

spm 9550: Networks- I

Dr. ir. Igor Nikolic

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Lecture goals

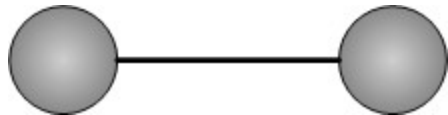
- Understand the notion of networks as graphs consisting of nodes and edges
- Understand different topologies and how they affect the network
- Know the meaning of the basic network metrics
- Understand basic network evolution processes

Network (Graph) theory

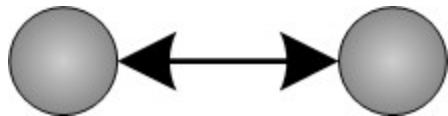
- graph theory is the study of graphs, mathematical structures used to model pairwise relations between objects from a certain collection.
- Everything is an Node or an Edge.



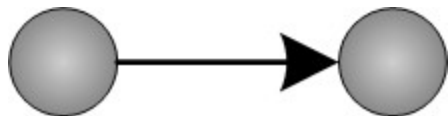
Vocabulary of graphs



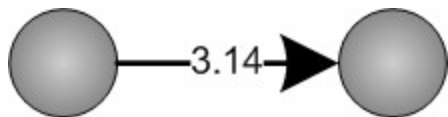
Undirected



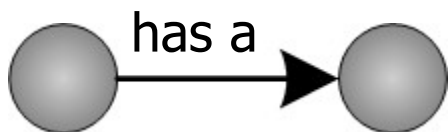
Bi-directional



Directed

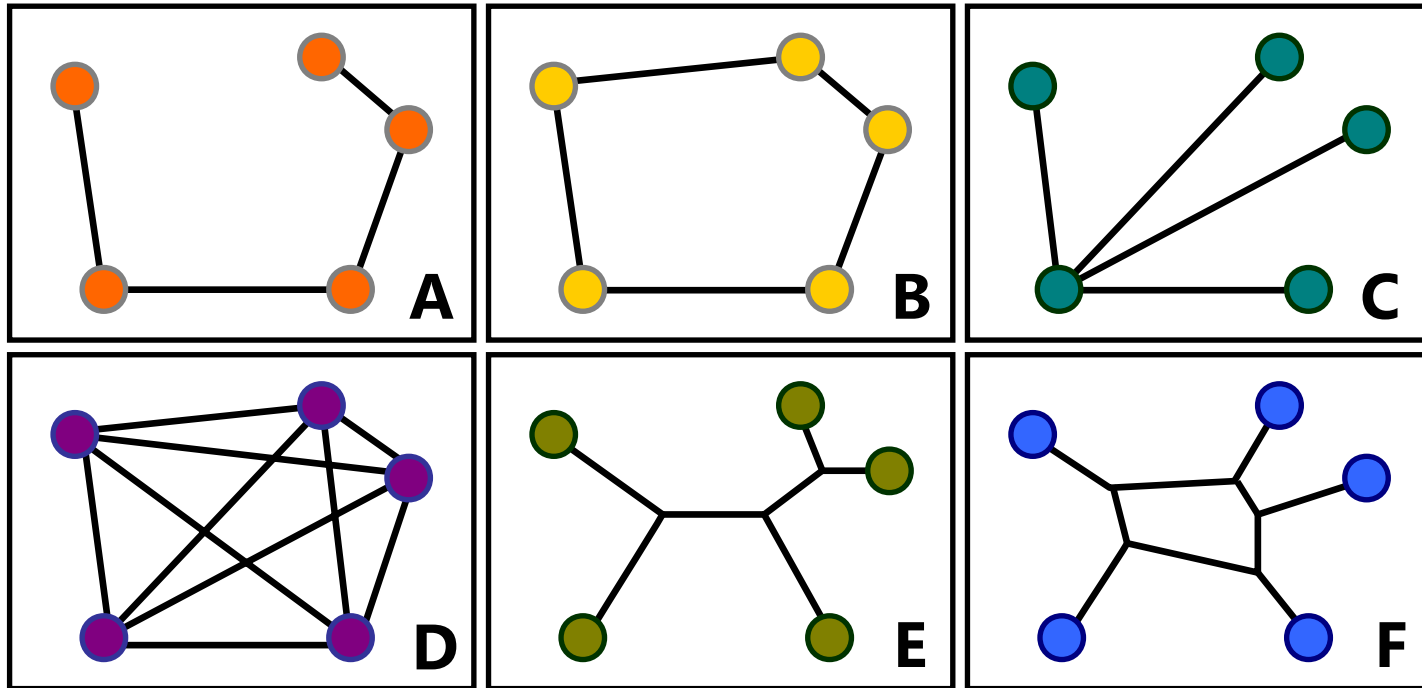


Weighted and directed



Property graph

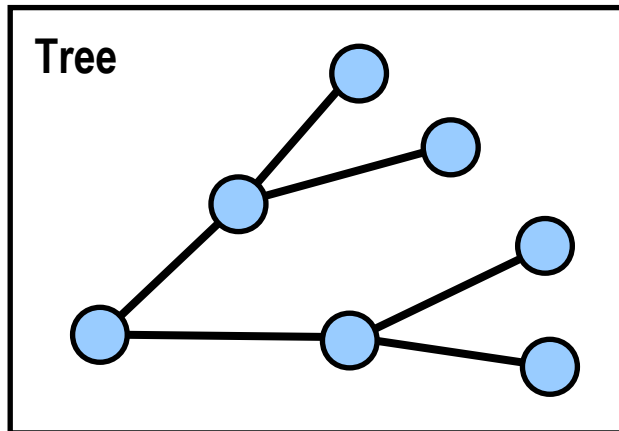
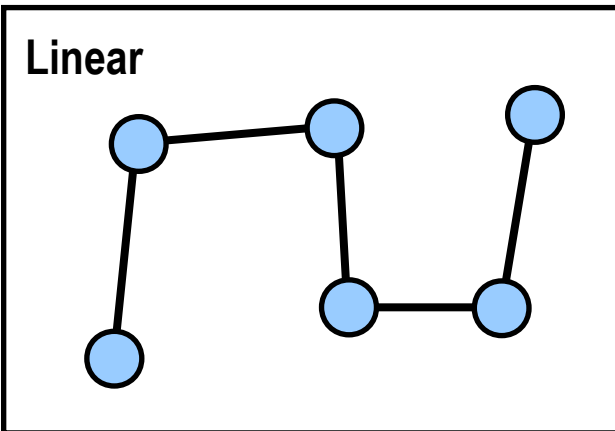
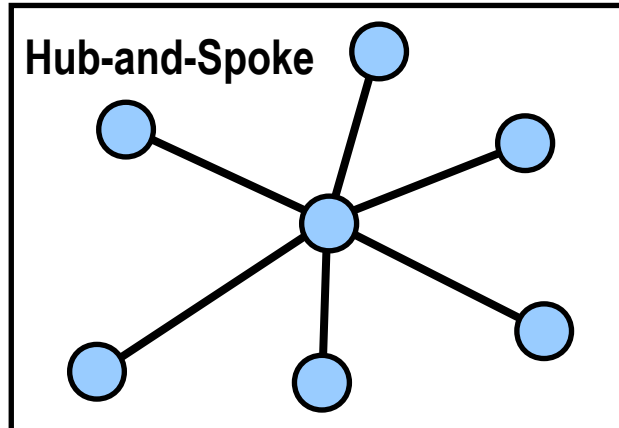
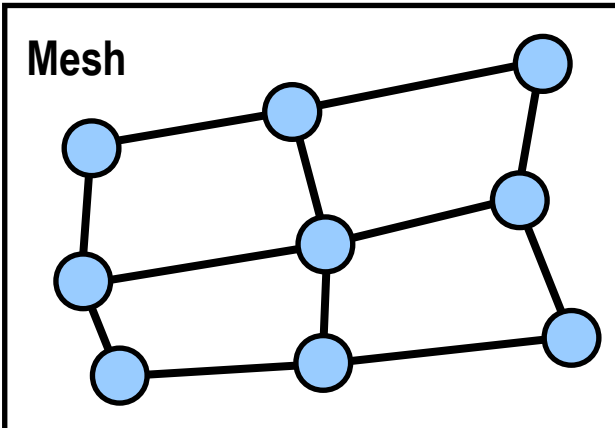
Network Topology



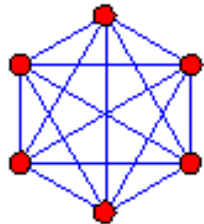
Strategies to Service a Set of Locations

Network topology

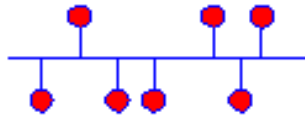
Network Topology - 1



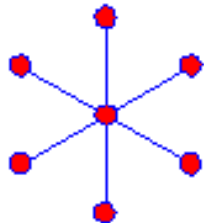
Network Topology - 2



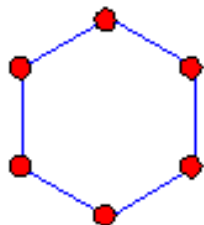
a) Fully Connected Topology



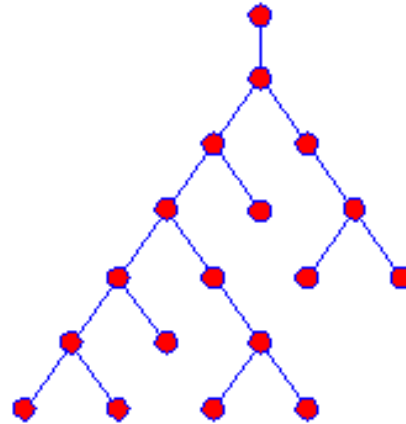
b) Bus Topology



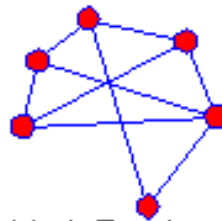
d) Star Topology



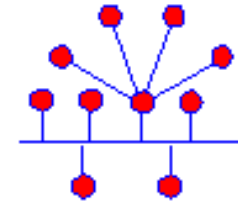
d) Ring Topology



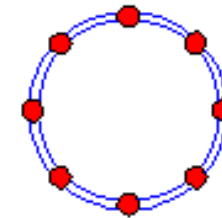
e) Tree Topology



f) Mesh Topology



g) Hybrid Topology
(example: combination of
Star topology and Bus topology)



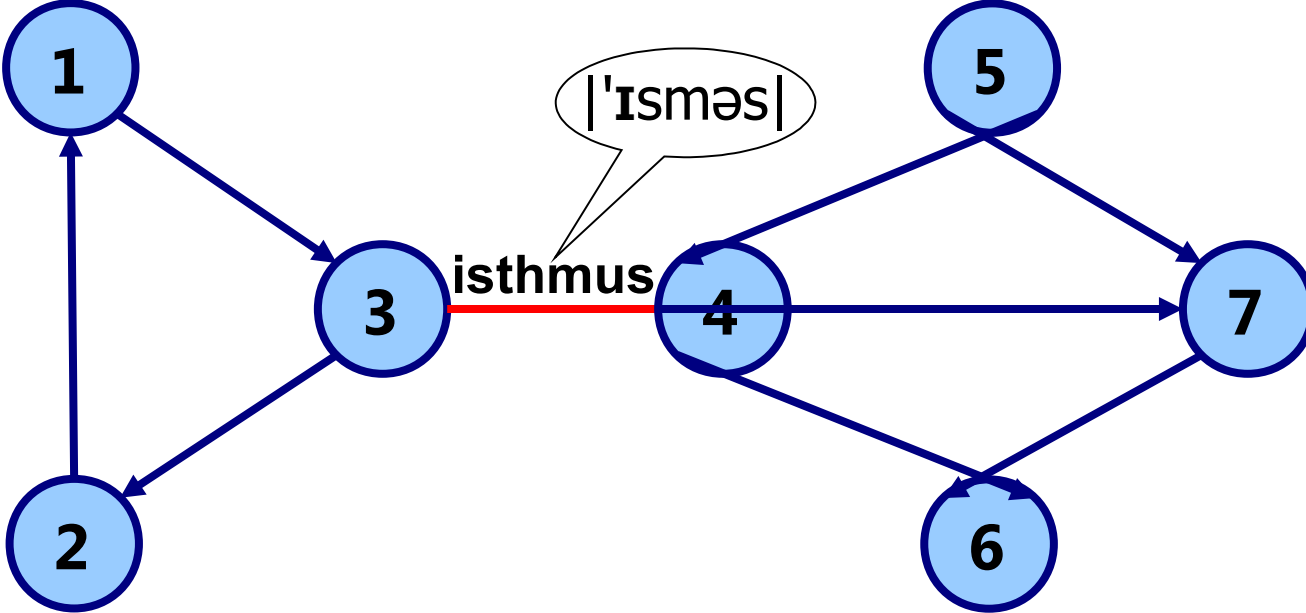
h) Dual Ring Topology



i) Linear Topology

Nodes ● — Branches

Isthmus Connection

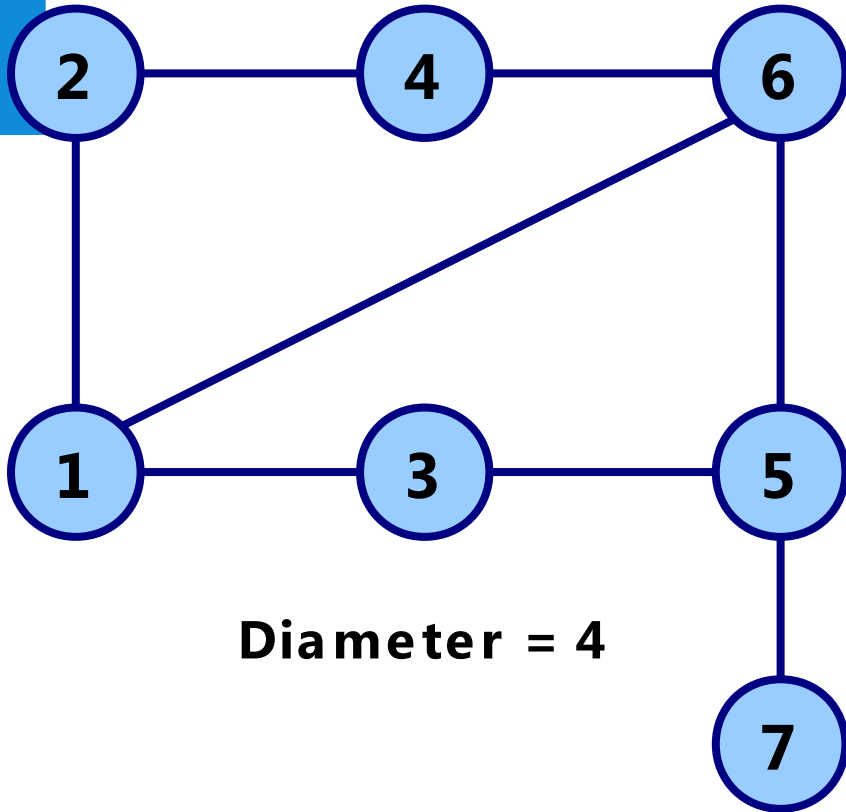


Measuring networks

Network metrics

- Network diameter
- Shortest Average Path Length
- Minimum spanning tree (Dijkstra length)
- Degree distribution

Diameter of a Graph - “longest shortest path”



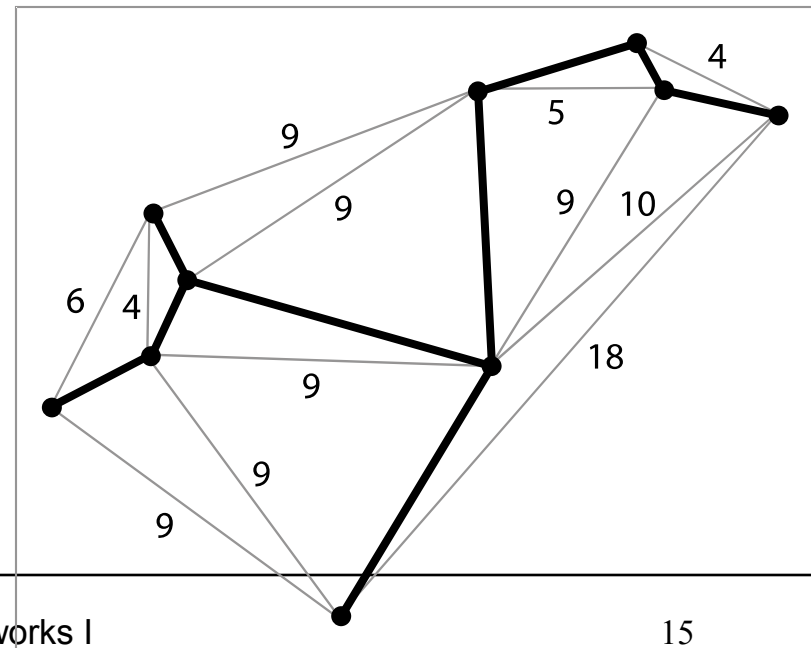
Distance							
	1	2	3	4	5	6	7
1	0	1	1	2	2	1	3
2	1	0	2	1	3	2	4
3	1	2	0	3	1	2	2
4	2	1	3	0	2	1	3
5	2	3	1	2	0	1	1
6	1	2	2	1	1	0	2
7	3	4	2	3	1	2	0

Average shortest path length

- average number of edges along the shortest paths for all possible pairs of network nodes.
- Can be considered as a measure of the efficiency of the network
 - Information or mass transport

Minimum spanning tree

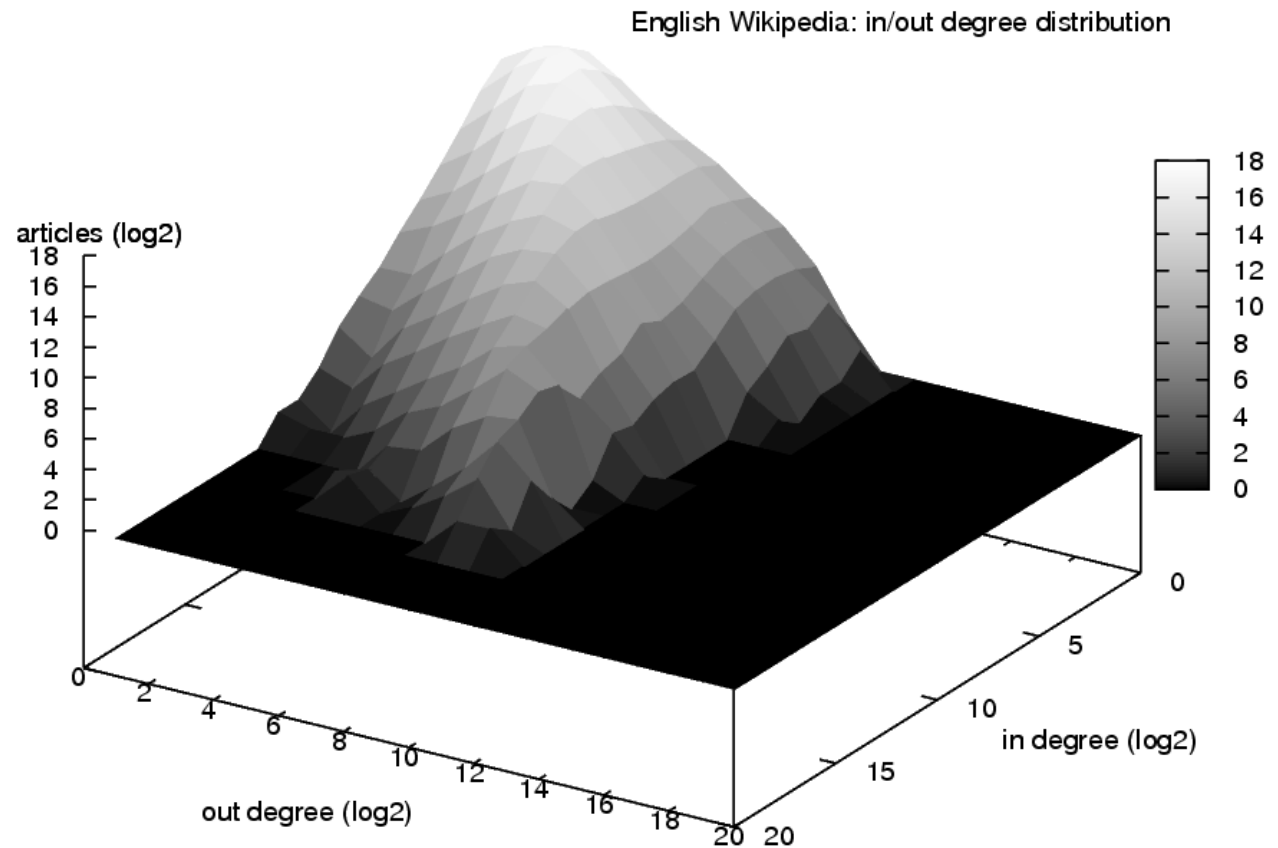
- Starting from some node (root)
- The shortest tree connecting all nodes to the root
- Search algorithms
- Travel itineraries



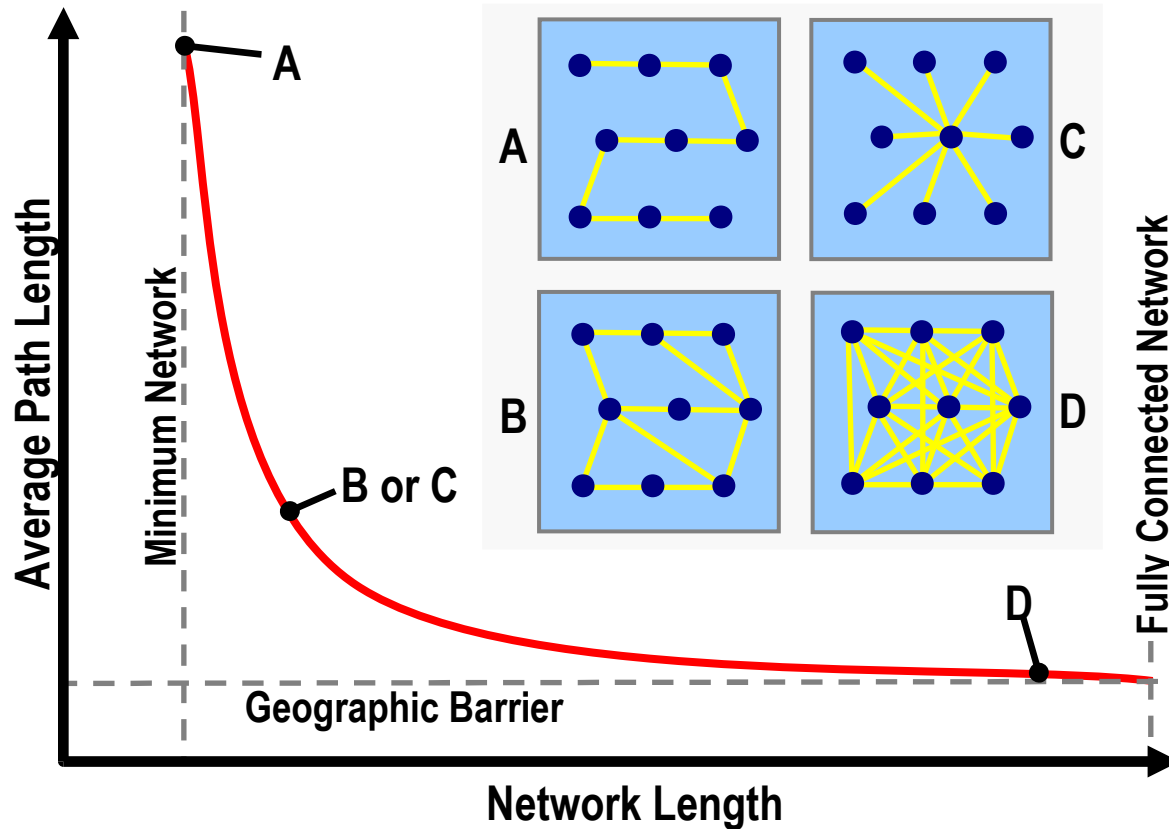
http://en.wikipedia.org/wiki/File:Minimum_spanning_tree.svg

Degree distribution

- Histogram of “degrees” of nodes
- Degree is the number of edges connected to a node

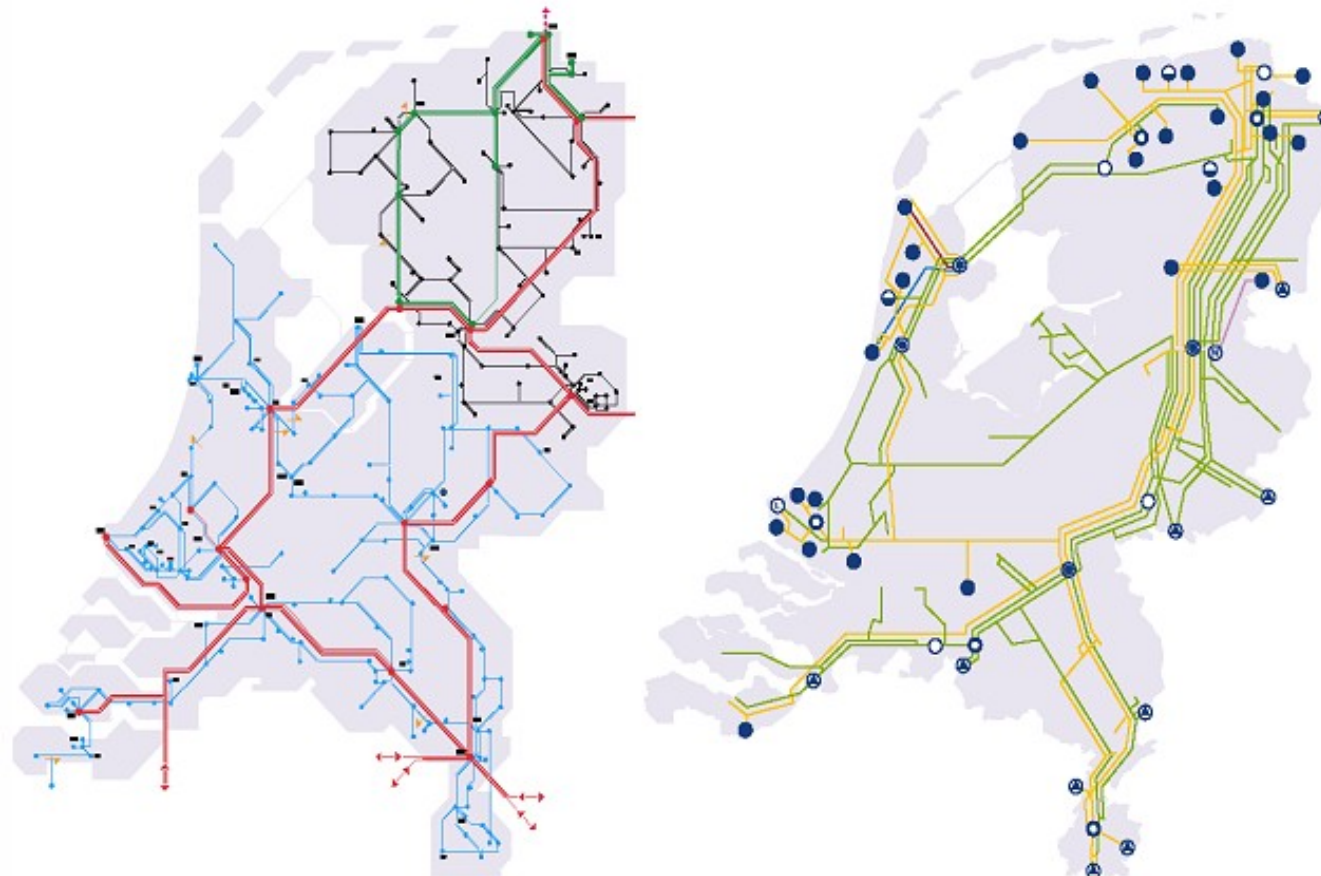


Topology and Network Connectivity

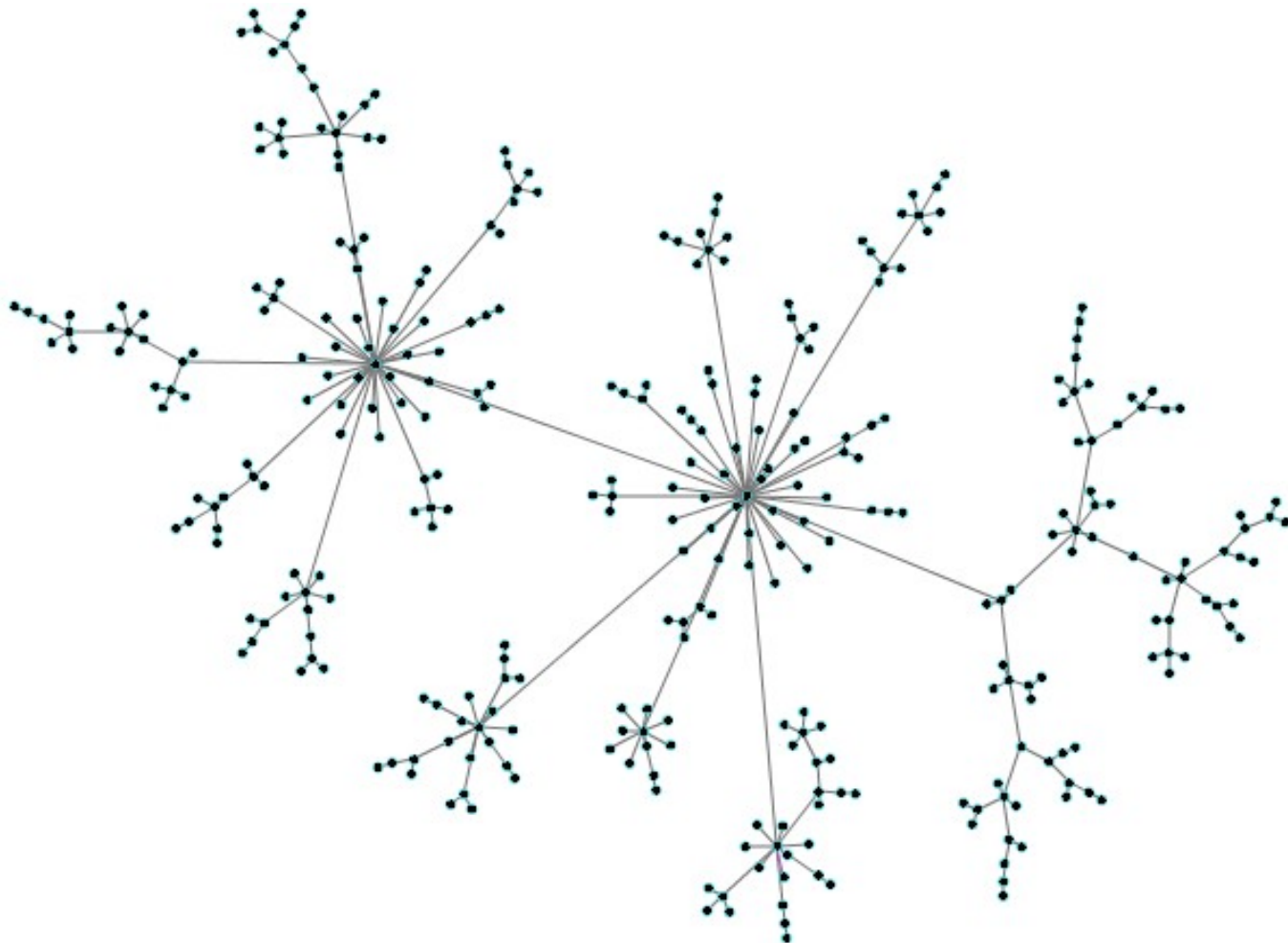


Network growth

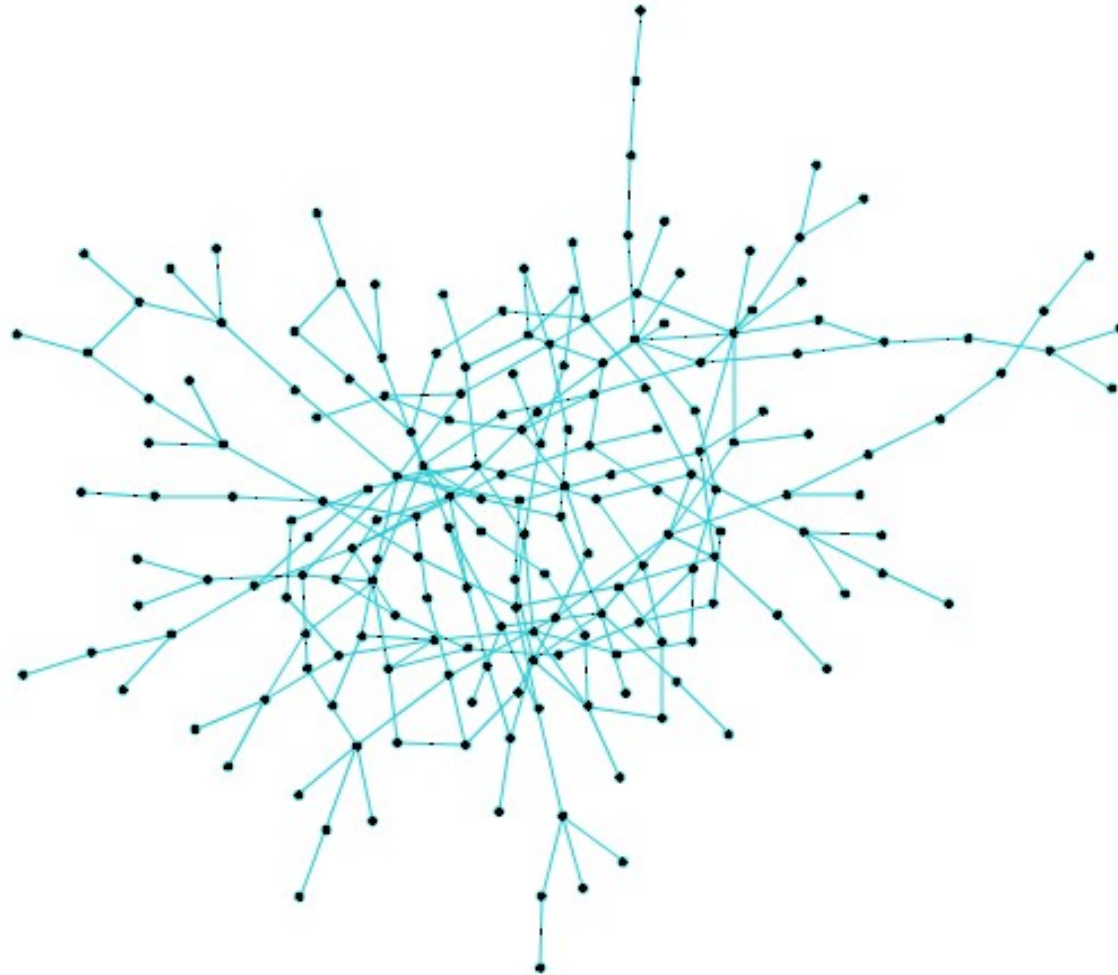
Path dependent growth Electricity vs Gas



Preferentially attached graph



Random graphs



Robustness vs Vulnerability

	random failures	targeted attacks
randomly grown	vulnerable	robust
preferentially grown	robust	vulnerable

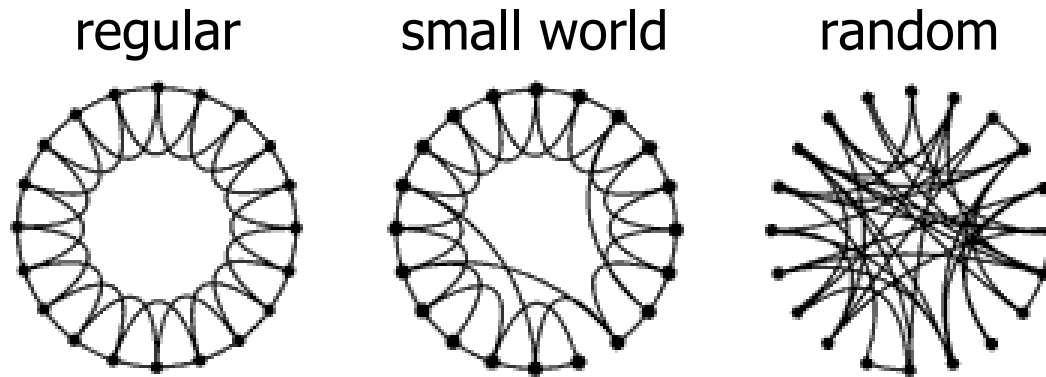
Complex Networks

- Network growth
 - not random
 - new nodes have preference for linking to 'privileged' nodes
 - 'power law' distribution of link numbers ('scale free' network)
- Repercussion for network vulnerability
 - robustness for random failures
 - extremely vulnerable to targeted attacks

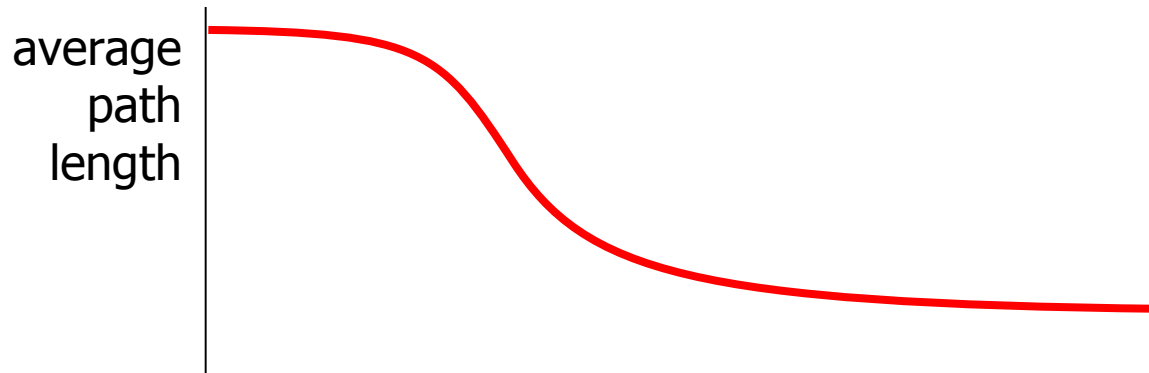
'Six Degrees' of Separation

- 1967: Stanley Milgram
- 160 letters:
 - 'If you know the target person on a personal basis, mail this folder directly to him (her).
[If not, mail it] to a personal acquaintance who is more likely than you to know the target person.'
- 42 made it to their destination
- median number of intermediate persons: 5.5
- some required 10 intermediates

Small World Theory



increasing randomness



Wiki co-authorship network

