A few network concepts

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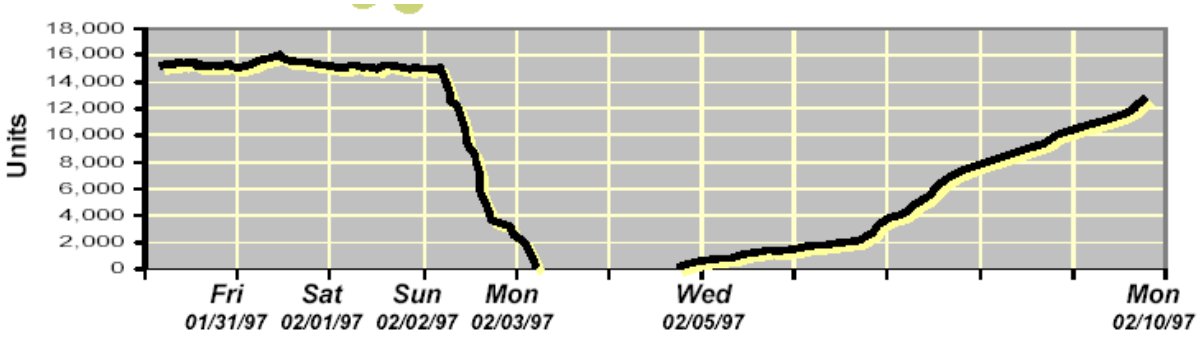
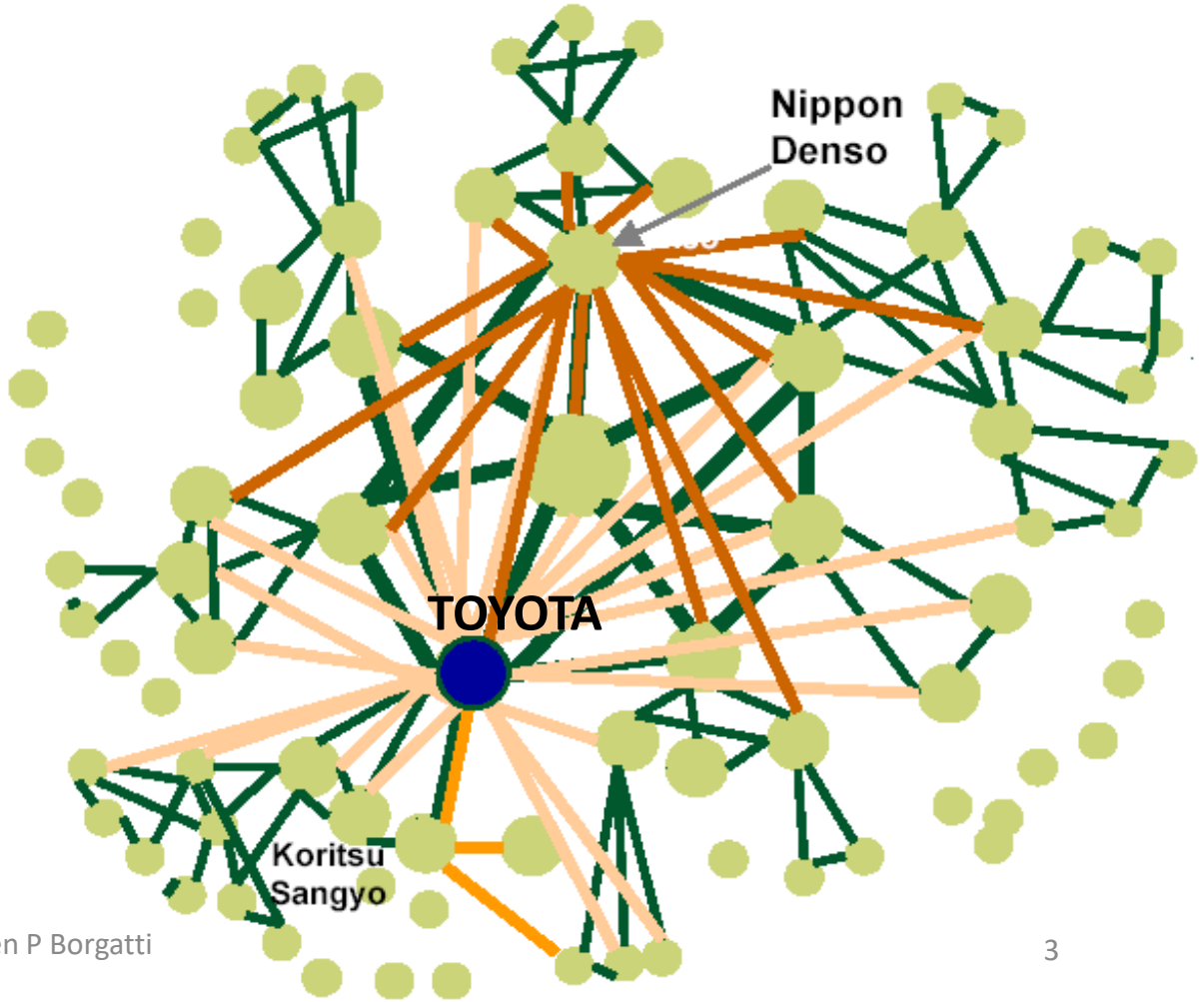
My charge

- “actual knowledge isn’t required… ”
- For your part, my thinking at the moment is that 10-15 minutes on the conceptual distinctions between attributional vs. structural approaches would be a great way to start the conversation, something along the lines of Wellman’s ‘paradigmatic characteristics’ of structural analysis but in the context of supply chains.
- I had in mind you presenting a few specific network concepts/operationalizations that would be particularly pertinent to SC researchers.

A supply network



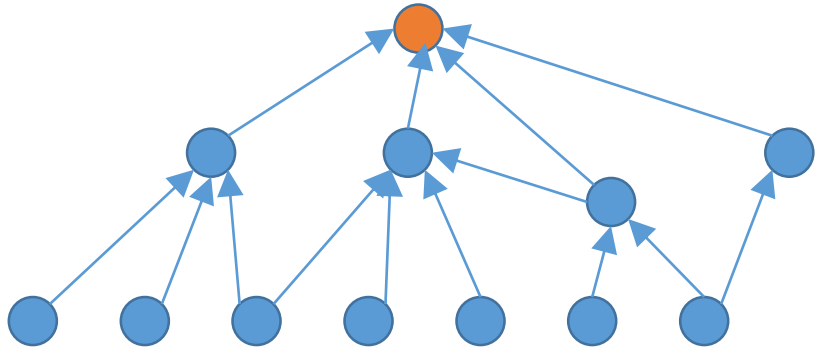
- Toyota 1997, at the time of the Aisin Seiki fire
  - Sole supplier of p-valves
- 200 nodes
- Supply ties, but also
  - Personnel exchange & cross-training
  - Technology/IP sharing
  - Providing consulting services such as logistics assistance
- I leave it to the SME's to work out ..
  - Which nodes to include
- Focal org = ego = OEM, etc.



Levels of analysis

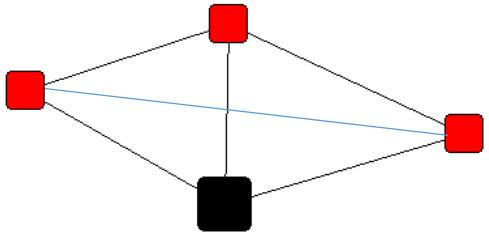
Level of Analysis	Sample Research Question	Notes
Whole network	Do organizations with more 1st tier suppliers have more elaborated relationship management systems	Requires collecting supply networks for many different OEMs, not just one
Node level	Do sole suppliers receive more attention from the focal org than other suppliers?	Unit of analysis is the supplier, but results hard to generalize. Better to replicate with another supply network
Dyad level	Do suppliers that share technology with each other also adopt the same management practices?	Unit of analysis is pairs of suppliers within the network. Again, best if replicated

Degree centrality

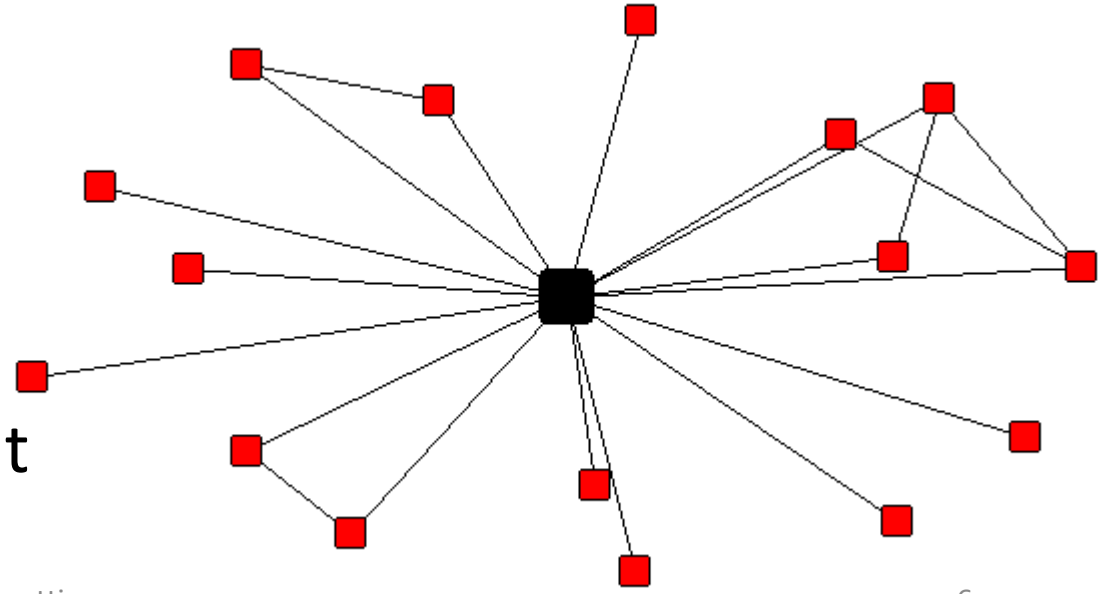


- The number of ties a node has
- Supply network S where S(i,j) > 0 implies node i supplies node j
- S is a directed network, so we have
  - Indegree – # of suppliers a node has
    - For the focal org, this is number 1st tier suppliers. Complexity of their relationship management situation → elaboration of their rel mgmt function
  - Outdegree – # of customers a node has
- At the supplier level, we might regard a node with high indegree as a good candidate for training in supply chain management
  - Outdegree signals a node that can affect many others – a critical node

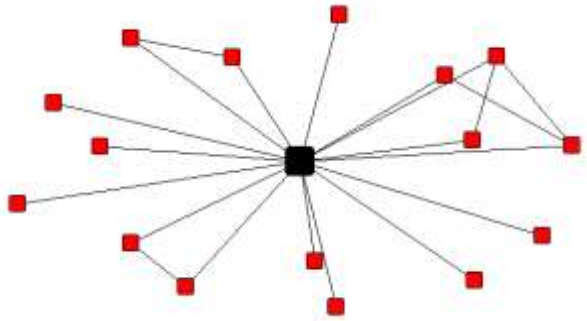
Structural holes



- Mostly known as a measure of social capital
- A node (ego) is said to have many structural holes if it is connected to (a) many nodes (alters), that (b) are unconnected to each other
- Ego in position to broker the relationships between the alters
  - Control
  - Bringing value to one alter based on inputs from another
  - Access to non-redundant information
  - Practice coordinating diverse others
- Often measured inversely as constraint



Constraint



- A node is constrained by an alter *j* to the extent that (a) it is heavily invested in that alter directly, and (b) it is invested in that alter indirectly through its other alters
- Alter-level (dyadic) constraint is given by $c_j = \left(p_j + \sum_q p_q p_{qj}\right)^2$
  - q and j are alters in ego's network
  - p_j = is proportion of ego's energy devoted to contact j (direct investment in j)
    - For binary data, this is 1/N, where N is the number of alters ego has
  - $\sum_q p_{iq} p_{qj}$ is highly related to density of the ego network
    - Measures extent to which ego is indirectly invested in all its alters
  - Overall constraint is the sum of all the alter-level constraints

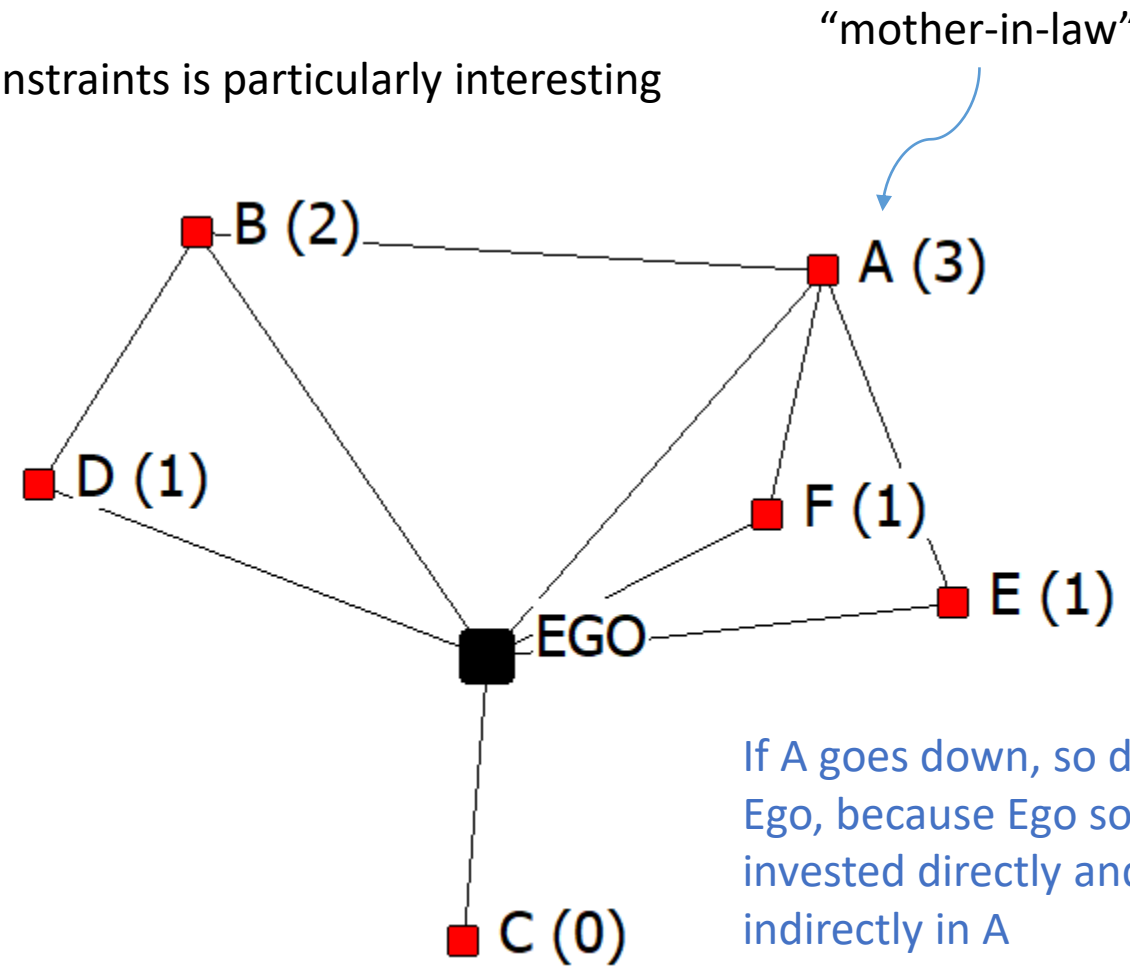
Constraint example

For the SC context, I think looking at the alter-level constraints is particularly interesting

j	Direct	Indirect	Cj
A	0.17	0.22	0.15
B	0.17	0.13	0.09
C	0.17	0.00	0.03
D	0.17	0.06	0.05
E	0.17	0.04	0.04
F	0.17	0.04	0.04

Constraint = 0.40

$$c_{ij} = \left(p_{ij} + \sum_q p_{iq} p_{qj}\right)^2, \text{ q≠i,j}$$

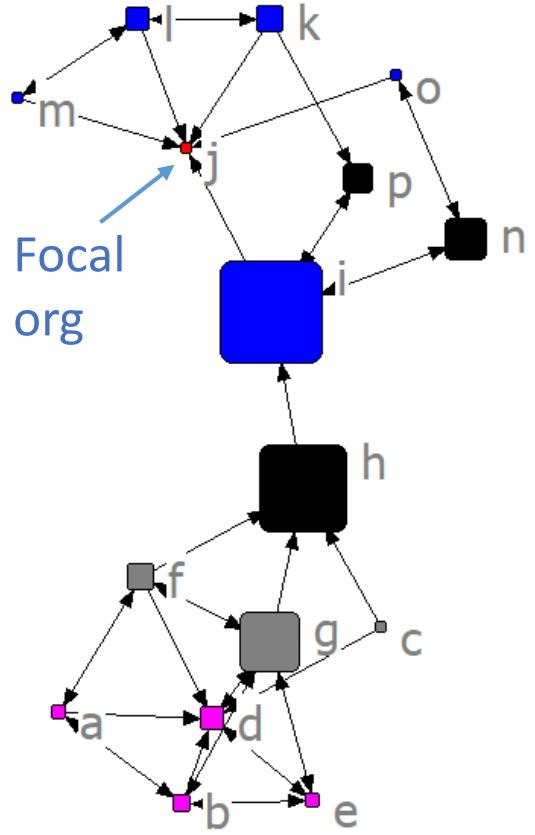


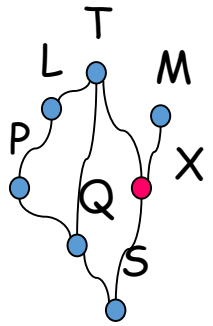
If A goes down, so does Ego, because Ego so invested directly and indirectly in A

Cj give the direct+indirect investment of ego in supplier j

Centrality metrics

- Closeness centrality
  - In-closeness: how long on average it takes from information to reach a node
  - Out-closeness: how long it takes from info emanating from node to each others
- Betweeness
  - Loosely, what proportion of all the optimal paths between pairs of nodes pass through a given node
    - $\sum_{i,j} \frac{g_{ikj}}{g_{ij}}$
  - Measure of control of flows, also brittleness of the network



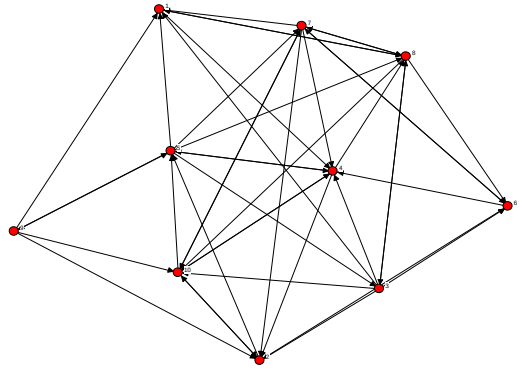


Characterizing whole networks

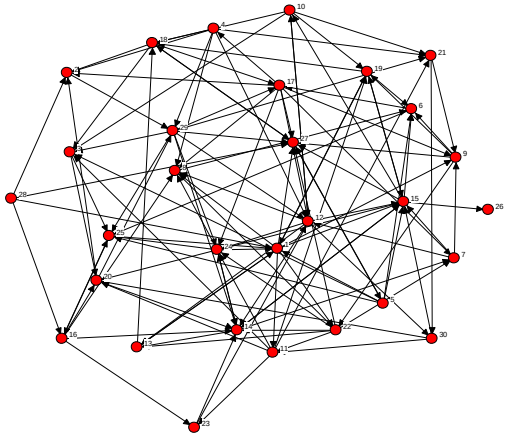
- Assume network defined by various collaborative relations among suppliers
  - Cross-training, personnel exchange
  - Aid in multiple in forms include work sharing, consulting on managing their suppliers, financial help
  - Technology exchange
- Several dimensions to explore
  - Cohesiveness of the network
  - Resilience / robustness to being fragmented
  - Shape of the network

Cohesion

- Extent to which network is tightly knit
  - Shared vision, redundancy of information
- Total number of ties
  - Measure of complexity
- Density
  - Number of ties / number possible, given N
- Avg degree
  - Avg number of connections per node
- Fragmentation
  - % of pairs of nodes that can't reach each other by any path



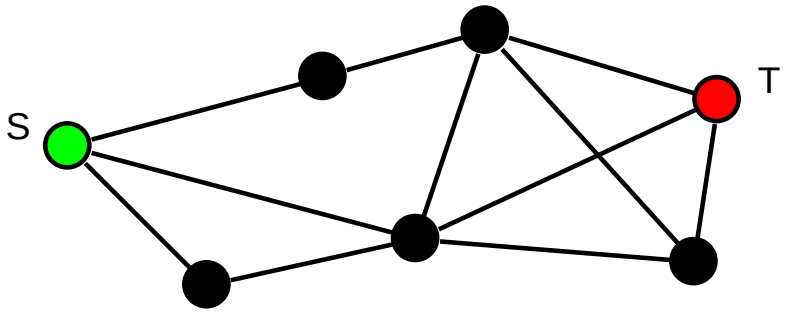
N = 10
Ties 40
Density 0.47
Avg Deg 4



N = 30
Ties 120
Density 0.14
Avg Deg 4

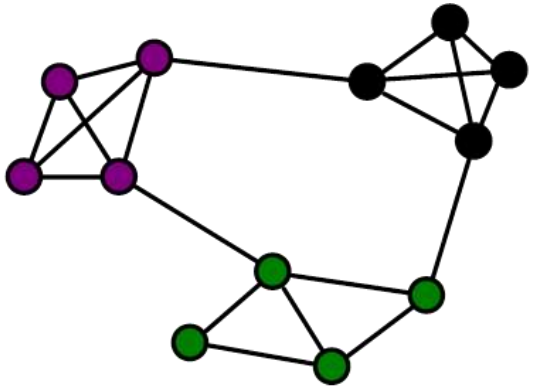
Robustness / resilience

- How resistant to disconnection or increased path lengths the network is
- Avg number of node or edge-independent paths from each node to every other
  - How many nodes or edges must be deleted to disconnect each pair of nodes?

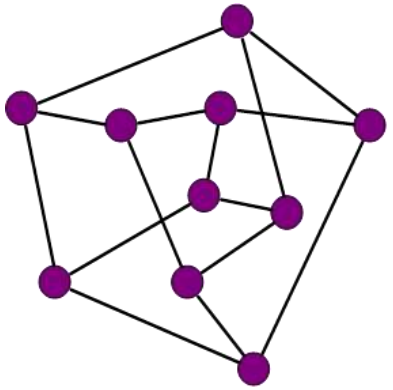


- Keyplayer software
  - How much does avg path length increase if you remove 1, or 2, or 3 nodes

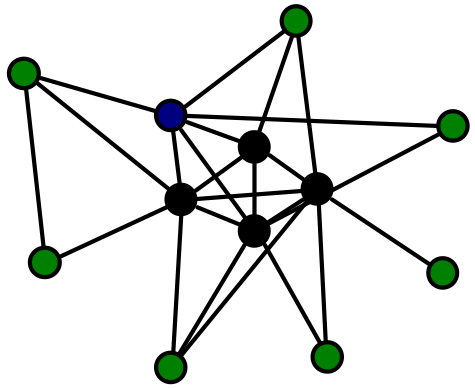
Network shape



Clique Structure



Diffuse Structure



Core-Periphery Structure

Prefer own kind (homophily)	Avoid friends of friends (anti-transitivity)	Random ties with variance in volume
$P(x_{ij} = 1) \leftarrow f(a_i = a_j)$	$P(x_{ij} = 1) \leftarrow 1 - f(x_{ik}x_{kj})$	$P(x_{ij} = 1) \leftarrow 1 - f(x_{i+}x_{j+})$
Silos/factions. Power struggles	Coordination by mutual adjustment	Unity of identity. Centralized power. Efficient coordination
Skunk works creating independent solutions: radical innovation	Individuals maximize diversity of inputs. Problem solving / incremental innovation	Diffusion of "best" practices, conventional wisdom.

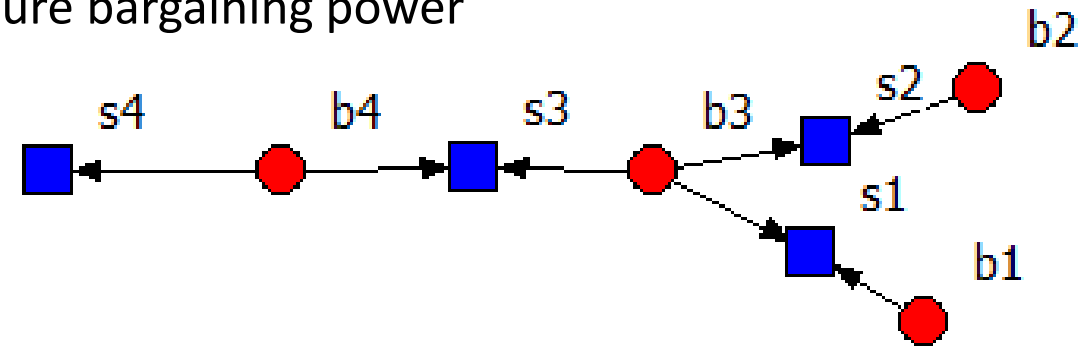
Induced centralities

Everett, M.G. and Borgatti, S.P., 2010. Induced, endogenous and exogenous centrality. *Social Networks*, *32*(4), pp.339-344.

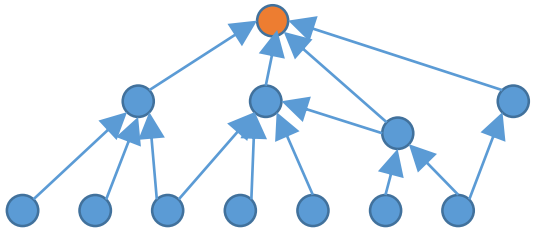
- A family of measures constructed as follows
- Measure a structural characteristic of the network as a whole and call it W
  - E.g., number of pairs of suppliers within 3 links of each other
- For each node j
  - Remove the node from network, recalculate the structural measure and call it Wj
  - Centrality of node j is W - Wj
  - Replace the node, go to next j
- This allows you to look at each node's contribution to some overall characteristic of the network that you value, such as avg path length

A few points to consider

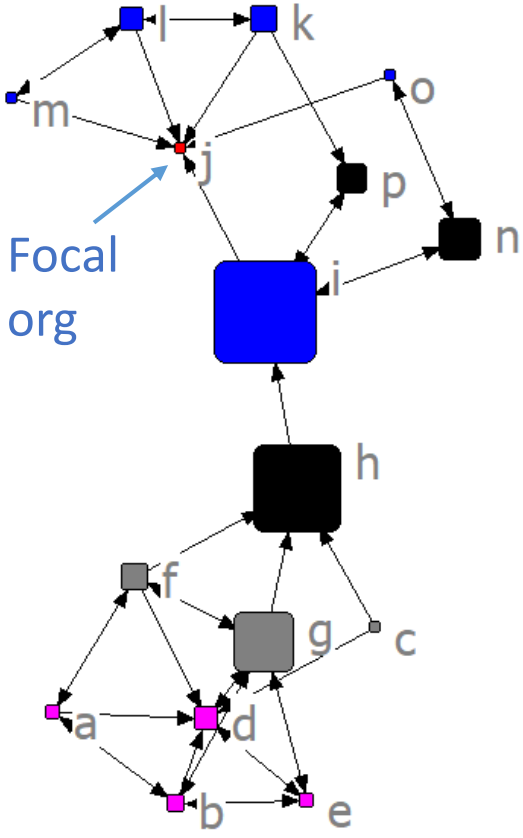
- Multiple research designs
  - Looking within a single supply network, which is a snowballed egocentric design
  - Add forward snowballing to capture other customers of the supplier
  - Doing a comparative study across, say hundreds of supply networks
    - E.g. hypothesize that orgs with more cohesive supply networks will be more profitable
  - Doing an industry level analysis of orgs and their 1st tier suppliers
    - Beta centrality to measure bargaining power



A few points to consider – cont.



- Most of the std measures do make sense for the “soft” relationships among the suppliers
- Some of the network measures don’t make much sense for the supply network per se – where the ties are who supplies whom
- Betweenness is an example
  - It carries assumption that something is flowing through the network through alternative paths
  - Modifications of the measure are possible
  - In fact, many new network metrics can be constructed for supply chain



Fin.