Strong and Weak Ties

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Thanks to
Easley, David, and Jon Kleinberg. "Networks, crowds, and markets." Cambridge Books (2012).

Social Network Analysis – What it does

- Networks bridge the local to the global — to offer explanations for how simple processes at the level of individual nodes and links can have complex effects that ripple through a population as a whole.

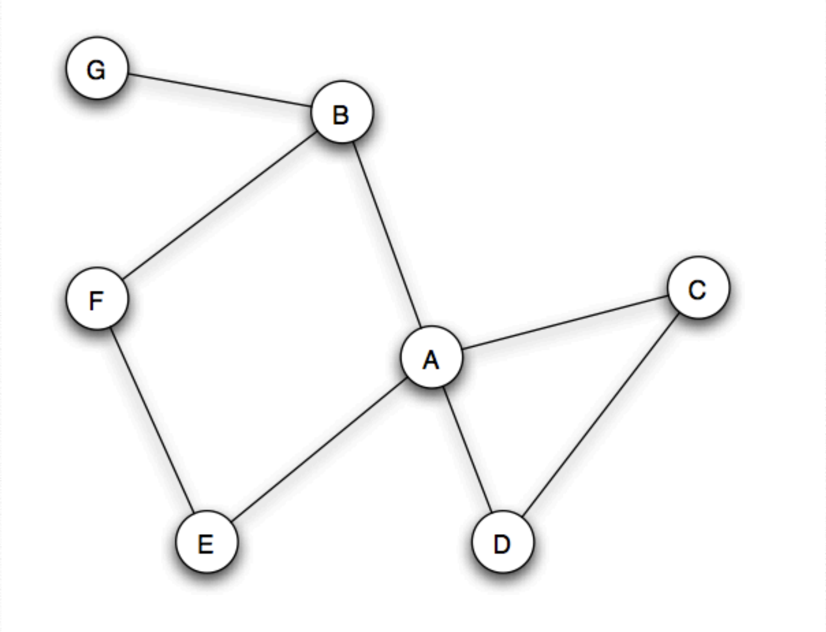
Key points

- How information flows through a social network..
- How different nodes can play structurally distinct roles in this process..
- How these structural considerations shape the evolution of the network itself over time...

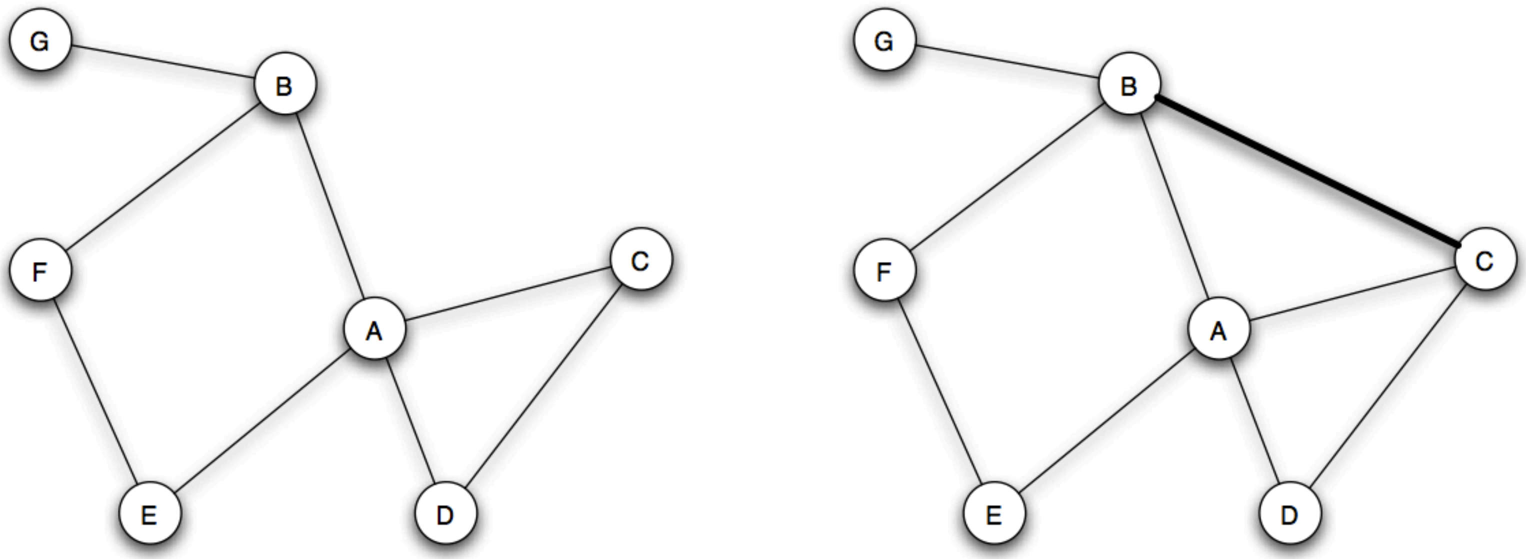
Granovetter's Problem

- How did people find new jobs?
- Through personal contacts..
- acquaintances, not close friends..
- So, how does the graph come into the picture?

How are friendships formed?



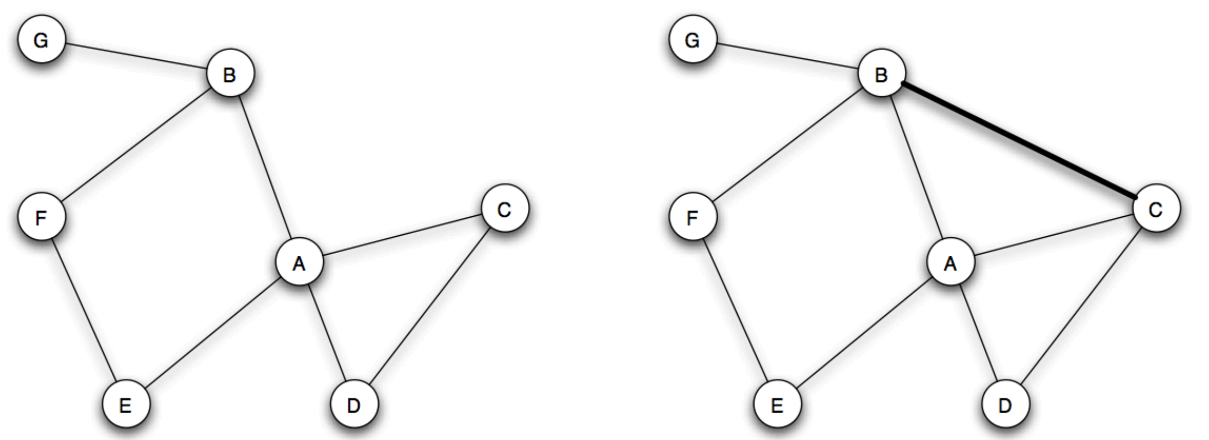
How are friendships formed?



(a) *Before B-C edge forms.* (b) *After B-C edge forms.*

What may be going on here?

Triadic Closure



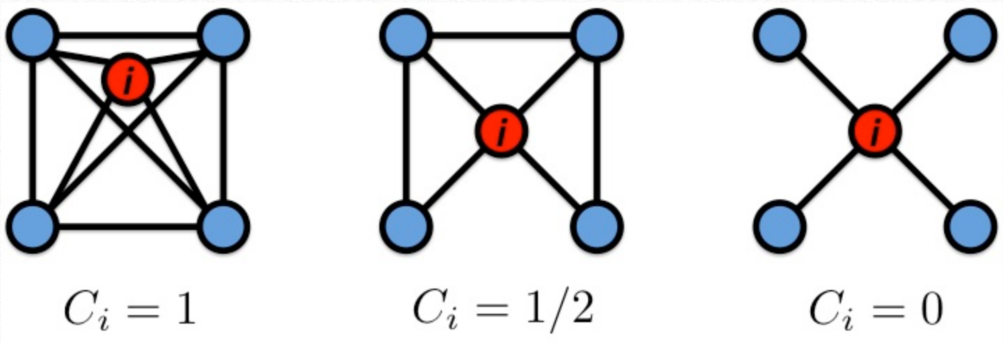
(a) *Before B-C edge forms.* (b) *After B-C edge forms.*

- If two people in a social network have a friend in common, then there is an increased likelihood that they will become friends themselves at some point in the future

Clustering Coefficient

- What fraction of your neighbours are connected?
  - Node i with degree k_i
  - Clustering Coefficient C_i for a vertex i is in [0,1]

$$C_i = \frac{2e_i}{k_i(k_i - 1)}$$



Clustering coefficient is a "local" property – each vertex has one.

Watts & Strogatz, Nature 1998.

Clustering Coefficient

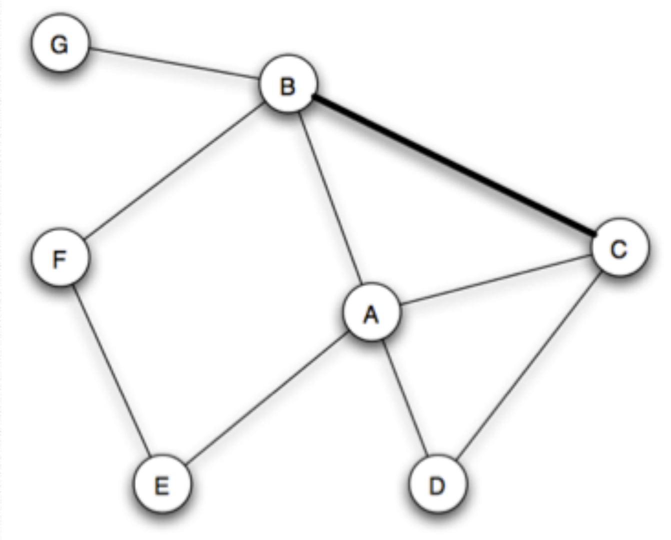
- ..is the fraction of pairs of A's friends that are connected to each other by edges.

- ..of a node A can also be defined as the probability that two randomly selected friends of A are friends with each other.

- The more the triadic closure (dynamic) is operating in the neighbourhood of a node, the higher the clustering coefficient (static) will be.

Reasons for Triadic Closure

- When they have a common friend A, there is an increased opportunity for B and C to meet.



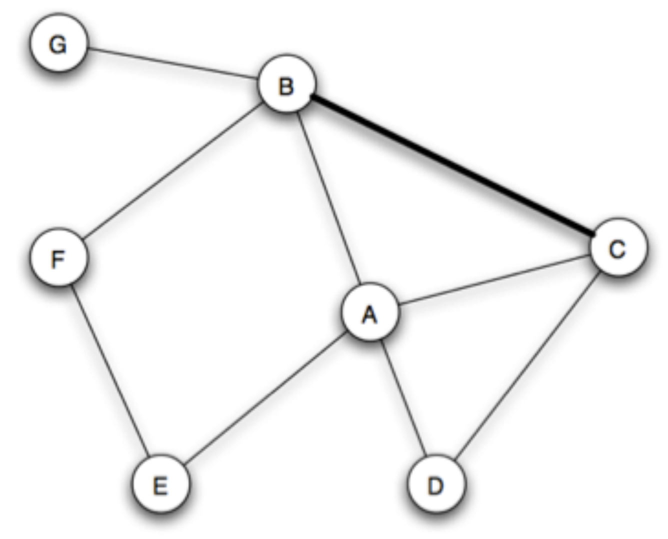
- Since each of B and C is friends with A (provided they are mutually aware of this) gives them a basis for trusting each other that an arbitrary pair of unconnected people might lack.

- A third reason is based on the incentive A may have to bring B and C together: if A is friends with B and C, then it becomes a source of latent stress in these relationships if B and C are not friends with each other.

The story so far...

- Acquaintances rather than friends were helpful in finding jobs.
- How friendships may be formed, and the idea of triadic closure (“formation of triangles”).
- The reasons for triadic closure.
- What are we trying to do?

  Differentiate between friends and acquaintances – strong and weak ties.

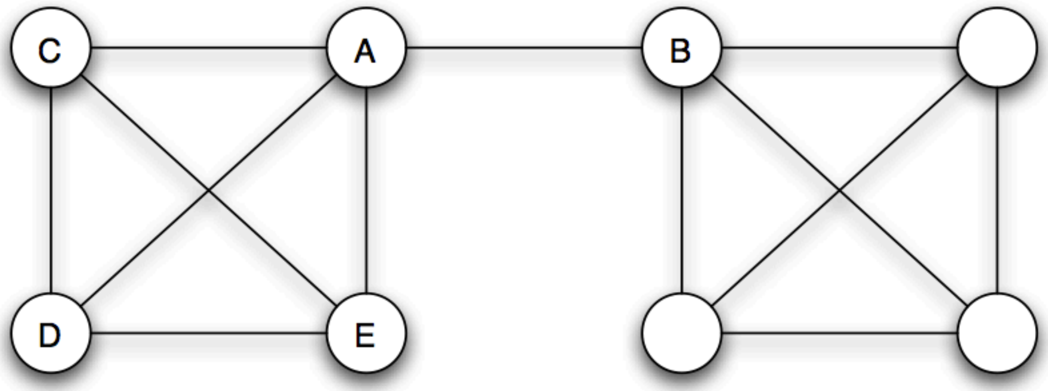


Why acquaintances...

- The close friends we have, we talk to them frequently, and share information more frequently with them.
- So, it is less likely that they have information we don't.
- The reasons for triadic closure.
- What are we trying to do?

  Differentiate between friends and acquaintances – strong and weak ties.

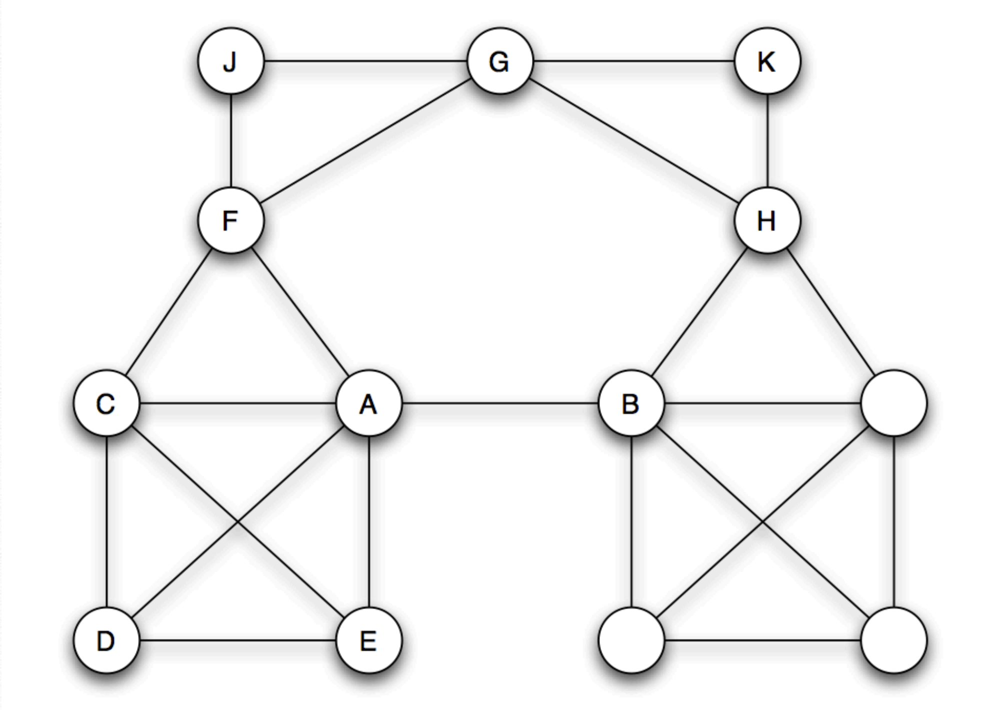
Bridges



A-B is a bridge; it's removal disconnects the graph into 2 components, with A and B lying in different components.

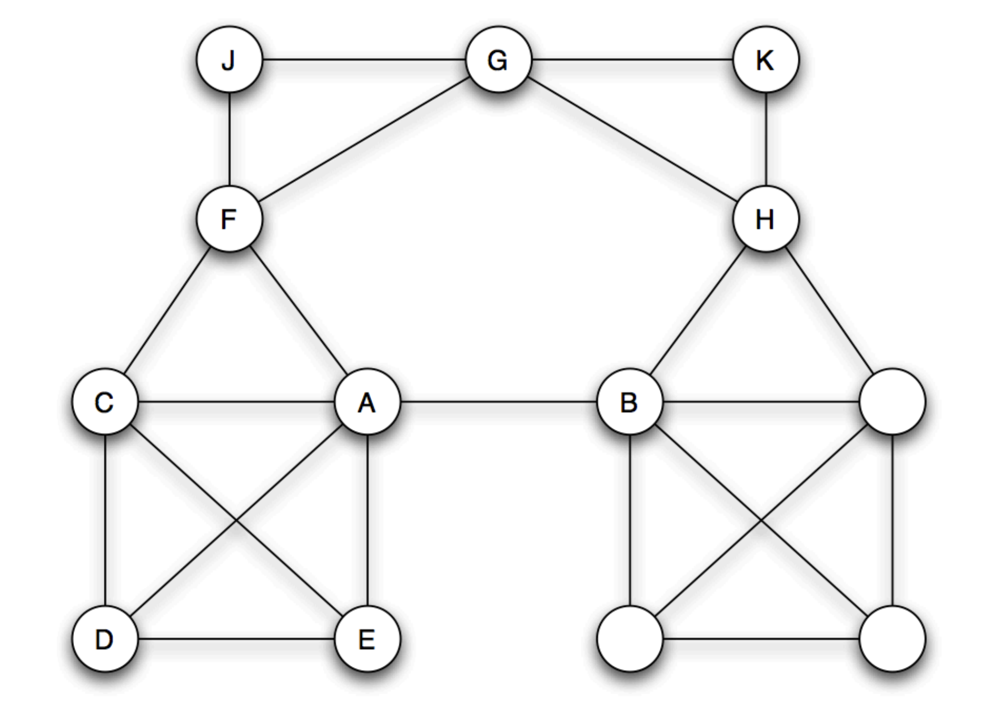
In real social networks, bridges may be rare, so…?

Local Bridges



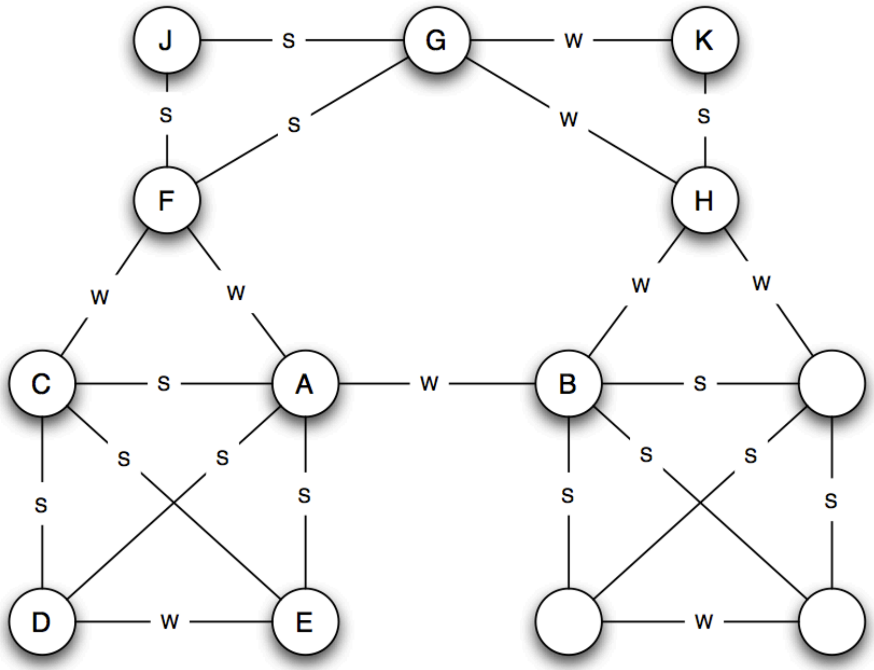
The A-B edge is a local bridge of span 4, since the removal of this edge would increase the distance between A and B to 4.

Local Bridges



We say that an edge joining two nodes A and B in a graph 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 between A and B to a value strictly more than two.

Local Bridges

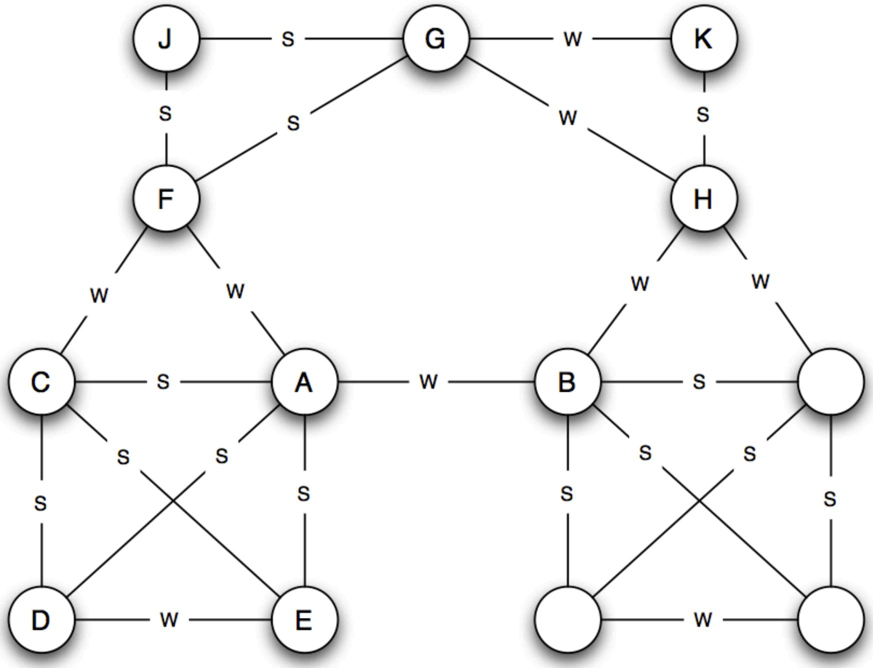


The labelling in the figure satisfies the Strong Triadic Closure Property at each node: if the node has strong ties to two neighbours, then these neighbours must have at least a weak tie between them.

Strong Triadic Closure Property

- If a node A has edges to nodes B and C, then the B-C edge is especially likely to form if A's edges to B and C are both strong ties.
- Granovetter's version:
- We say that a node A violates the Strong Triadic Closure Property if it has strong ties to two other nodes B and C, and there is no edge at all (either a strong or weak tie) between B and C.
- We say that a node A satisfies the Strong Triadic Closure Property if it does not violate it.

Strong Triadic Closure Property

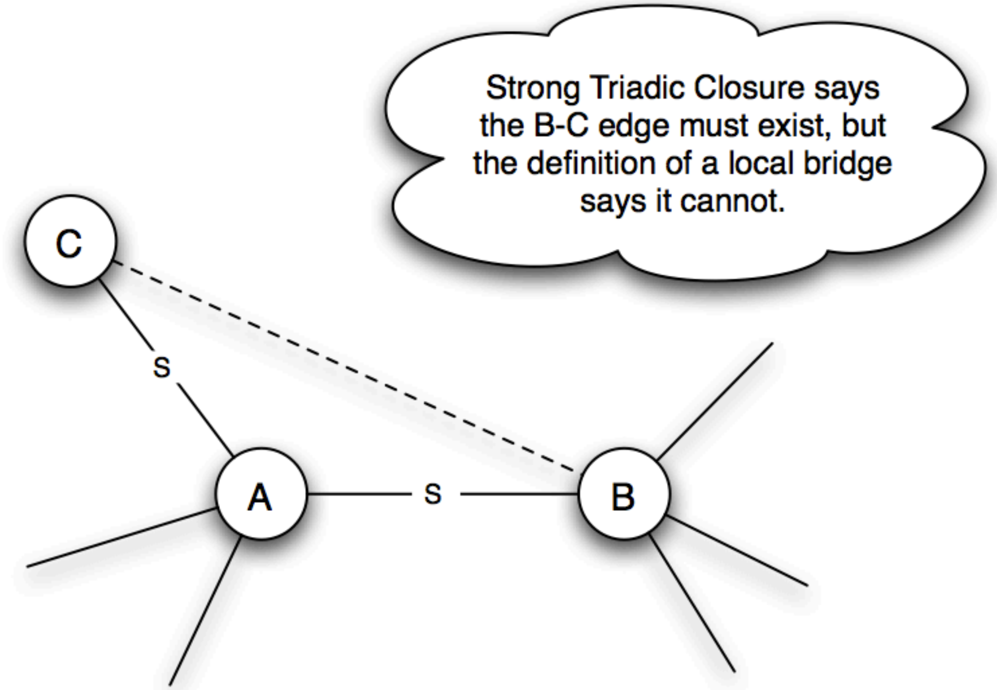


Each edge of the social network is labeled here as either a strong tie (S) or a weak tie (W), to indicate the strength of the relationship.

Local Bridges and Weak Ties

- A purely local, interpersonal distinction between kinds of links — whether they are weak ties or strong ties — as well as a global, structural notion — whether they are local bridges or not.
- What is the connection?
- Claim: If a node A in a network satisfies the Strong Triadic Closure Property and is involved in at least two strong ties, then any local bridge it is involved in must be a weak tie.
- Assuming the Strong Triadic Closure Property and a sufficient number of strong ties, the local bridges in a network are necessarily weak ties.
- *How to prove this?*

Local Bridges and Weak Ties



if the A-B edge is a strong tie, then there must also be an edge between B and C, meaning that the A-B edge cannot be a local bridge.

So, what happened?

- We found the connection between the local property of tie strength and the global property of serving as a local bridge.
- A way to think about the way in which interpersonal properties of social-network links are related to broader considerations about the network's structure.

Granovetter’s Problem

- Links two different perspectives on distant relationships.
- One interpersonal, using purely local considerations of friendship between two people being strong (friend) and weak (acquaintance).
- The other structural, how friendships span different parts of the entire network.

So, what did we learn?

- Simplifying assumptions (STCP) are useful when they lead to statements that are robust in practice.
  - Informally, a local bridge between nodes A and B tends to be a weak tie because if it weren't, triadic closure would tend to produce short-cuts to A and B that would eliminate its role as a local bridge.

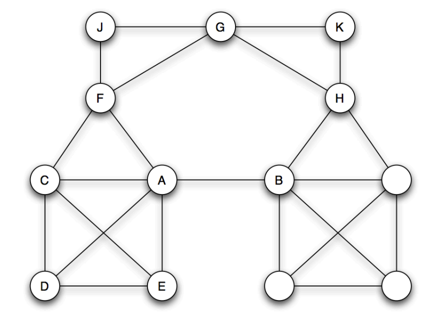
- When the underlying assumptions are stated precisely, as they are here, it becomes possible to test them on real-world data.

- This analysis provides a concrete framework for thinking about the initially surprising fact that life transitions such as a new jobs are often rooted in contact with distant acquaintances.
  - The argument is that these are the social ties that connect us to new sources of information and new opportunities.
  - 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 conduits to hard-to-reach parts of the network — this is the surprising strength of weak ties.

The story continues...

- For many years after Granovetter's work, these predictions remained untested on large social networks..
- Difficulty of finding data that would reliably capture these parameters.
- Enter digital communication data.
- Onnela et al. studied the who-talks-to-whom network maintained by a cell-phone provider that covered roughly 20% of a national population.

The story continues...



- So, how to define the metrics for a practical situation?

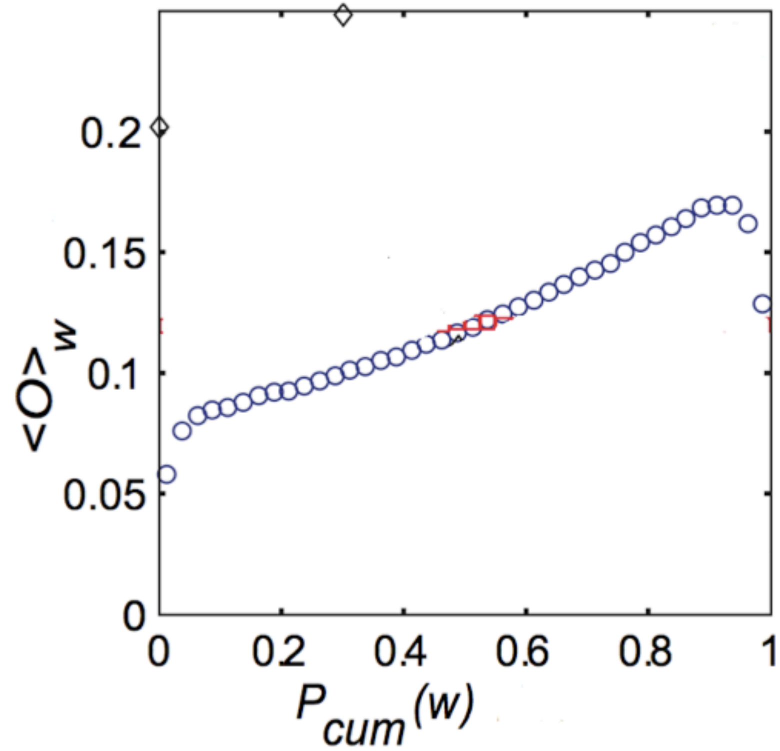
- Tie strength: we can make the strength of an edge a numerical quantity, defining it to be the total number of minutes spent on phone calls between the two ends of the edge.

- It is also useful to sort all the edges by tie strength, so that for a given edge we can ask what percentile it occupies this ordering of edges sorted by strength.

- *What about local bridges and "almost" local bridges?*

- Define the neighbourhood overlap of an edge connecting A and B as…
  - $$\frac{\text{number of nodes who are neighbours of both A and B}}{\text{number of nodes who are neighbours of at least one of A and B}}$$

Tie-strength & Network Structure in Large-Scale Data



A plot of the neighbourhood overlap (O) of edges as a function of their percentile (P) in the sorted order of all edges by tie strength. The fact that overlap increases with increasing tie strength is consistent with the theoretical predictions.

Thank you!

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