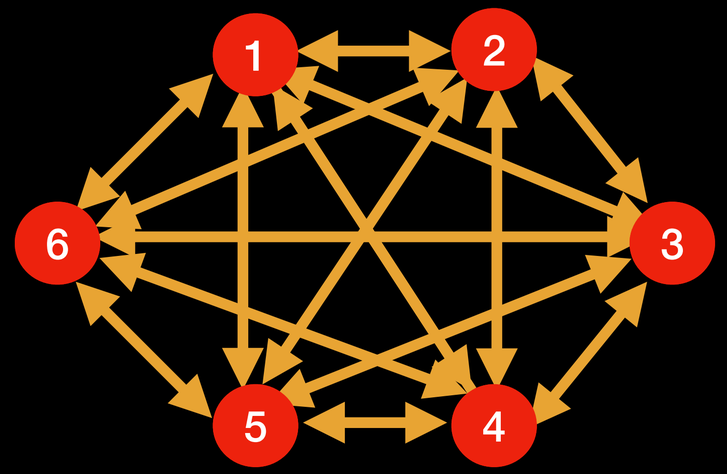
Introduction to Network Analysis. Node centrality

Dr. Stanislav Sobolevsky

Video lectures

Complex urban system

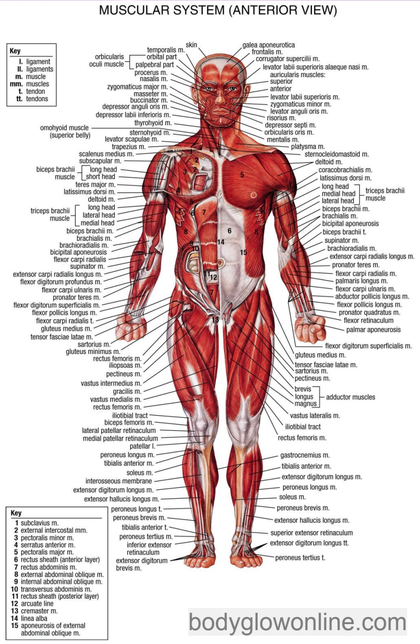


COMPLEX

[adj., v. kuh m-pleks, kom-pleks; n. kom-pleks]
–adjective
1.
composed of many interconnected parts; compound; composite: a complex highway system.
2.
characterized by a very complicated or involved arrangement of parts, units, etc.: complex machinery.
3.
so complicated or intricate as to be hard to understand or deal with: a complex problem.
Source: dictionary.com

Complexity, a scientific theory which asserts that some systems display behavioral phenomena that are completely inexplicable by any conventional analysis of the systems' constituent parts. These phenomena, commonly referred to as emergent behaviour, seem to occur in many complex systems involving living organisms, such as a stock market or the human brain.
Source: John L. Casti, Encyclopædia Britannica

Complexity



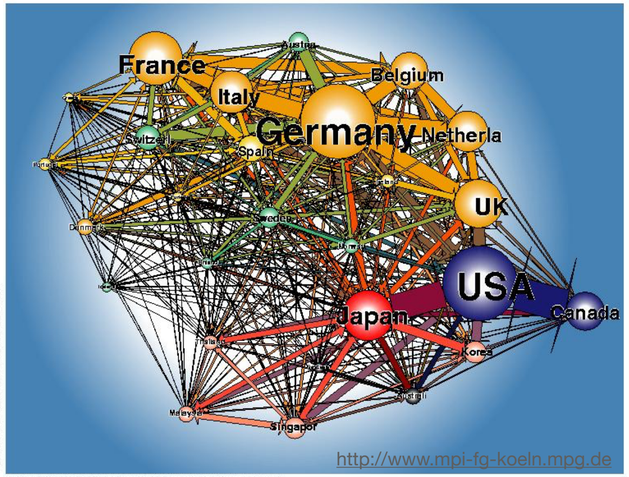
bodyglowonline.com

Human brain

...Society can only be understood through a study of the messages and the communication facilities which belong to it...
Norbert Weiner

The "Day of 7 Billion" has been targeted by the United States Census Bureau to be in July 2012.
http://en.wikipedia.org/wiki/World_population

Human society



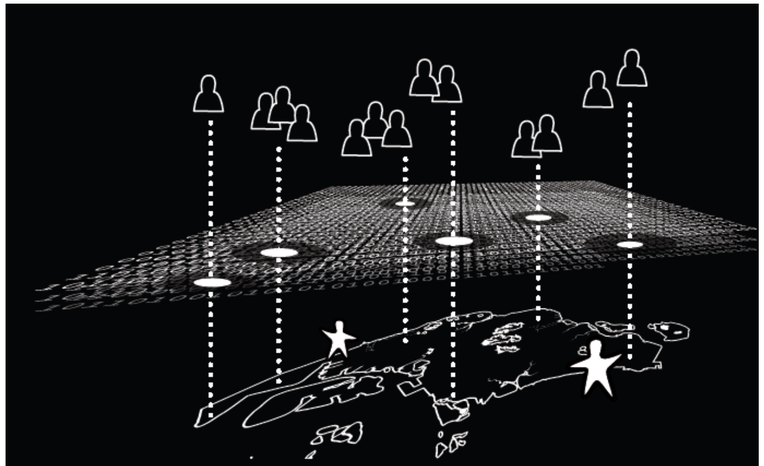
http://www.mpi-fg-koeln.mpg.de

Complexity

Human economy

Human cities

http://senseable.mit.edu/livesingapore/



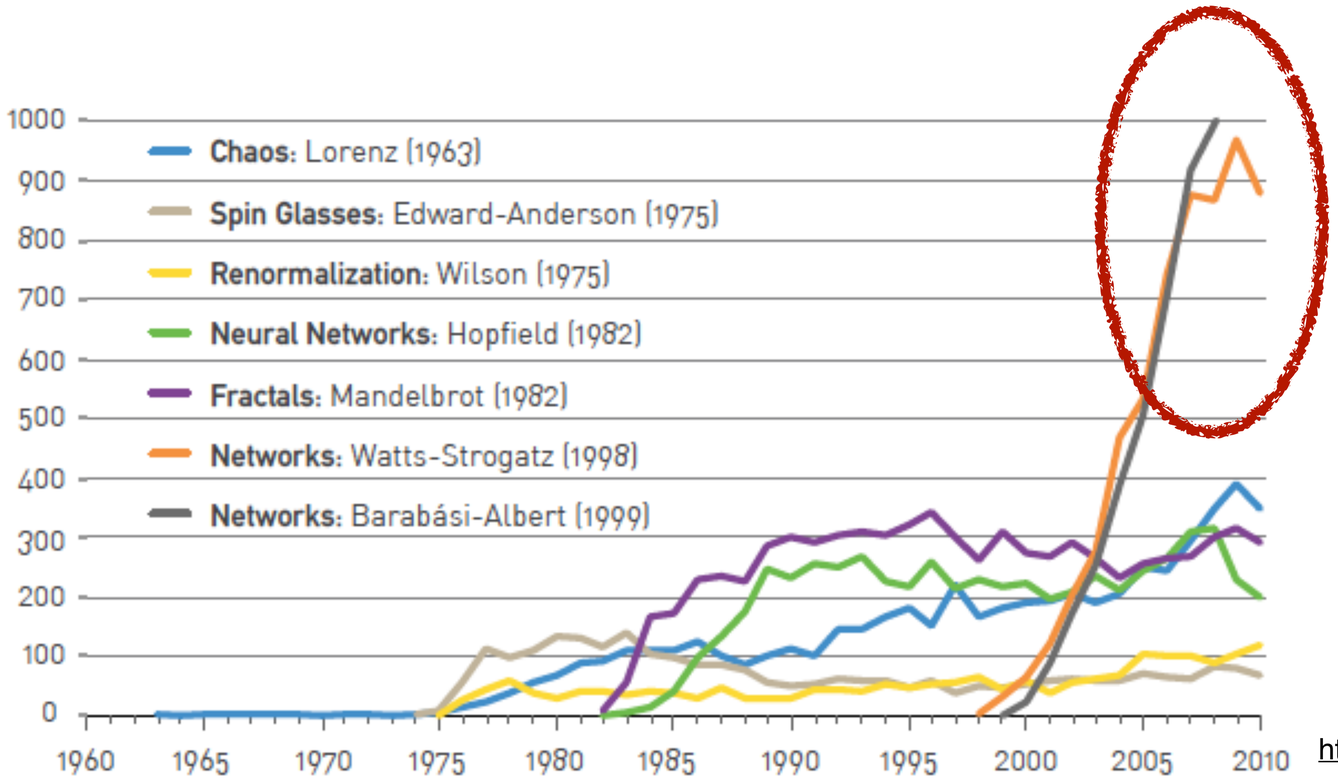
Behind each complex system there is a **network**

A.-L. Barabasi **Network Science : Introduction 2012**

Scientific impact

Barabási, Albert-László, and Réka Albert. "Emergence of scaling in random networks." S*cience* 286.5439 (1999): 509-512.
39000 citations

Watts, Duncan J., and Steven H. Strogatz. "Collective dynamics of ‘small-world’networks." *Nature* 393.6684 (1998): 440-442.
45000 citations



Scale-free

power-law degree distribution

preferential attachment

Small world

handshake rule

http://barabasi.com/networksciencebook

Economic impact

Google	- 1.5T
Facebook	- 850B
Cisco	- 220B
UBER	- 100B
Twitter	- 50B

Biotech
Pharmacology
Healthcare: Genetics
Telecom
Banking and Finance
Transportation
Urban planning

Layers of Urban Networks

NETWORKS

- Human dynamics
- Traffic and road infrastructure
- Human interactions and social networks
- Professional interactions, collaboration
- Utility infrastructure: energy grid, water supply etc
- Waste removal
- Trade; goods supply and logistics
- Individual purchases
- Disease spread
- Knowledge propagation and innovation

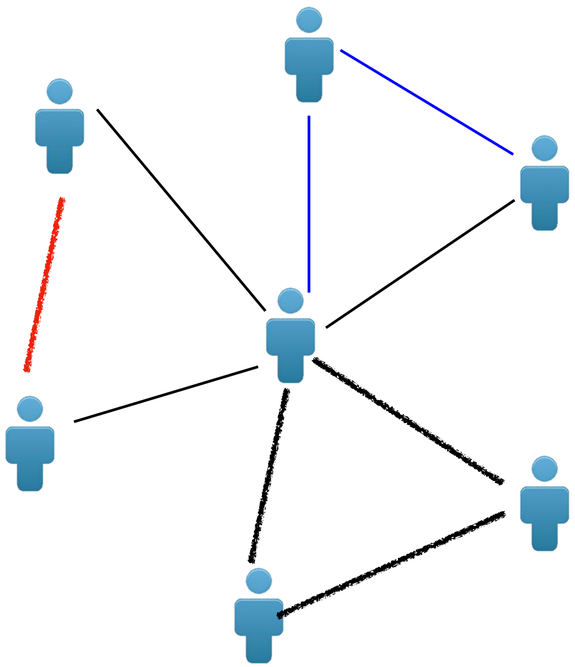
Further Topics

- ✓ Urban Network Examples
- ✓ Network Concept and Model
- ✓ Centrality
- ✓ Routing algorithms
- ✓ Community detection
- ✓ Modeling

Class structure

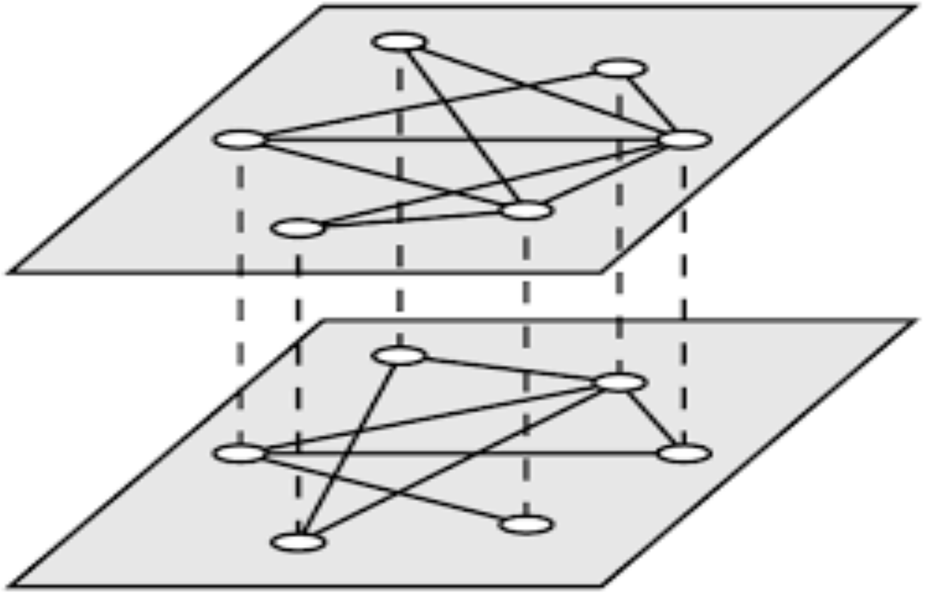
- ✓ Lectures
- ✓ Labs
- ✓ Project discussion
- ✓ Homework (40%)
- ✓ Class project:
  - Discussion (2-4)
  - Report (40%)
  - Presentation (20%)

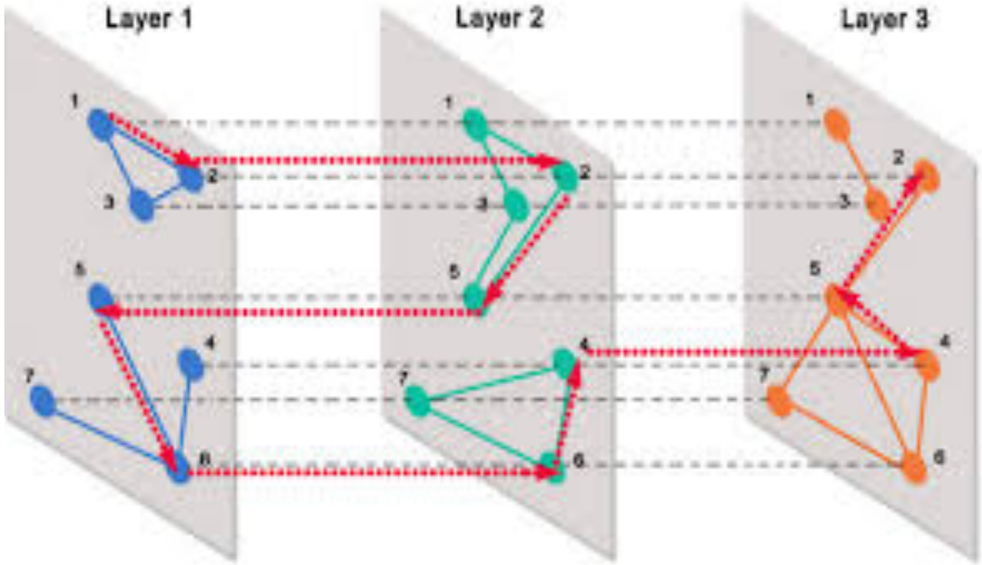
Individual relations



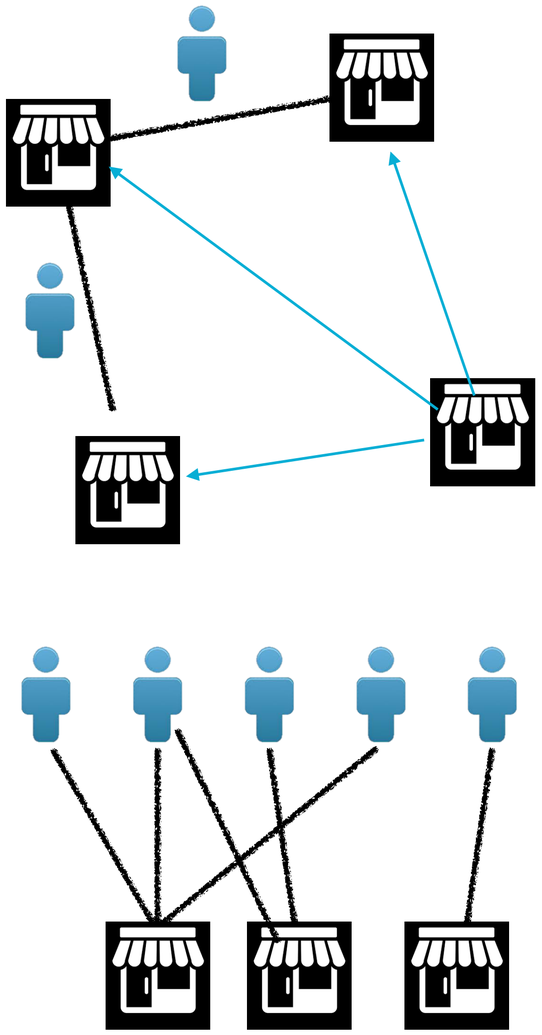
- Friendship
- Romantic
- Family ties
- Professional collaboration

Multilayer/multiplex networks



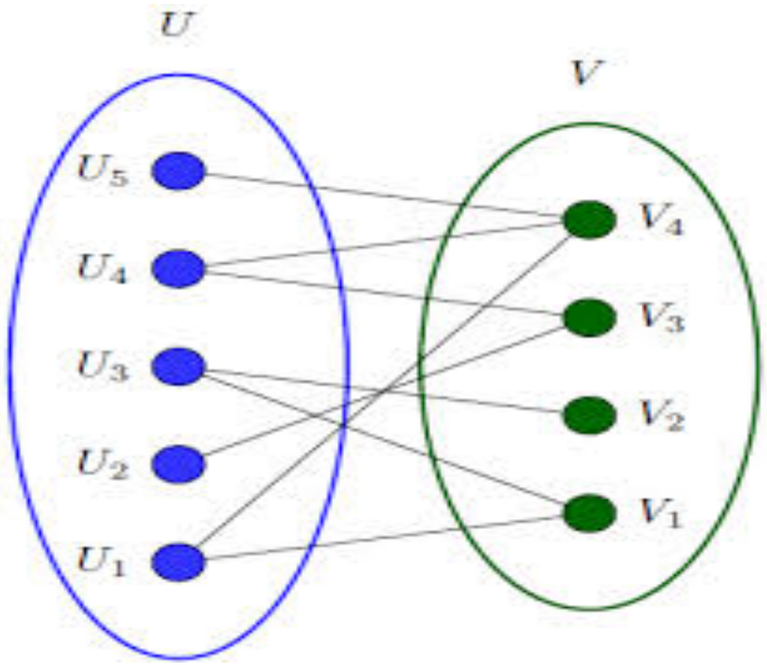


Business connections

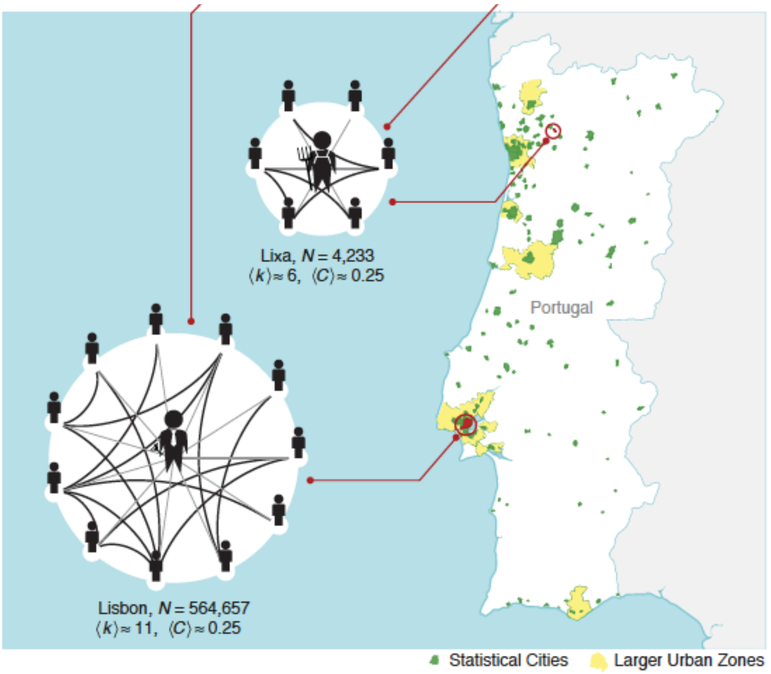


- Sharing customers
- Supplier relations

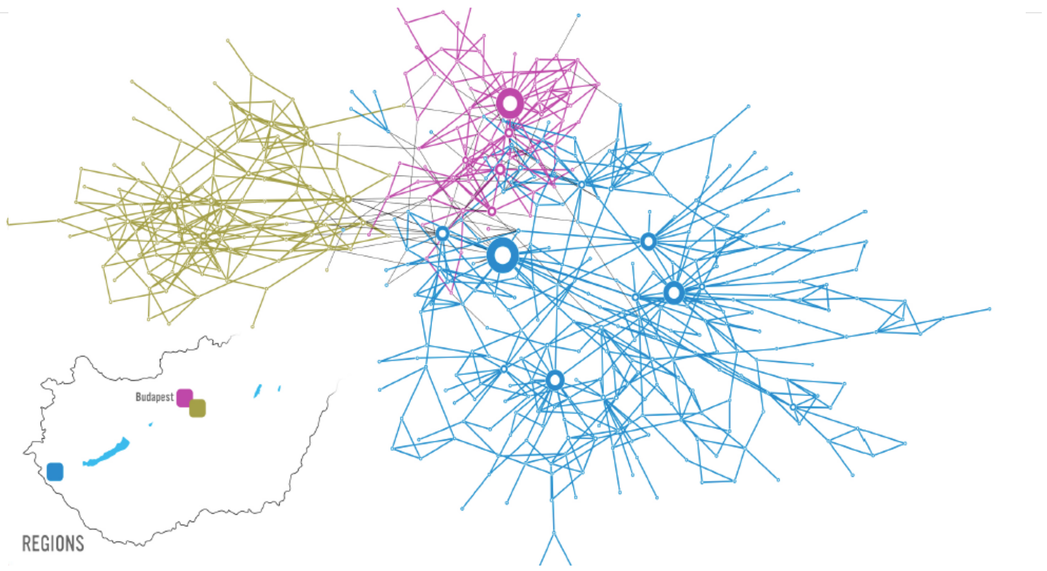
Bi-partite networks



Individual human interactions



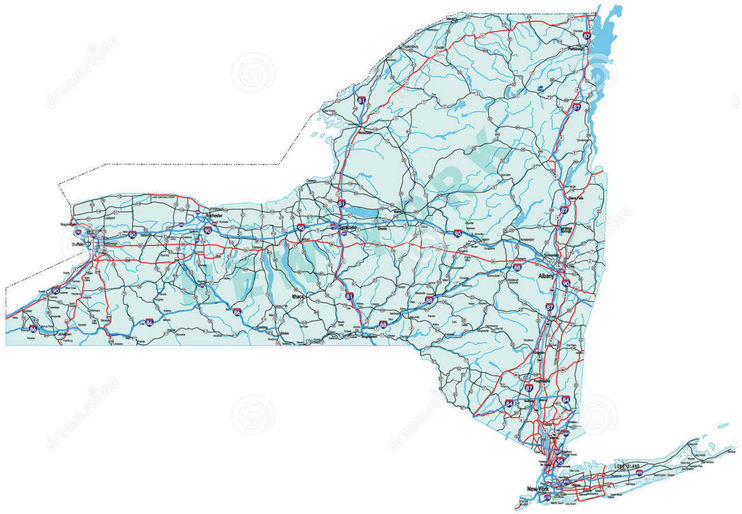
Schläpfer, M., Bettencourt, L. M., Grauwin, S., Raschke, M., Claxton, R., Smoreda, Z., ... & Ratti, C. (2014). The scaling of human interactions with city size. *Journal of The Royal Society Interface*, *11*(98), 20130789.

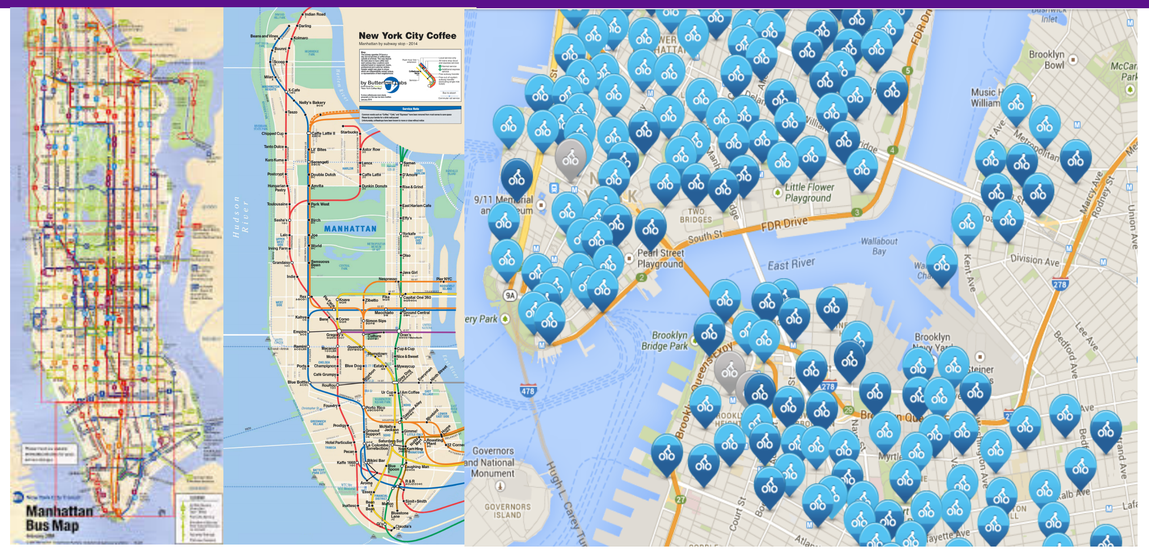


http://barabasi.com/networksciencebook

Human mobility networks

Urban transportation





Bus/subway/train routes

road network

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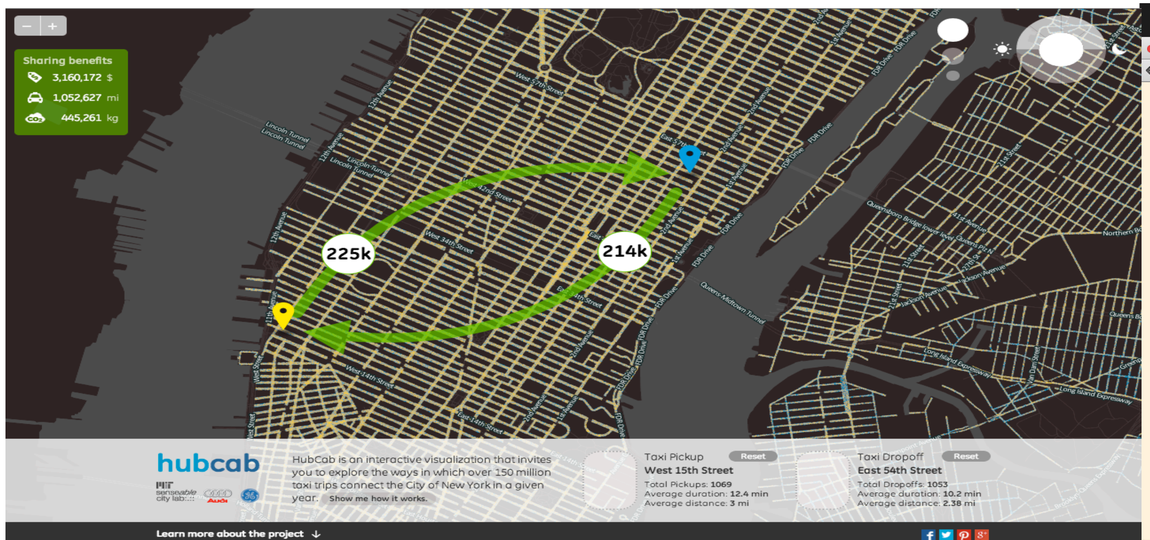
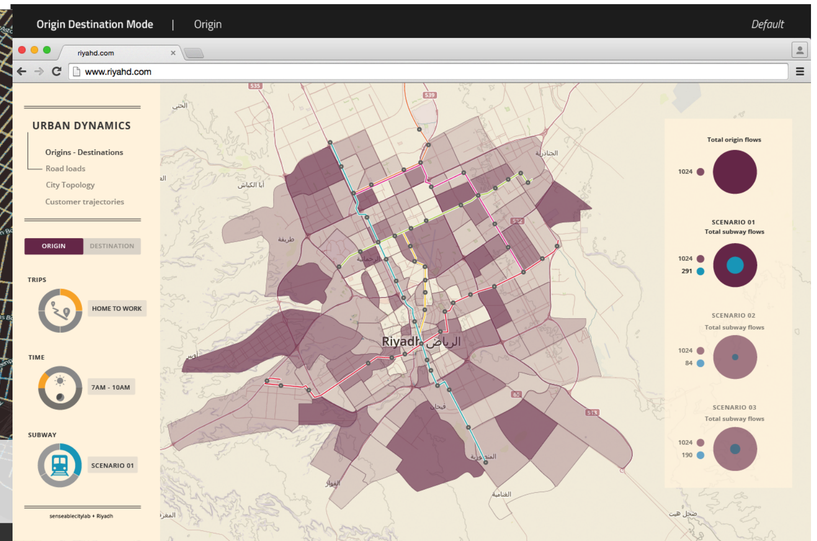
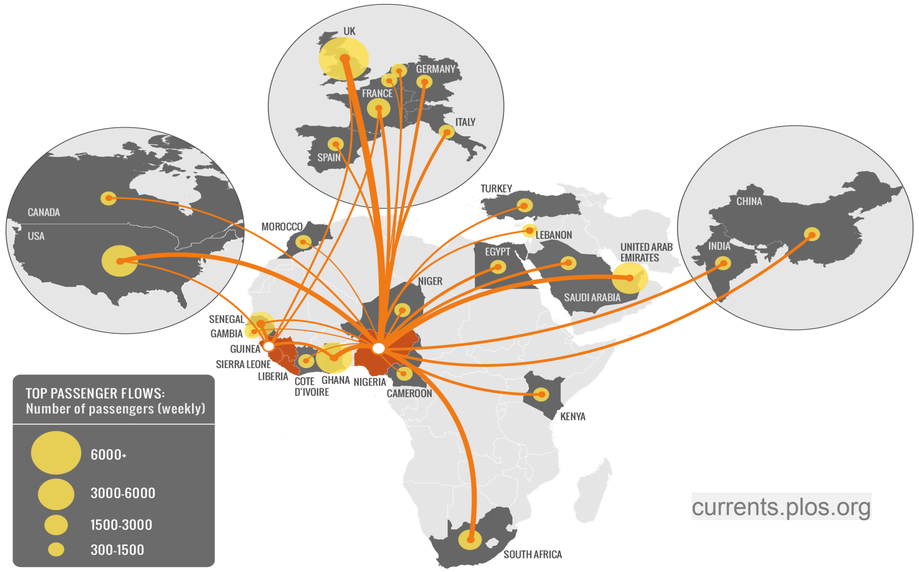




Epidemic networks



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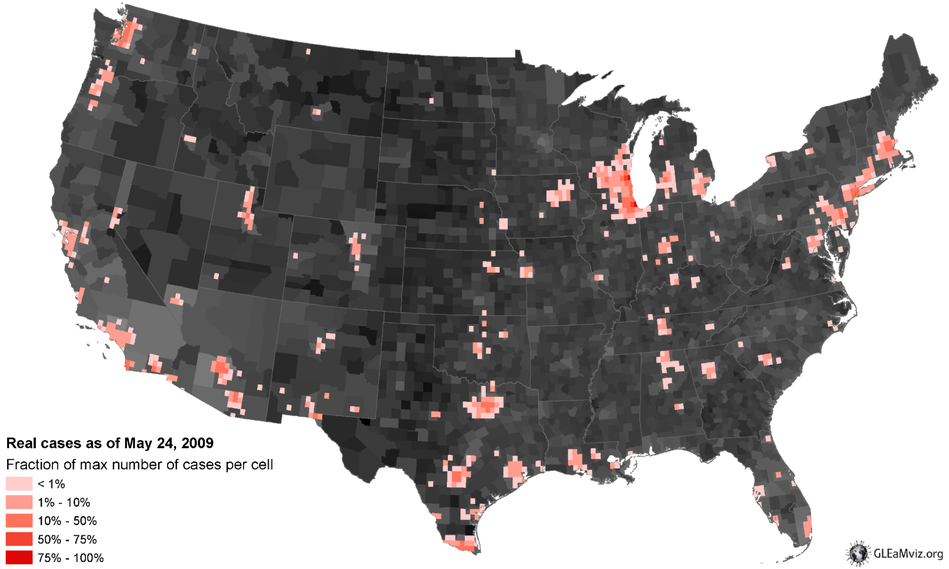
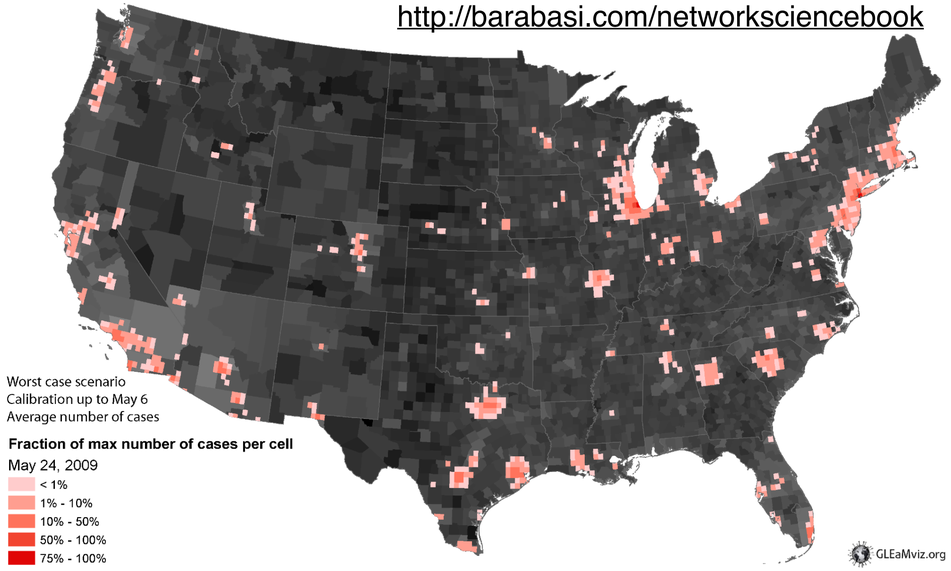
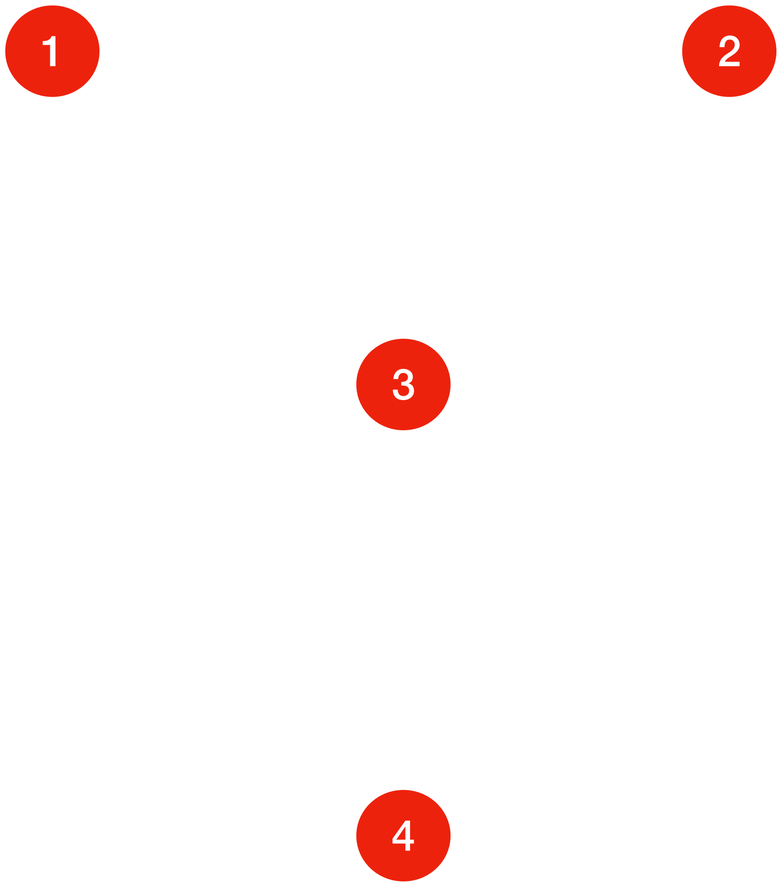
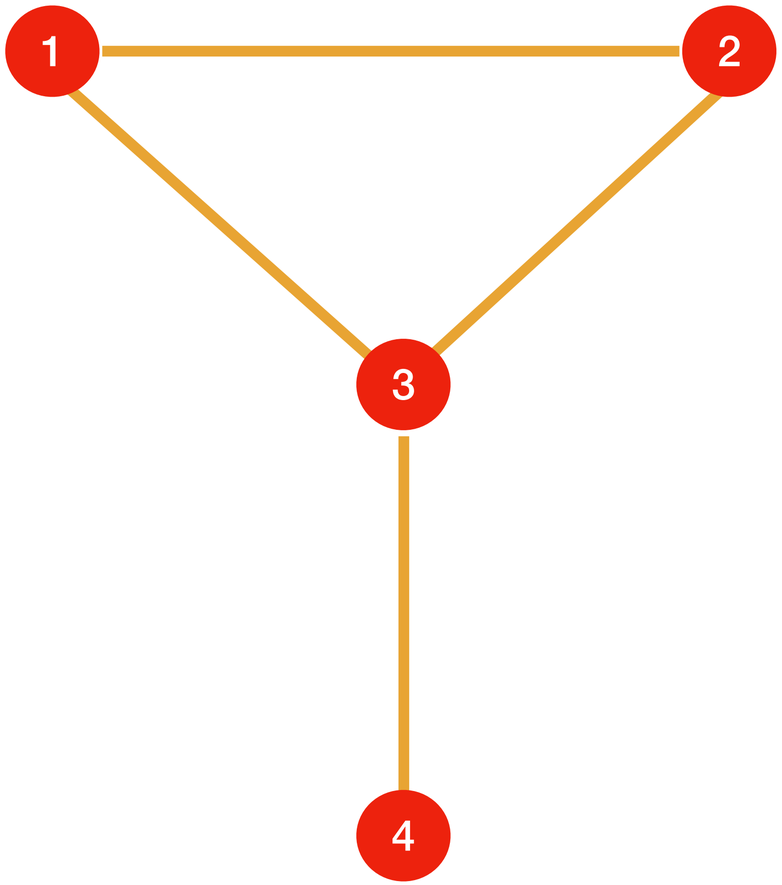




Concept of a network: nodes

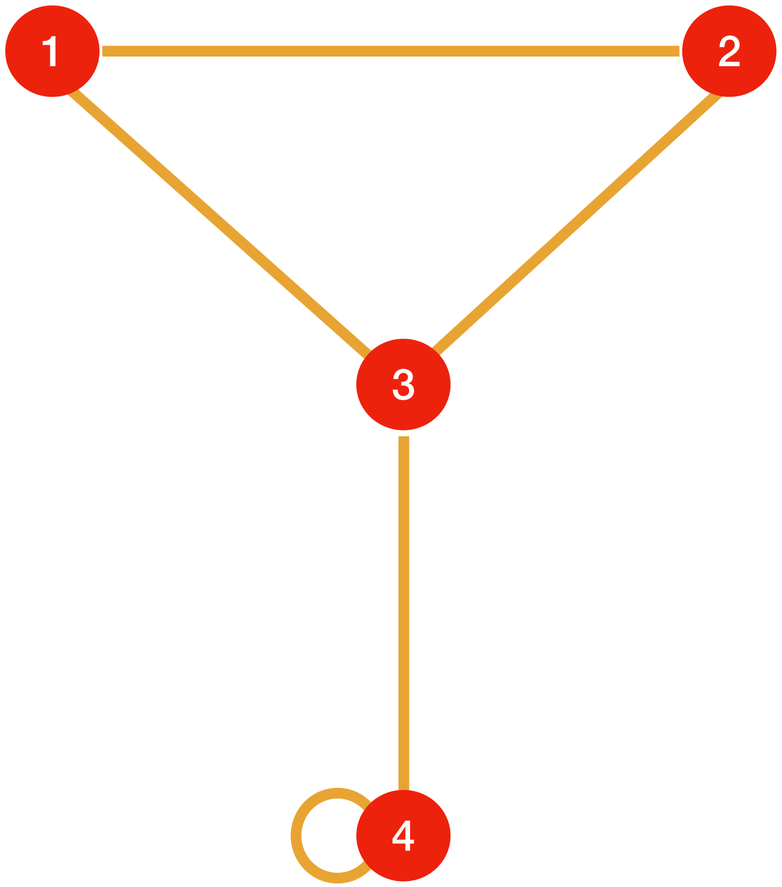


Concept of a network: edges

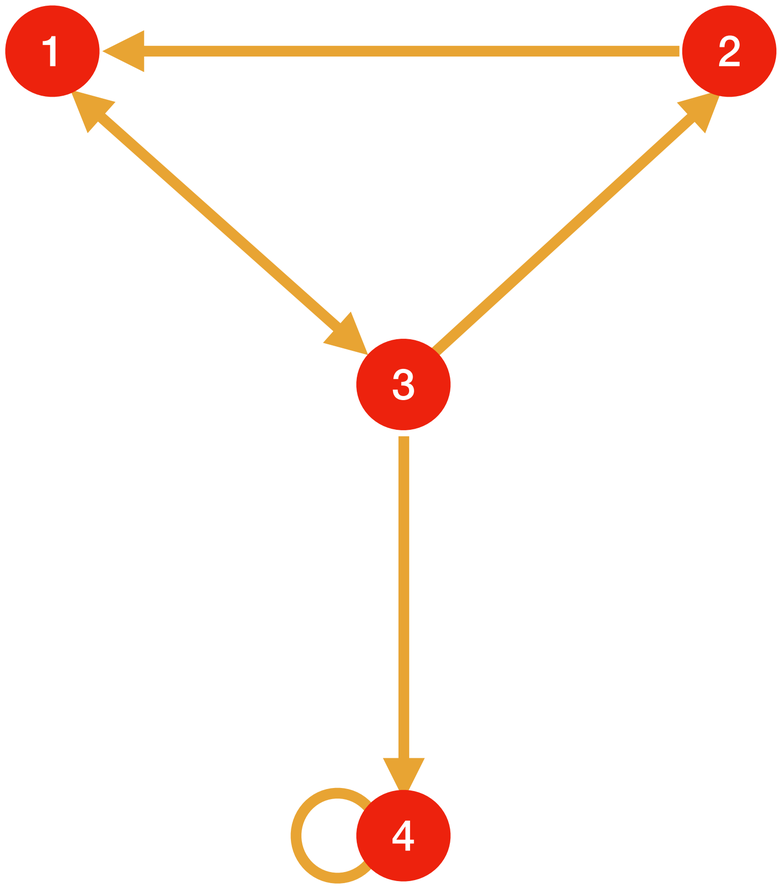


$$G = (N, E)$$

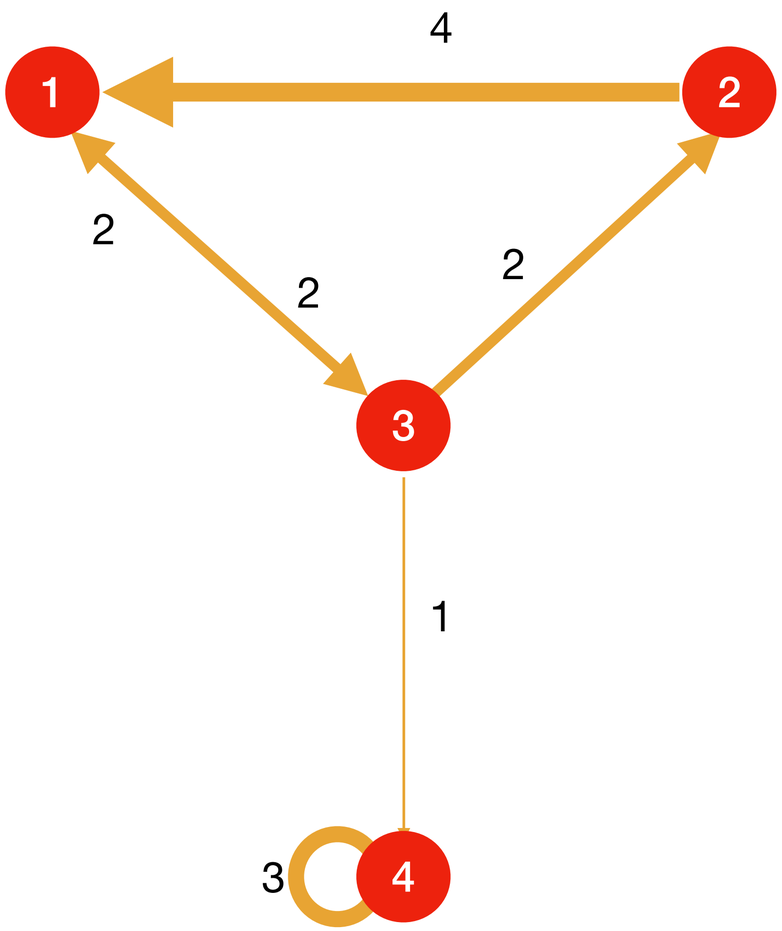
Loop edges



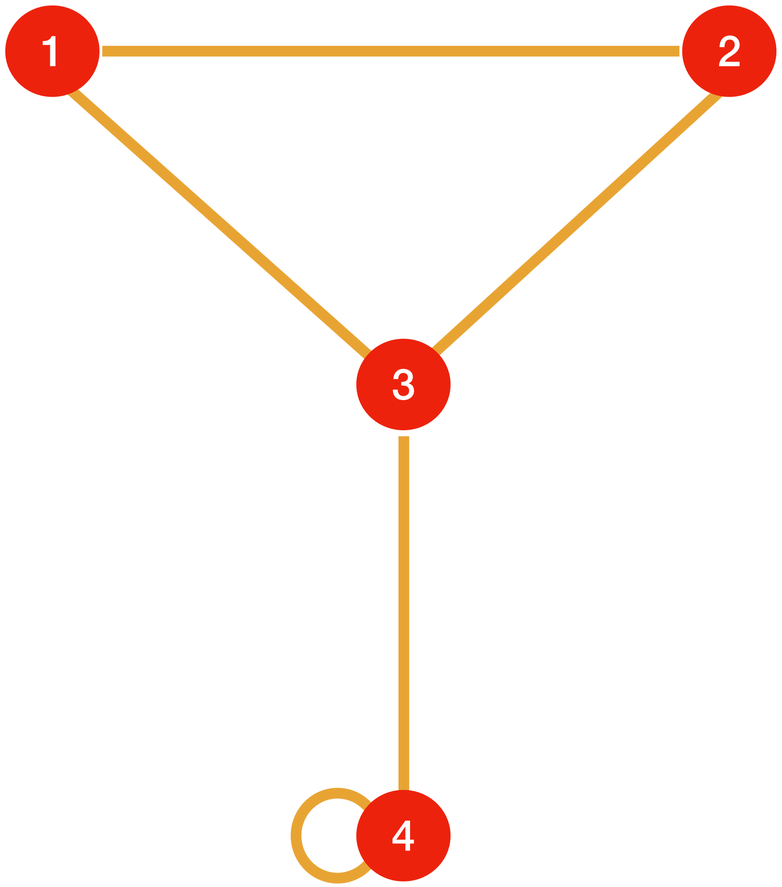
Directed network



Weighted network



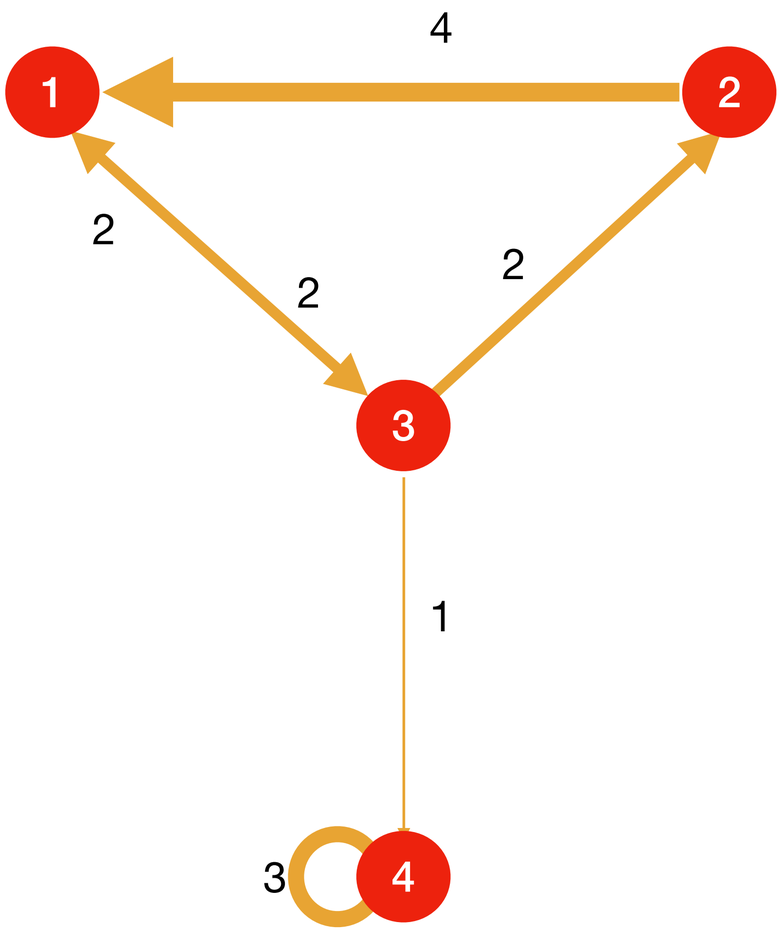
Numeric representation



O	D
1	2
1	3
2	2
3	4
4	4

	1	2	3	4
1	0	1	1	0
2	1	0	1	0
3	1	1	0	1
4	0	0	1	1

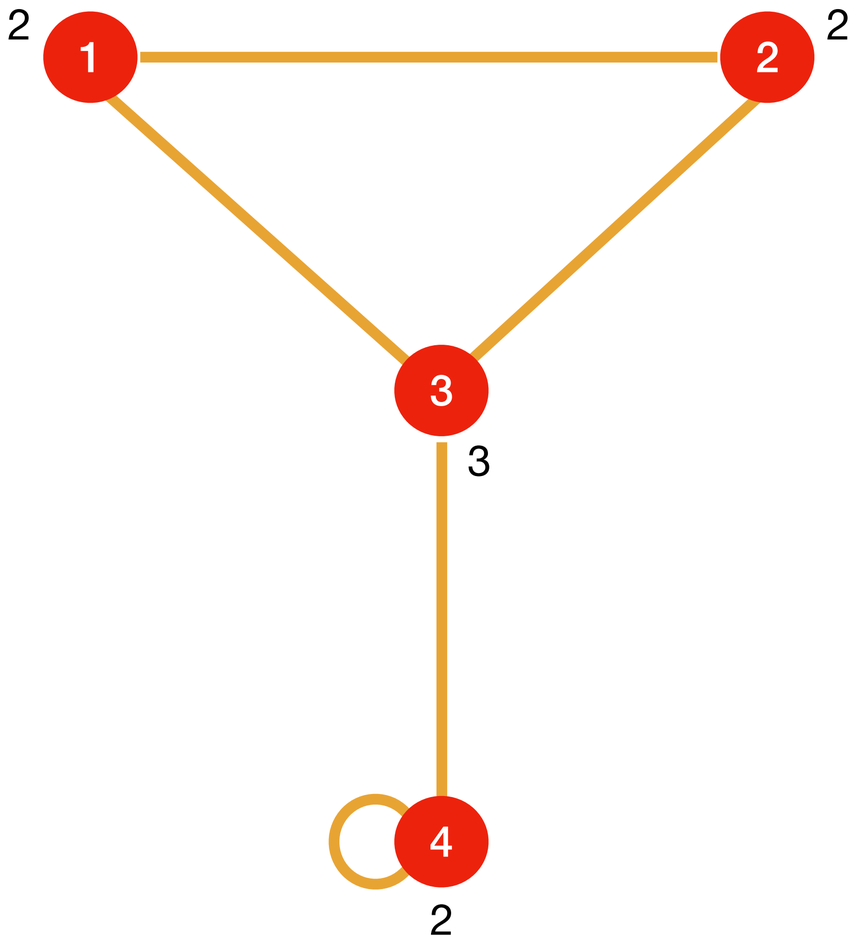
Concept of a network



O	D	W
2	1	4
1	3	2
3	1	2
3	2	2
3	4	1
4	4	3

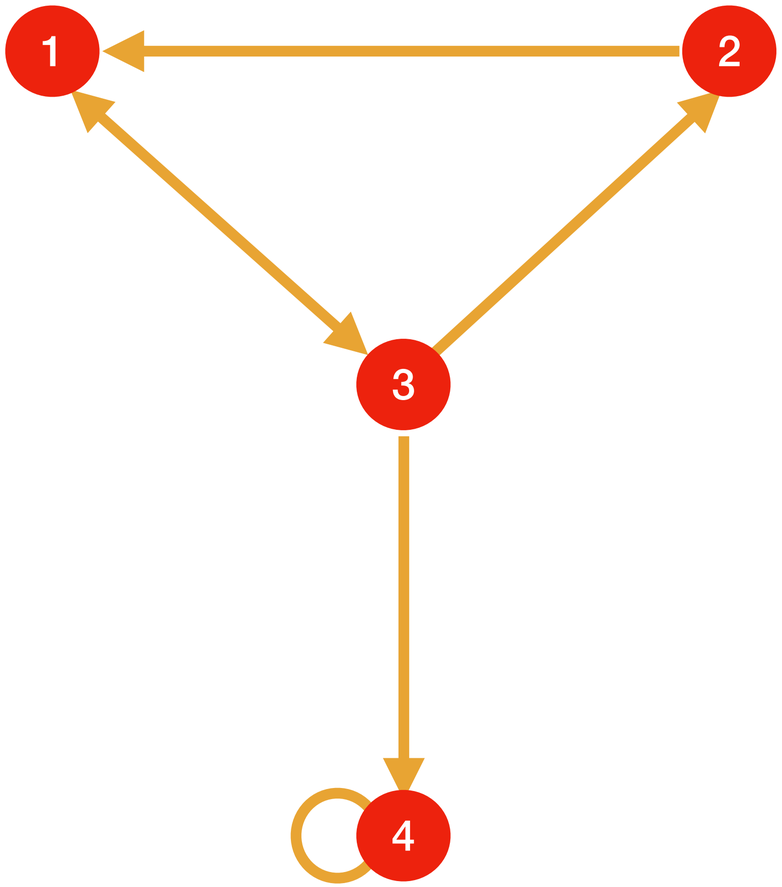
	1	2	3	4
1	0	0	2	0
2	4	0	0	0
3	2	2	0	1
4	0	0	0	3

Node degree



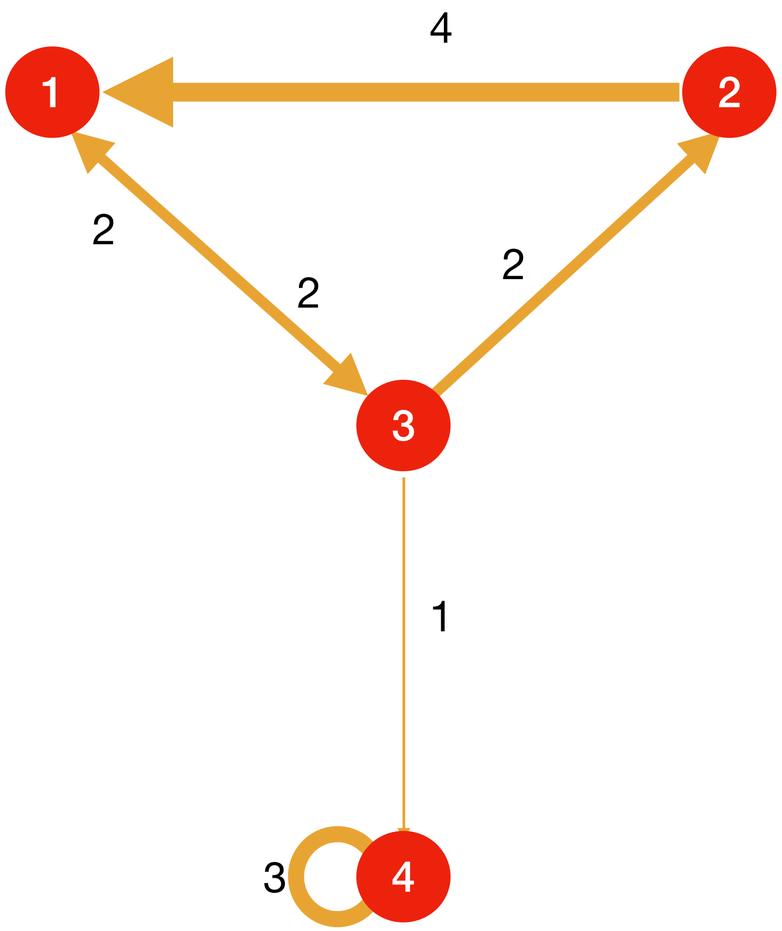
	1	2	3	4	D
1	0	1	1	0	2
2	1	0	1	0	2
3	1	1	0	1	3
4	0	0	1	1	2

Directed network: node in/out degree



	1	2	3	4	Out
1	0	0	1	0	1
2	1	0	0	0	1
3	1	1	0	1	3
4	0	0	0	1	1
In	2	1	1	2	6

Weighted network: node strength



	1	2	3	4	Out
1	0	0	2	0	2
2	4	0	0	0	4
3	2	2	0	1	5
4	0	0	0	3	3
In	6	2	2	4	14

Possible projects

- ✓ Regional/district delineation through community detection in human mobility/interaction networks
- ✓ Modeling human mobility/interaction networks, temporal networks
- ✓ Vulnerability of transportation networks