

Networks

Introduction and Graph Theory

Topics

- What is a Network?
- Networks and Interconnectivity
- Origins and Applications
- Characteristics
- Impact

net·work

/'net, wərk/

noun

noun: network; plural noun: networks

1. an arrangement of intersecting horizontal and vertical lines.

synonyms: web, lattice, net, matrix, mesh, crisscross, grid, reticulum, reticulation; plexus
"a network of arteries"

- a complex system of roads, railroads, or other transportation routes.

"a network of railroads"

synonyms: maze, labyrinth, warren, tangle
"a network of lanes"

2. a group or system of interconnected people or things.

"a trade network"

synonyms: system, complex, nexus, web, webwork
"a network of friends"

- a group of people who exchange information, contacts, and experience for professional or social purposes.

"a support network"

- a group of broadcasting stations that connect for the simultaneous broadcast of a program.
"the introduction of a second TV network"

- a number of interconnected computers, machines, or operations.

"specialized computers that manage multiple outside connections to a network"

- a system of connected electrical conductors.

Networks Are Interconnected



Pros

- Induces remarkable non-locality
- Information Flow
- Power and Energy Flow
- Business Practices
- Social Practices



Cons

- Vulnerability / Cascading Effect
- Network Effects in Asian Financial Crisis
- Power Blackouts

Interconnectivity



Power Blackout (2003)



Image source: <http://zdnet4.cbsistatic.com/hub/i/r/2015/04/01/48ebdf07-1a3f-4d95-95ac-d168a288f545/resize/1170x878/b60db0c3035f905ac60684bc68b8d8ff/10blackout.png>

Story: <http://www.zdnet.com/pictures/no-april-fools-the-top-10-it-fiascos-of-all-time/10/>

Blackout (2003)

On August 14, 2003, a power systems operator in Ohio was annoyed by an alarm about a power flow problem. So, he turned it off.

Hours later, as evening fell on a hot summer's day, blackouts across eight US states and Canada spread over 256 power stations and 50 million people. What had happened? Afterwards, it was discovered that the Unix-powered General Electric energy management system, the GE Energy's XA/21, was mishandling the situation, thanks to a race condition.

The net result was that FirstEnergy Corp, the Ohio utility where the blackout began, wasn't aware of just how bad the power grid was until the demand was overwhelming one power plant after another. It took more than a week for power to be fully restored.

Published: April 1, 2015 -- 04:00 GMT (21:00 PDT)
Caption by: Steven J. Vaughan-Nichols

The grid network tried to divert the load away from the failing links. However, the remaining links were not strong enough to handle the excess load.

Origins and Applications of Network Science



Networks at the Heart of Complex Systems

Cellular network: Genes

Neural network: Neurons

Social networks: Professionals, friends, family etc.

Communication networks: communication devices

Power grid: generators and transmission lines

Trade networks: goods and services

Two forces that Helped Shape Network Science

The emergence of **network maps** (in last 15-20 years)

- Large scale maps of Internet
- Protein-Protein interaction maps
- Social network maps (Facebook, Twitter, LinkedIn)
- Neural Connections in mammalian brains



The **universality** of network characteristics

- Architectures of networks emerging in various domains of science, nature, and technology are similar to each other
- Governed by same organizing principles

Characteristics of Network Science

Interdisciplinary nature

- Graph theory (Maths)
- Statistics
- Physics
- Engineering (control and information theory)

Quantitative and Empirical

- Mathematical Models
- Each model is tested on real world data

Computational nature

- Built on algorithms, database management and data mining
- Software availability

Societal & Scientific Impact

Societal Impact

- Economic impact (e.g., Market capitalization value of Facebook)
- Health: Human Genome project provides first comprehensive list of all human genes
- Network biology
- Security and fighting terrorism
- Halting deadly viruses and fighting epidemics
- Neuro-science and mapping the brain
- Management and uncovering the internal structure of an organization

Scientific Impact

- Network science has emerged as a new *discipline*

Predicting Epidemic Using Social Networks



Network of Flights in Europe

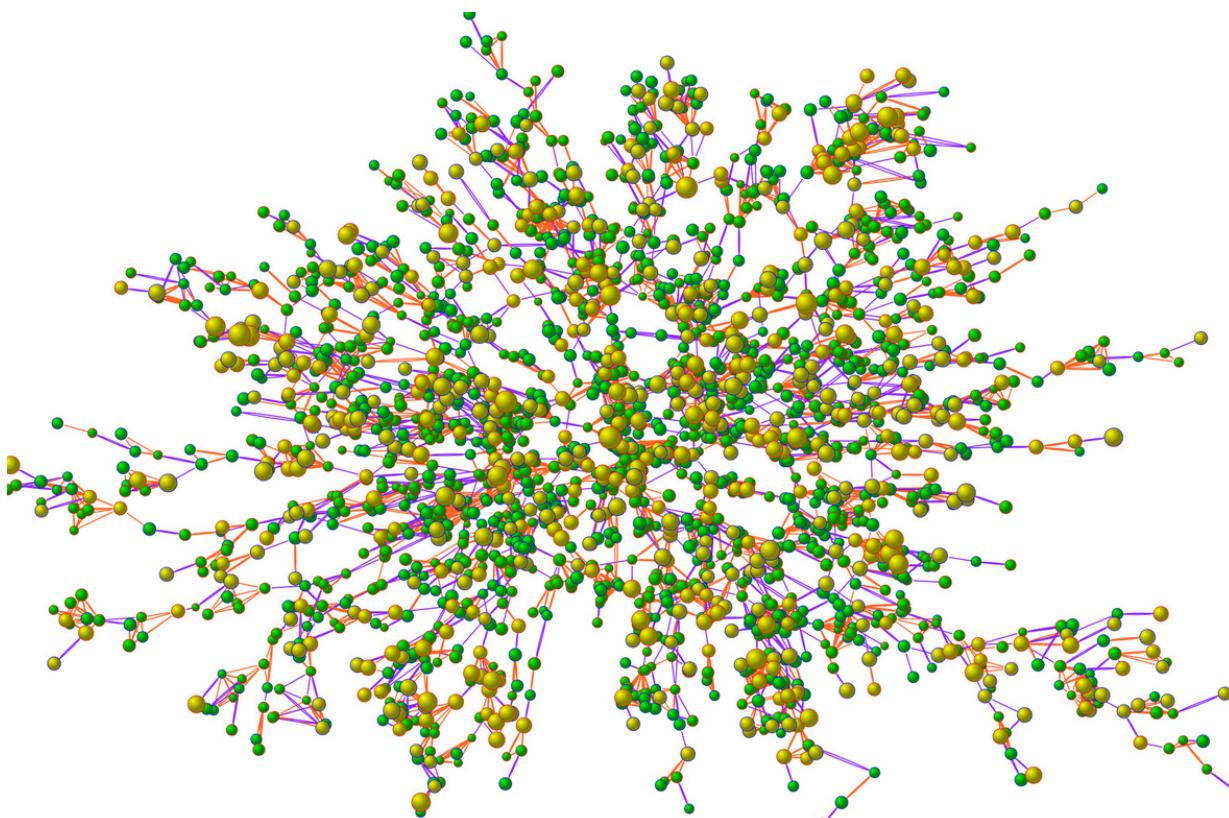


Do Proteins Have their Own Networks



Obesity and Social Networks





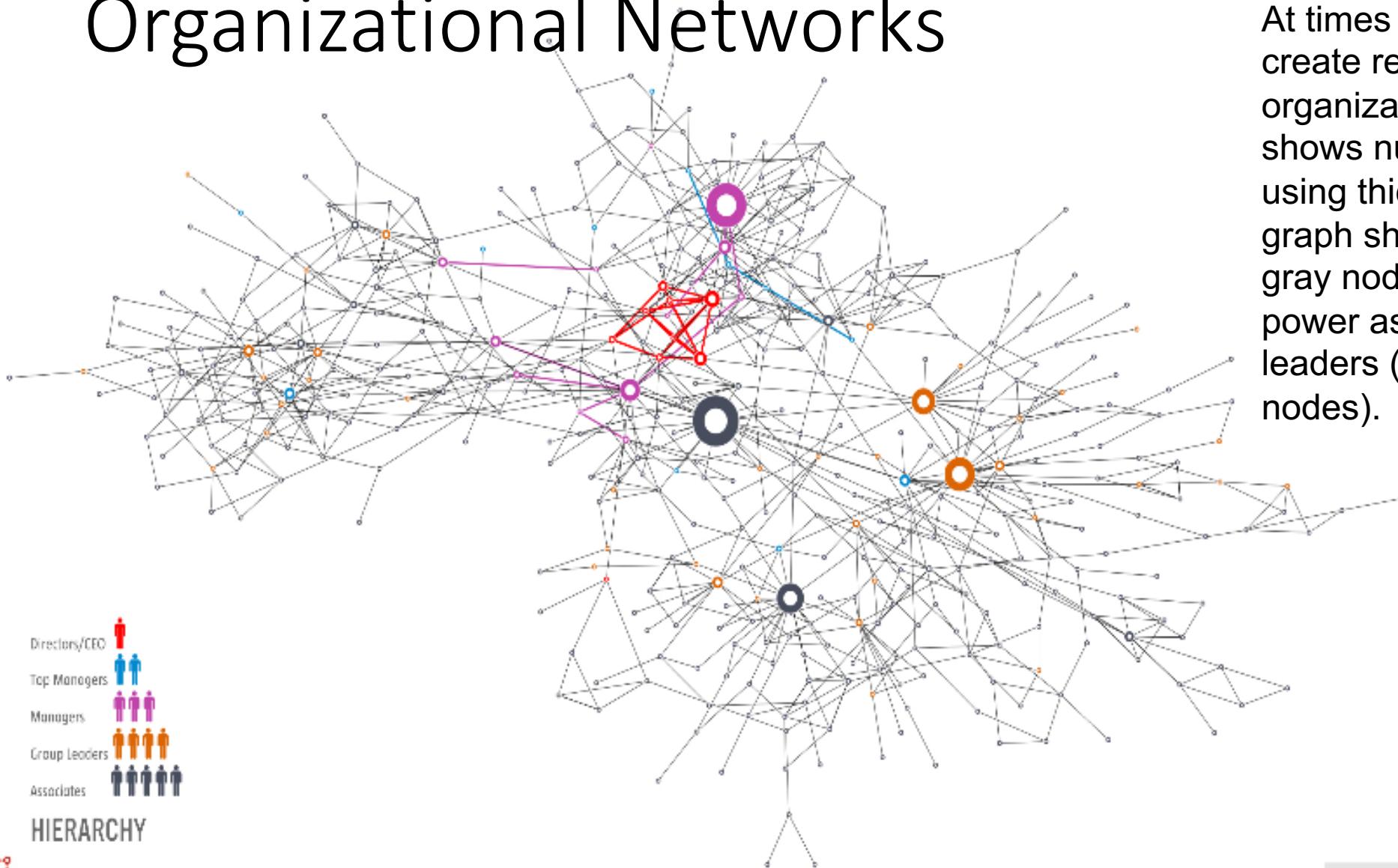
If a person you consider a friend becomes obese, the researchers found, your own chances of becoming obese go up 57 percent. Among mutual friends, the effect is even stronger, with chances increasing 171 percent.

Christakis and Fowler also looked at the influence of siblings, spouses and neighbors. Among siblings, if one becomes obese, the likelihood for the other to become obese increases 40 percent; among spouses, 37 percent. There was no effect among neighbors, unless they were also friends.

The researchers analyzed data over a period of 32 years for 12,067 adults, who underwent repeated medical assessments as part of the Framingham Heart Study.

Each node represents a person. Yellow node is high BMI obese person; green is non-obese person.

Organizational Networks

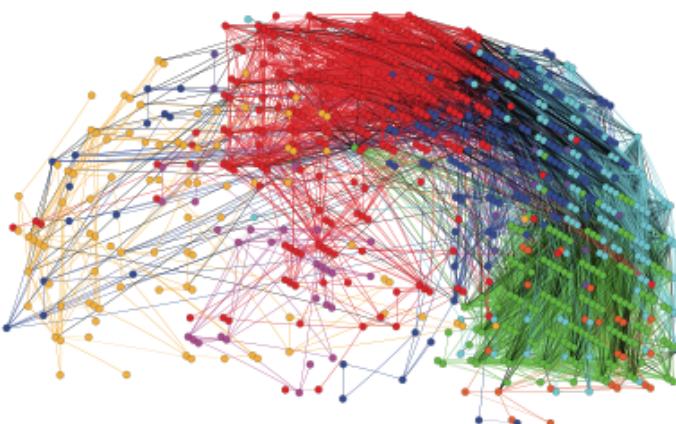
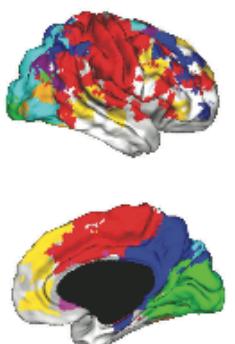


At times official positions do not create real leaders. The organizational network chart here shows number of connections using thickness of the node. The graph shows an associate (dark gray node) wielding high network power as compared to official leaders (red, blue, purple, orange nodes).

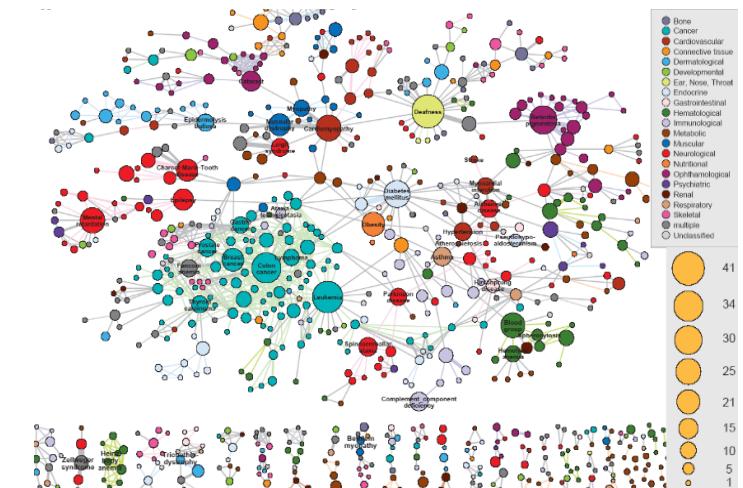


How the Brain is Like a Social Network

(source: <https://hearsystems.com/2012/08/neural-social-media/>)



Disease Network



http://www.barabasilab.com/pubs/CCNR-ALB_Publications/200705-14_PNAS-HumanDisease/200705-14_PNAS-HumanDis-HDN-DGN.gif

- Flight AA #11 - Crashed into WTC North
- Flight AA #77 - Crashed into Pentagon
- Flight UA #93 - Crashed in Pennsylvania
- Flight UA #175 - Crashed into WTC South
- Other Associates of Hijackers

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Source: <http://pear.accc.uic.edu/ojs/index.php/fm/article/view/941/863>

KREBS, Valdis. Uncloaking Terrorist Networks. *First Monday*, [S.I.], apr. 2002. ISSN 13960466. Available at: <<http://pear.accc.uic.edu/ojs/index.php/fm/article/view/941/863>>. Date accessed: 11 Nov. 2016.

Key Points

Terrorist Network:

- Low Density
- Low chances of detection

Facebook Network:

- Black holes (e.g., China)

Brain:

- Different communities of cells



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