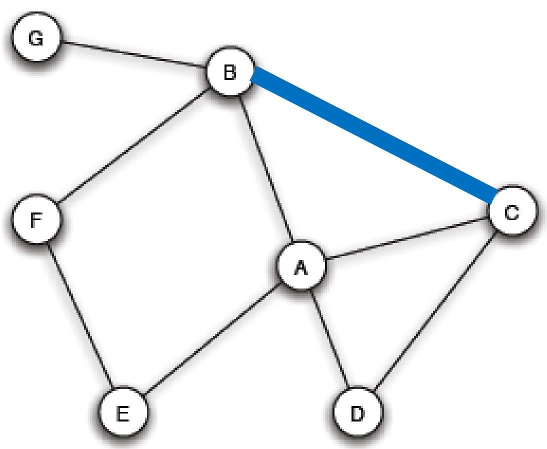
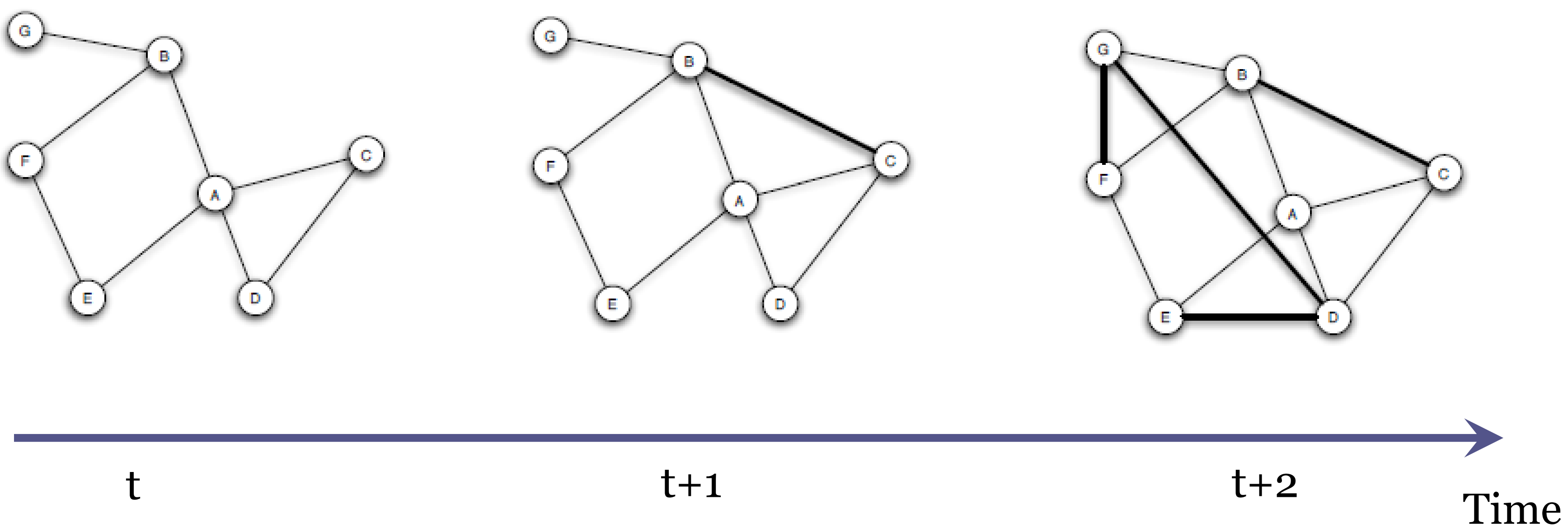
- The term "triadic closure" comes from the fact that the B-C edge has the effect of "closing" the third side of this triangle.



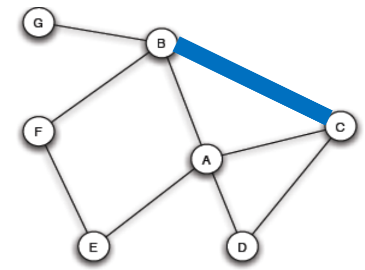
In this friendship net, C-B is more likely to form or C-G?

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.



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.

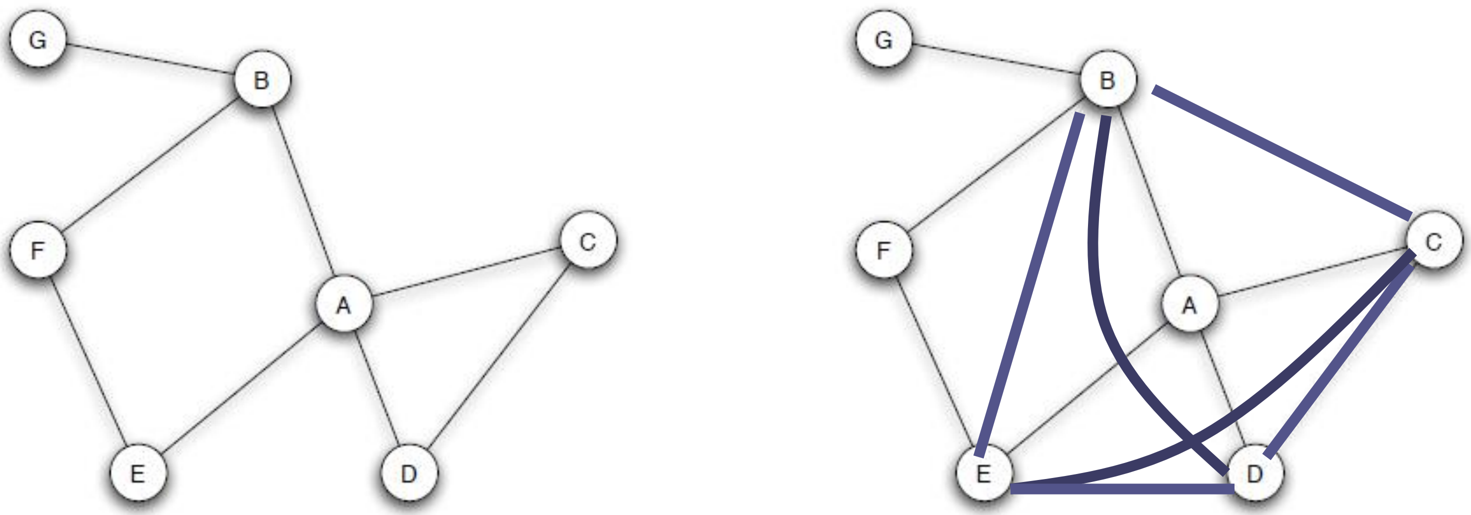
- CF of a node *A* is defined as the probability that two randomly selected friends of A are friends with each other.

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

Clustering Coefficient- Cnt.

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

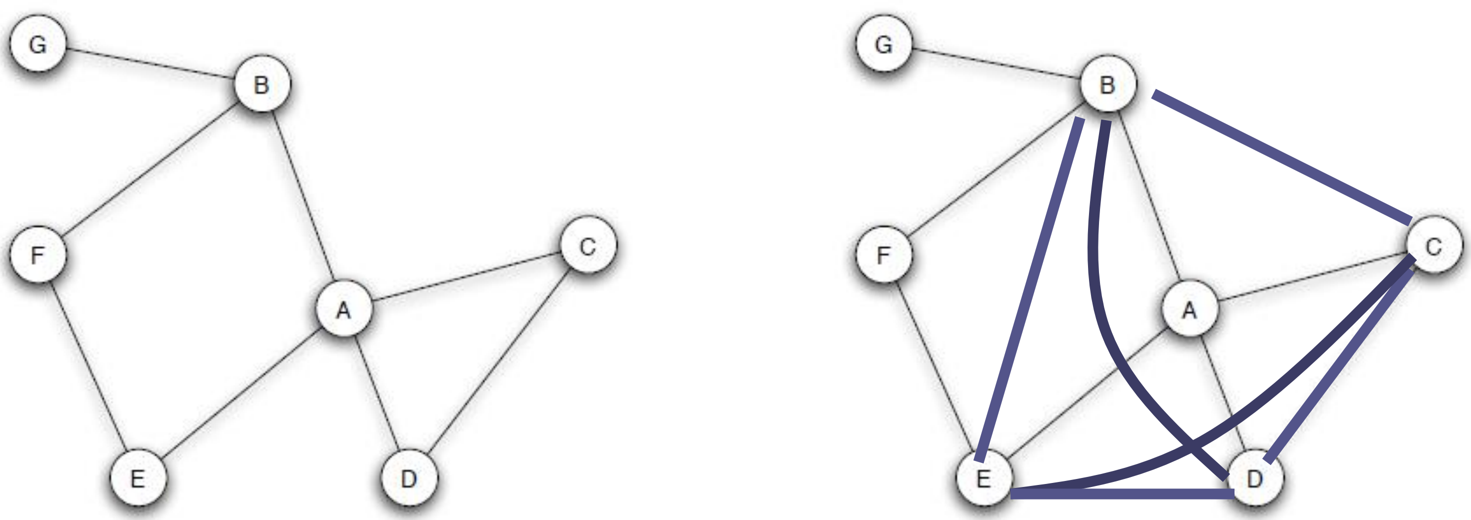
$$CF(A) = \frac{\textit{Number of connections btw A's friends}}{\textit{Possible Number of connections btw A's friends}} = 1/6$$



Clustering Coefficient- Cnt.

- Range btw?
  - [0-1]

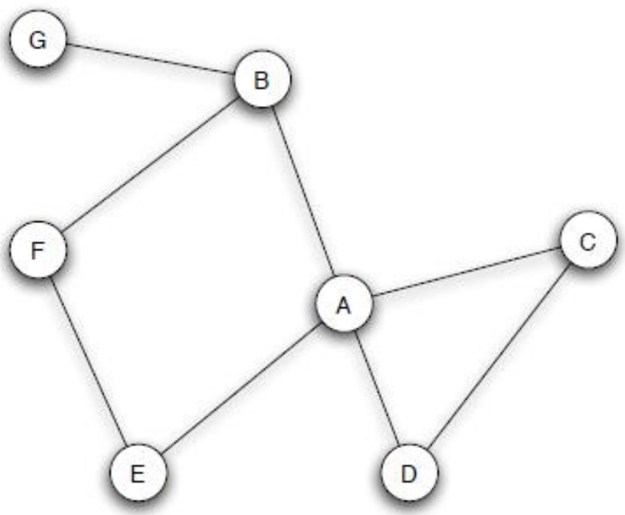
$$CF(A) = \frac{\textit{Number of connections btw A's friends}}{\textit{Possible Number of connections btw A's friends}}$$

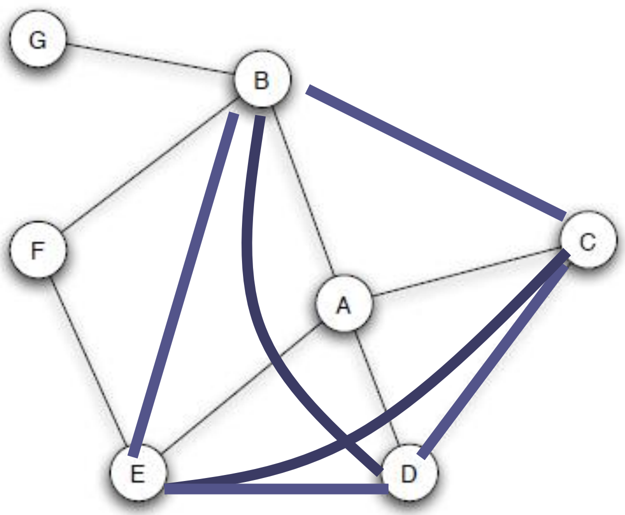


Clustering Coefficient- Cnt.

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

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





Clustering Coefficient- Cnt.

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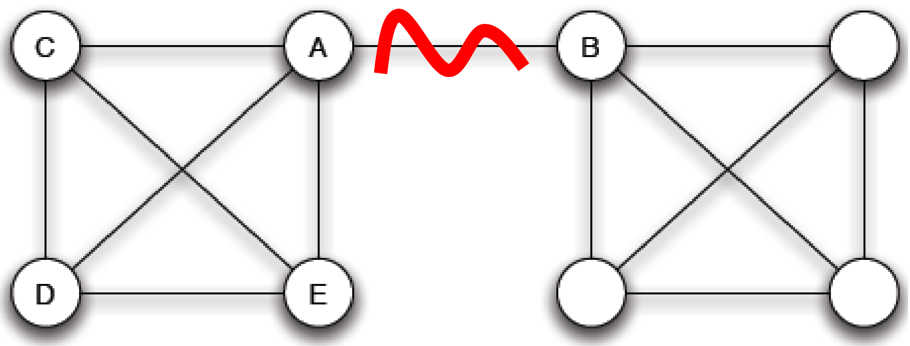
- Empirical study by Bearman and Moody (2004):
  - Teenage girls who have a low clustering coefficient in their network of friends are significantly more likely to contemplate suicide than those whose clustering coefficient is high!

Bridges and Local Bridges

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



Bridges and Local Bridges- Cnt.

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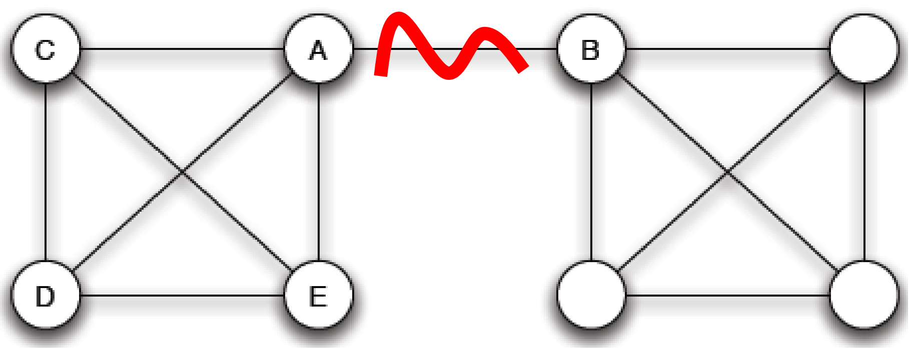
- Two Important Points about Bridges:
  - A Bridge is the only route btw its endpoints!
  - Bridges provide access to parts of the network that are unreachable by other means!



Bridges and Local Bridges- Cnt.

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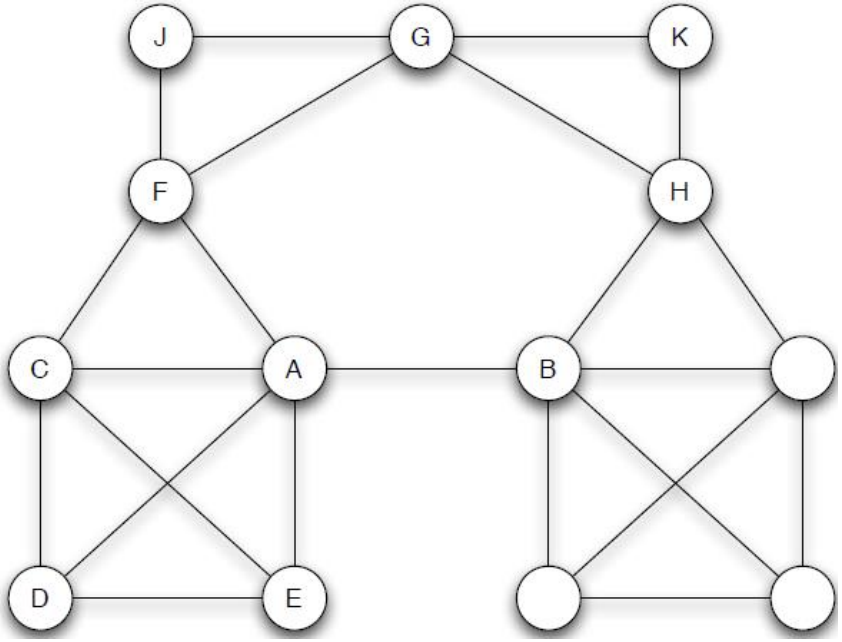
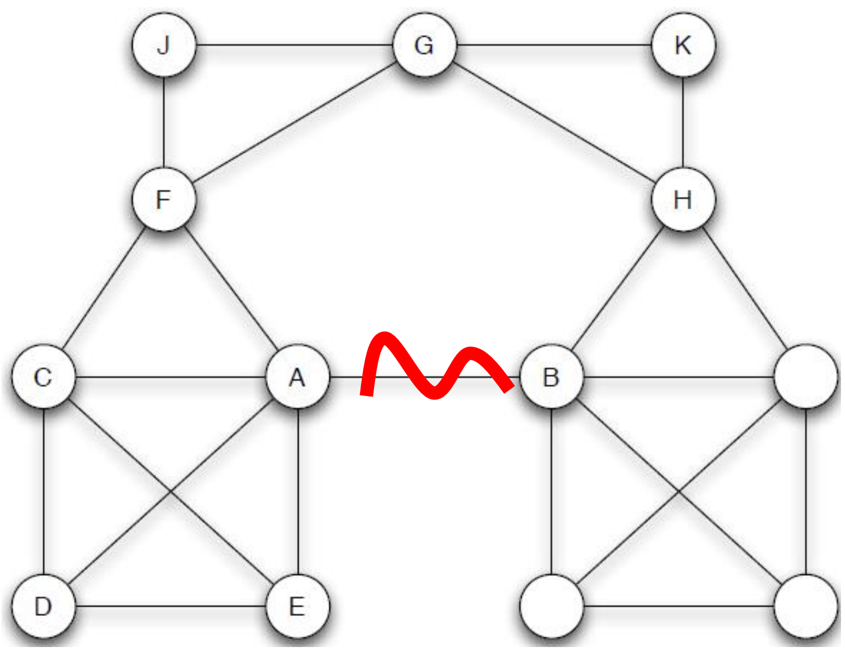
- Aren't bridges rare in real-world networks?
  - Consider the availability of a giant component in real-world nets!
  - There could be others paths that connect two nodes!
    - **A**-**B**, **A**-F-G-H-**B**, etc



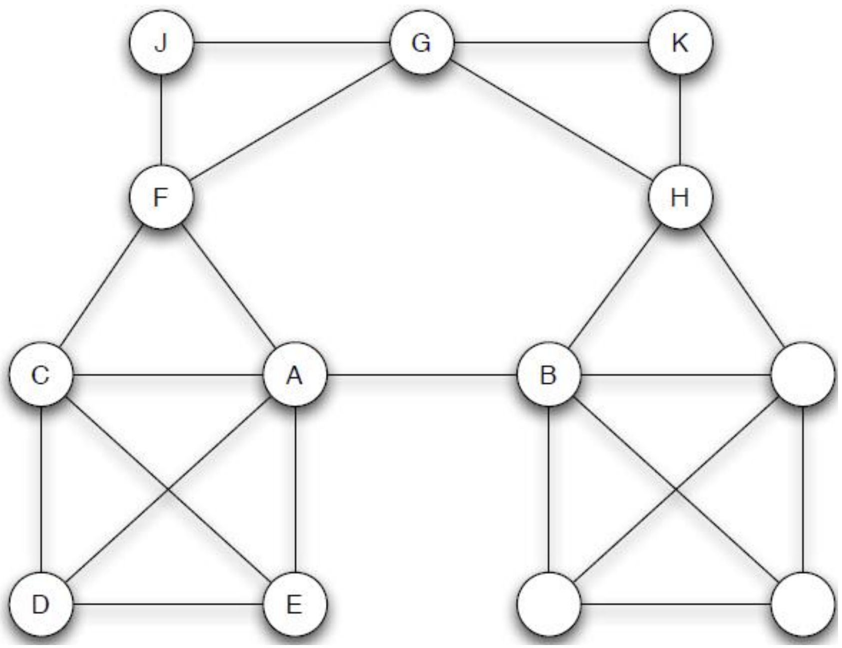
Bridges and Local Bridges- Cnt.

- Local Bridges:
  - An edge E(A,B) is a local bridge if its endpoints 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.

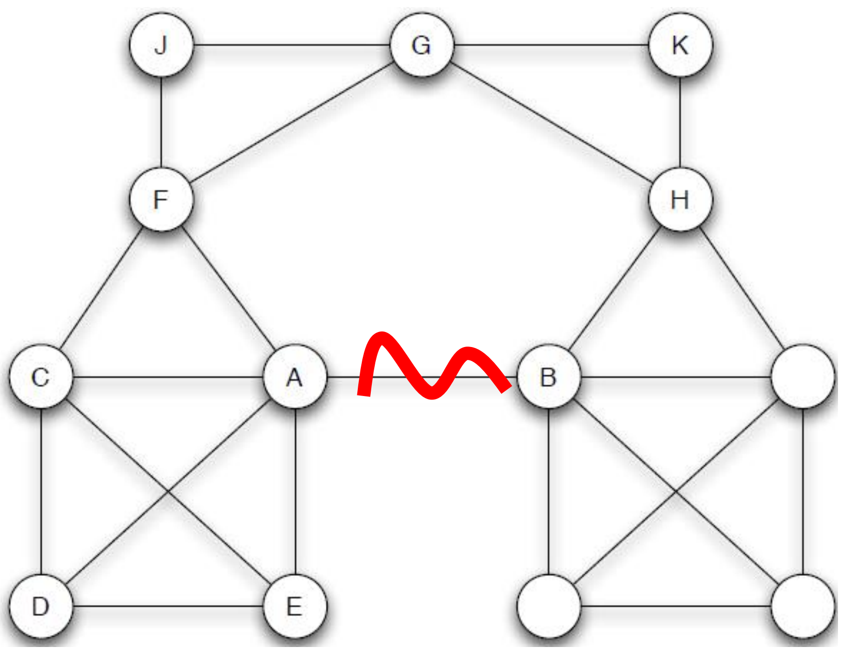
- Beside E(A,B), is there any other local bridge in this net?
  - Local bridges never form the side of any triangle in the net!
  - Local Bridge→ edge not in a triangle!



Bridges and Local Bridges- Cnt.

- 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

Length of the shortest path btw two nodes

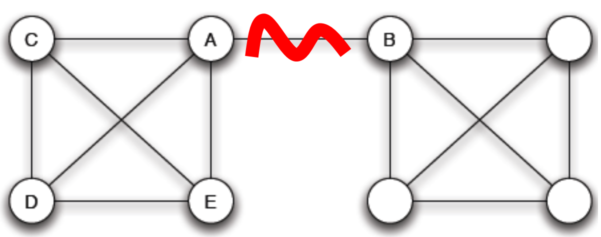


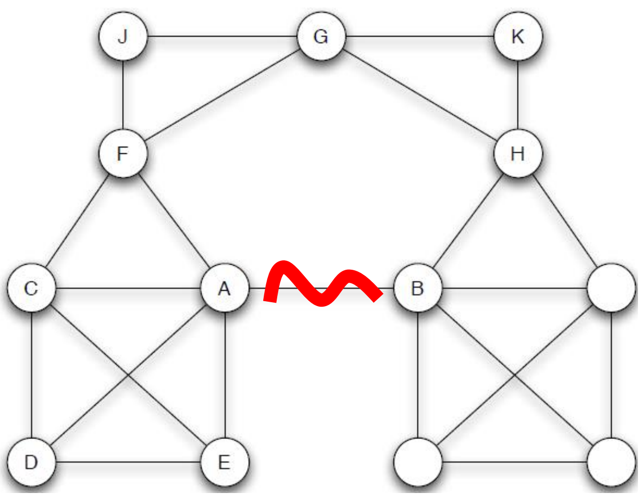
Local bridges with large span play roughly the same role as bridges:

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

Bridges and Local Bridges- Cnt.

- 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 her access to things she otherwise wouldn't necessarily hear about.





Strong Triadic Closure

- 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)

Strong Triadic Closure- Cnt.

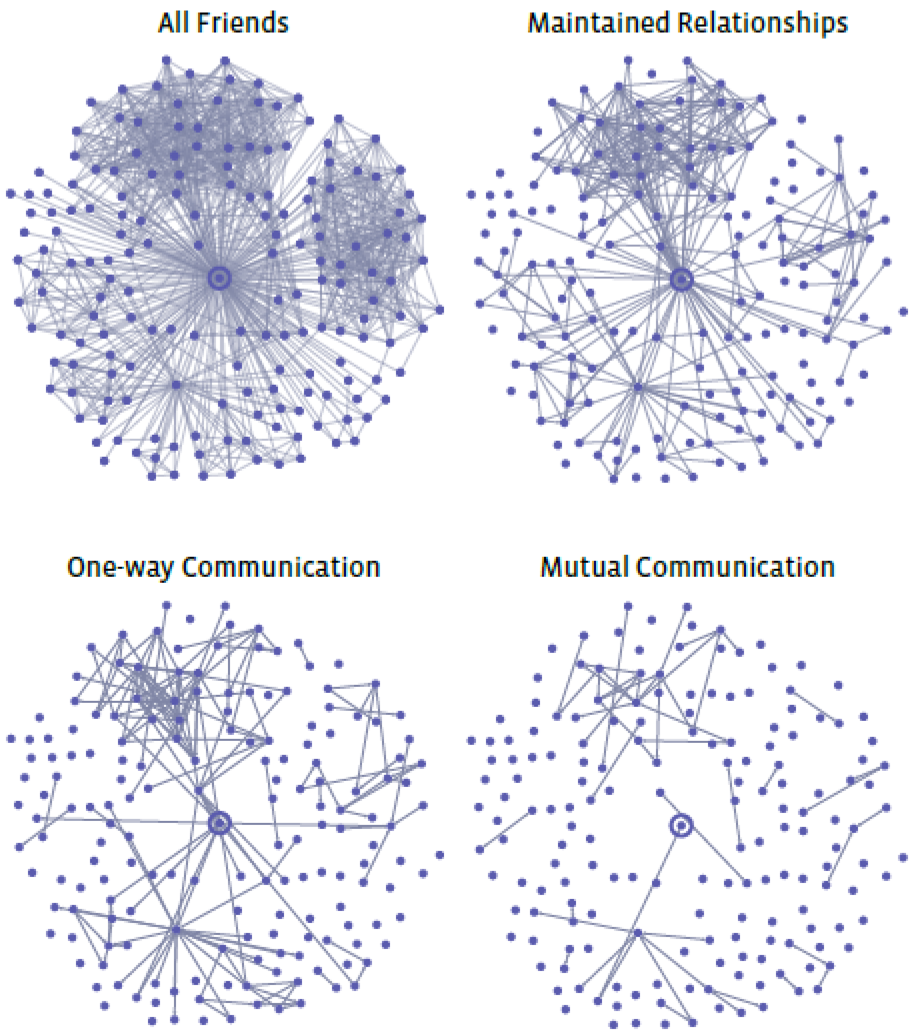
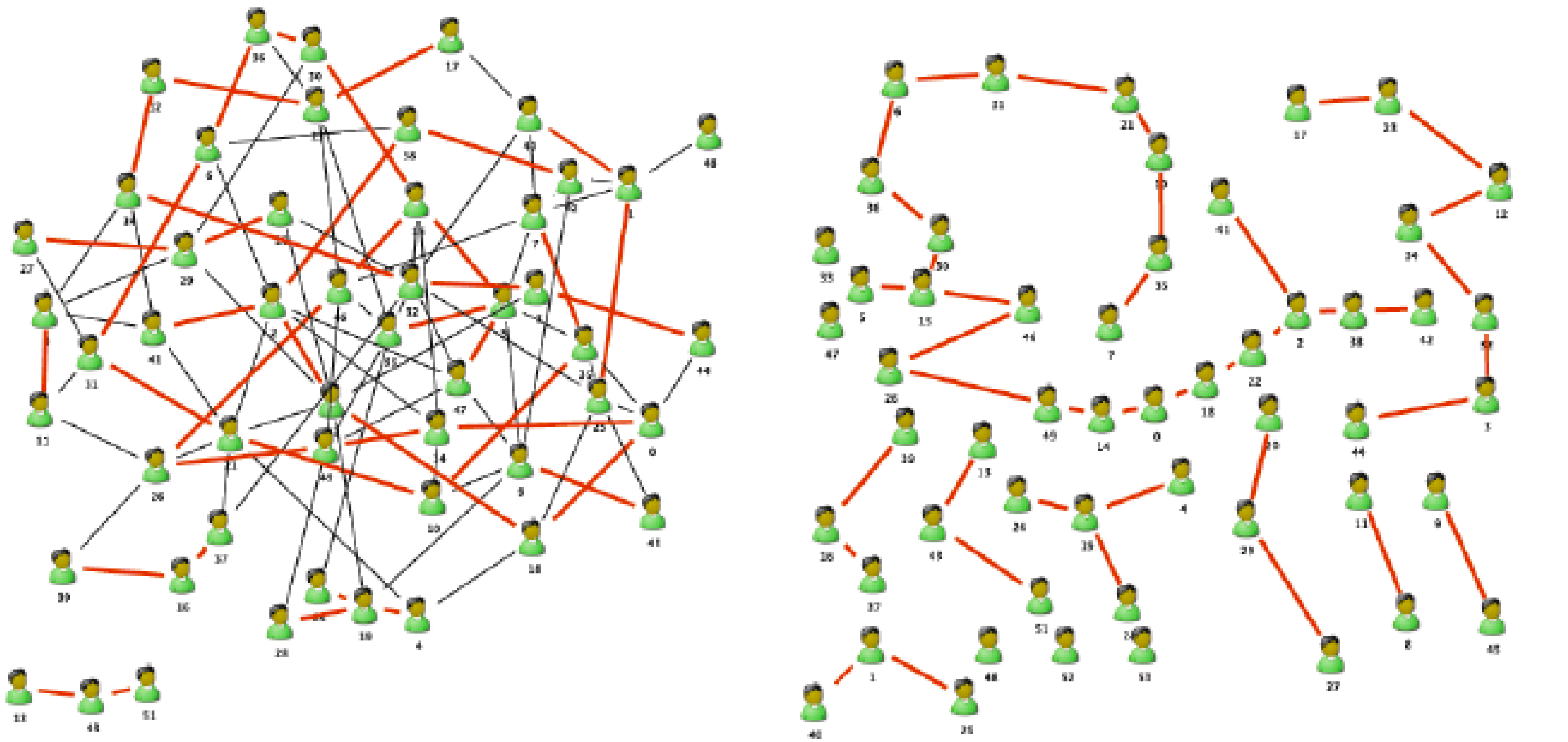


Figure 3.8: Four different views of a Facebook user's network neighborhood

Strong Triadic Closur



(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.

Source: Social networks that matter: Twitter under the microscope.Huberman et al. 2008. arxiv.org/pdf/0812.1045.pdf

Strong Triadic Closure- Cnt.

- Strong Triadic Closure
  - 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.

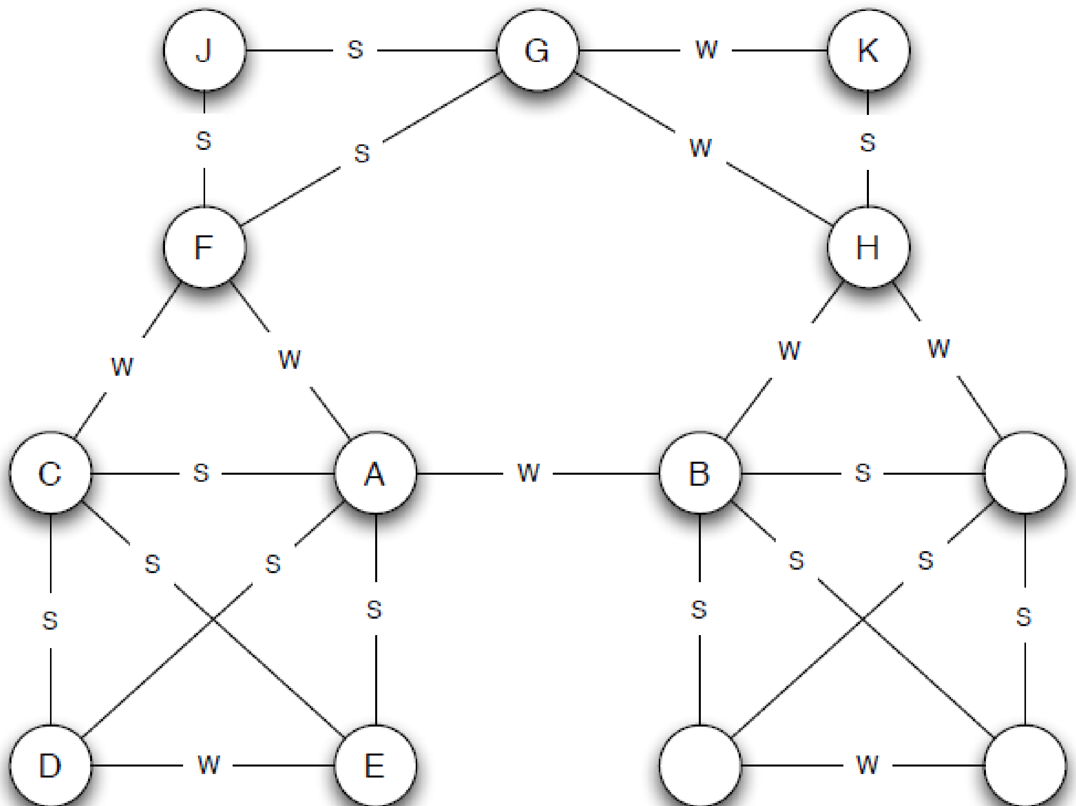
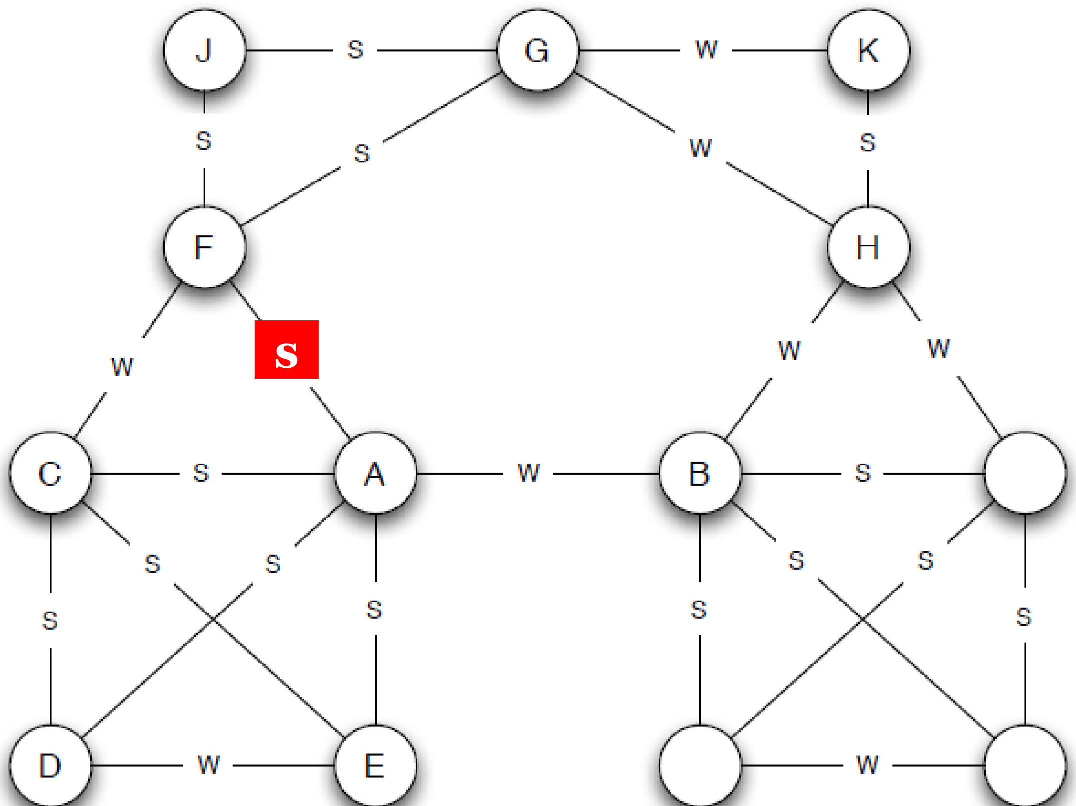


Figure 3.5: Each edge of the social network from Figure 3.4 is labeled here as either a *strong tie* (S) or a *weak tie* (W), to indicate the strength of the relationship. The labeling in the figure satisfies the Strong Triadic Closure Property at each node: if the node has strong ties to two neighbors,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

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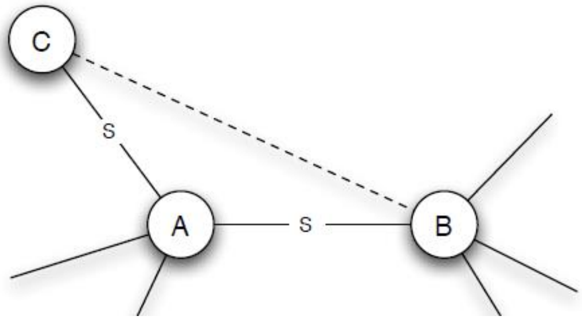
- If node A satisfies strong triadic closure and is involved in at least two strong ties then any local bridge adjacent to A must be a weak tie.
- Proof by contradiction:
  - A satisfies strong triadic closure and is involved in at least 2 strong ties
  - Suppose A-B is a local bridge
  - Strong Triadic Closure says: (B,C) must exist
  - But since (A,B) is a bridge (B,C) must not exist (endpoints of a bridge have no friends in common)



The Strength of Weak Ties

- The argument is that weak ties (acquaintances) are social ties that 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.
- This dual role - as weak connections but also valuable links to hard-to-reach parts of the network - is the surprising strength of weak ties.

Summary

- We defined bridges:
  - edges with nodes in different connected components.
- We defined local bridges as:
  - edges not in triangles!
- We defined two types of edges:
  - Strong and Weak Ties
- An edge is:
  - either strong or weak, and
  - either local bridge or not local bridge!
- We defined strong triadic closure:
  - Two strong ties imply a third strong / weak tie
- We discussed local bridges are weak ties

Tie Strength in Real-World Nets

- For many years, Granovetter's theory was untested on real-world large-scale networks!
- But nowadays we can study Granovetter's theory on such networks due to their availability!

Tie Strength in Real-World Nets- Cnt.

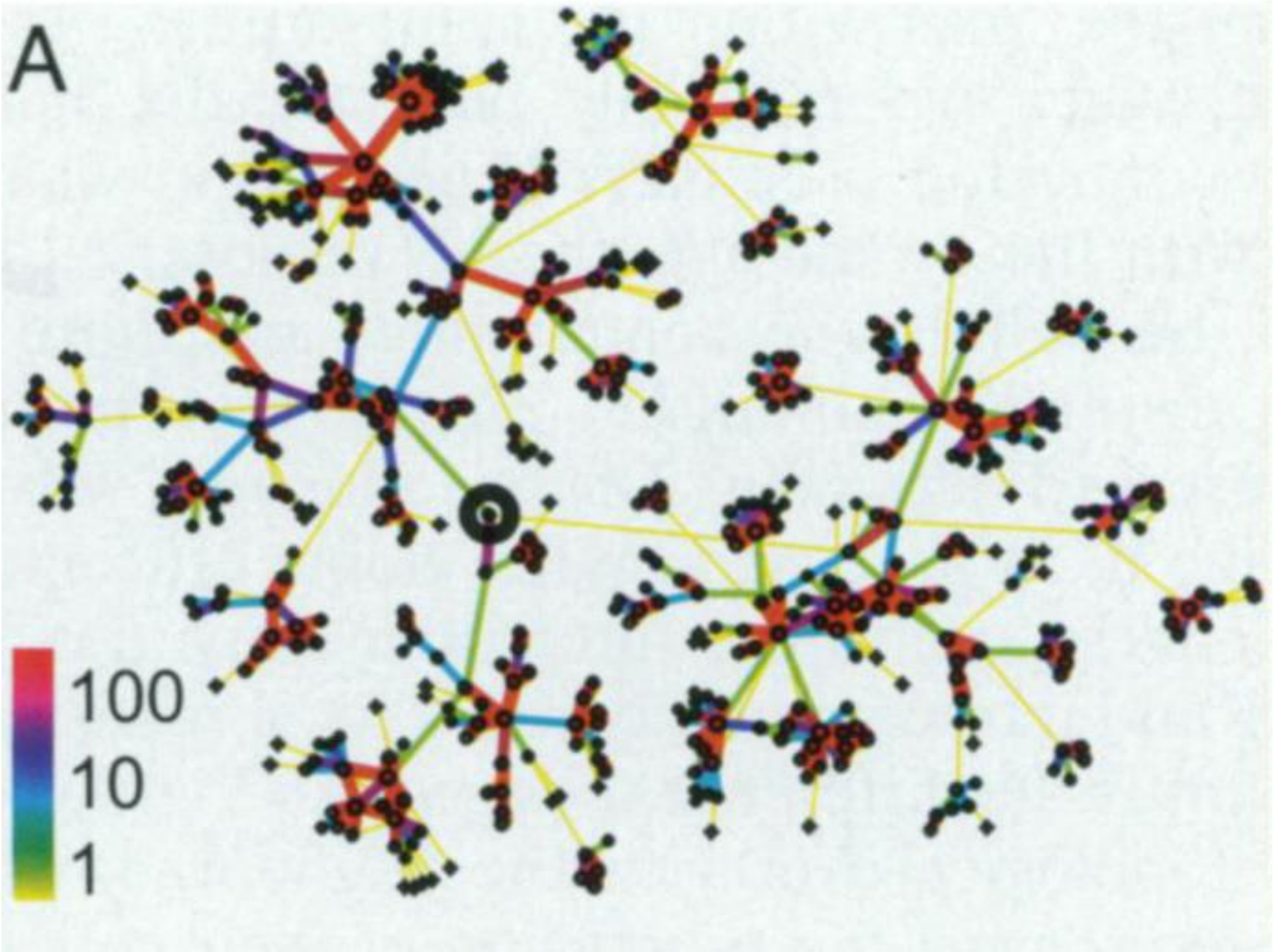
- Onnela et al., (2007) studied who-talks-to-whom net:
  - A node is a user
  - An edge forms btw two users who made phone calls to each other in both directions
  - 20% of the national population (18 week observation period)
  - Mainly used for personal communication
  - **First Observation**: a giant component covering 84% nodes

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

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:
  - Strength
    - we can make the strength of an edge a numerical quantity, defining it to be the total number of minutes spent on phone calls between two nodes.
  - Local Bridges
    - we define **neighborhood overlap** for each edge!

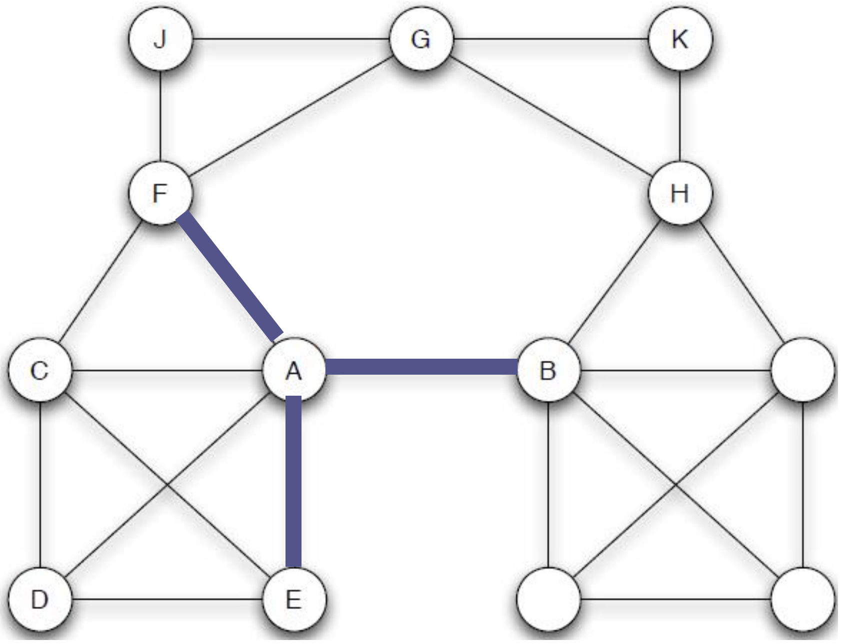
Source: Structure and tie strengths in mobile communication networks. Onnela, et al. National Academy of Sciences. 2007.

Tie Strength in Real-World Nets- Cnt.

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

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

Don't count A and B here!

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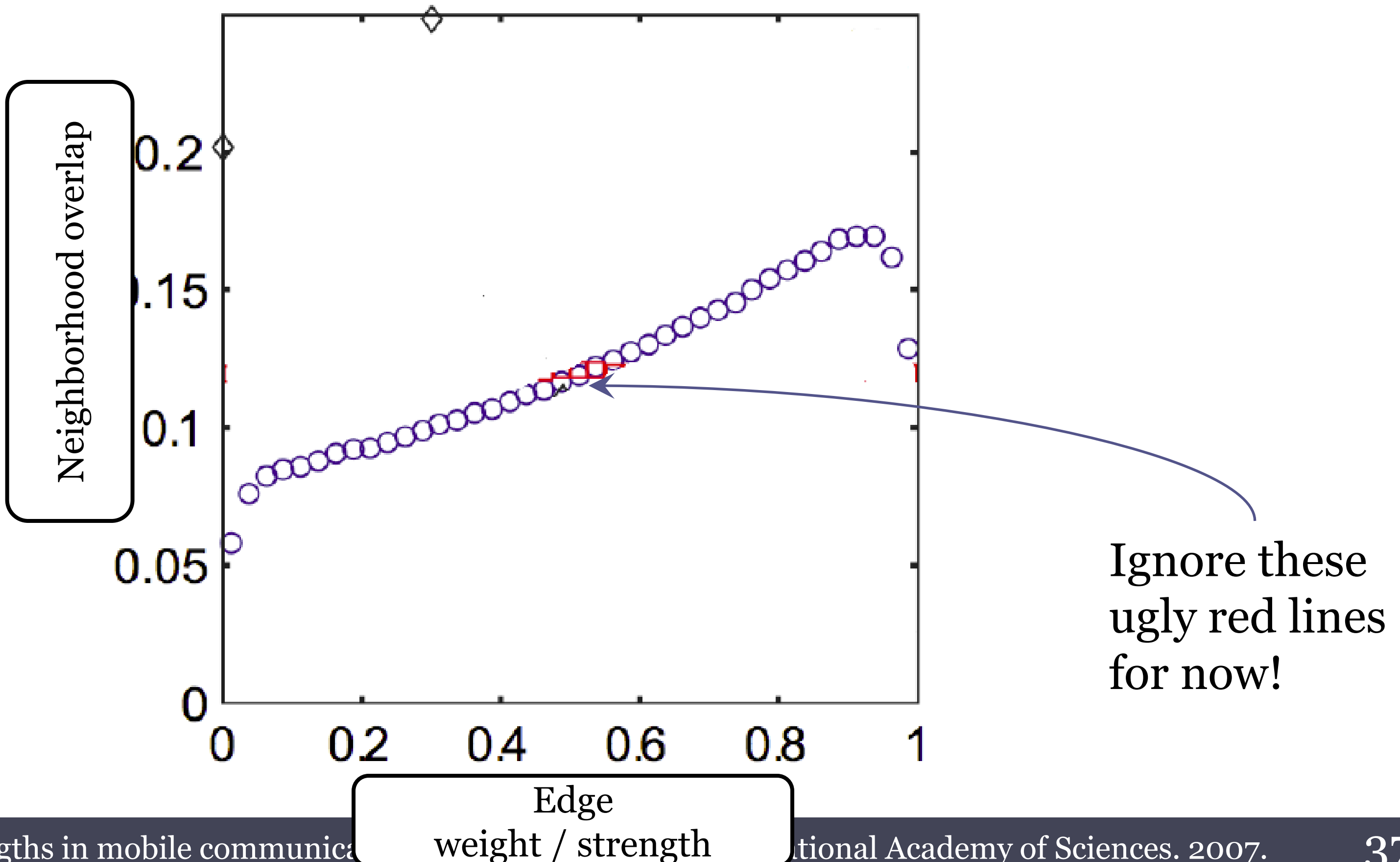
Nodes      Neighborhood overlap
-------    --------------------
A-F        1/6
A-E        3/4
A-B        0/8 (Overlap = 0 for
                local bridges)
```

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

Question 1.- Cnt.

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



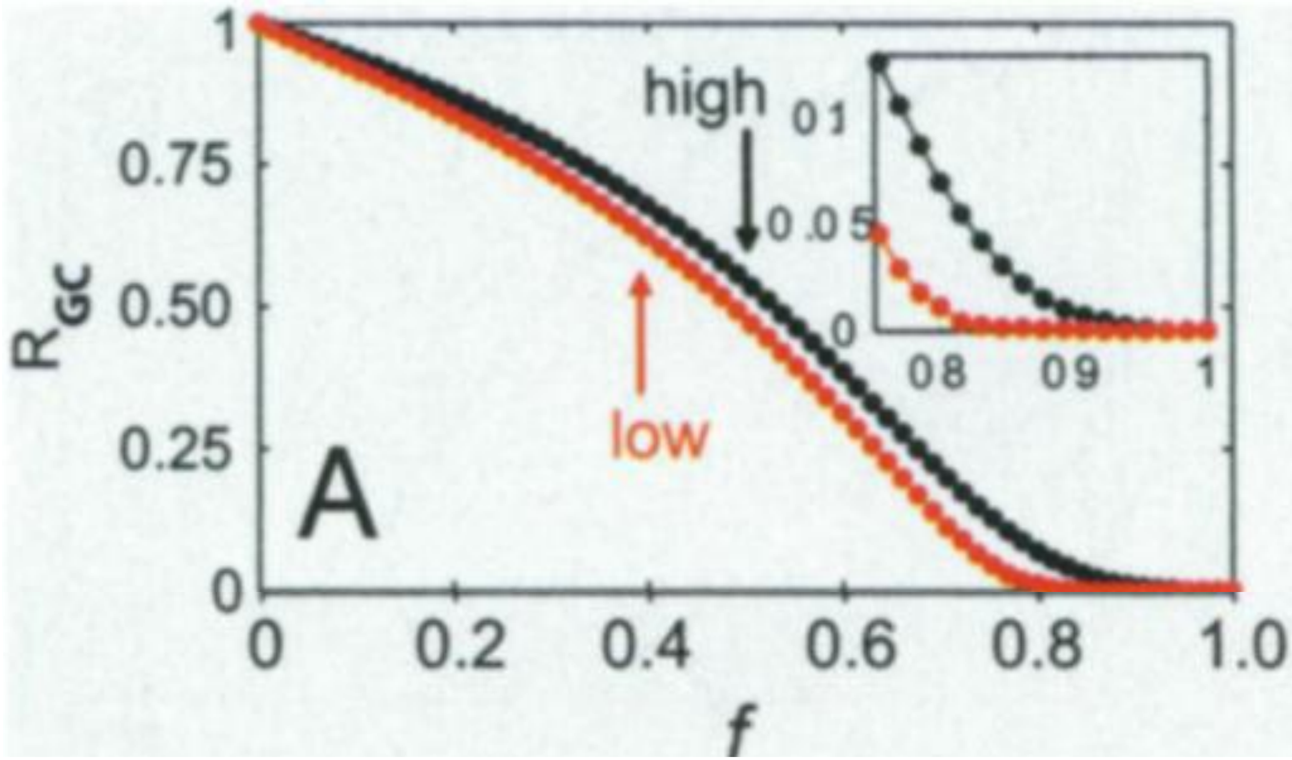
Question 2.- Cnt.

- How weak ties serve to link together different communities that each contain large number of stronger ties?
- Indirect Analysis:
  - Delete edges from the network one at a time, starting with the strongest ties first!
    - The giant component shrank steadily (its size wend down gradually).

Question 2.- Cnt.

- How weak ties serve to link together different communities that each contain large number of stronger ties?
- Indirect Analysis:
  - Delete edges from the network one at a time, starting with the weakest ties first!
    - The giant component shrank rapidly (its size wend down gradually).

Question 2.- Cnt.



Size of the largest component

The fraction of removed links

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

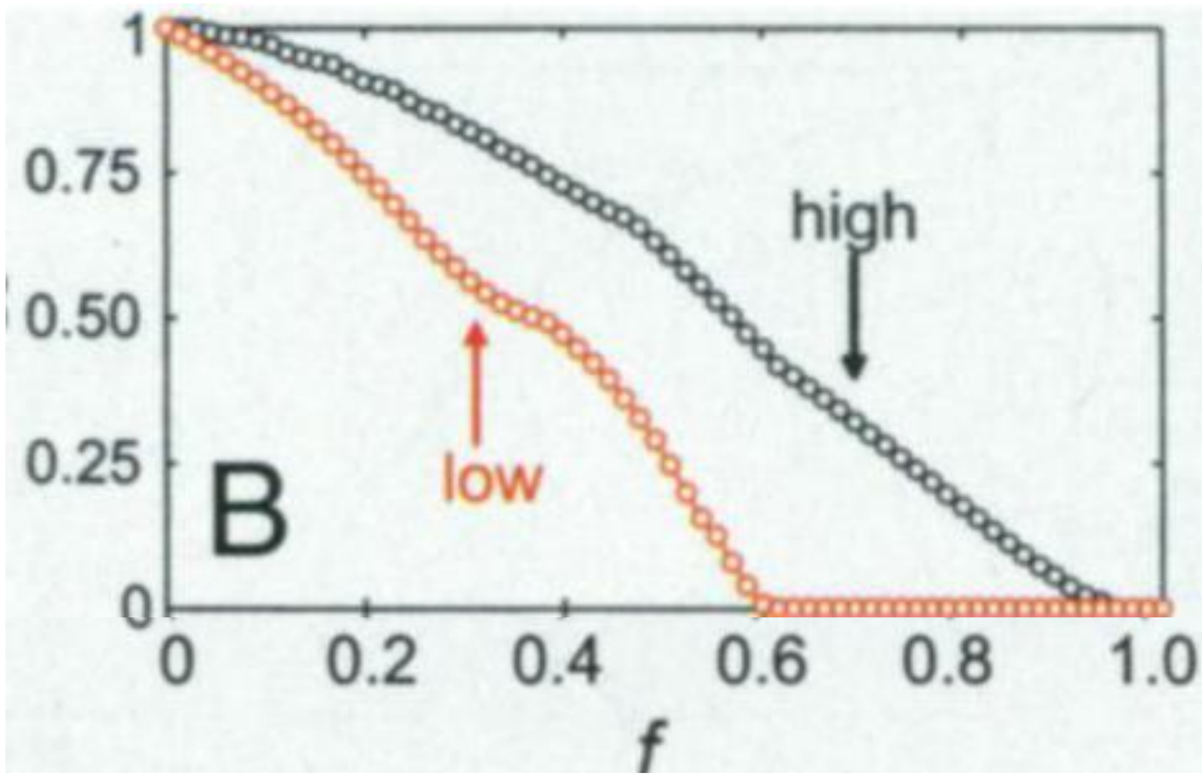
The removal of the low weight links leads to a breakdown of the network.

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

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

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.

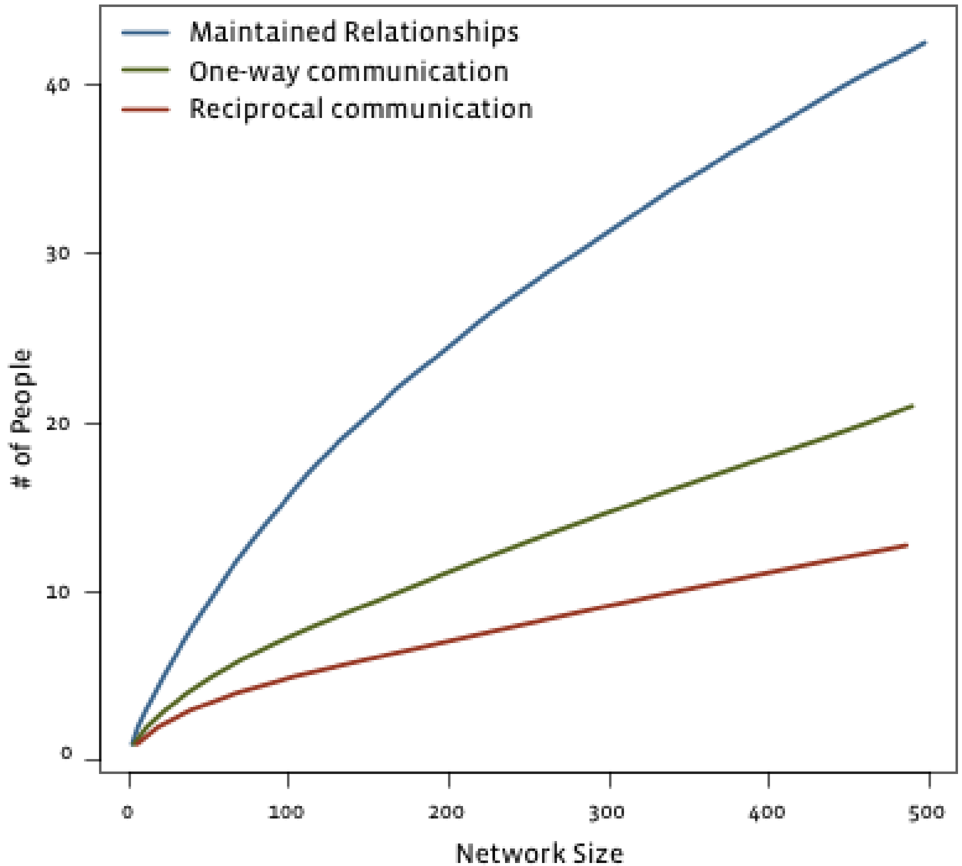
Question 2.- Cnt.

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

Tie Strength in Real Nets

Number of users with whom a user communicate is generally between 10 and 20!

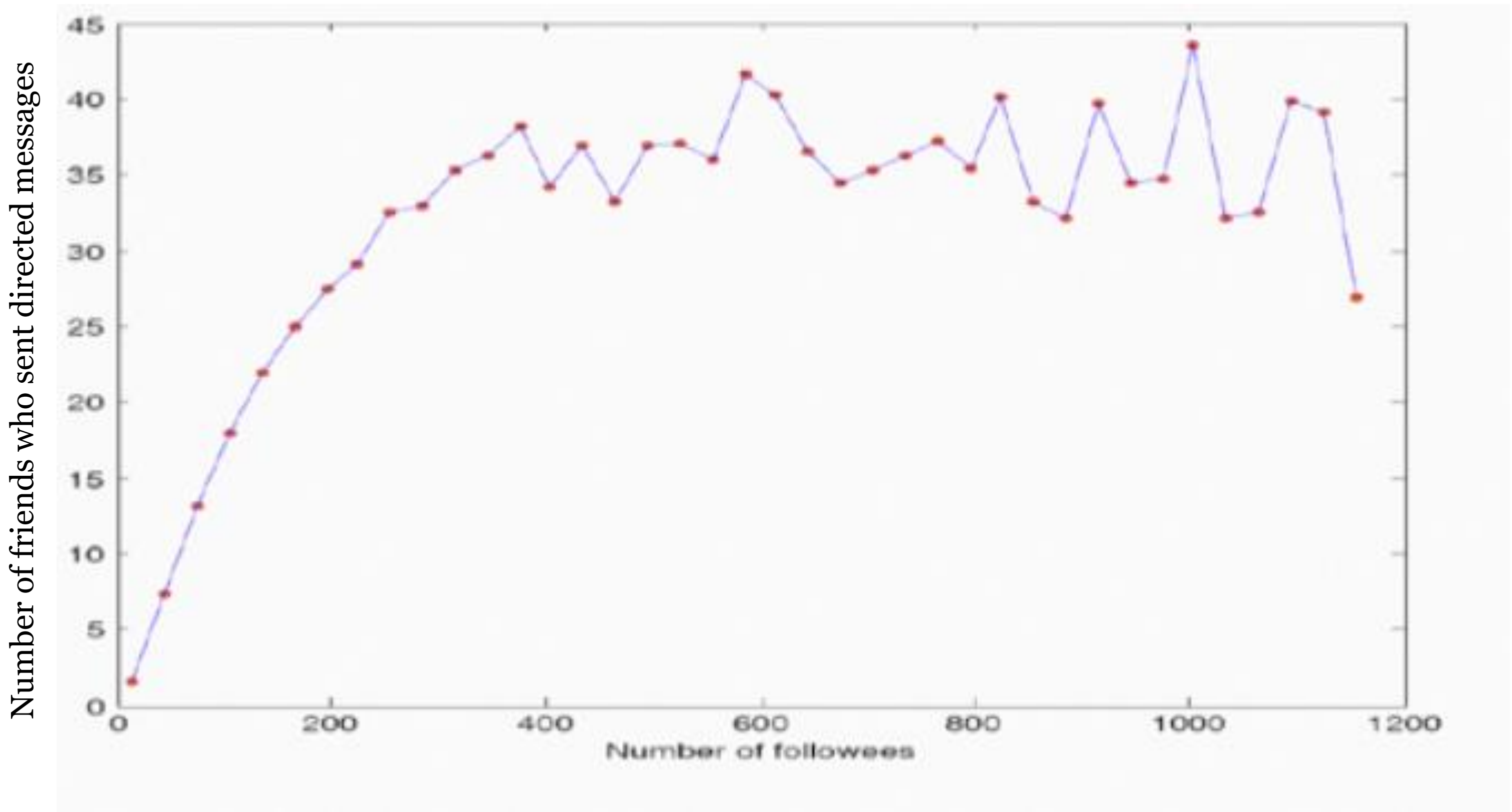
Number of users they follow even passively (e.g. by reading about them) is under 50!



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].)

Tie Strength in Real twitter



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 in Real Nets- Cnt.

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- 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!

Questions?

Reading

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