

Is Network Science a Science?



Roger Wattenhofer

Confession

I don't have a

facebook®

account.

... but I always loved networks*

- *Computer Networks
 - Wireless Networks
 - Social Networks
 - Mobile Networks
 - Biological Networks
 - Economic Networks

IS NETWORK SCIENCE...



...A SCIENCE?



Some Success Stories of Network Science

Milgram,
Watts-Strogatz,
& Kleinberg

Markov Chains,
Stationary Distribution,
& PageRank

Spectral
Graph Theory



CHECKLIST



it's cool to be in network science



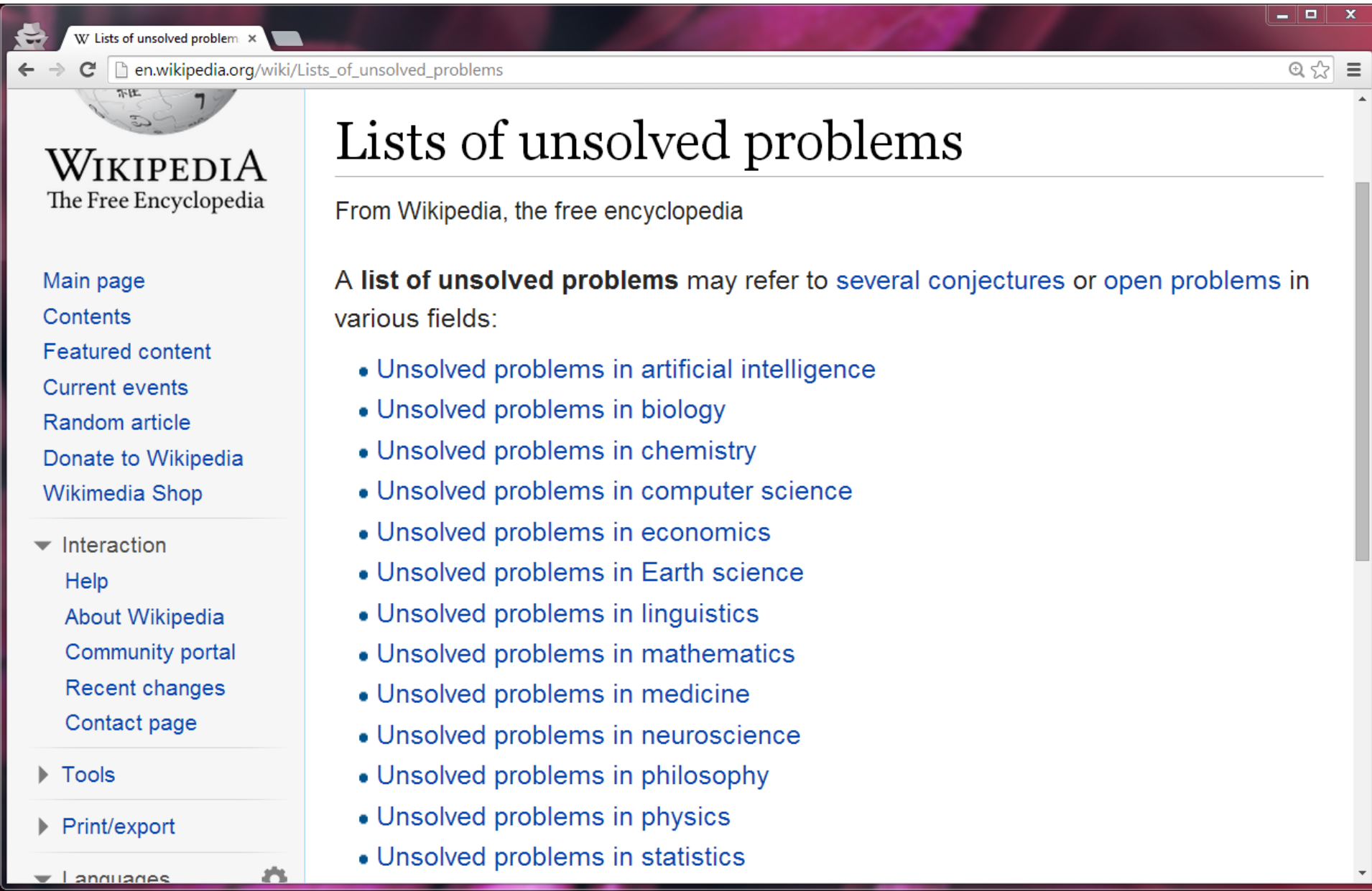
success stories



workshop established

But...

Real Science has (Open) Problems



The image shows a screenshot of a web browser window displaying the Wikipedia page titled "Lists of unsolved problems". The browser's address bar shows the URL "en.wikipedia.org/wiki/Lists_of_unsolved_problems". The page content includes the Wikipedia logo, a navigation sidebar on the left, and the main article text. The article text starts with "From Wikipedia, the free encyclopedia" and "A **list of unsolved problems** may refer to several conjectures or open problems in various fields:". Below this is a bulleted list of fields: artificial intelligence, biology, chemistry, computer science, economics, Earth science, linguistics, mathematics, medicine, neuroscience, philosophy, physics, and statistics.

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Print/export

Languages

Lists of unsolved problems

From Wikipedia, the free encyclopedia

A **list of unsolved problems** may refer to several conjectures or open problems in various fields:

- Unsolved problems in artificial intelligence
- Unsolved problems in biology
- Unsolved problems in chemistry
- Unsolved problems in computer science
- Unsolved problems in economics
- Unsolved problems in Earth science
- Unsolved problems in linguistics
- Unsolved problems in mathematics
- Unsolved problems in medicine
- Unsolved problems in neuroscience
- Unsolved problems in philosophy
- Unsolved problems in physics
- Unsolved problems in statistics

Science: Still Interesting in 100 Years

EITHER

OR

Engineering: Interesting Right Now!

Complexity Theory

Can a Computer Solve
Problem P in Time t ?

Distributed



Complexity Theory

Network

Can a ~~Computer~~ Solve
Problem P in Time t ?

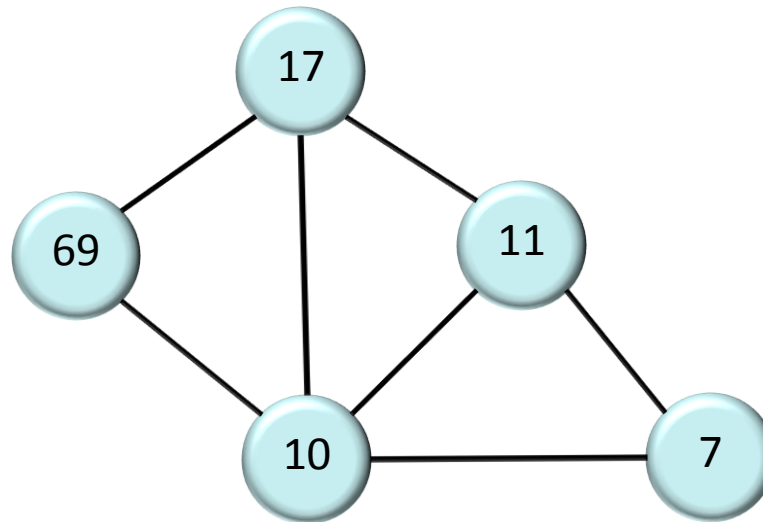
Network
~~Distributed~~

↓ Complexity Theory

Network
Can a ~~Computer~~ Solve
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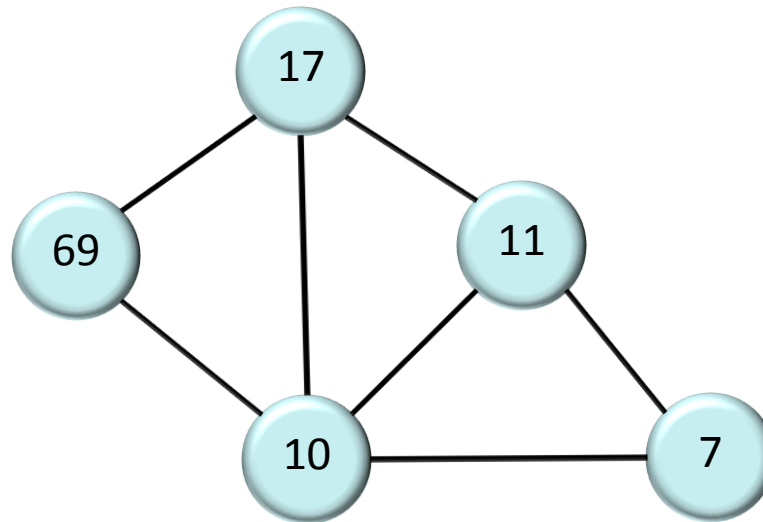
Distributed (Message-Passing) Algorithms

- Nodes are agents with unique ID's that can communicate with neighbors by **sending messages**. In each **synchronous round**, every node can send a (different) message to each neighbor.



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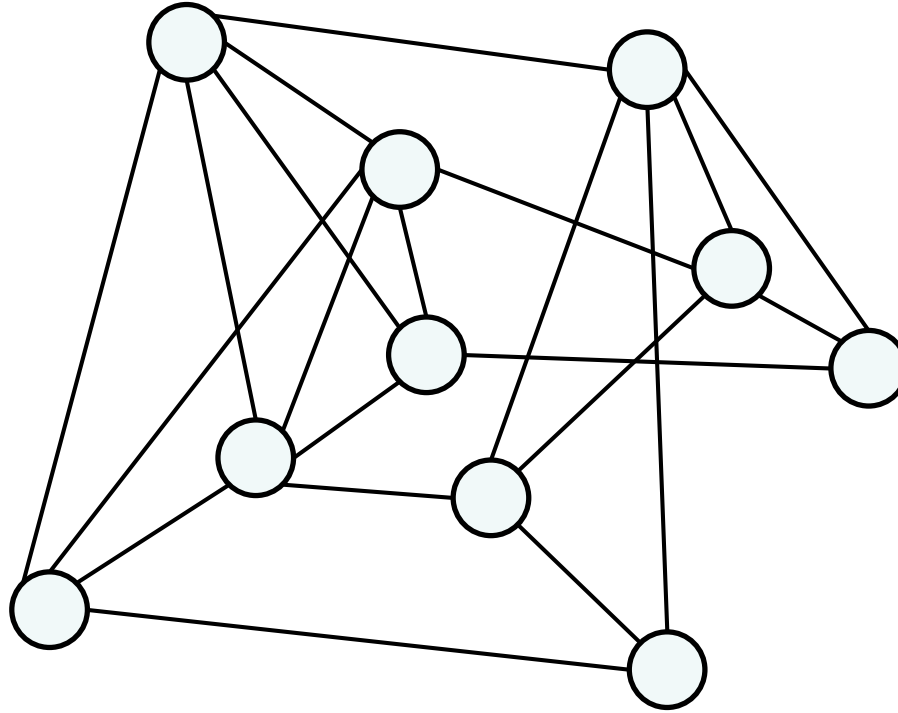
each round:
every node:
1. send msgs
2. rcv msgs
3. compute

- **Distributed (Time) Complexity**: How many rounds does problem take?

An Example

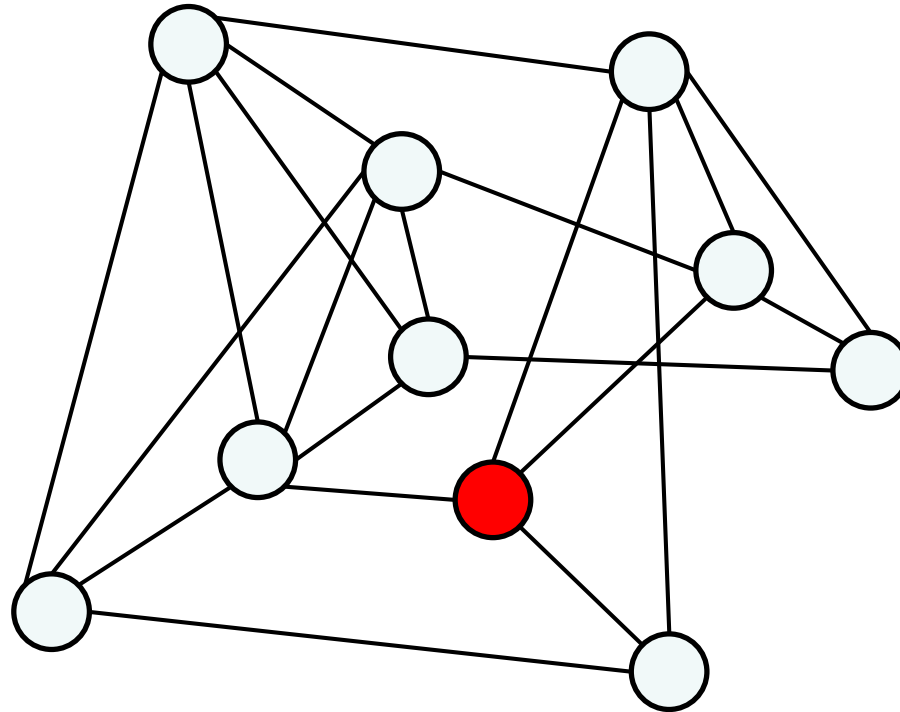
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How Many Nodes in Network?



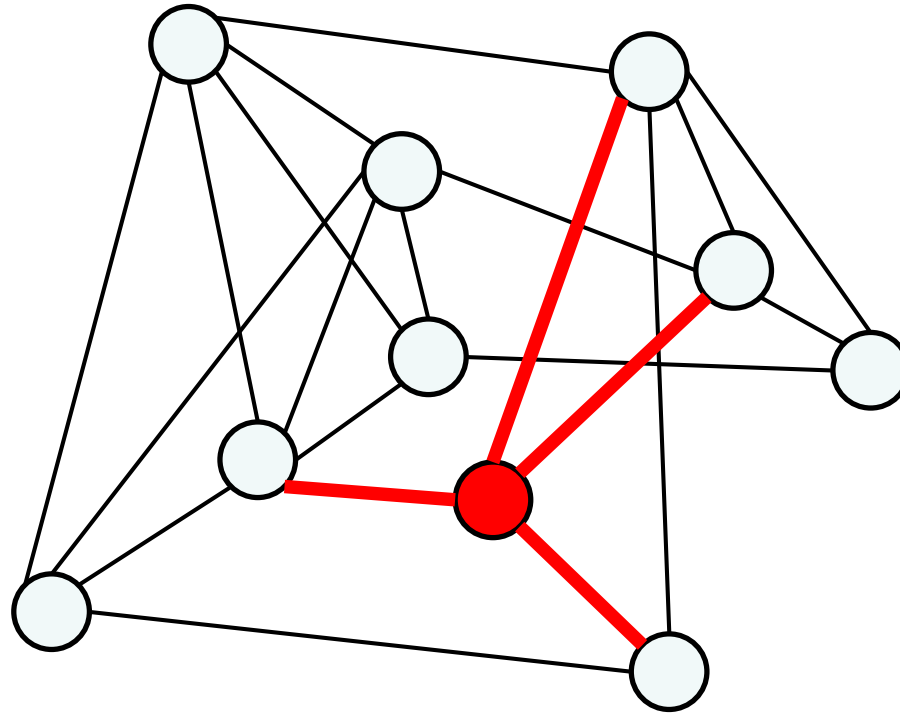
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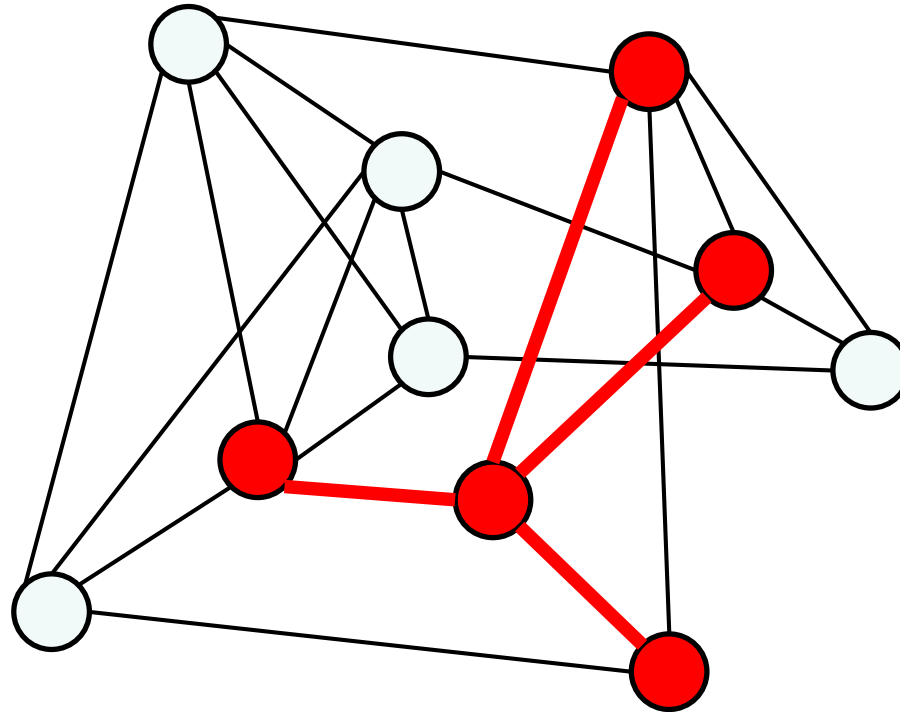
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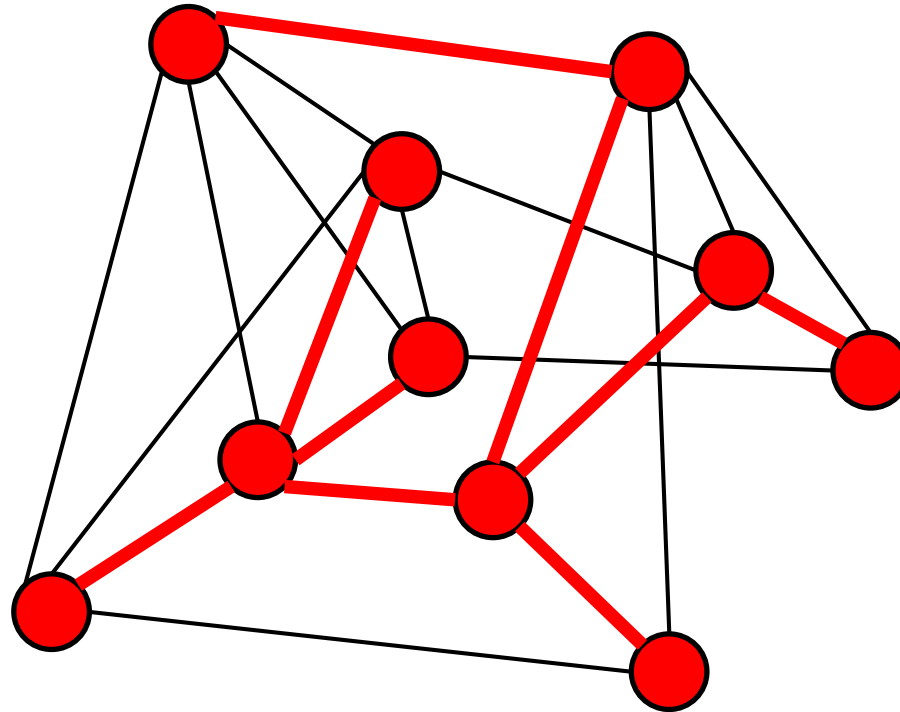


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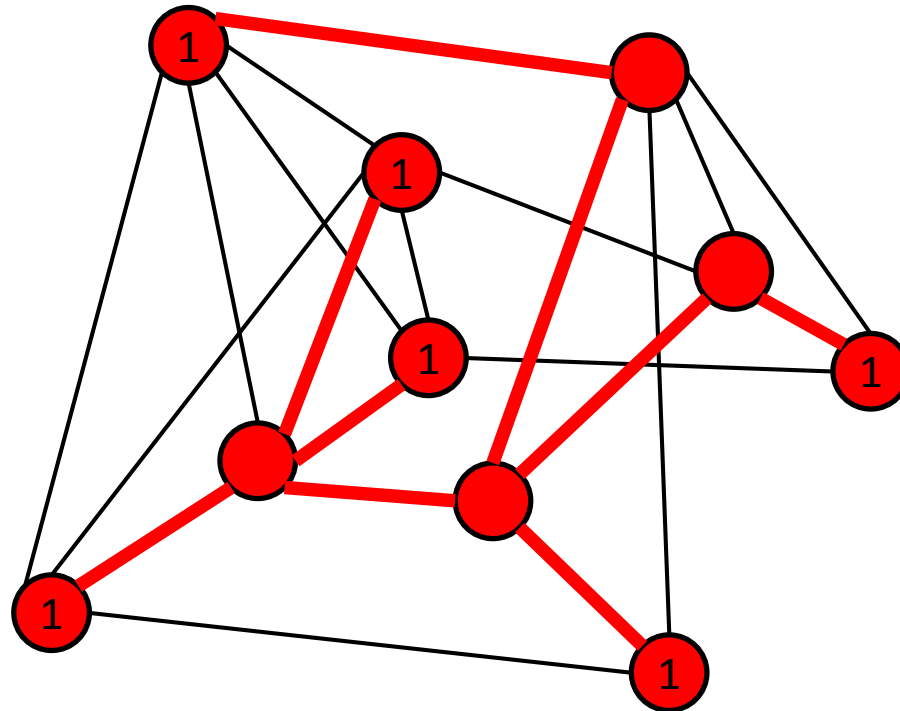
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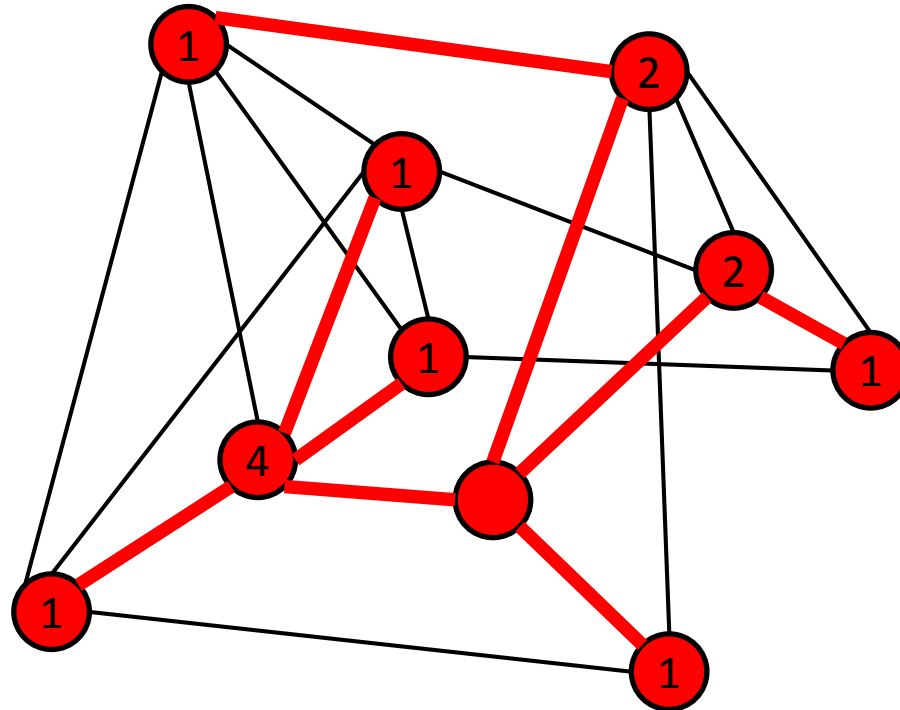
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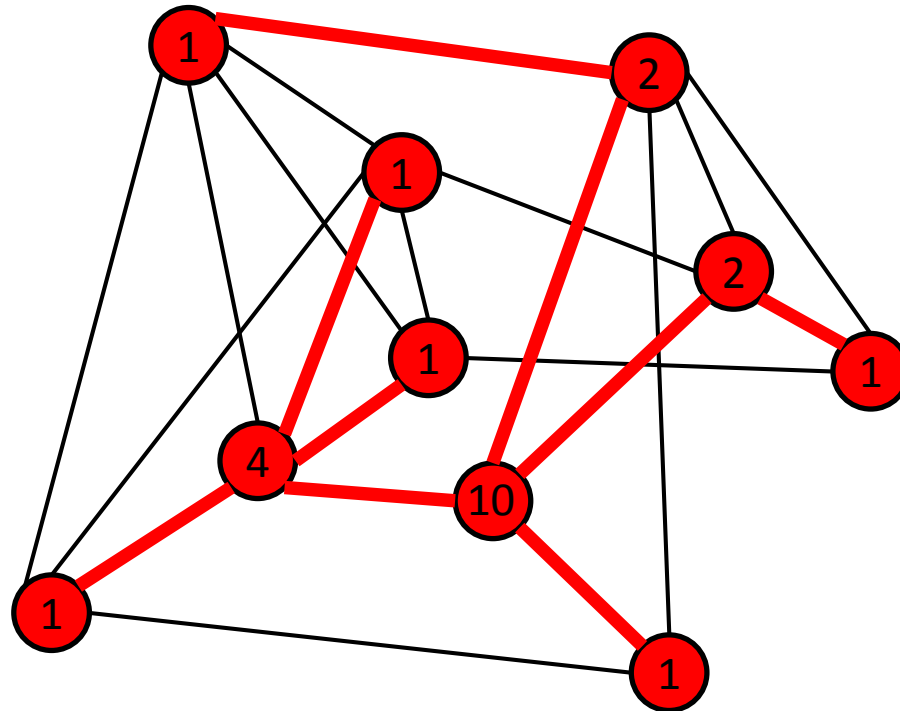
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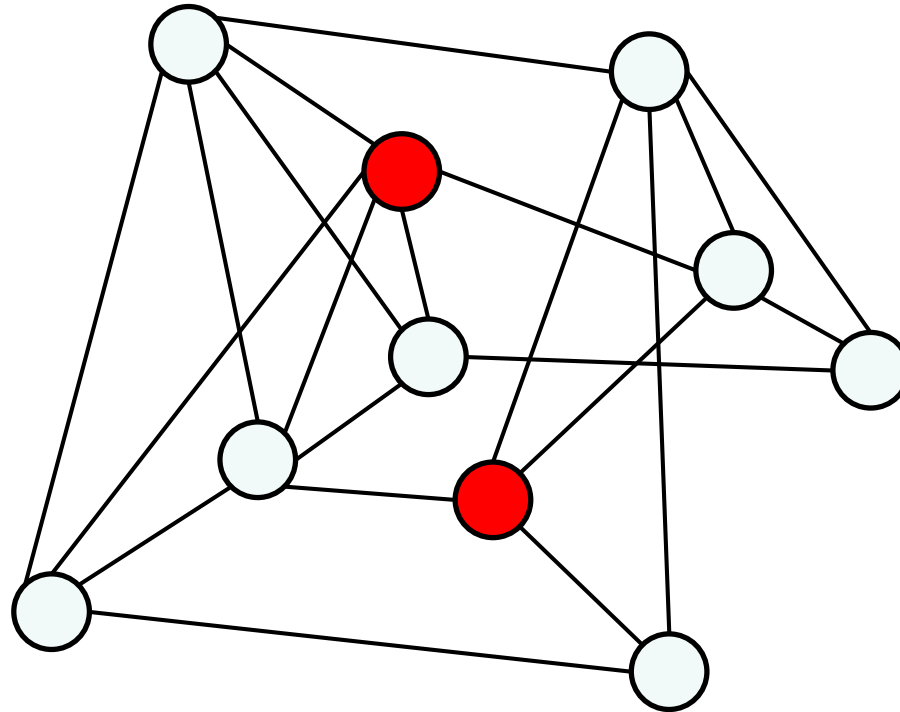


How Many Nodes in Network?



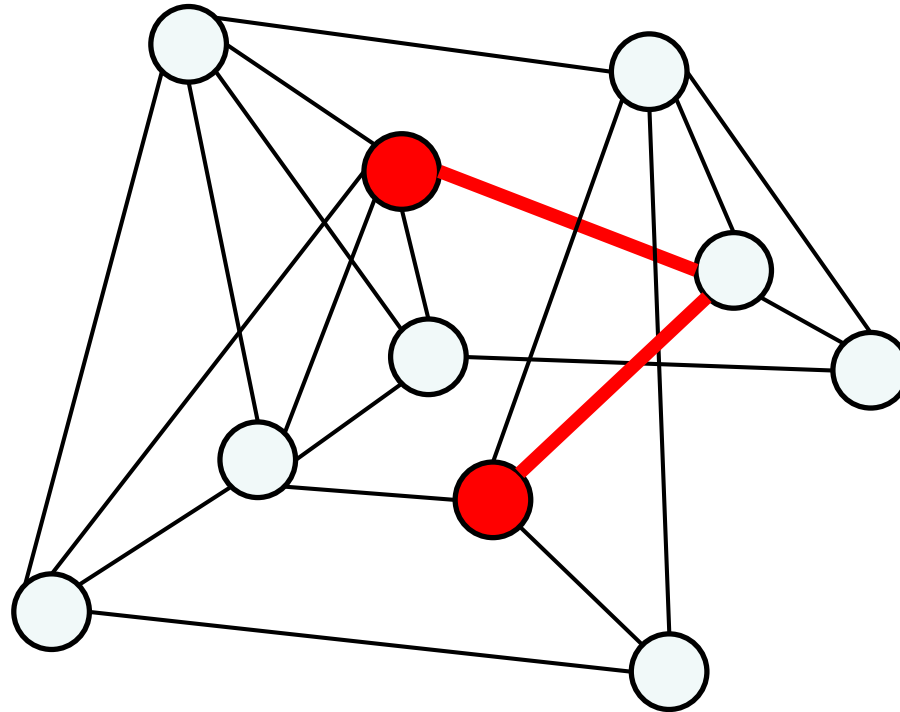
With a simple flooding/echo process, a network can find the number of nodes in **time** $O(D)$, where D is the diameter (size) of the network.

Diameter of Network?



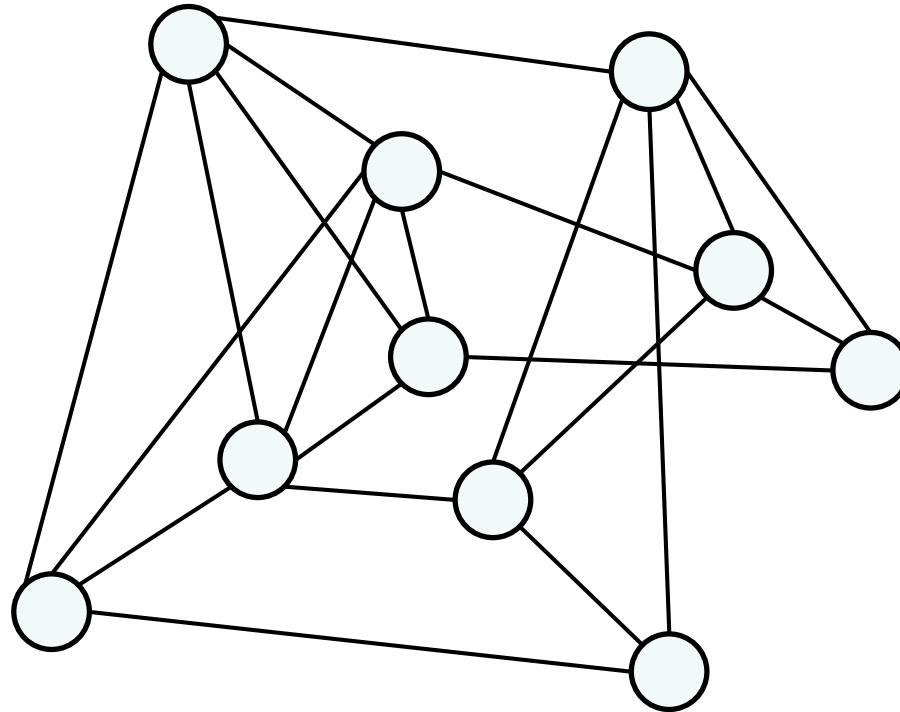
- **Distance** between two nodes = Number of hops of shortest path

Diameter of Network?



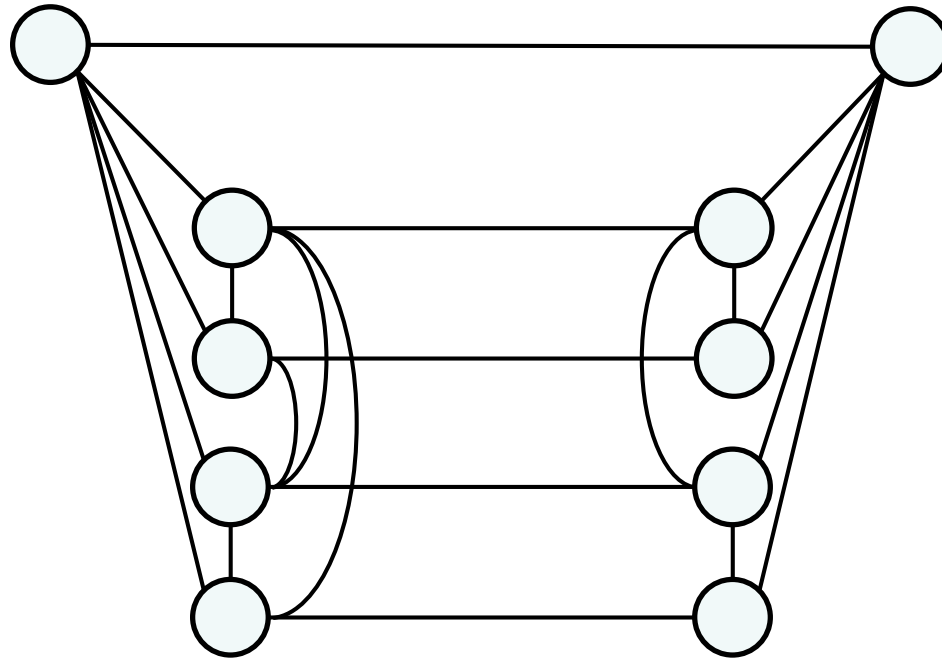
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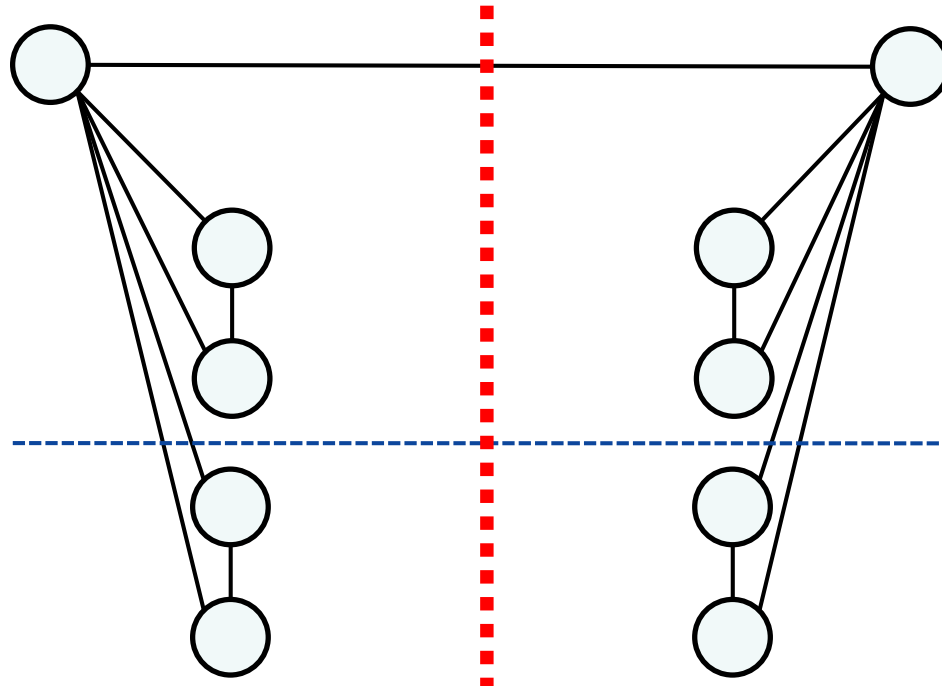


- **Distance** between two nodes = Number of hops of shortest path
- **Diameter** of network = Maximum distance, between any two nodes

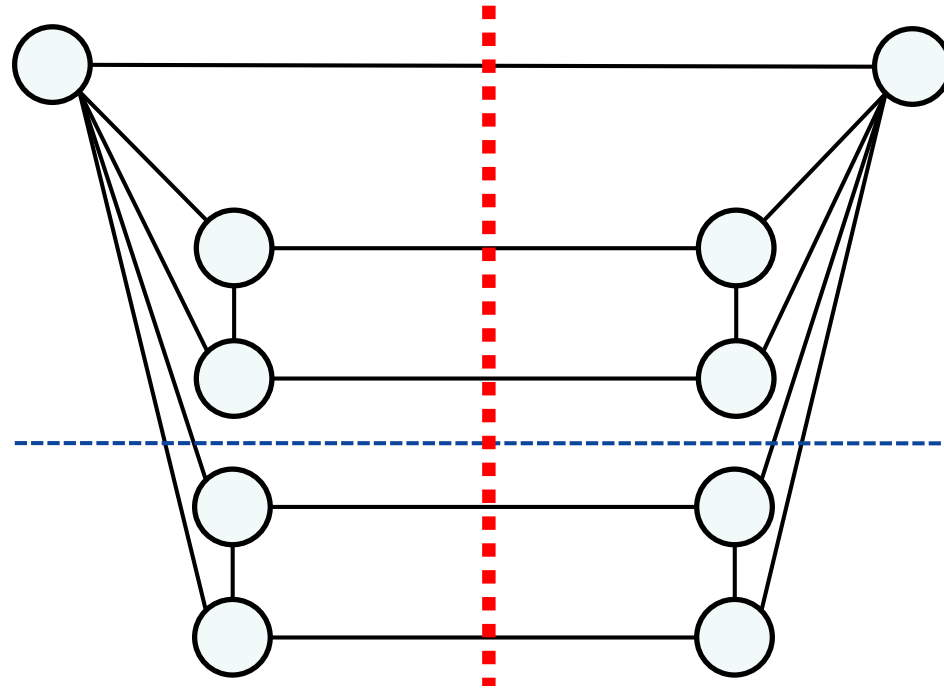
Diameter of Network?



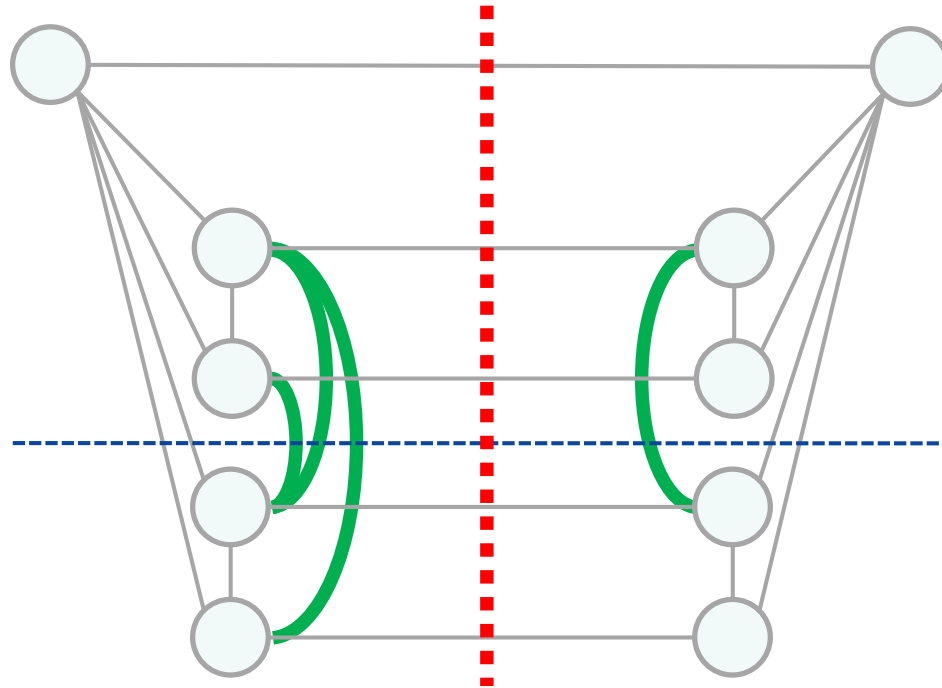
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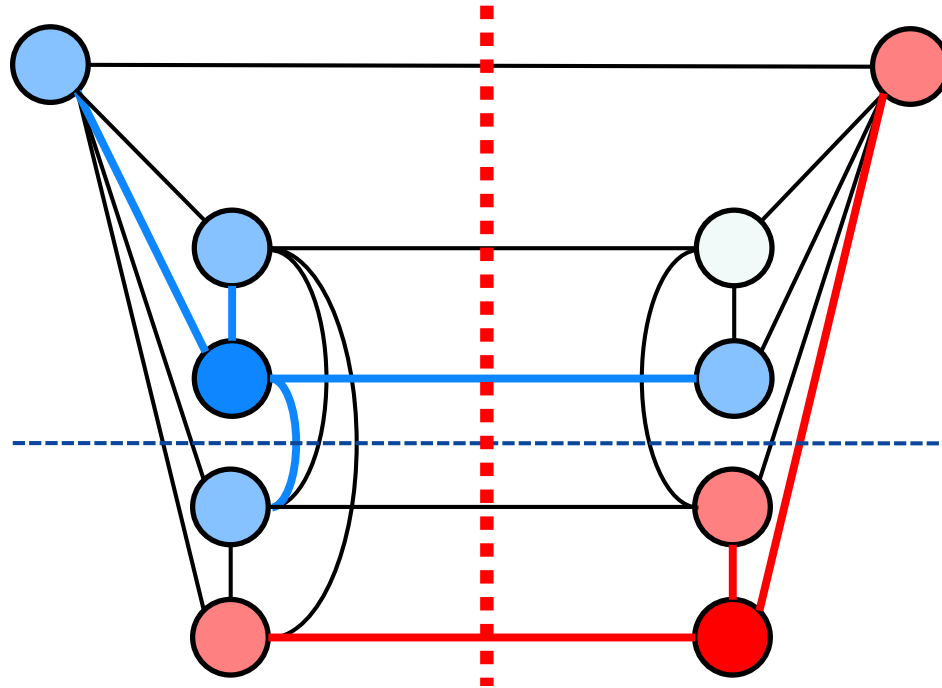
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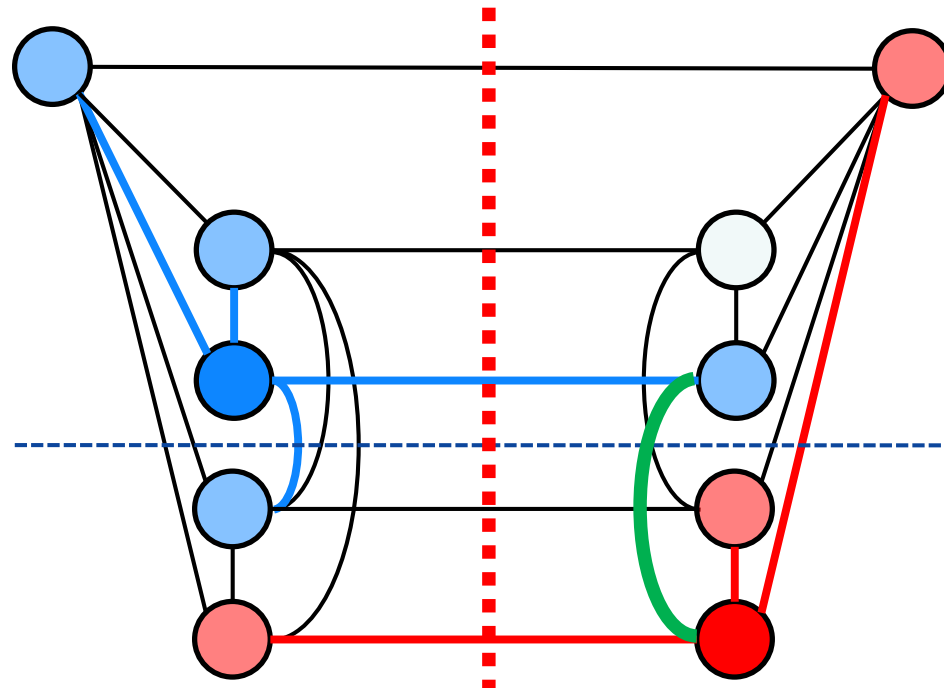
Diameter of Network?



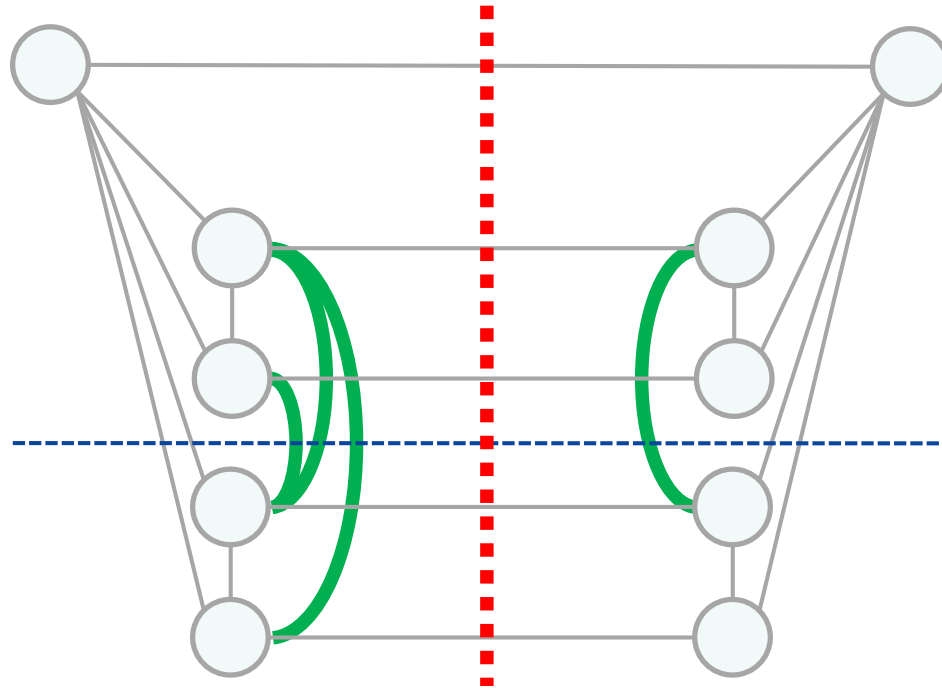
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Diameter of Network?

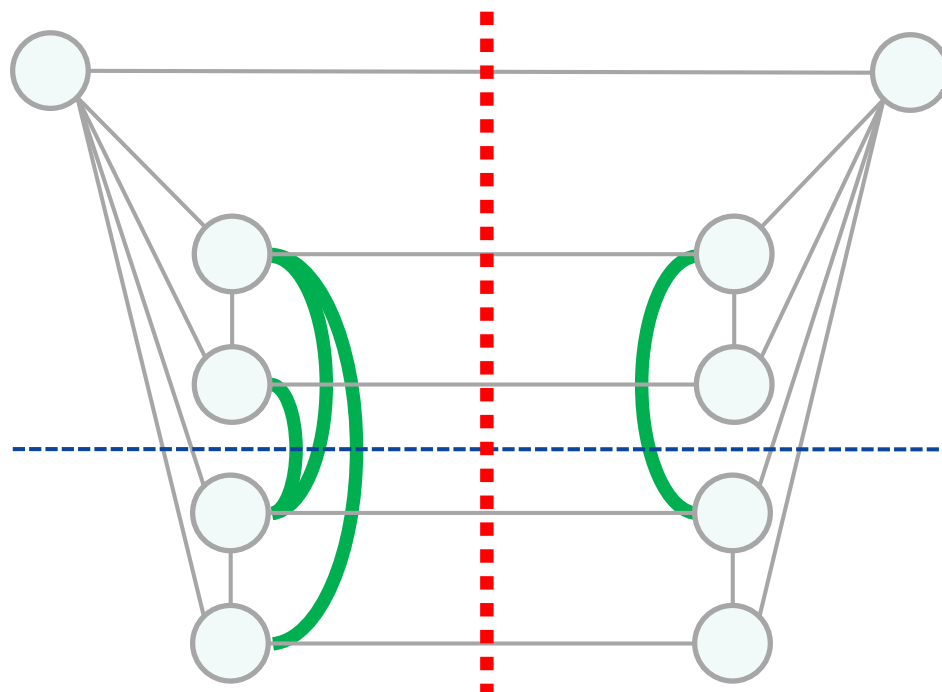


Diameter of Network?



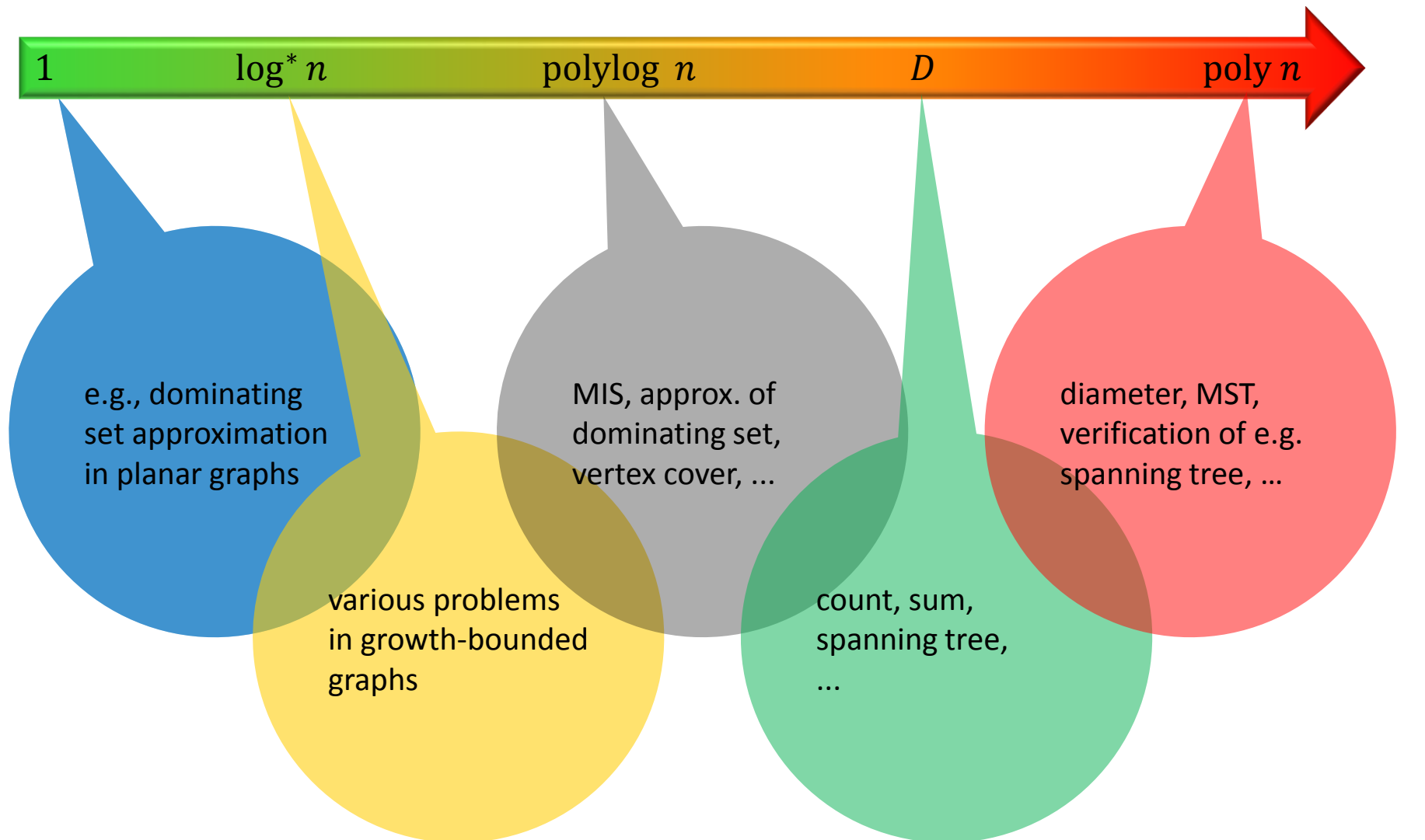
Networks Cannot Compute Their Diameter in Sublinear Time!

(even if diameter is just a small constant)

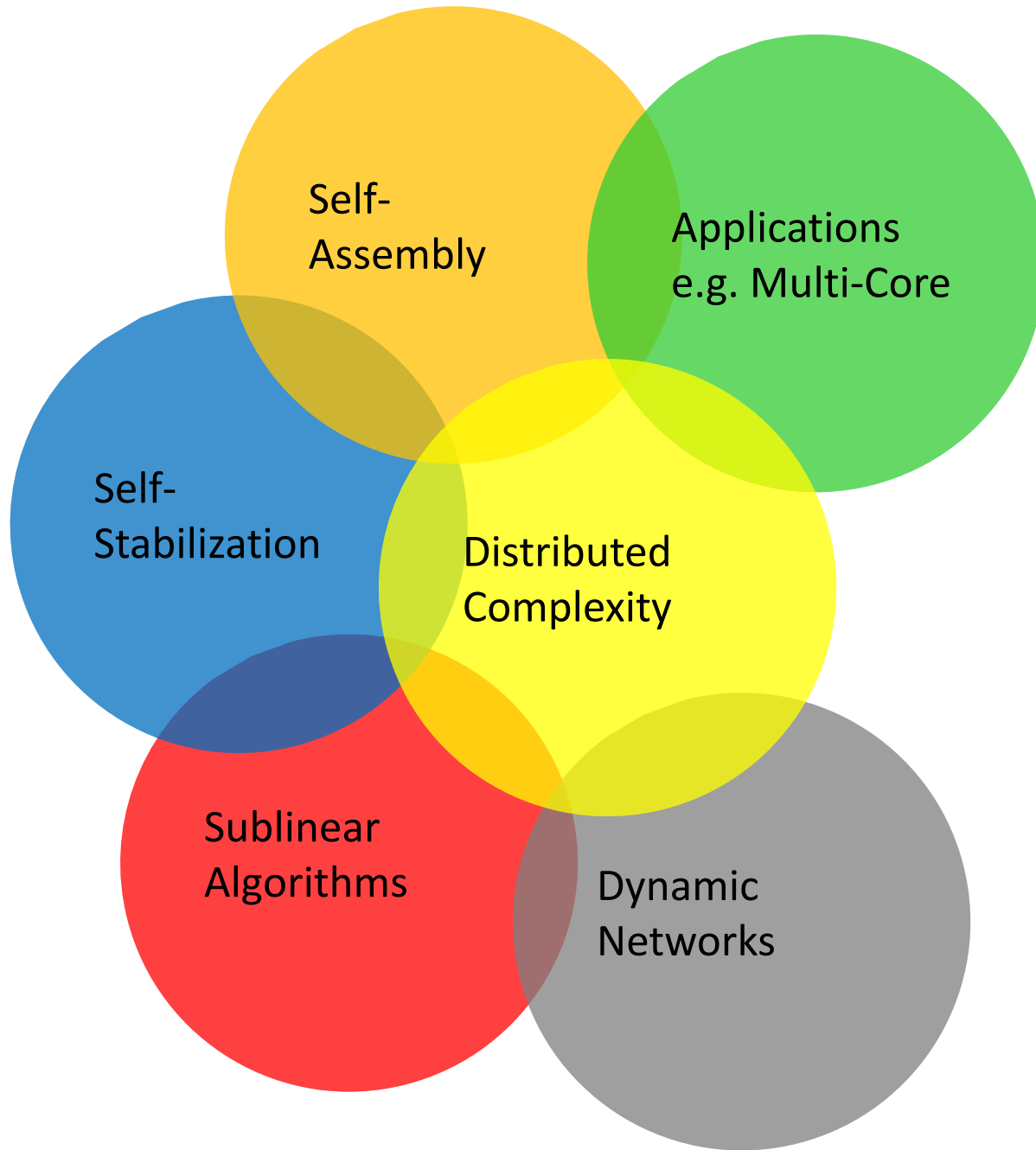


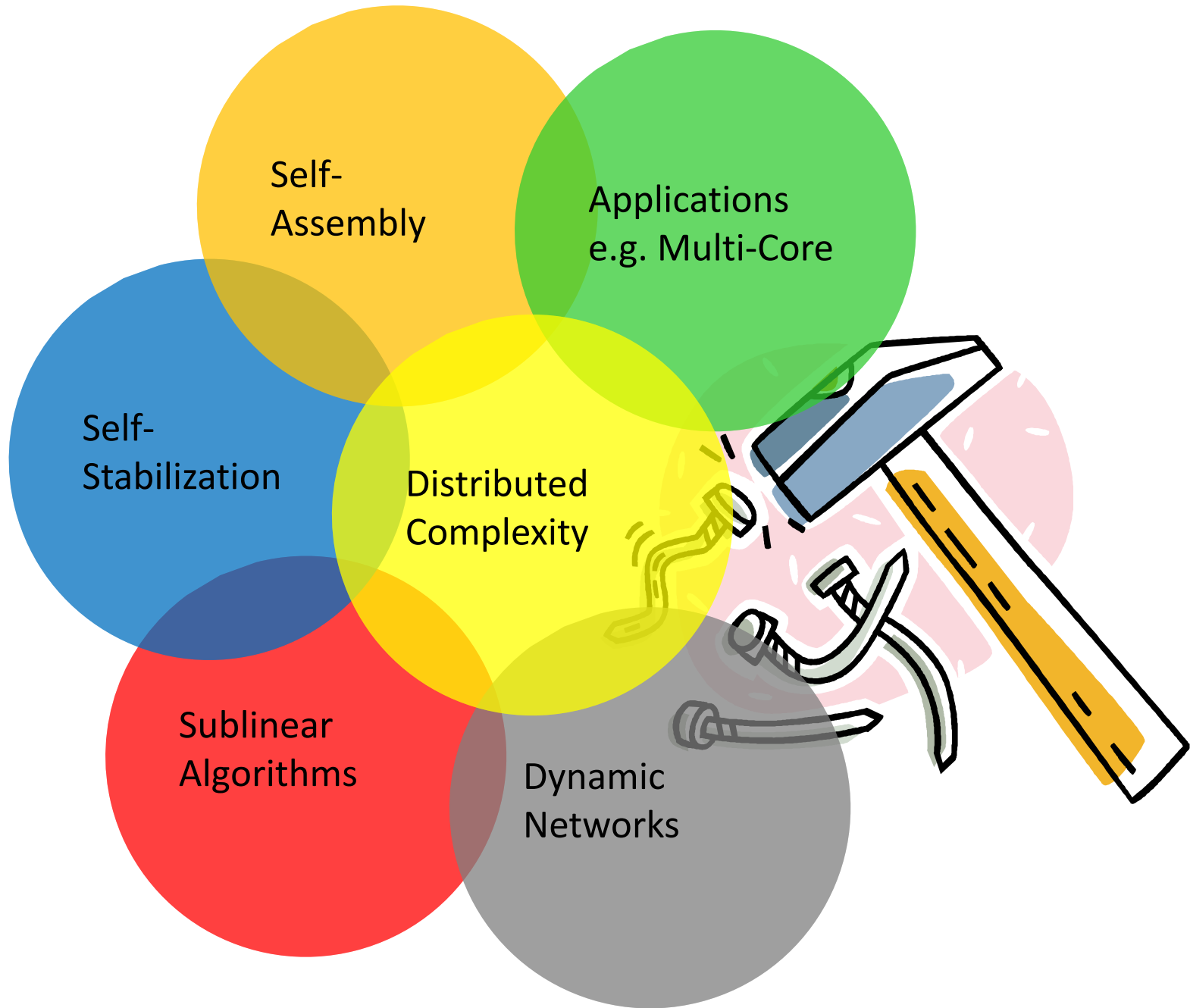
Pair of rows connected neither left nor right? Communication complexity:
Transmit $\Theta(n^2)$ information over $O(n)$ edges $\rightarrow \Omega(n)$ time!

Distributed Complexity Classification



e.g., [Kuhn, Moscibroda, W, 2014]





Self-Assembly

Applications
e.g. Multi-Core

Self-Stabilization

Distributed Complexity

Sublinear Algorithms

Dynamic Networks

Science: Still Interesting in 100 Years

EITHER

OR

Engineering: Interesting Right Now!




Bitcoin

Bank of Bitcoin



Spending Money



Source
DONALD E. KNUTH
COMPUTER SCIENCE DEPARTMENT
STANFORD UNIVERSITY
STANFORD, CA 94305-9045

11-3167/1210
01

428

Date: 10 Aug 98

Pay to the Order of: Gabriel Valtente **Destination**

\$ 20.56 **Amount**

Two and 56/100 Dollars

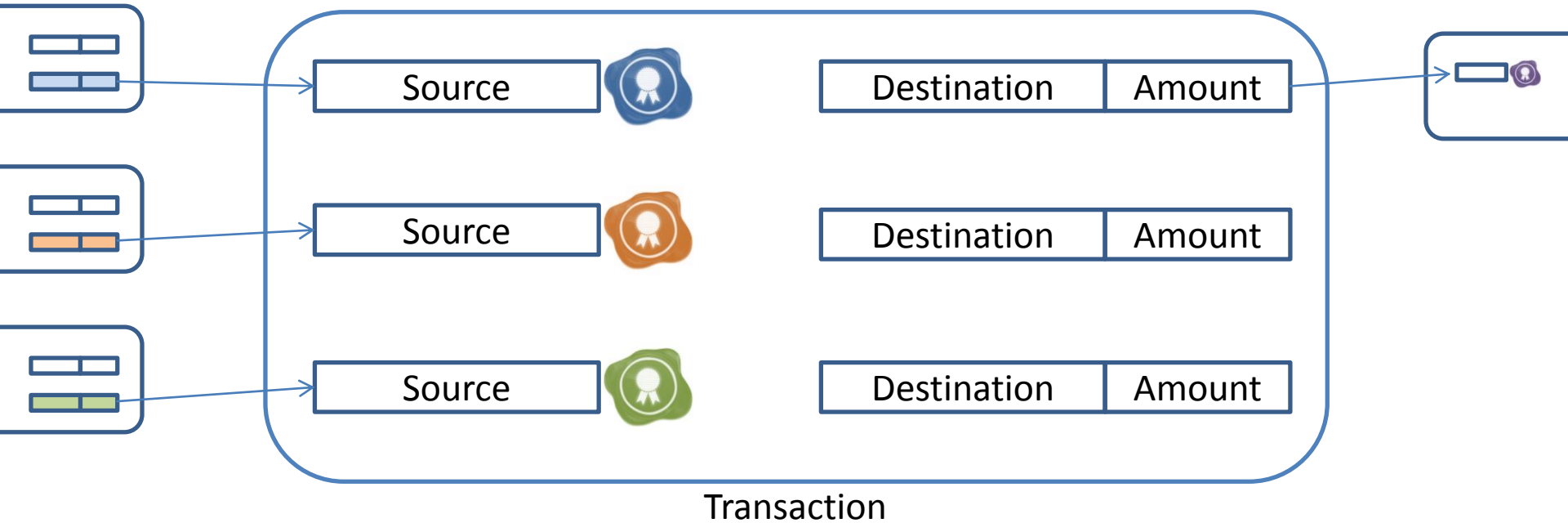
America California Bank
2390 El Camino Real, Palo Alto, California 94306

For: 1450

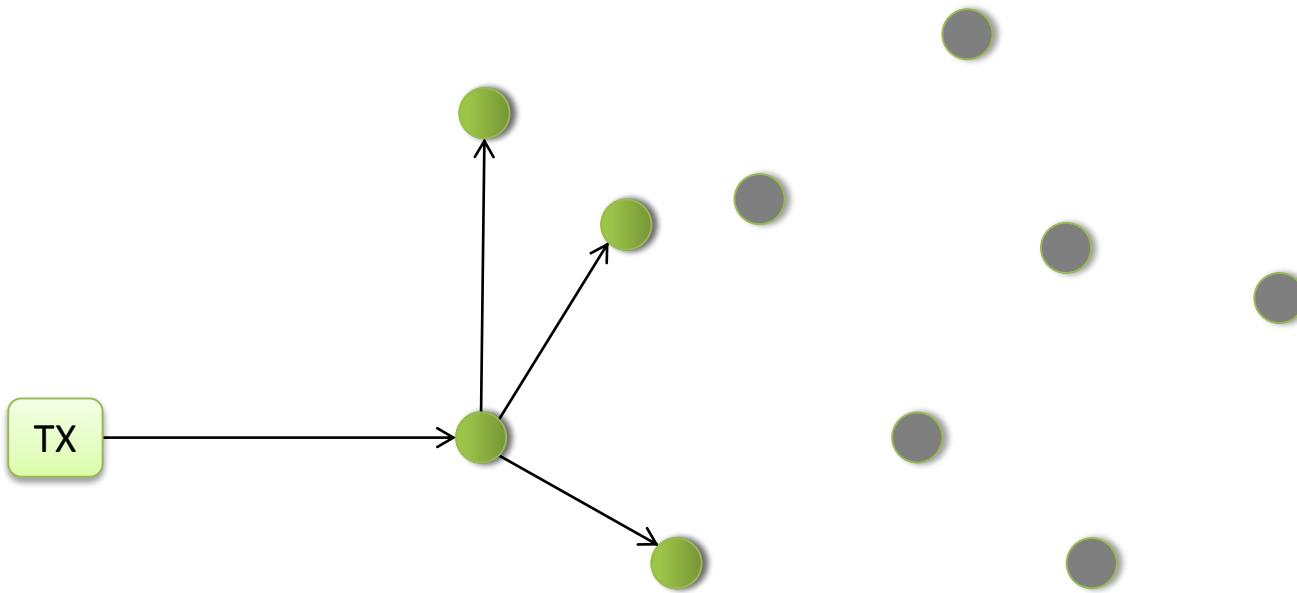
Signature
Donald Knuth

1: 1210316731:0428 011558490611

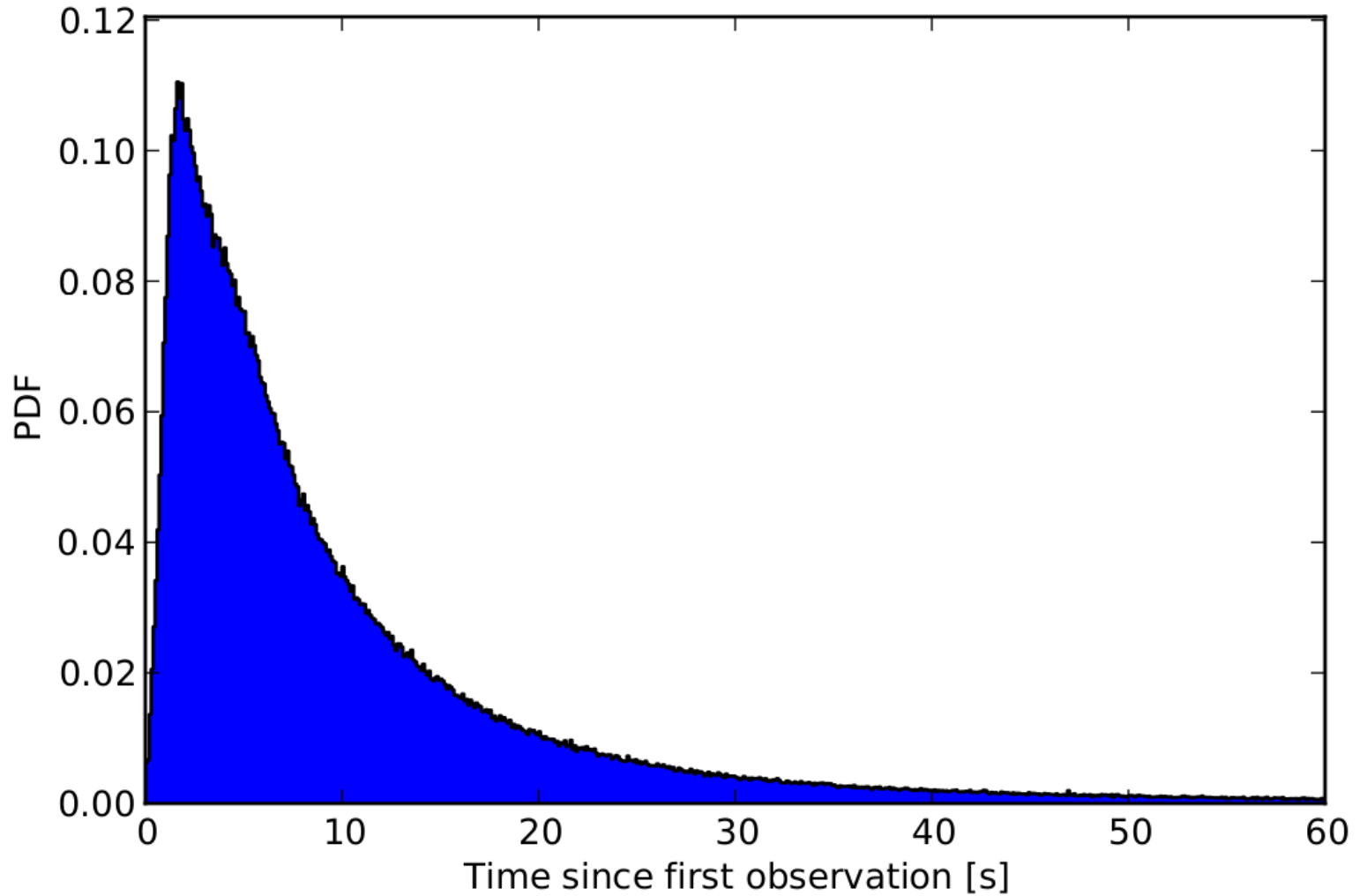
Moving Money



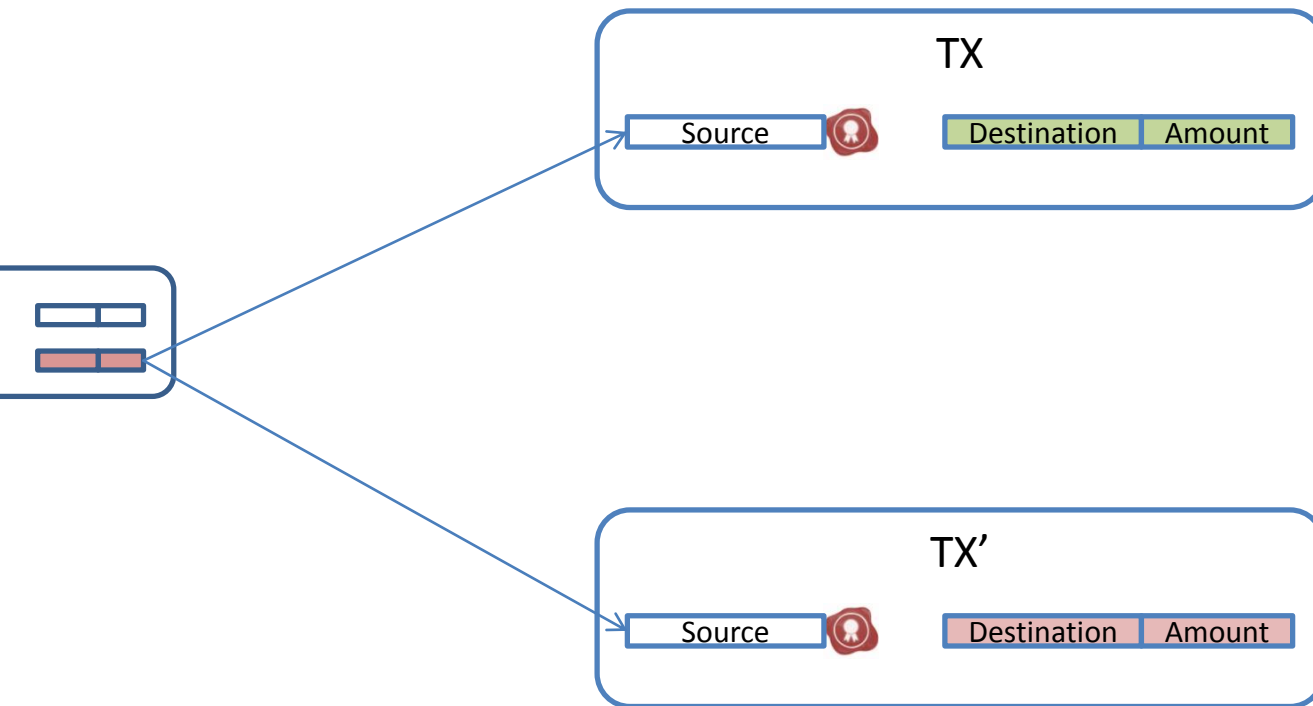
Distributing the Bank



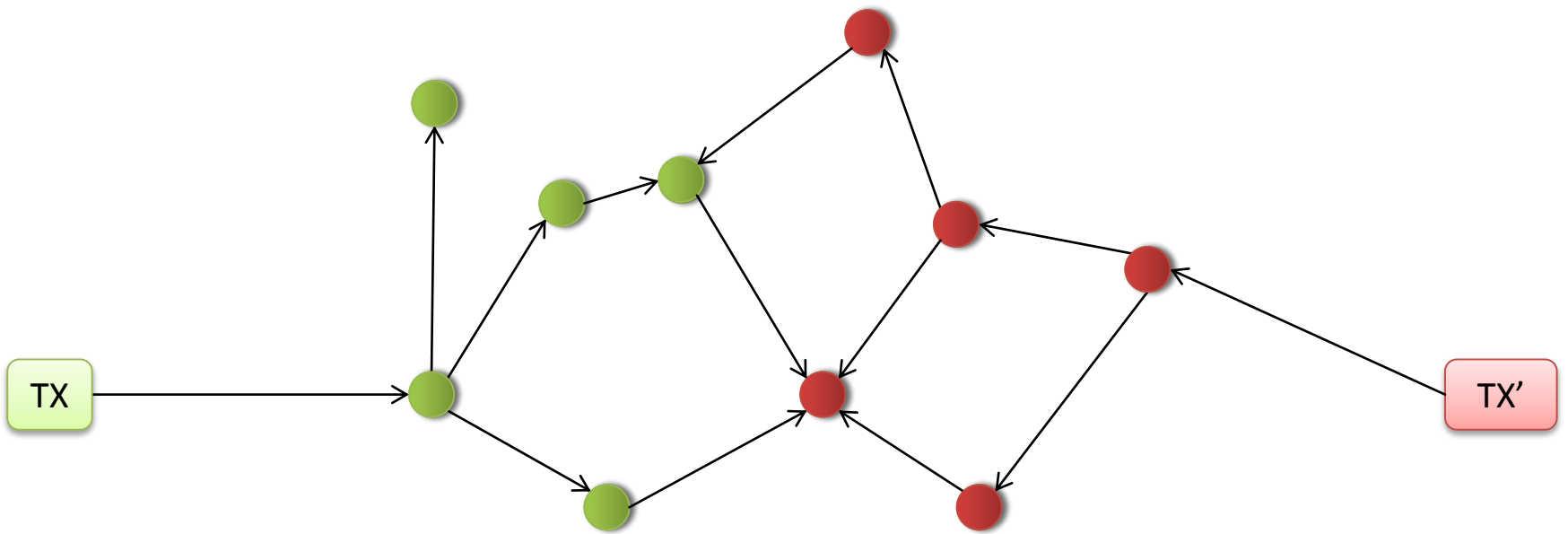
Propagation Time



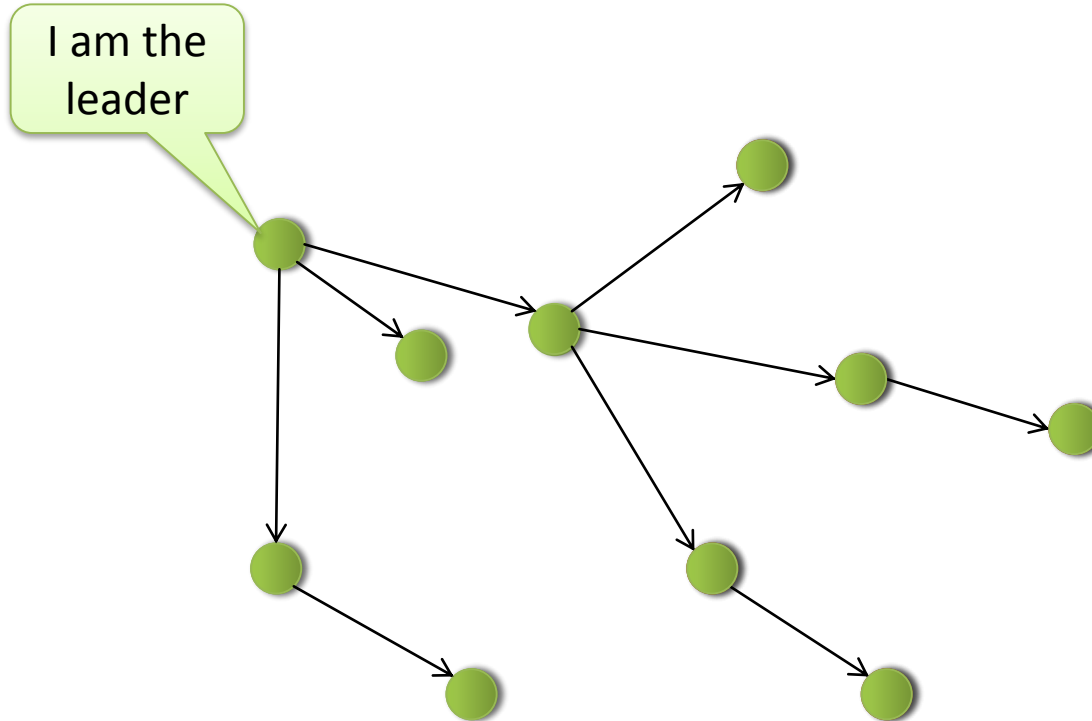
Double-spending



Double-spending in the Network



Distributing the Bank

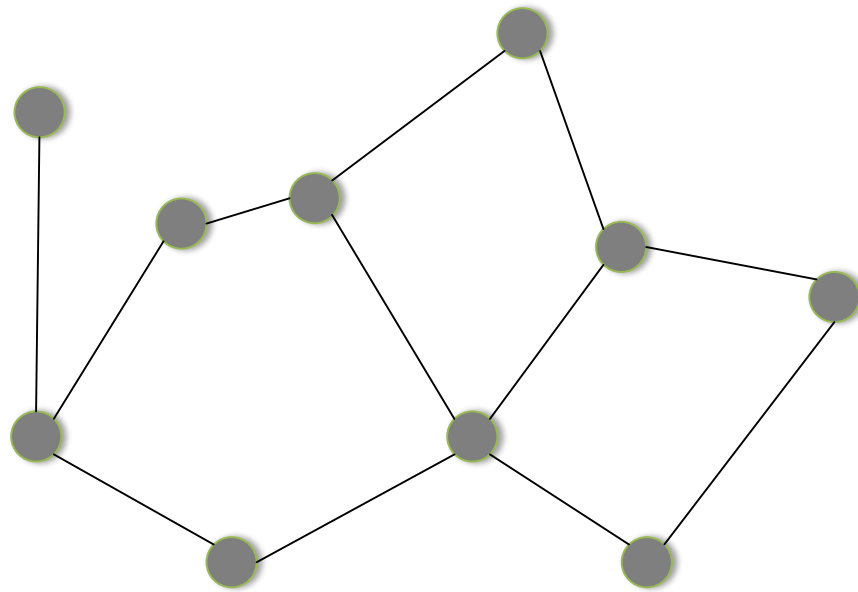


Double-spending in the Real World

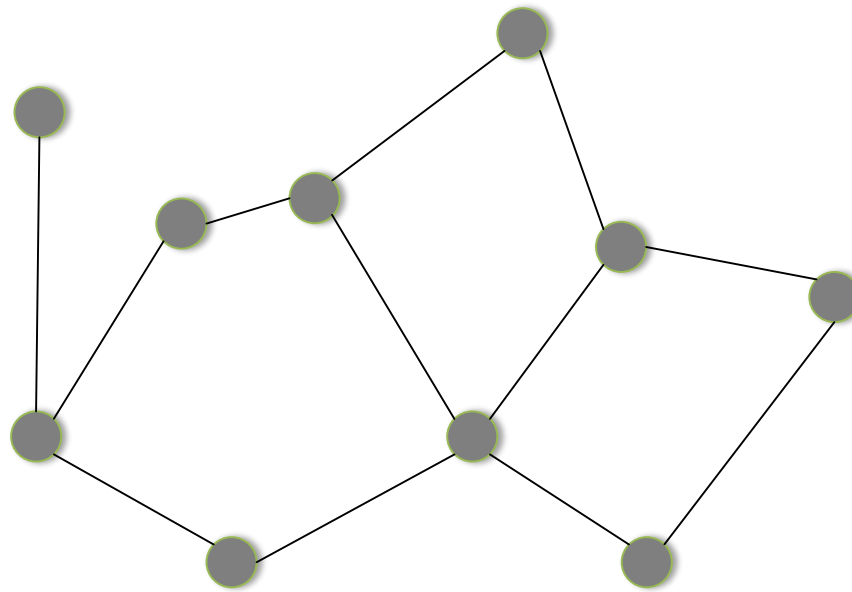
[Bamert, Decker, Elsen, W, Welten, 2013]



Where would you inject your transaction?



Double-spending, the Theory



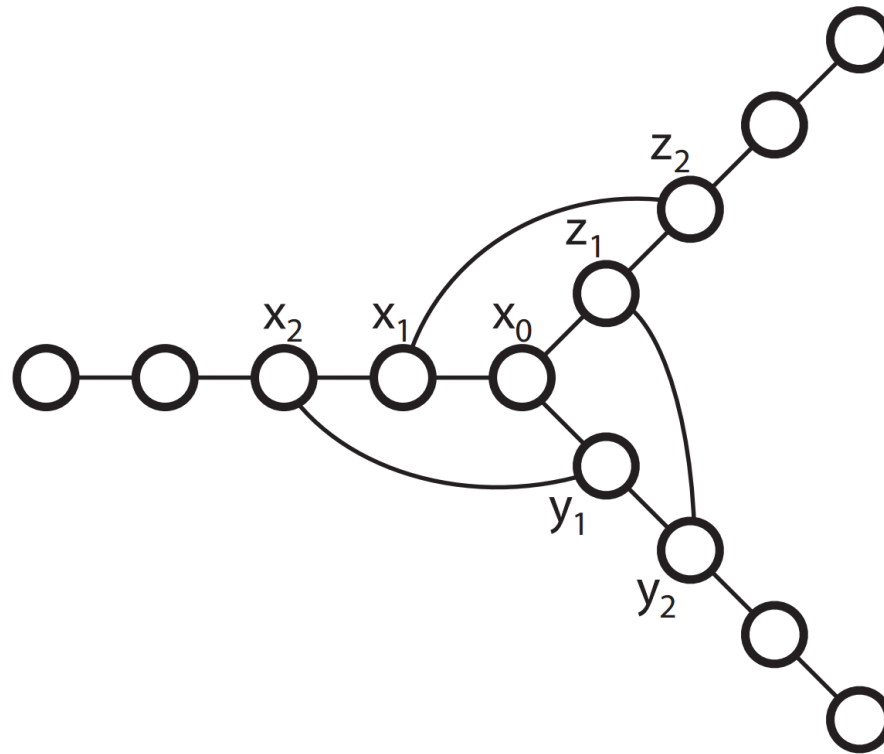
Player 1: Where to inject original transaction?

Player 2: Where to inject copy?

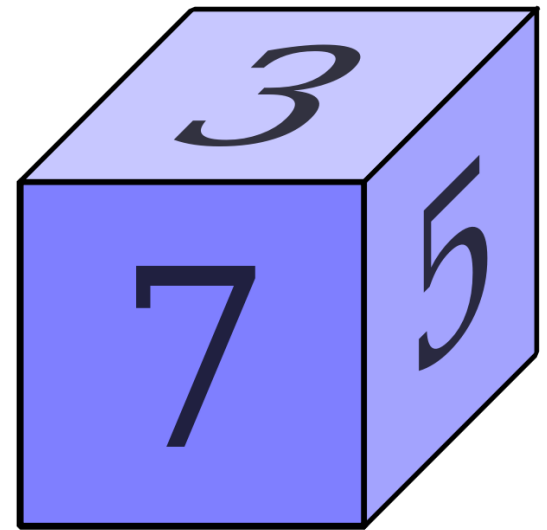
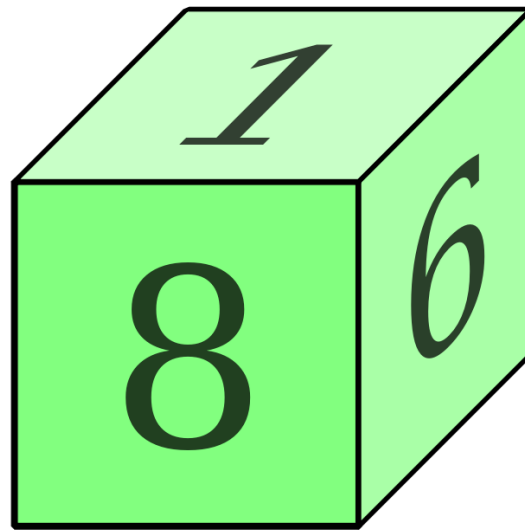
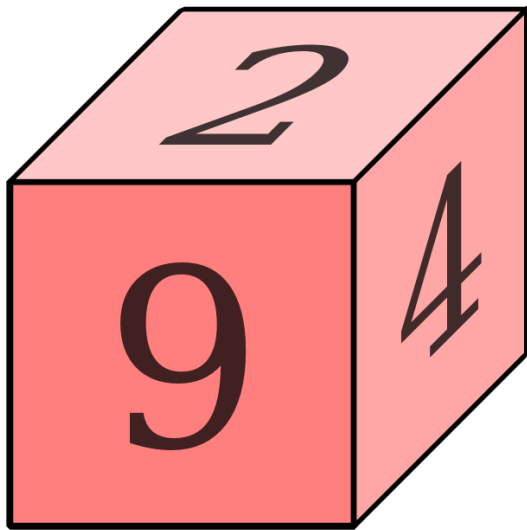
**SECOND IS
THE FIRST
LOSER**

Really?

Sometimes, being second is better!



Another Example: Nontransitive Dice

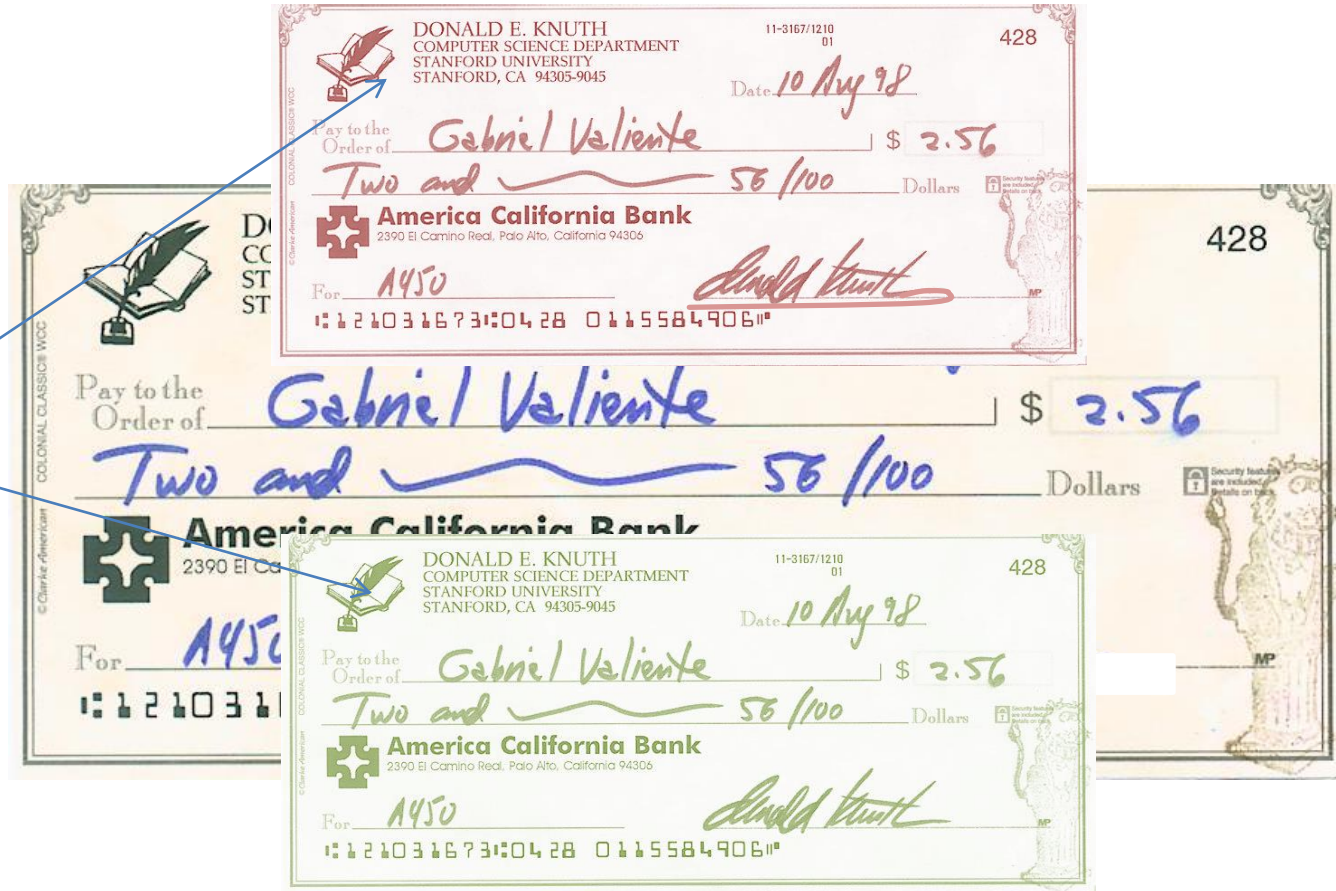


Transaction Malleability

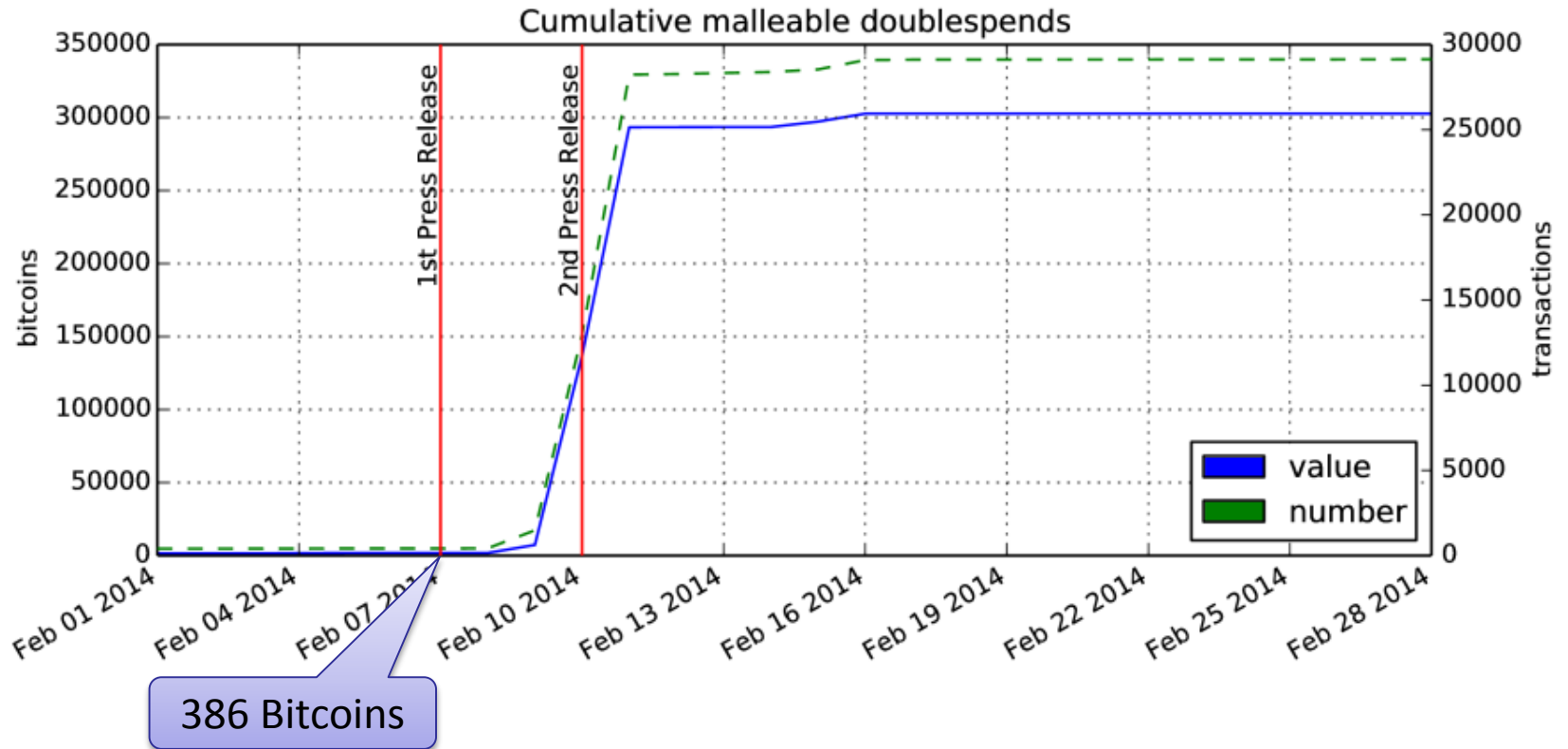


February 10, 2014: “Addressing Transaction Malleability: MtGox has detected unusual activity on its Bitcoin wallets and performed investigations during the past weeks.”

Transaction Malleability



Transaction Malleability in Real Life

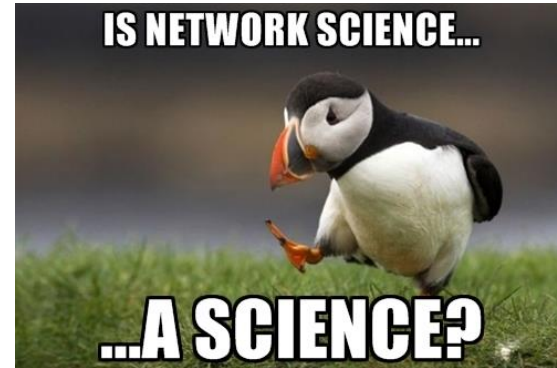
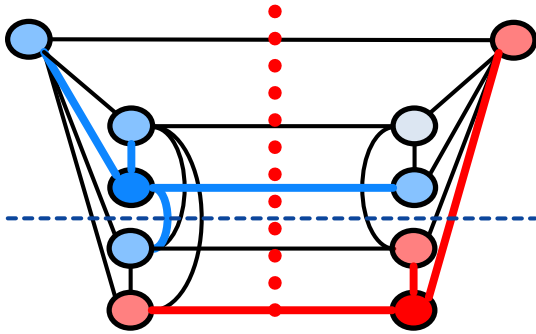




WHERE ARE THE

\$5000M, DUDE?

Summary



Thank You!

Questions & Comments?



Thanks to my co-authors, mostly
Christian Decker
Silvio Frischknecht
Stephan Holzer

www.disco.ethz.ch