Social Network Analysis 1

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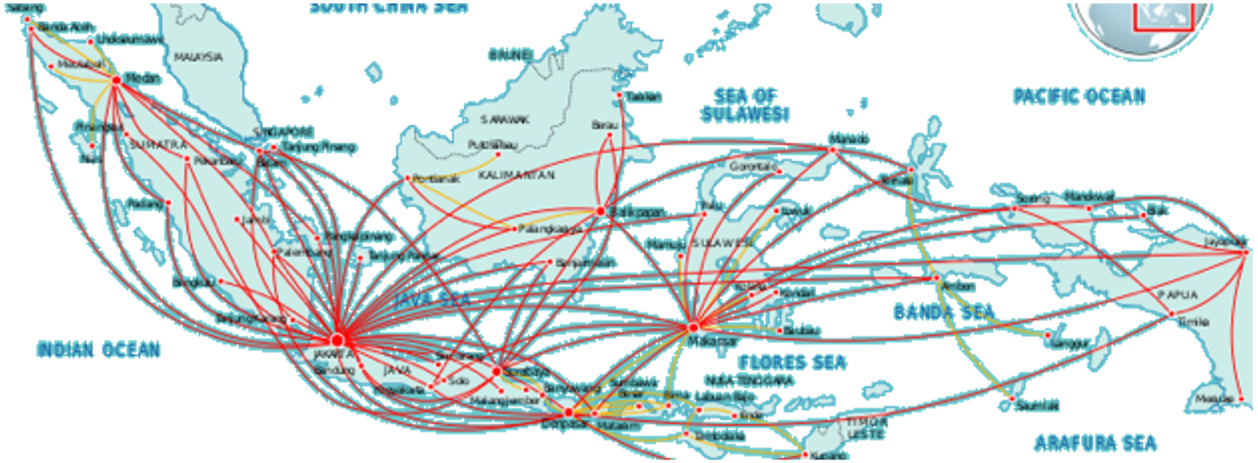
Learning Outline

- Handshake with Social Network Analysis
- Network Representation
- Tie Strength Identification
- Key Player Identification
- Measuring Overall Social Network Structure

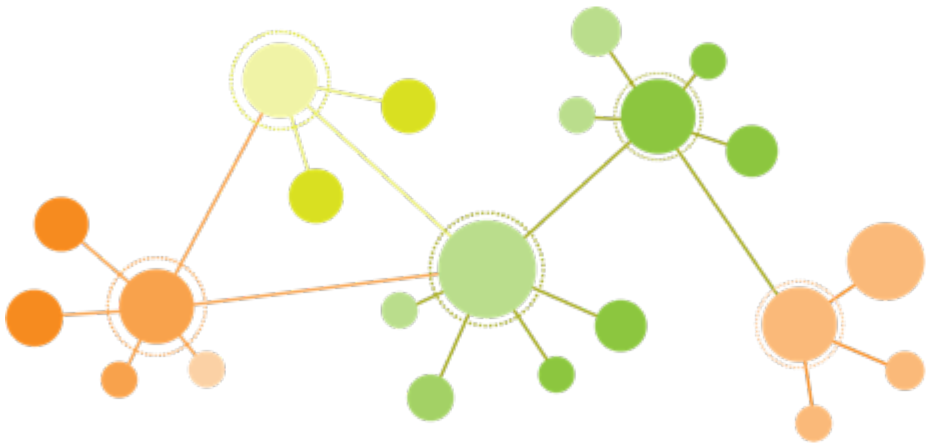
Handshake with
Social Network Analysis

What is a Network?

- Powerful for describing complex systems by explaining interconnection between elements.
- Can be adopted universally in various fields e.g. mathematics, computer science, economics, sociology, chemistry, biology, etc.



Social Network



- Build upon:
  - **Nodes as users**
  - **Edges as interaction flow between users**
  - **Graph type to indicate the nature of interaction**
  - **Weight to indicate the importance level of an interaction**
- Focused on relationships and interconnected behaviors of various entities e.g. objects, people and organizations.
- The more specific area associated with SNA is the dynamic network behavior study formally known as Dynamic Network Analysis (DNA).

Network Representation

Let’s study their interactions
as a network

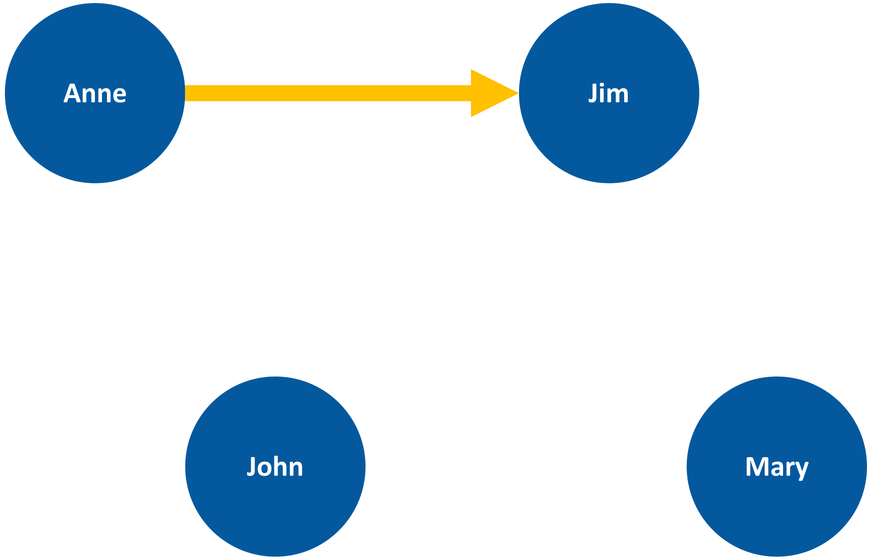
Anne

Jim

John

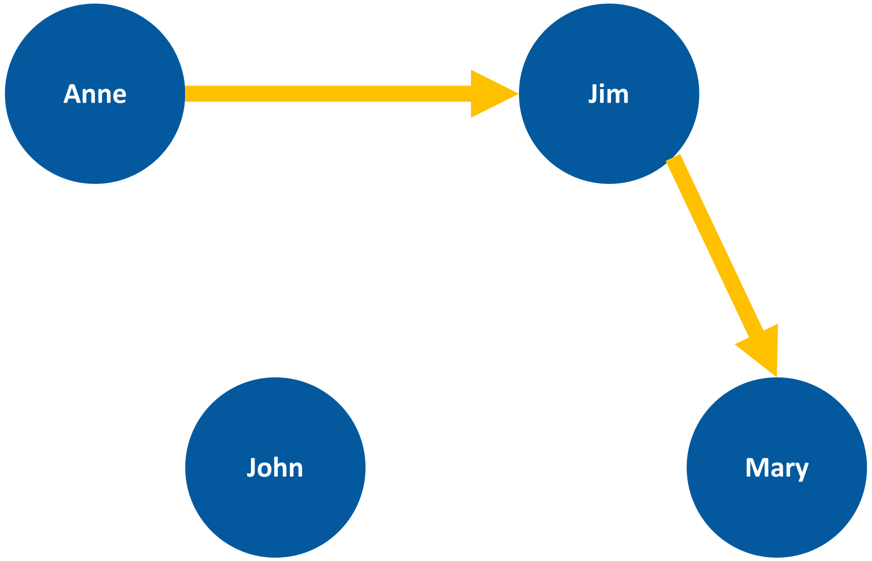
Mary

Anne : Jim, tell Mary and John they're invited



Anne : Jim, tell Mary and John they're invited

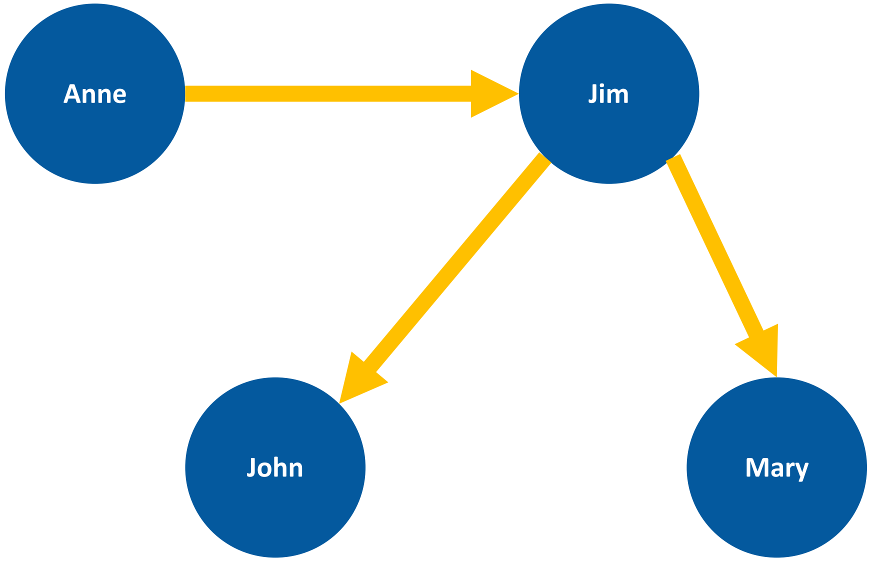
Jim : Mary, you and your dad should come for dinner

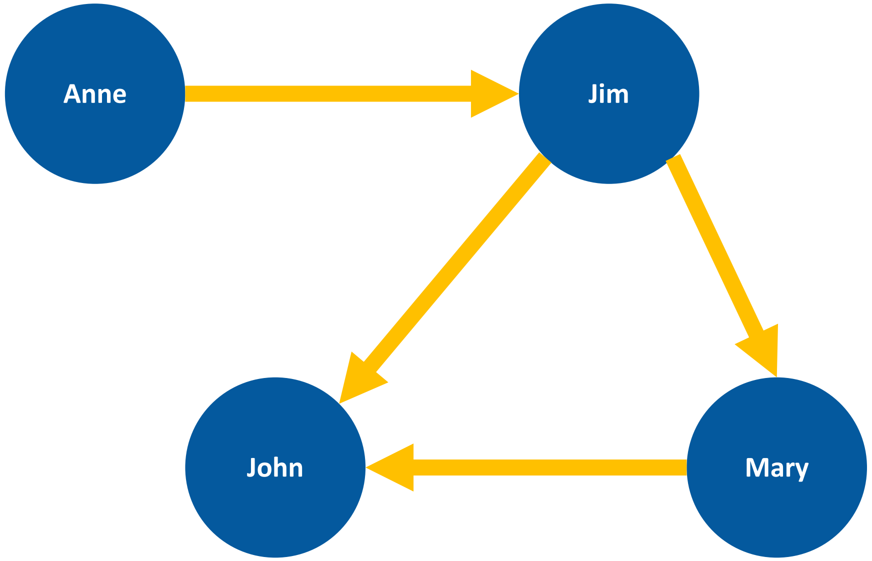


Anne : Jim, tell Mary and John they're invited

Jim : Mary, you and your dad should come for dinner

Jim : Mr. John, you should both come for dinner





Anne : Jim, tell Mary and John they're invited

Jim : Mary, you and your dad should come for dinner

Jim : Mr. John, you should both come for dinner

Mary : Dad, we are invited for tonight

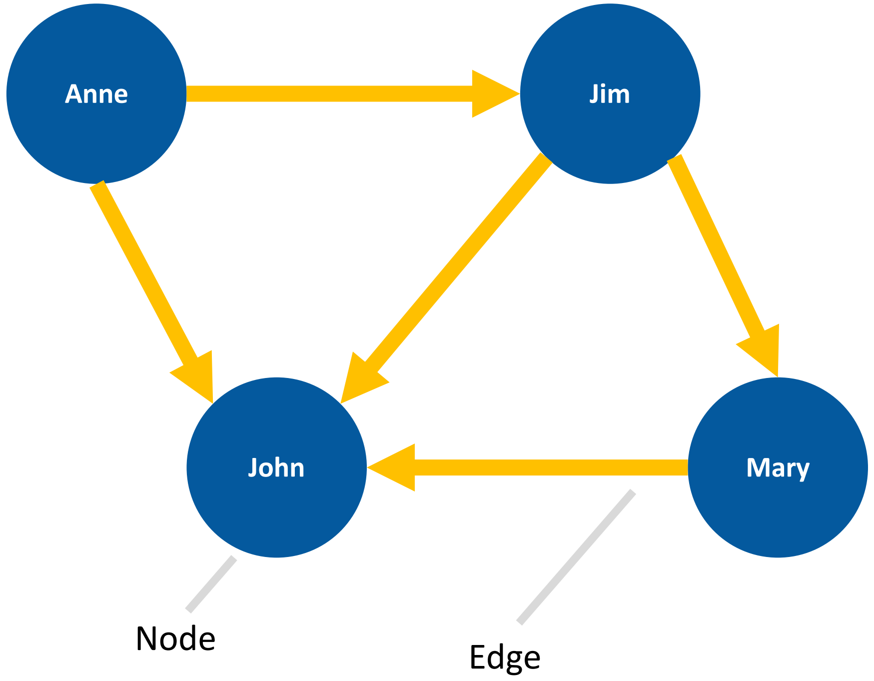
Anne : Jim, tell Mary and John they're invited

Jim : Mary, you and your dad should come for dinner

Jim : Mr. John, you should both come for dinner

Mary : Dad, we are invited for tonight

Anne : John, did Jim tell you about the dinner? You must come



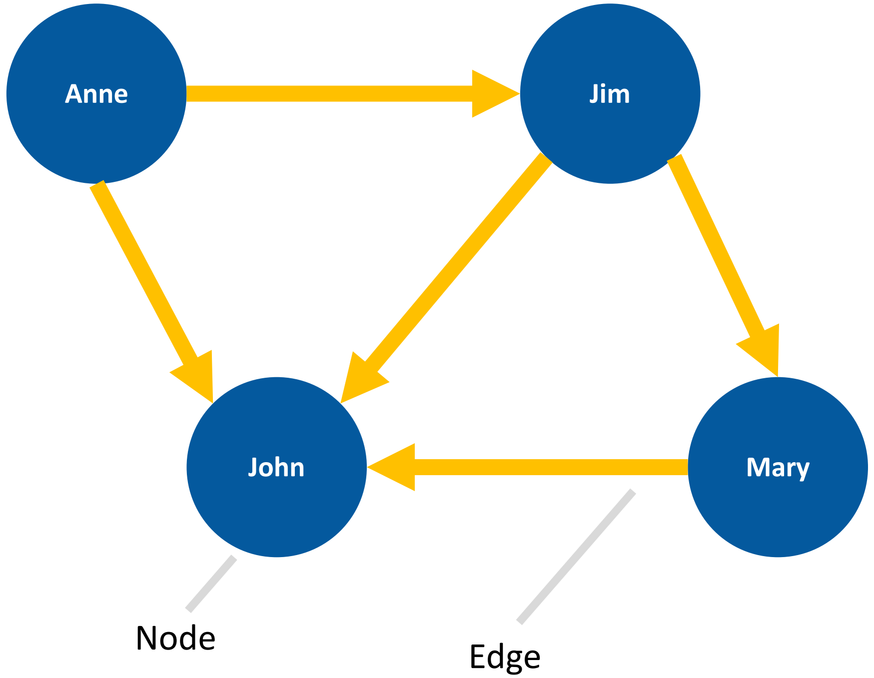
Network Type: Directed

Edge List

Vertex	Vertex
Anne	Jim
Anne	John
Jim	John
Jim	Mary
Mary	John

Adjacency Matrix

Vertex	Anne	Jim	John	Mary
Anne	-	1	1	0
Jim	0	-	1	1
John	0	0	-	0
Mary	0	0	1	-



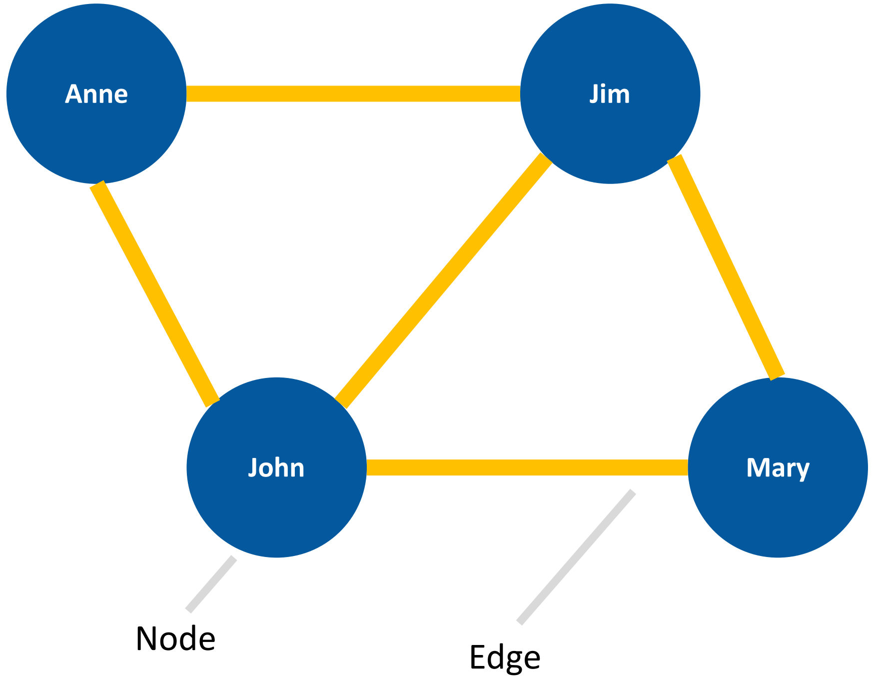
Network Type: Undirected

Edge List

Vertex	Vertex
Anne	Jim
Anne	John
Jim	John
Jim	Mary
Mary	John

Adjacency Matrix

Vertex	Anne	Jim	John	Mary
Anne	-	1	1	0
Jim	1	-	1	1
John	1	1	-	0
Mary	0	1	1	-



Network Type: Weighted

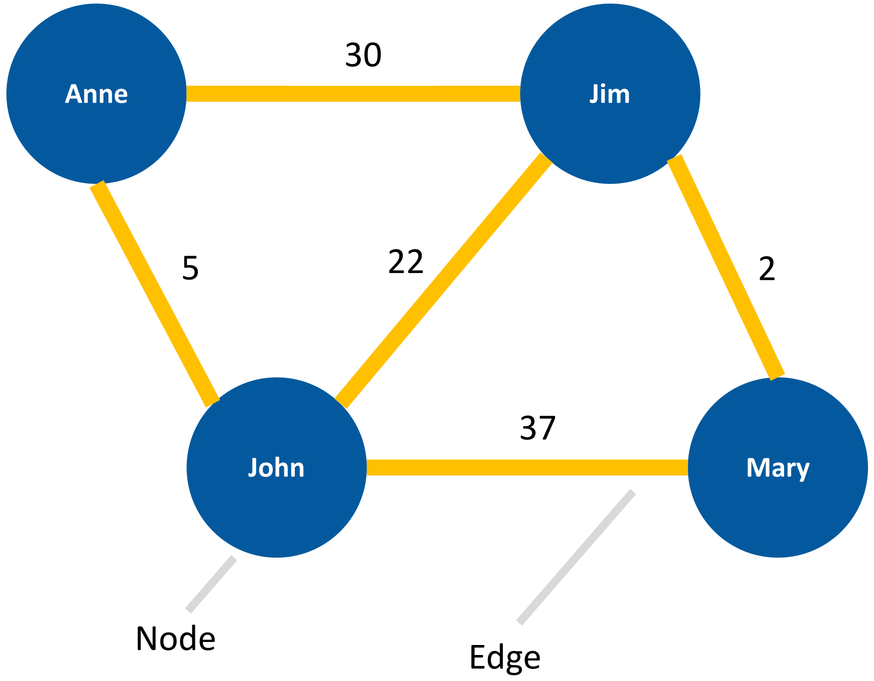
Edge List

Vertex	Vertex	Weight
Anne	Jim	30
Anne	John	5
Jim	John	22
Jim	Mary	2
Mary	John	27

Weight could be
- Frequency of interactions in period of observation
- Number of items exchanged in period
- Individual perceptions of strength of relationship
- Cost of communications or exchange, e.g. distance

Adjacency Matrix

Vertex	Anne	Jim	John	Mary
Anne	-	30	5	0
Jim	30	-	22	2
John	5	22	-	1
Mary	0	2	37	-



Tie Strength

Edge Weight as Relationship Strength

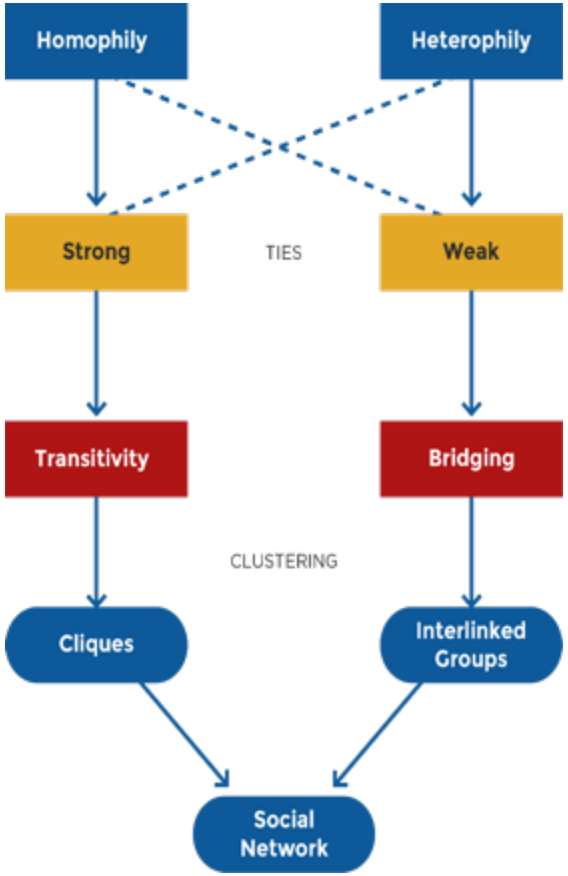
Edges can represent **interactions, flows of information or goods, similarities/affiliations,** or **social relations**

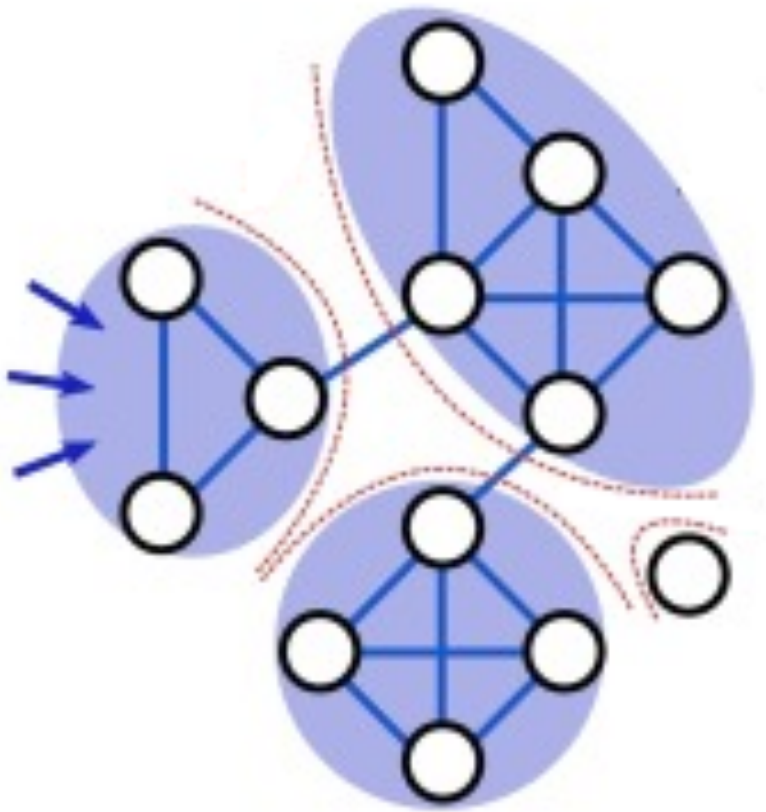
Specifically for social relations, a ‘proxy’ for the strength of a tie can be:

- The frequency of interaction or the amount of exchange
- Reciprocity in interaction or flow
- The type of interaction or flow between the two parties (e.G., Intimate or not)
- Other attributesof the nodes or ties (e.G., Kin relationships)
- The structure of the nodes’ neighborhood (e.G. Many mutual ‘friends’)

Surveys and interviews allows us to establish the existence of mutual or one-sided strength/affection with greater certainty, but proxies above are also useful

Homophily, Transitivity, and Bridge



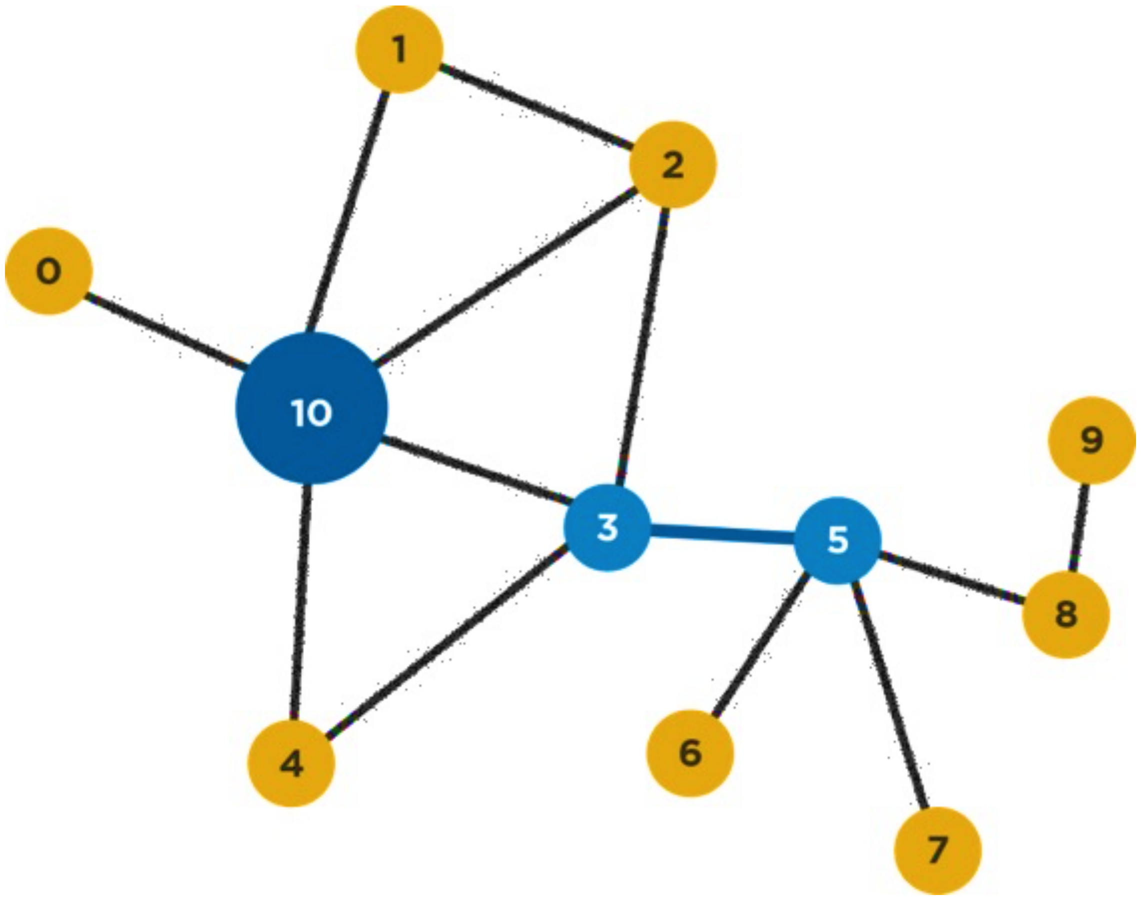


- Homophily is the tendency to relate to people with similar characteristics (status, beliefs, etc.)
- Transitivity in SNA is a property of ties: if there is a tie between A and B and one between B and C, then in a transitive network A and C will also be connected
- Bridges are nodes and edges that connect across groups

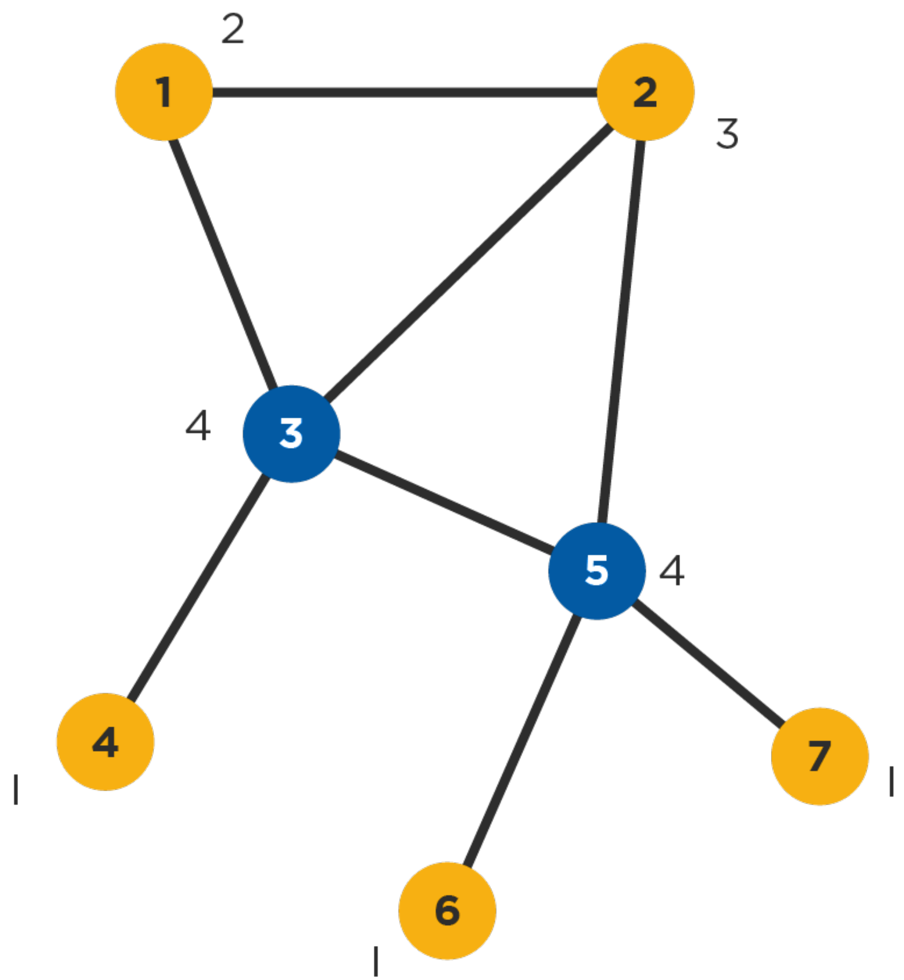
Key Player Identification

Who is the Most Important Person?

Who is the Most Important Person?



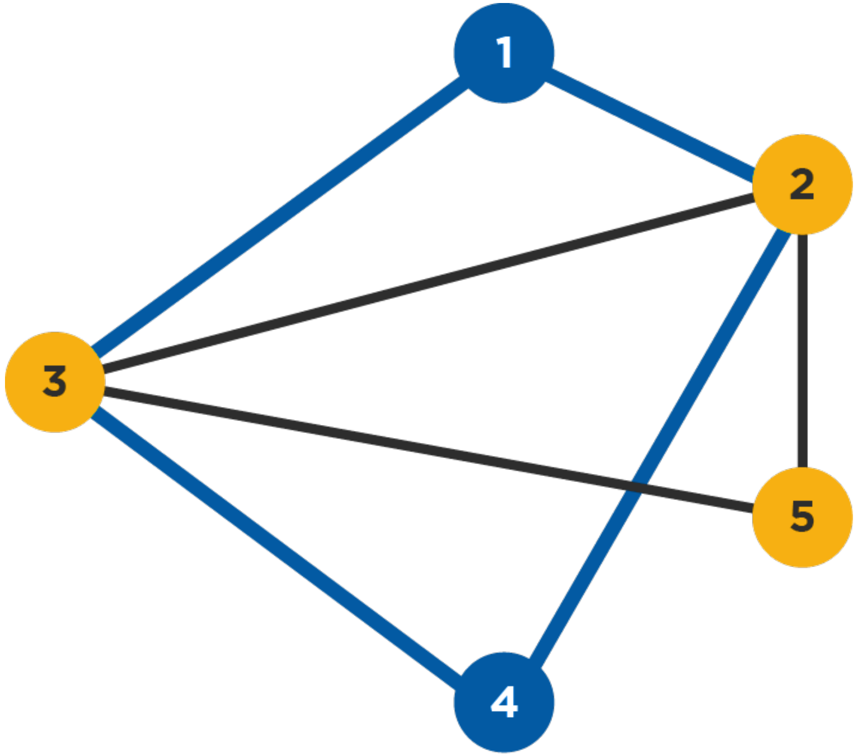
Degree Centrality



- A node's (in-) or (out-) degree is the number of links that lead into or out of the node
- In an undirected graph they are of course identical
- Often used as measure of a node's degree of connectedness and hence also influence and/or popularity
- Useful in assessing which nodes are central with respect to spreading information and influencing others in their immediate 'neighborhood'

Nodes 3 and 5 have the highest degree (4)

Paths and Shortest Paths

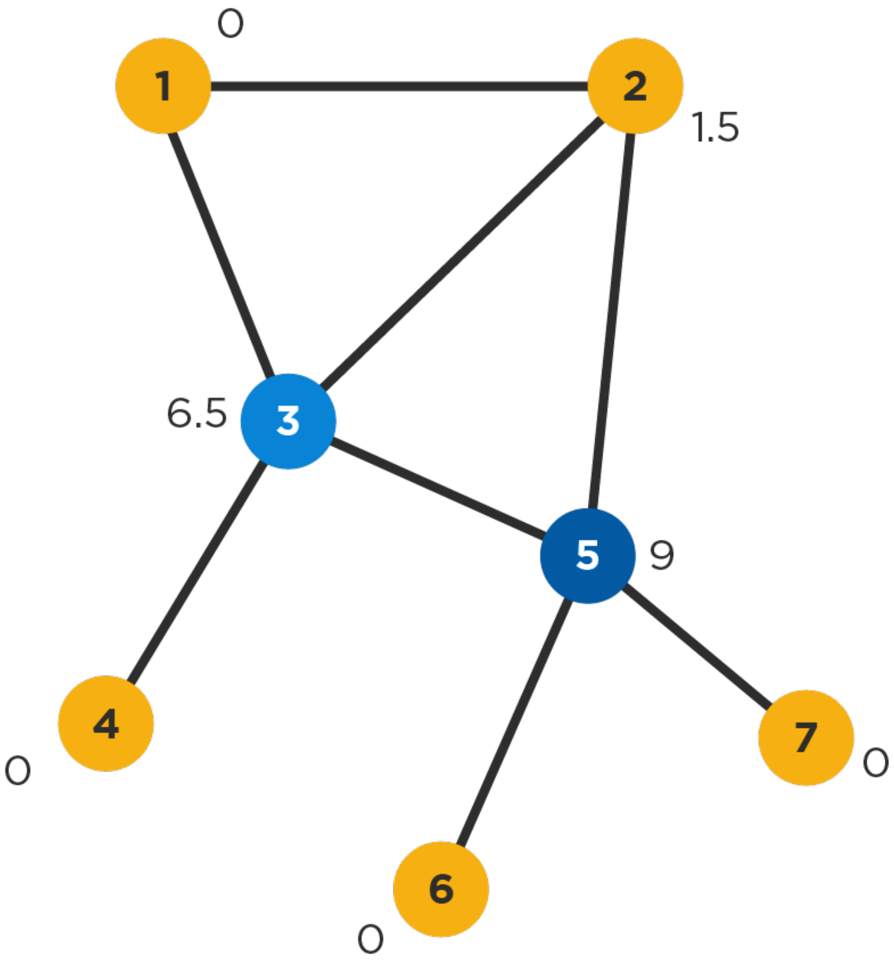


Hypothetical Graph

Shortest Path(s)

- A path between two nodes is any sequence of non-repeating nodes that connects the two nodes
- The shortest path between two nodes is the path that connects the two nodes with the shortest number of edges (also called the distance between the nodes)
- In the example to the right, between nodes 1 and 4 there are two shortest paths of length 2: {1,2,4} and {1,3,4}
- Other, longer paths between the two nodes are {1,2,3,4}, {1,3,2,4}, {1,2,5,3,4} and {1,3,5,2,4} (the longest paths)
- Shorter paths are desirable when speed of communication or exchange is desired (often the case in many studies, but sometimes not, e.g. in networks that spread disease)

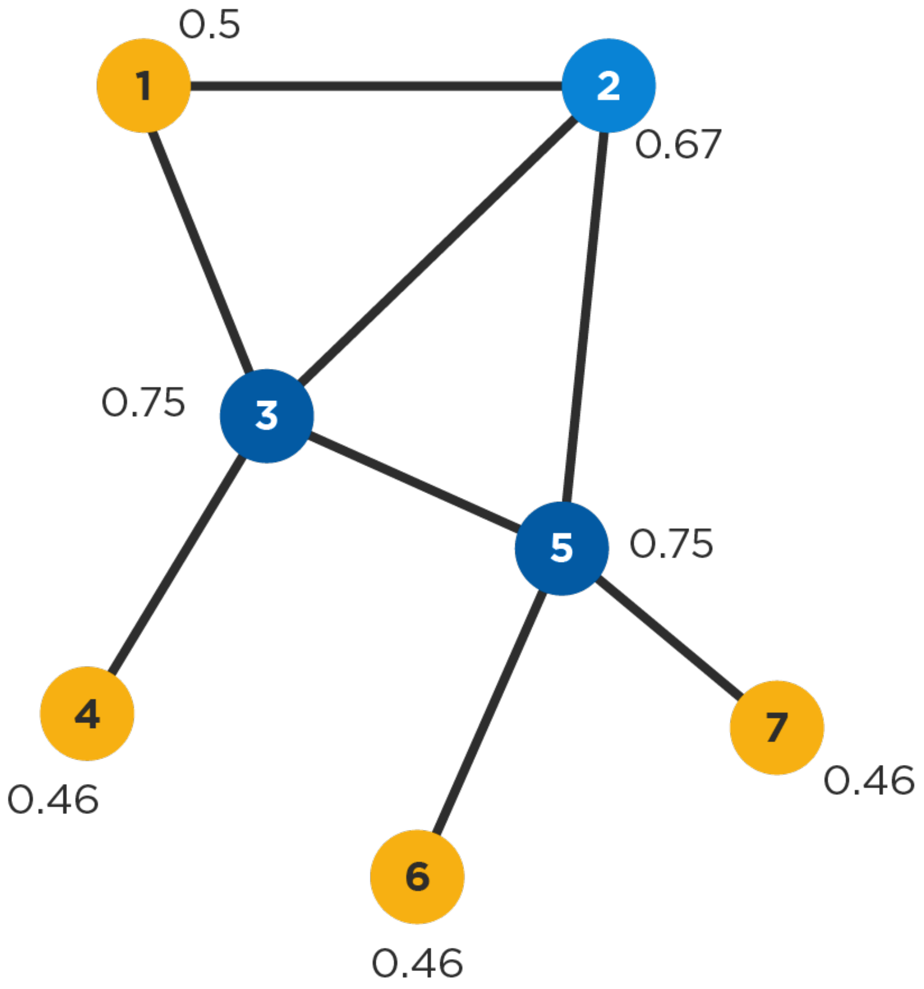
Betweenness Centrality



- For a given node v, calculate the number of shortest paths between nodes i and j that pass through v, and divide by all shortest paths between nodes i and j
- Sum the above values for all node pairs i,j
- Sometimes normalized such that the highest value is 1 or that the sum of all betweenness centralities in the network is 1
- Shows which nodes are more likely to be in communication paths between other nodes
- Also useful in determining points where the network would break apart (think who would be cut off if nodes 3 or 5 would disappear)

Node 5 has higher betweenness centrality than 3

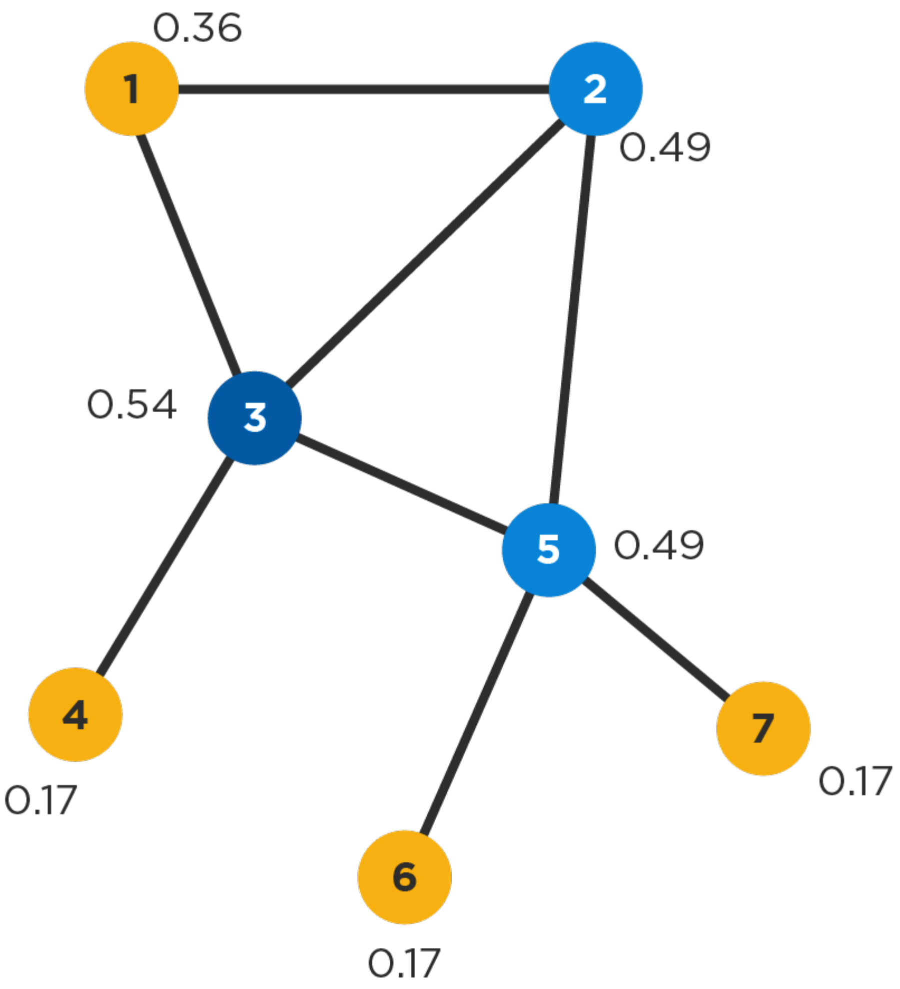
Closeness Centrality



- Calculate the mean length of all shortest paths from a node to all other nodes in the network (i.e. how many hops on average it takes to reach every other node)
- Take the reciprocal of the above value so that higher values are ‘better’ (indicate higher closeness) like in other measures of centrality
- It is a measure of *reach*, i.e. the speed with which information can reach other nodes from a given starting node

Nodes 3 and 5 have the highest (i.e. best) closeness, while node 2 fares almost as well

Eigenvector Centrality



- A node's eigenvector centrality is proportional to the sum of the eigenvector centralities of all nodes directly connected to it
- In other words, a node with a high eigenvector centrality is connected to other nodes with high eigenvector centrality
- This is similar to how Google ranks web pages: links from highly linked-to pages count more
- Useful in determining who is connected to the most connected nodes

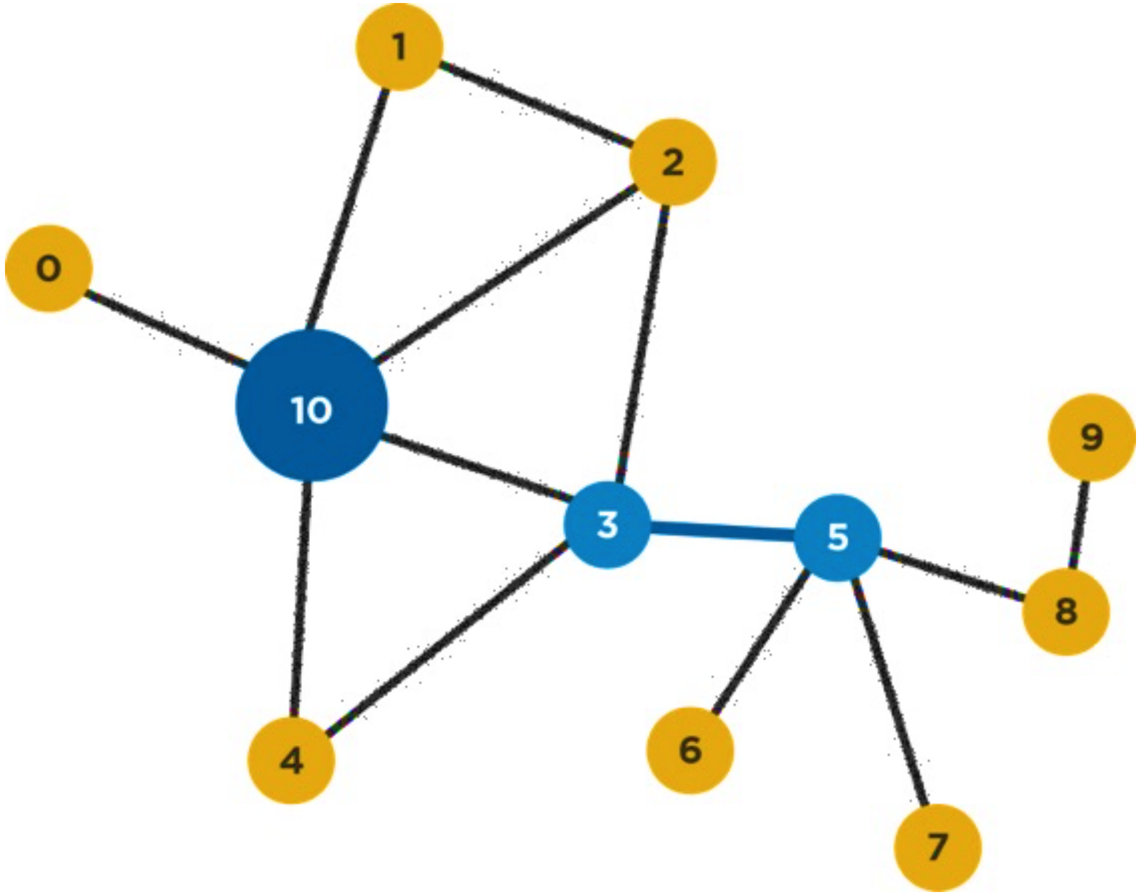
Node 3 has the highest eigenvector centrality, closely followed by 2 and 5

Interpretation of Measures

Centrality measure	Interpretation in social networks
Degree	How many people can this person reach directly?
Betweenness	How likely is this person to be the most direct route between two people in the network?
Closeness	How fast can this person reach everyone in the network?
Eigenvector	How well is this person connected to other well-connected people?

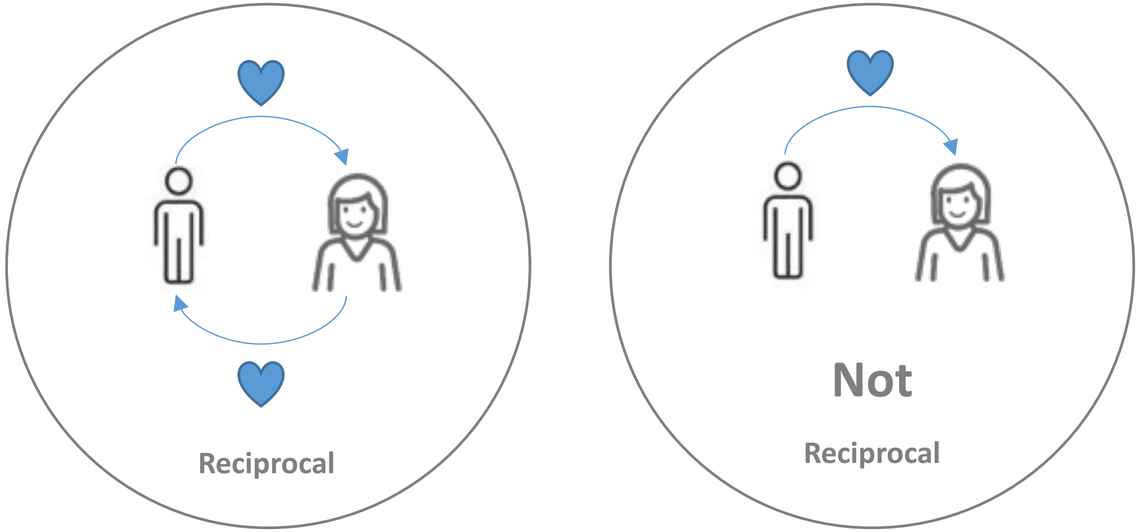
Sets of Key Players

Sets of Key Players



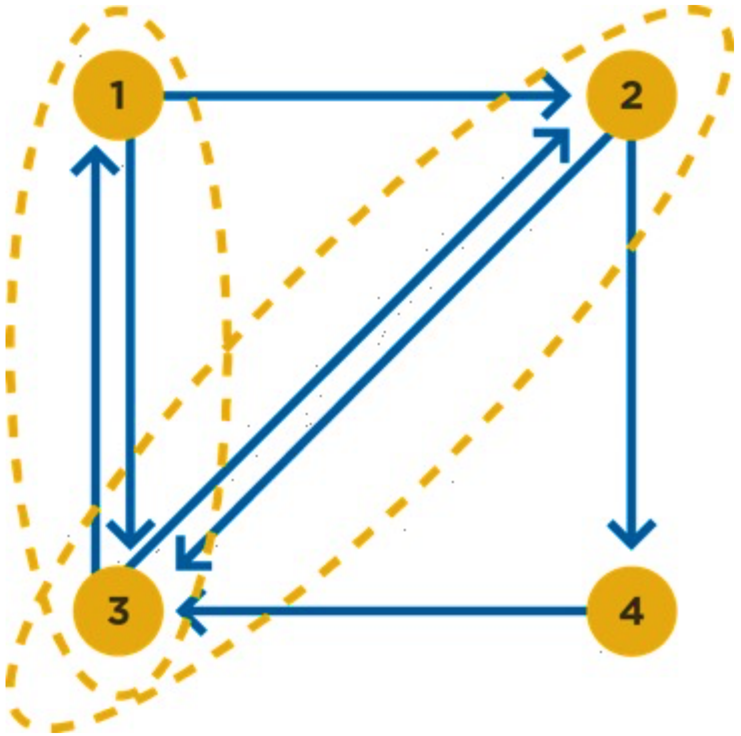
Overall Social Network Structure

Reciprocity (degree of)



The ratio of the number of reciprocated relations over the total number of relations

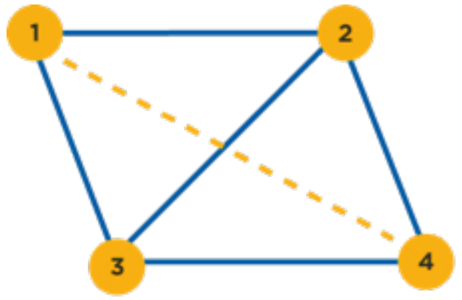
Reciprocity (degree of)



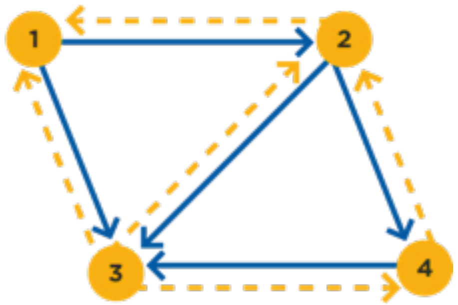
Reciprocity for network = 0.4

- The ratio of the number of relations which are reciprocated (i.e. there is an edge in both directions) over the total number of relations in the network
- …where two vertices are said to be related if there is at least one edge between them
- In the example to the right this would be 2/5=0.4 (whether this is considered high or low depends on the context)
- A useful indicator of the degree of mutuality and reciprocal exchange in a network, which relate to social cohesion
- Only makes sense in directed graphs

Density



Density → $\frac{5}{6} = 0.83$

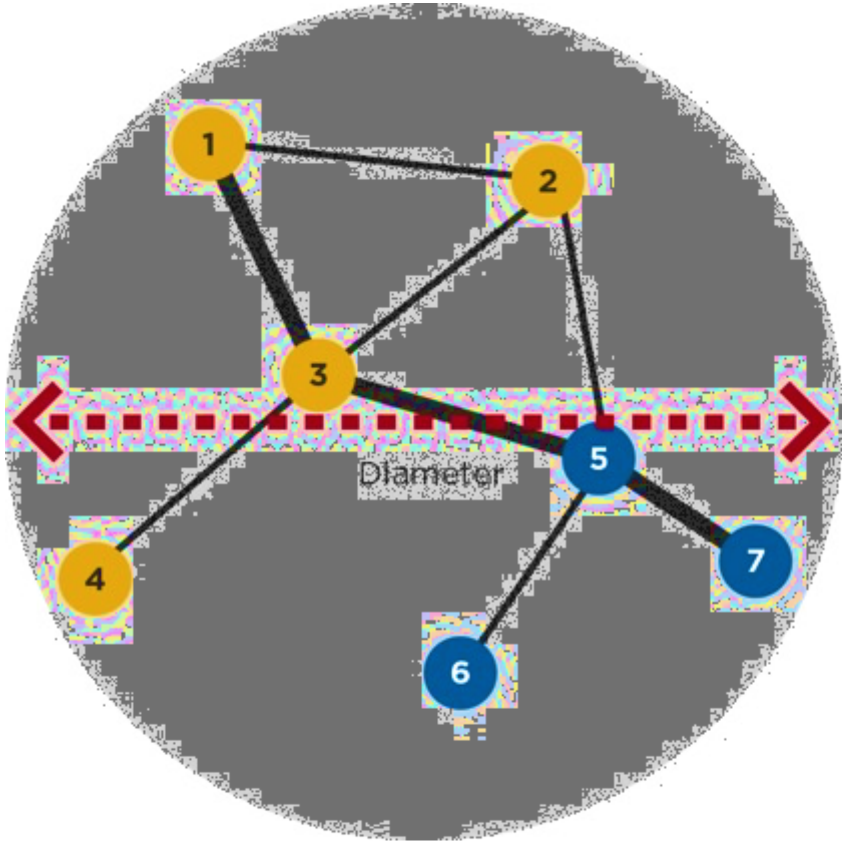


Density → $\frac{5}{12} = 0.42$

Edge present in network
Possible but not present

- A network's *density* is the ratio of the number of edges in the network over the total number of possible edges between all pairs of nodes (which is *n(n-1)/2*, where *n* is the number of vertices, for an undirected graph)
- In the example network to the right density=5/6=0.83 (i.e. it is a fairly *dense* network; opposite would be a *sparse* network)
- It is a common measure of how well connected a network is (in other words, how closely knit it is) – a perfectly connected network is called a *clique* and has density=1
- A directed graph will have half the density of its undirected equivalent, because there are twice as many possible edges, i.e. *n(n-1)*
- Density is useful in comparing networks against each other, or in doing the same for different regions within a single network

Average and Longest Distance



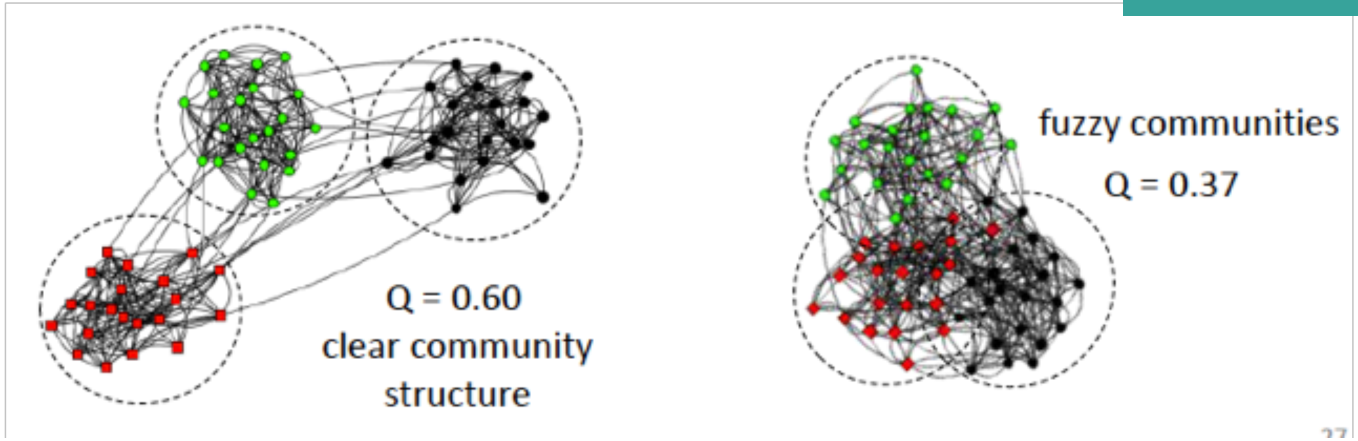
- The longest shortest path (distance) between any two nodes in a network is called the network's *diameter*
- The diameter of the network on the right is 3; it is a useful measure of the *reach* of the network (as opposed to looking only at the total number of vertices or edges)
- It also indicates how long it will take at most to reach any node in the network (sparser networks will generally have greater diameters)
- The average of all shortest paths in a network is also interesting because it indicates how far apart any two nodes will be on average (average *distance*)

Modularity

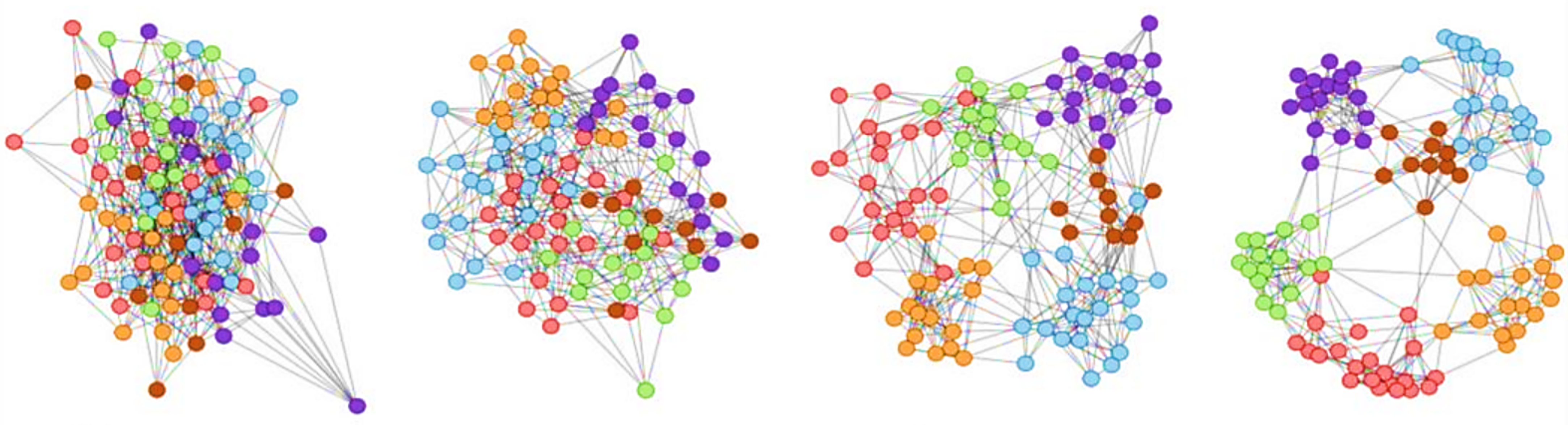
$$Q = \frac{1}{2m}\sum_{ij}\left(A_{ij} - \frac{k_i k_j}{2m}\right)\delta(C_i, C_j)$$

Edges inside the community

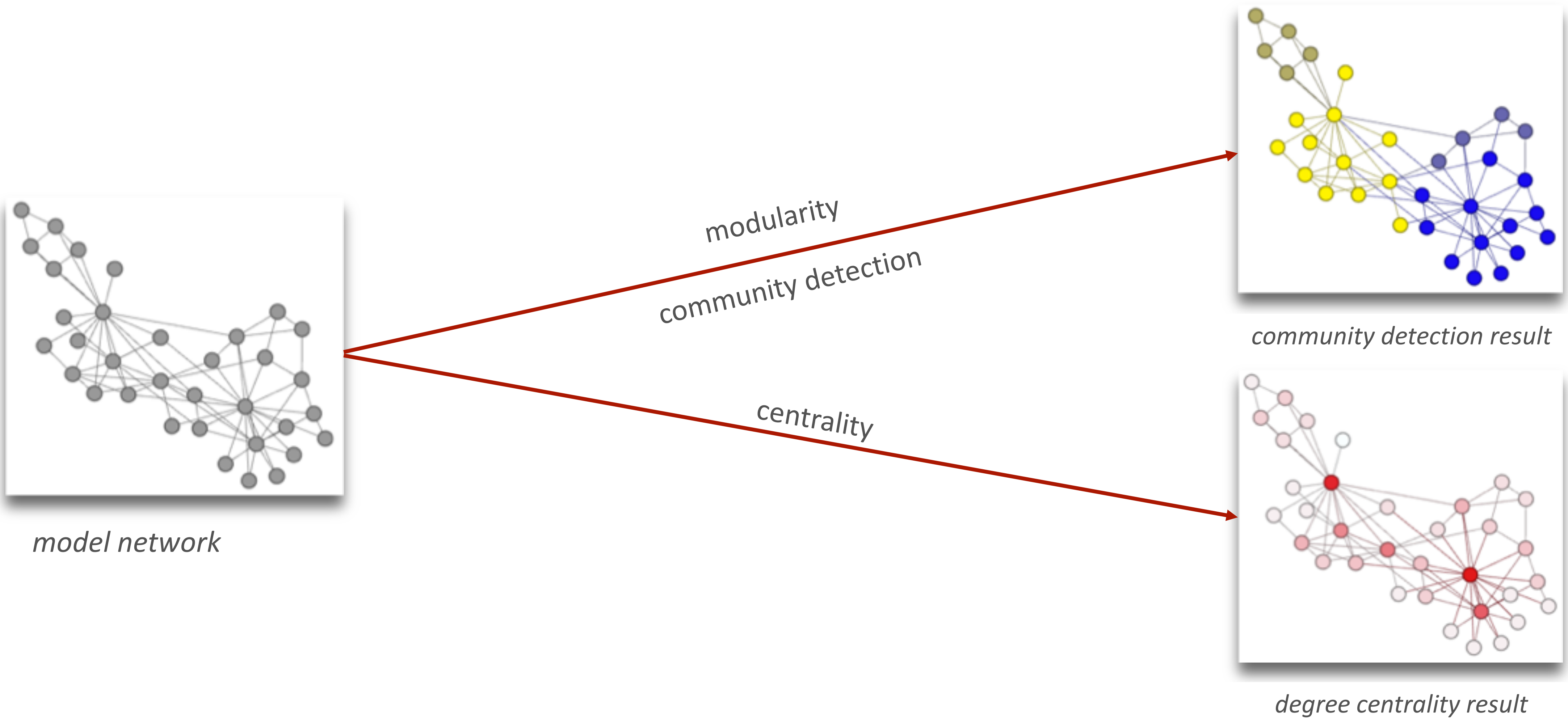
Expected number of edges if i,j places at random



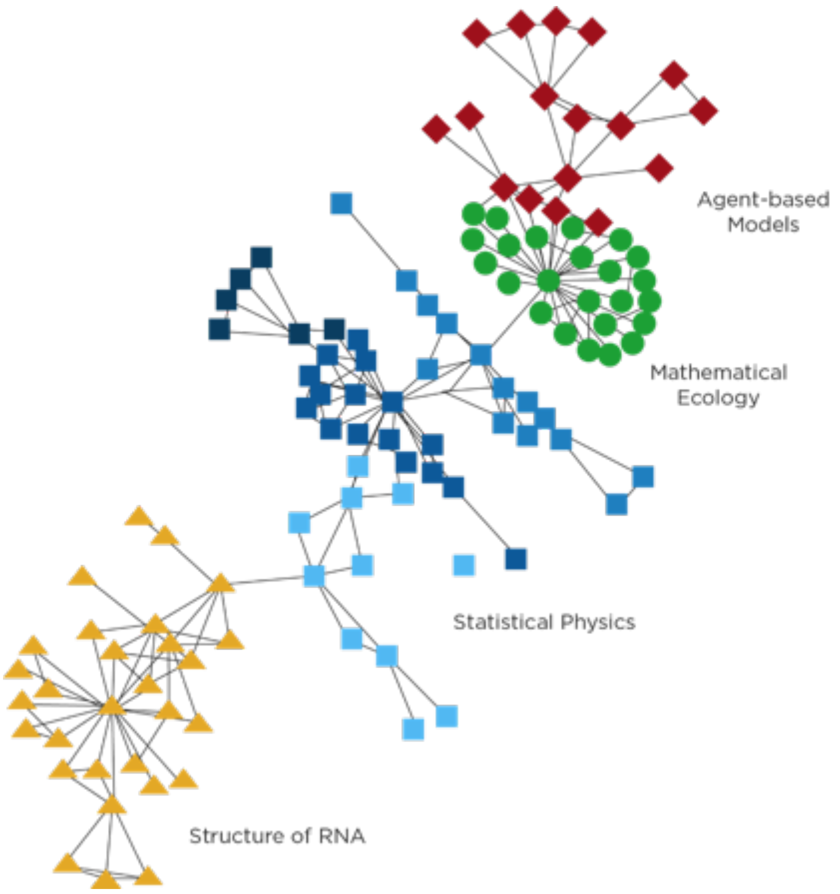
Modularity



0 ← Modularity → 1


modularity
community detection
centrality
model network
community detection result
degree centrality result

Finding Community



- Collaboration network of scientist at Santa Fe Institut (Girvan & Nirwan)
- 27| scientist (vertices) / 1 | 8 nodes from largest component edge = scientist coauthor one of more publications
- Komunitas : kumpulan titik titik dimana jumlah hubungan internal antar titik lebih besar dari pada jumlah hubungan dengan titik eksternal

I just need my friend,

friend of my friend, friend of friend of my friend, friend of friend of friend of my friend, friend of friend of friend of friend of my friend, friend of friend of friend of friend of friend of my friend,

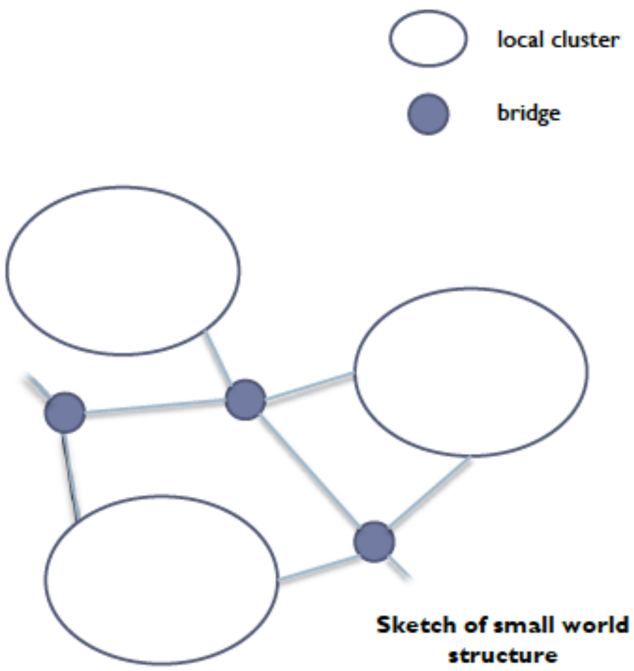
to contact him

This is
Dian

This is
Peter Parker

Small Worlds

- A small world is a network that looks almost random but exhibits a significantly high clustering coefficient(nodes tend to cluster locally) and a relatively short average path length (nodes can be reached in a few steps
- It is a very common structure in social networks because of transitivity in strong social ties and the ability of weak ties to reach across clusters
- Such a network will have many clusters but also many bridges between clusters that help shorten the average distance between nodes

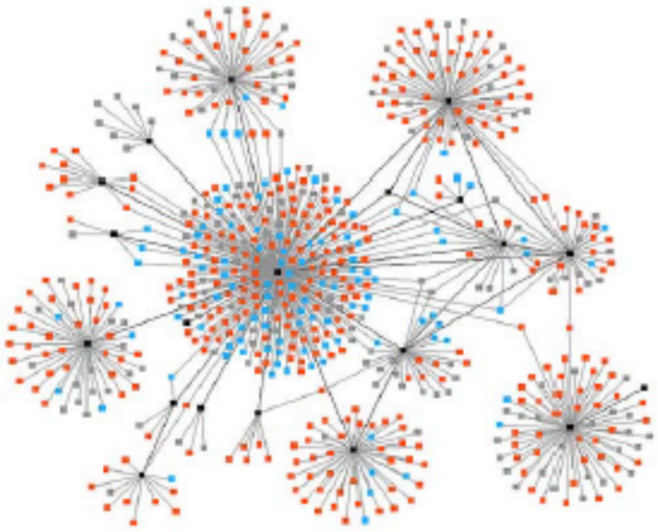


Sketch of small world structure

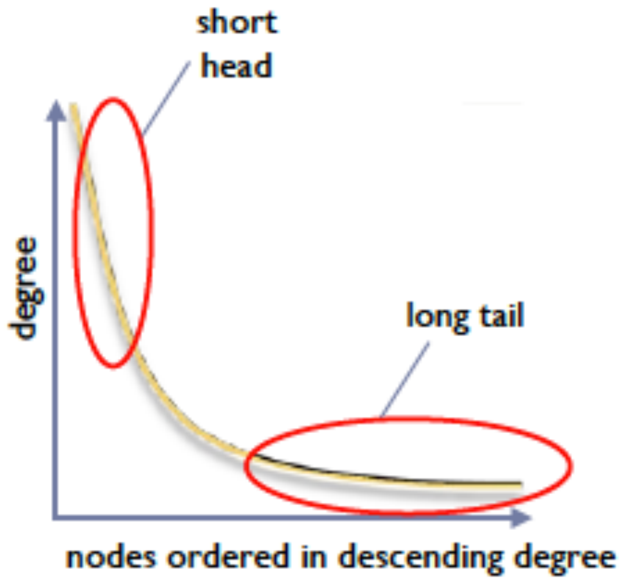
You may have heard of the famous "6 degrees" of separations

Preferential Attachment

A property of some networks, where, during their evolution and growth in time, a the great majority of new edges are to nodes with an already high degree; the degree of these nodes thus increases disproportionately, compared to most other nodes in the network

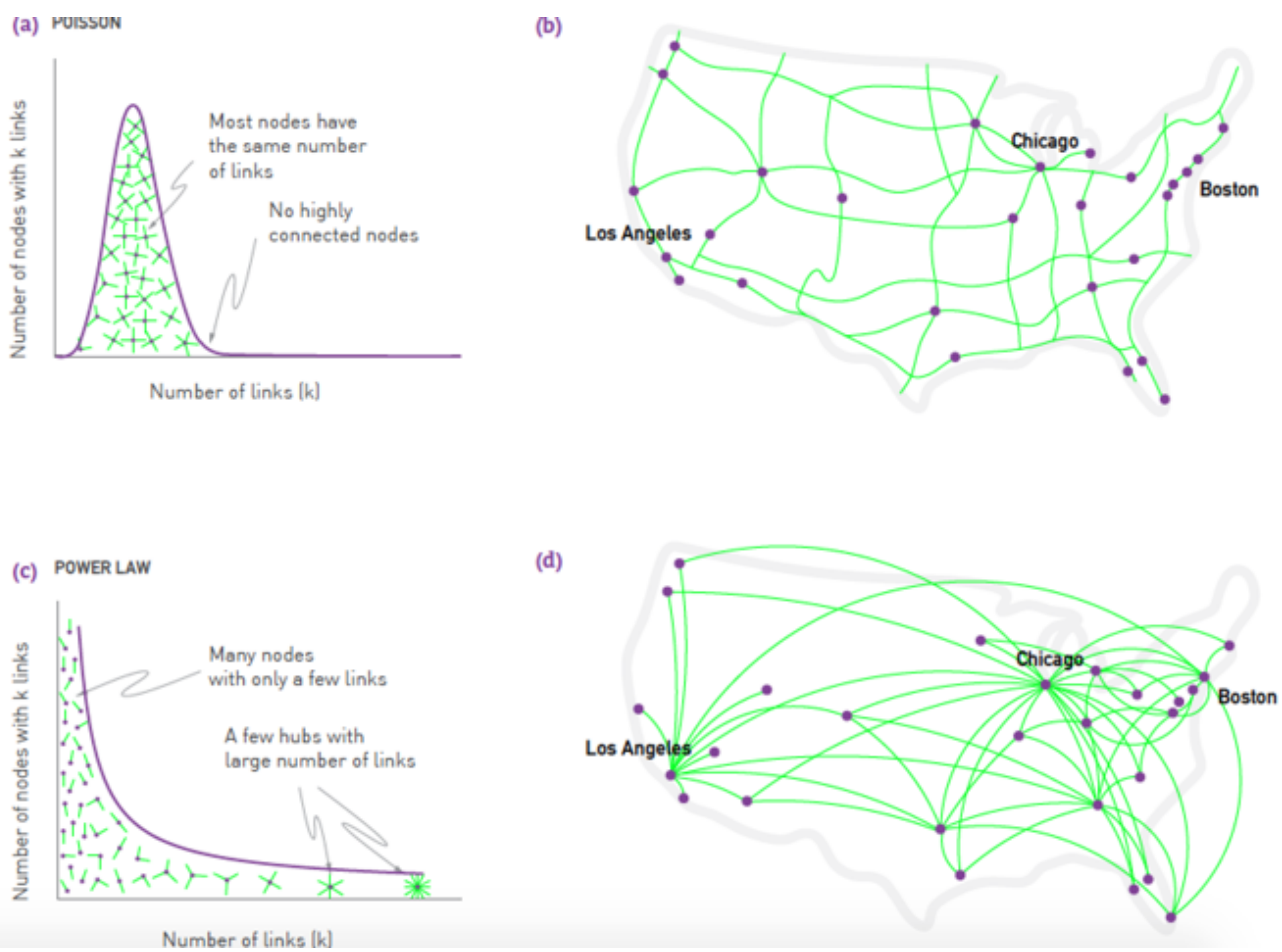


Example of network with preferential attachment



Skectch of long-tailed degree distributions

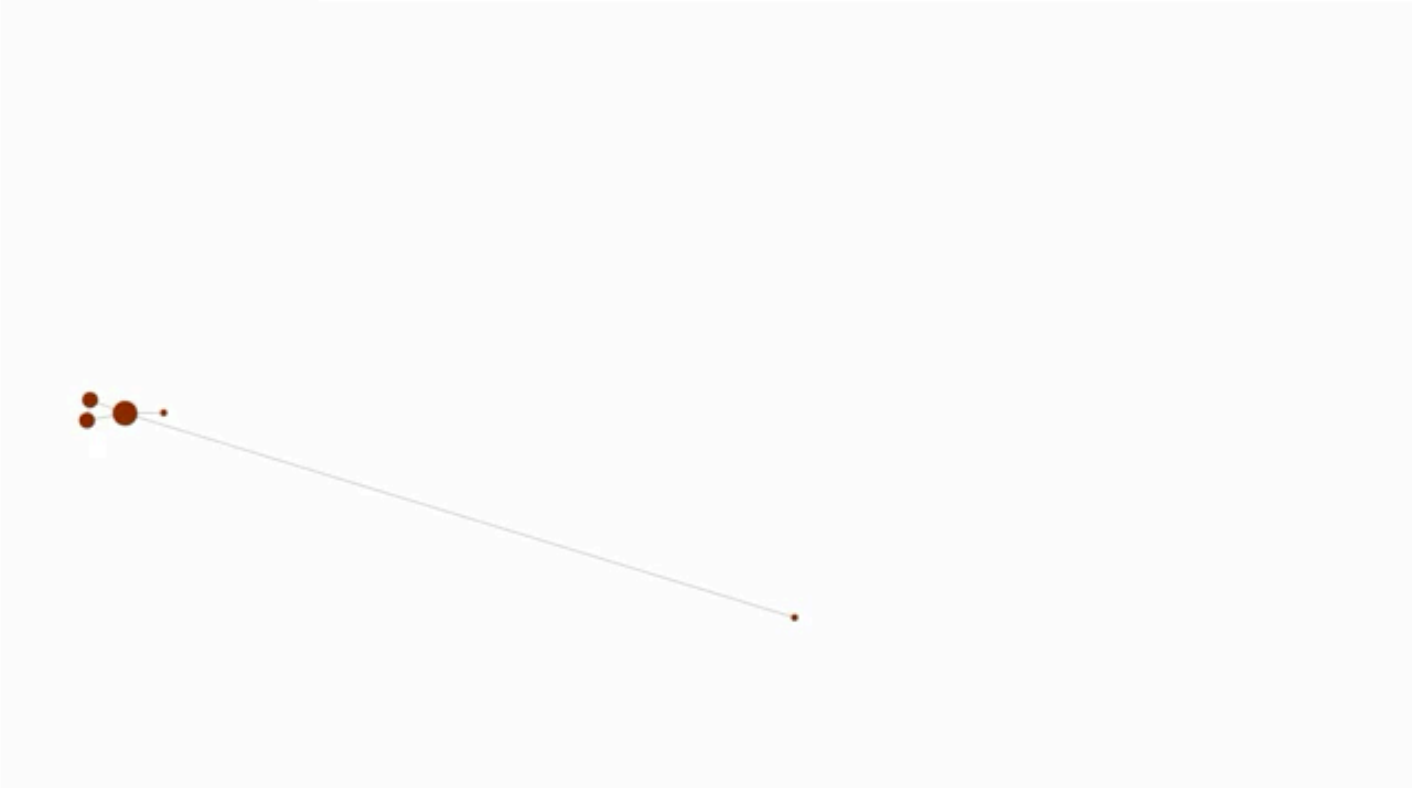
Social Network Characteristic



Reasons for Preferential Attachment

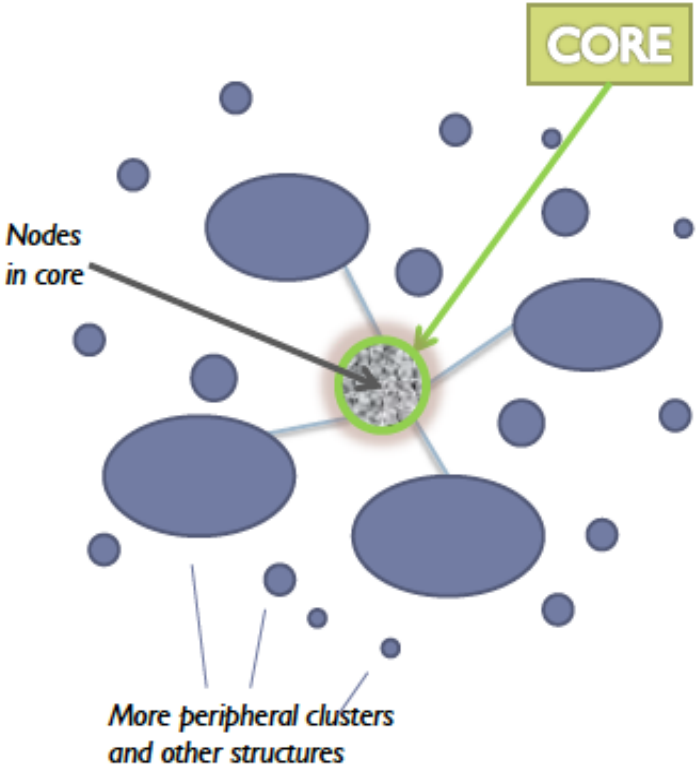
POPULARITY	QUALITY	MIXED MODEL
We want to be associated with popular people, ideas, items, thus further increasing their popularity, irrespective of any objective measurable characteristics	We evaluate people and everything else based on objective quality criteria, so higher quality nodes will naturally attract more attention faster	Among nodes of similar attributes, those that reach critical mass first will become ‘star’ with many friends and followers (‘halo effect’)
also known as ‘the rich get richer’	also known as ‘the good get better’	may be impossible to predict who will become a star, even if quality matters

Social Network Characteristic: Power Law



power law distributions

Core-Periphery Structures



Thank You

Dian Ramadhani