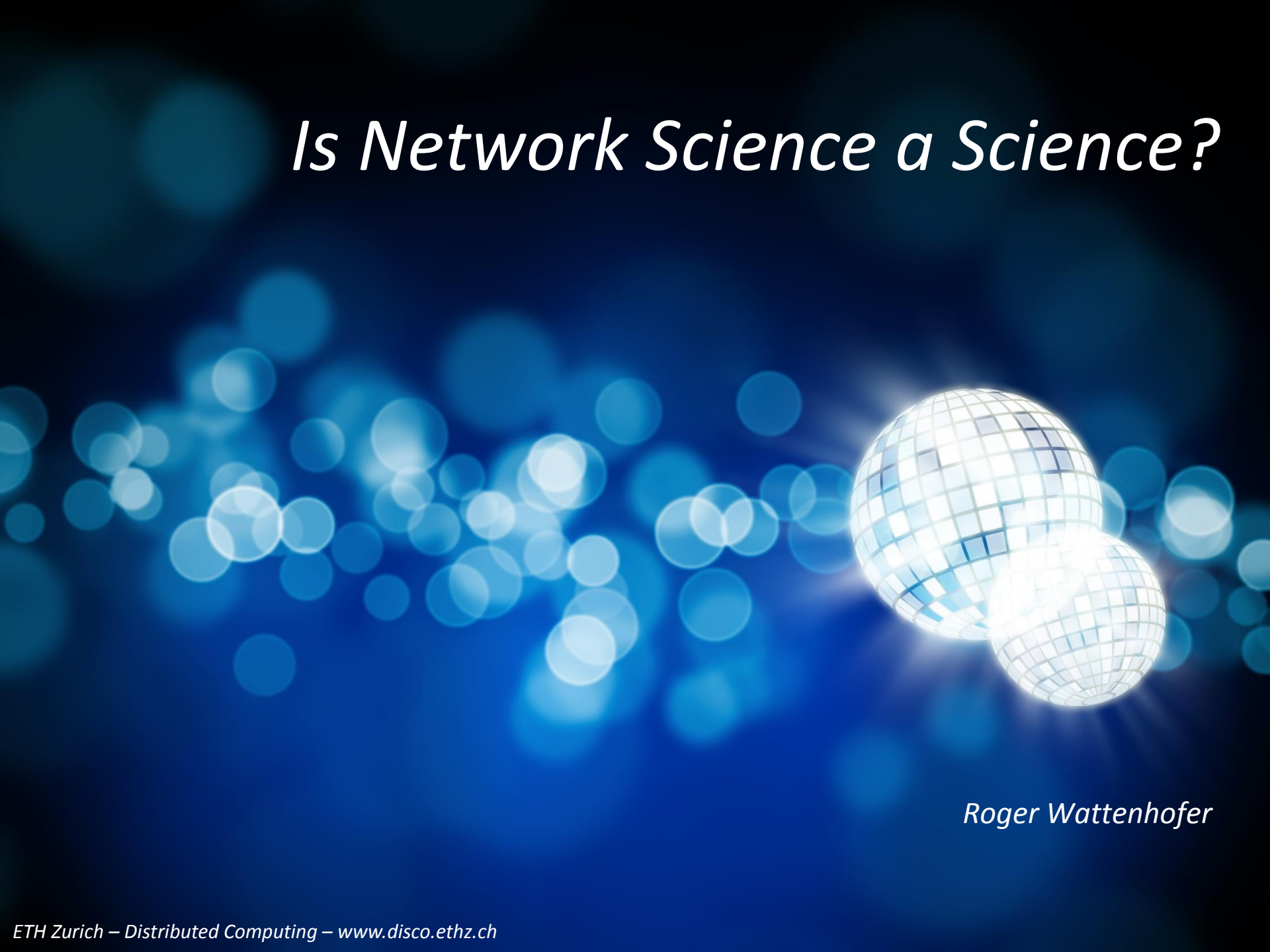
Is Network Science a Science?



Roger Wattenhofer

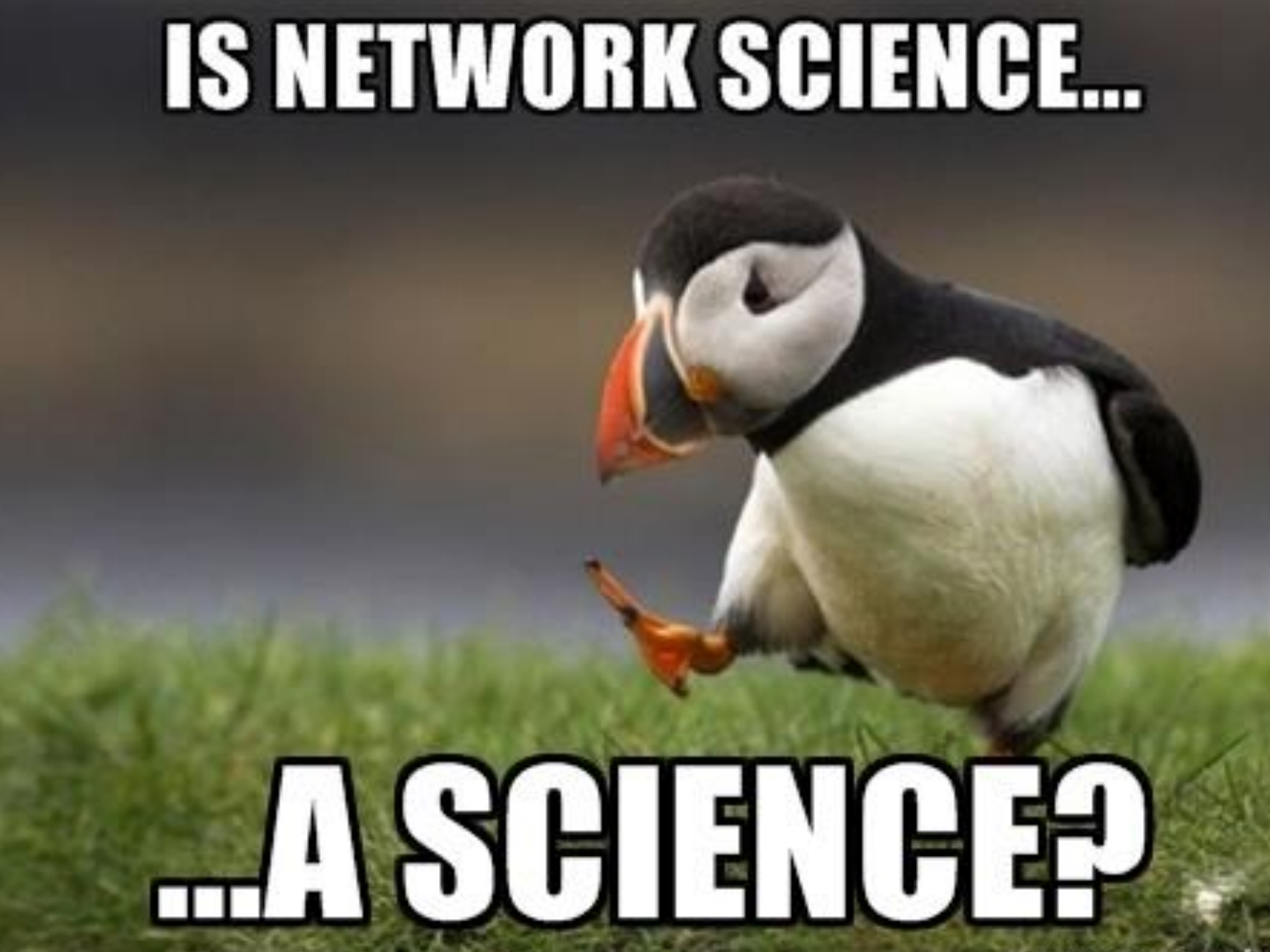
Confession

I don’t have a

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

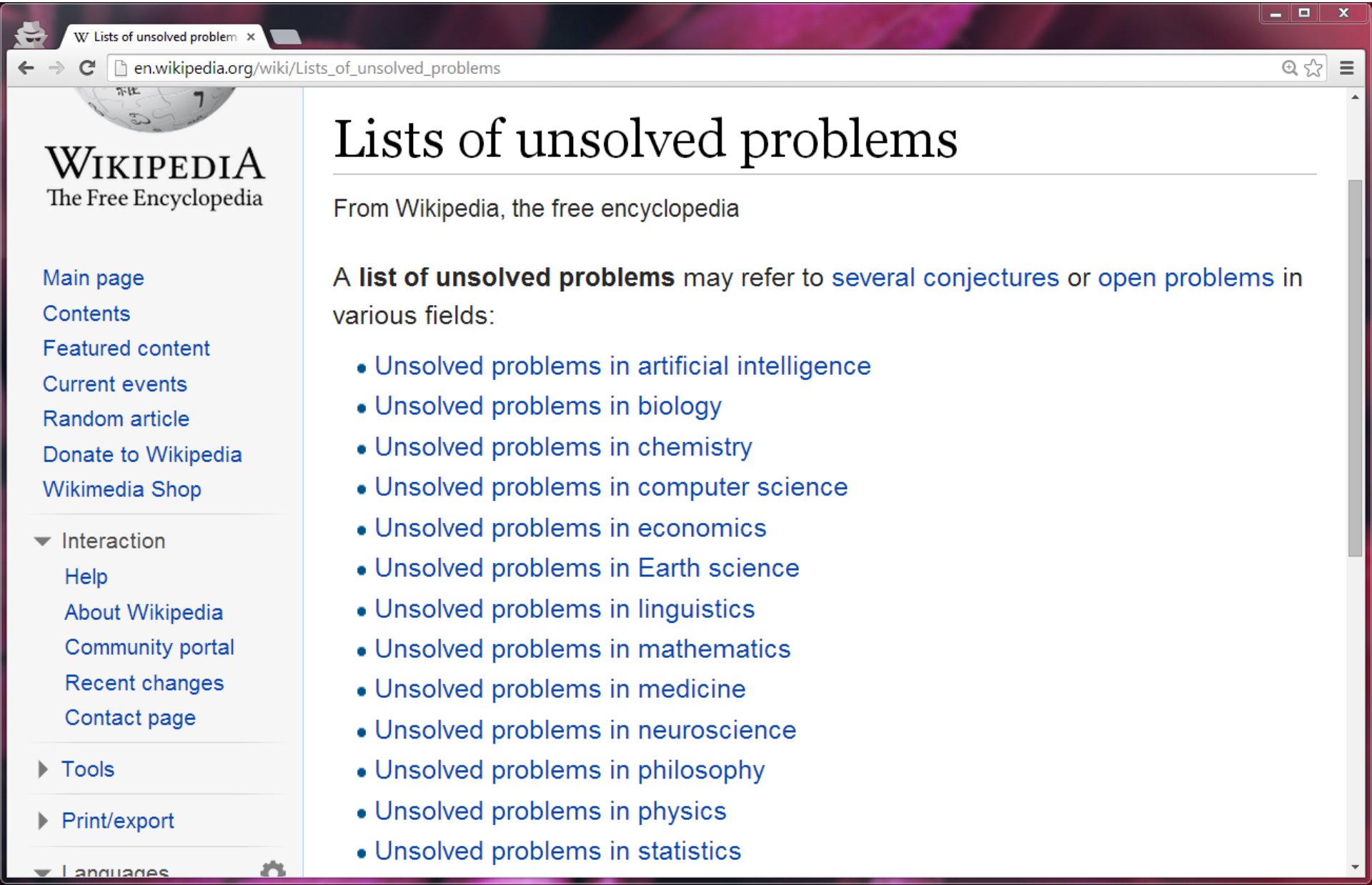
Markov Chains,
Stationary Distribution,
& PageRank

Spectral
Graph Theory


CHECKLIST
it’s cool to be in network science
success stories
workshop established

But…

Real Science has (Open) Problems



Science: Still Interesting in 100 Years

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~~

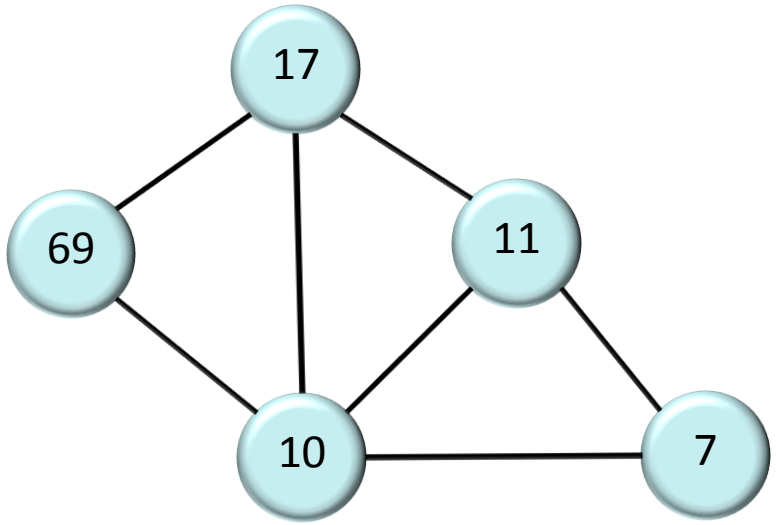
Complexity Theory

Network

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

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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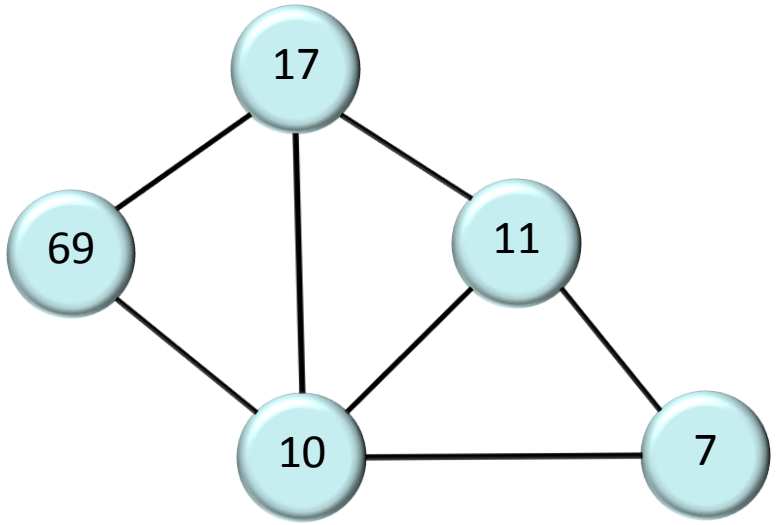


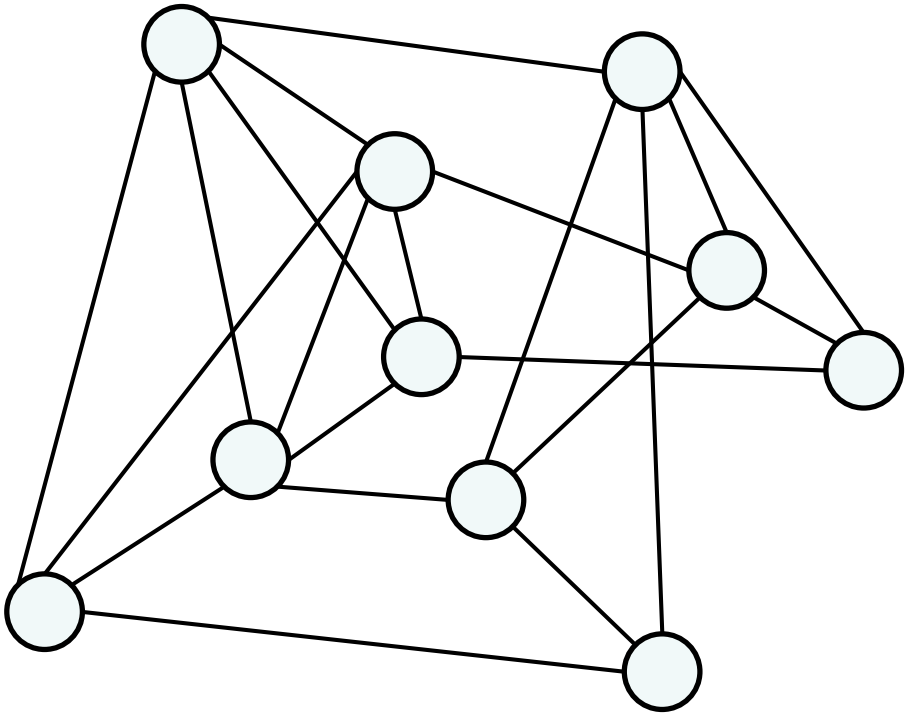

```
each round:
every node:
1. send msgs
2. rcv msgs
3. compute
```

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

An Example

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

How Many Nodes in Network?



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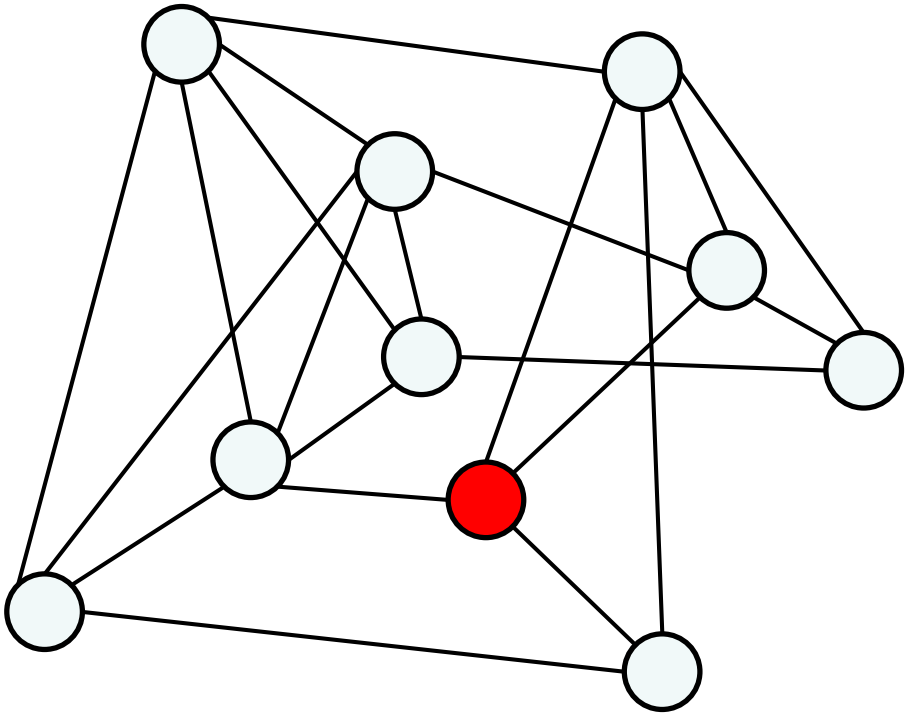

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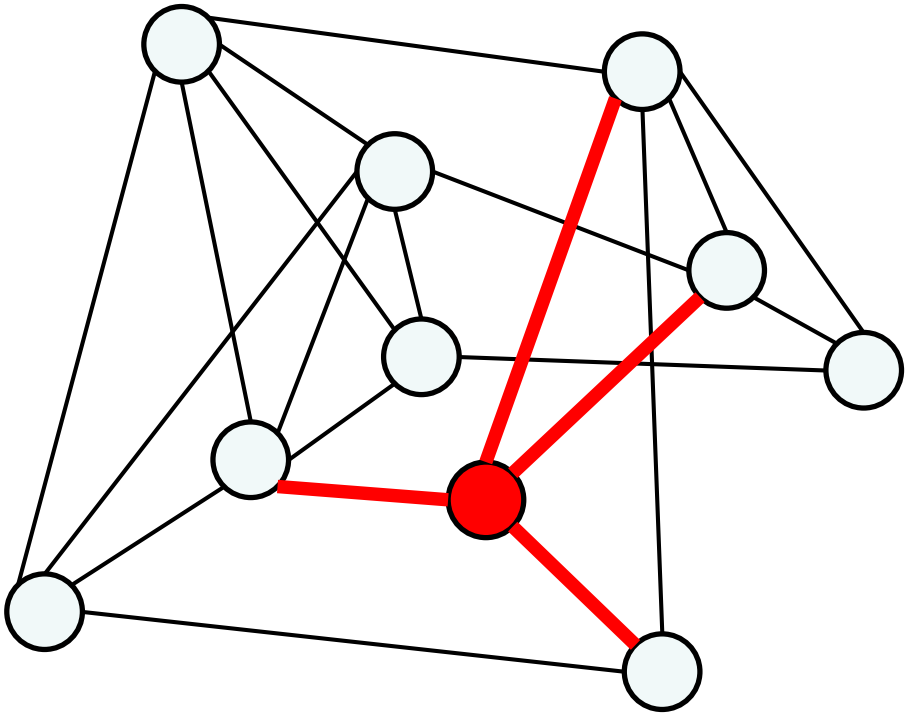

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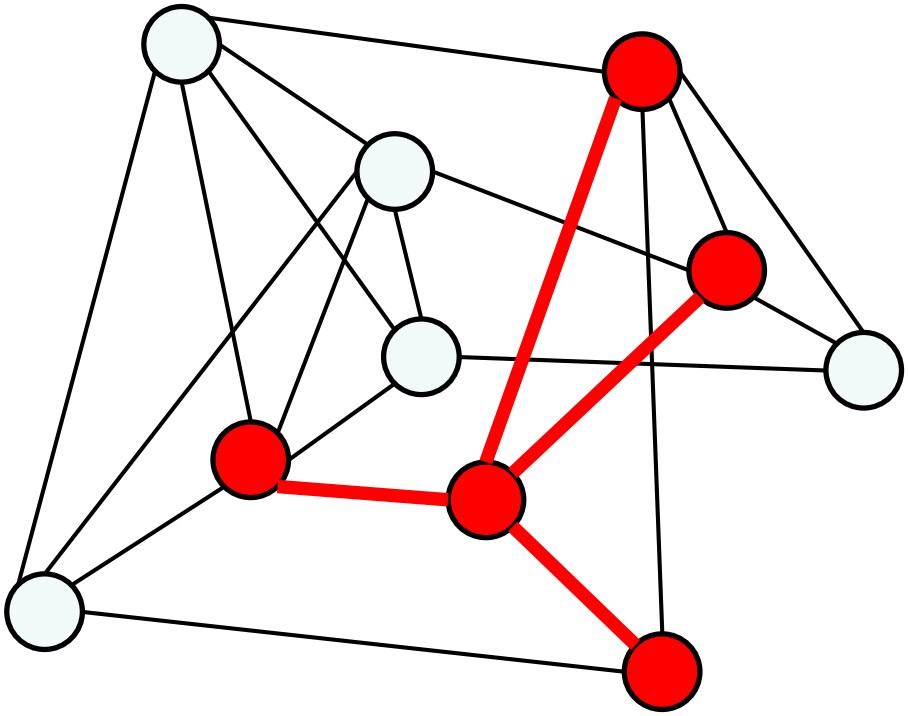
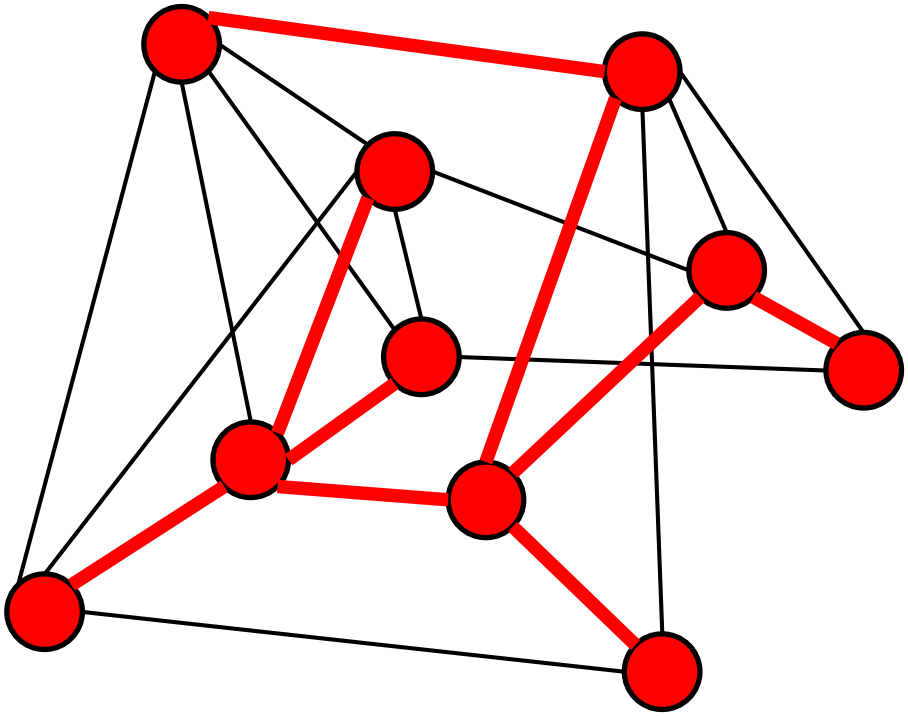


How Many Nodes in Network?



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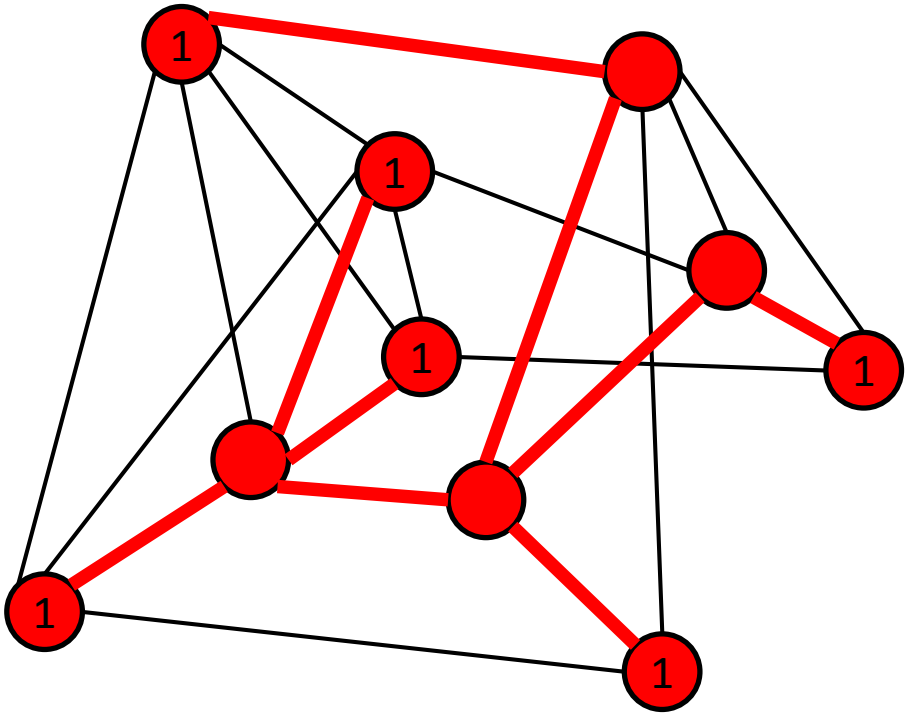

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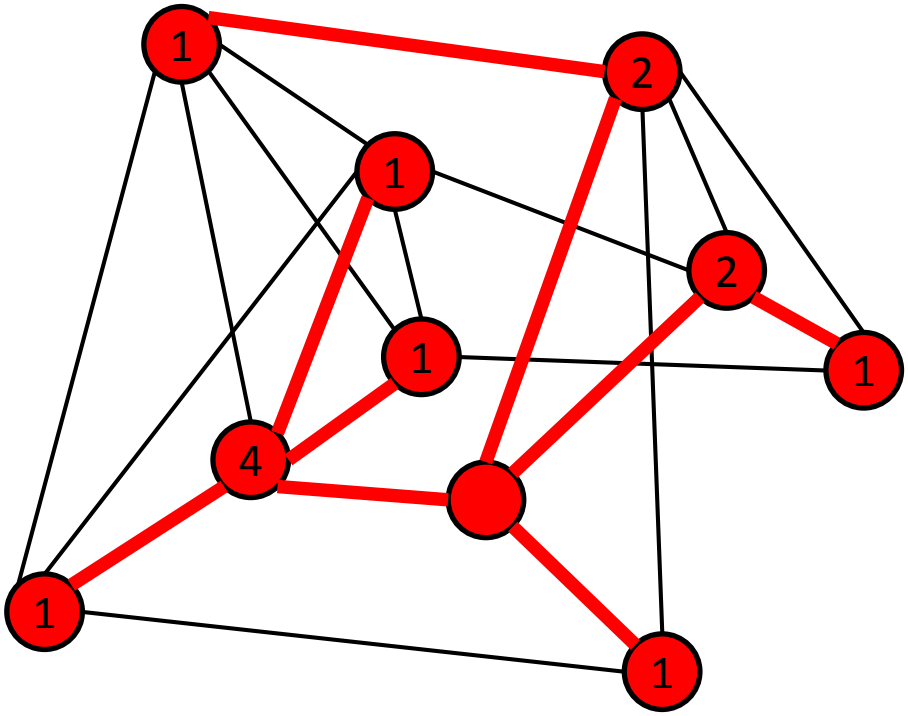

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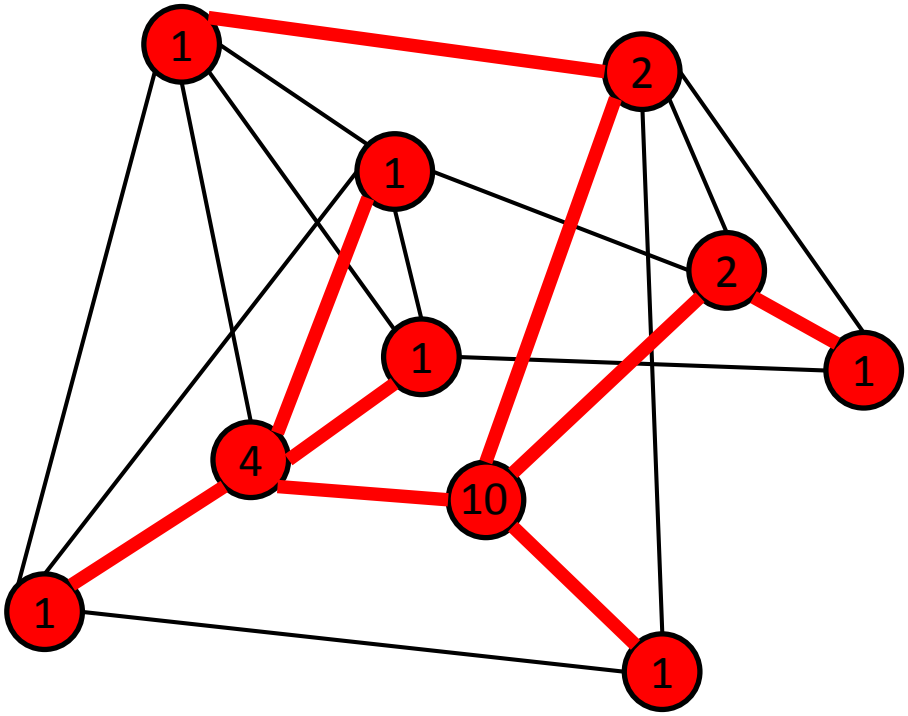
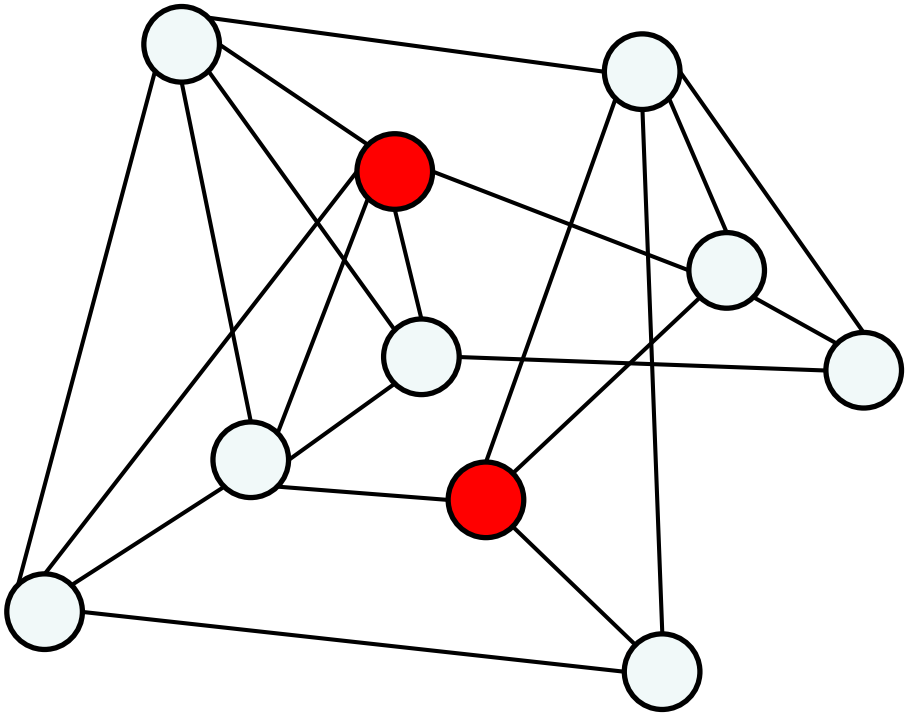


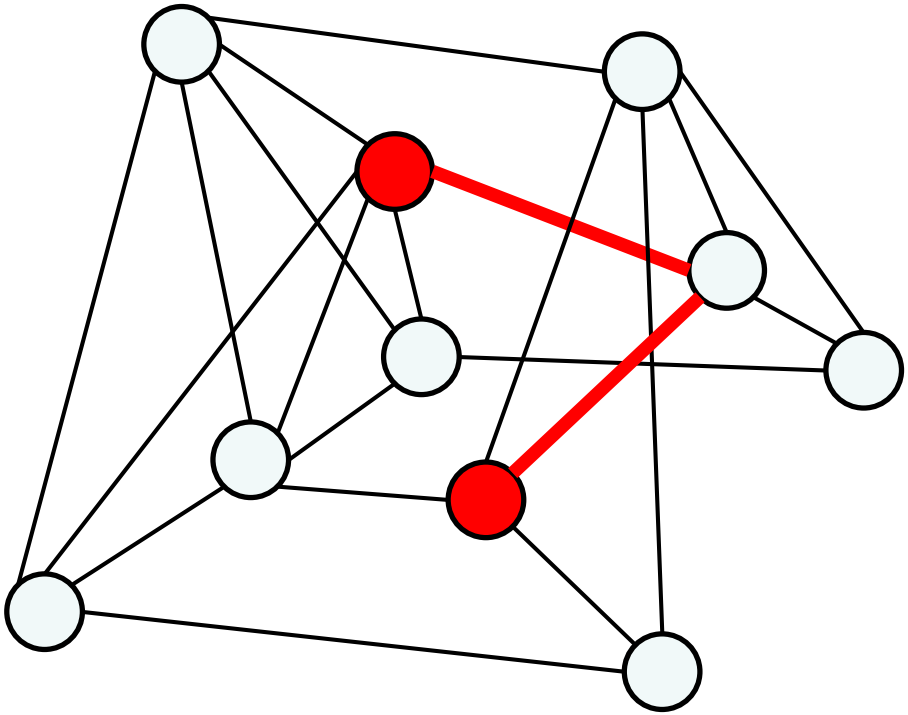
With a simple flooding/echo process, a network can find the number of nodes in time $O(D)$, where D is the diameter (size) of the network.

Diameter of Network?



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

Diameter of Network?



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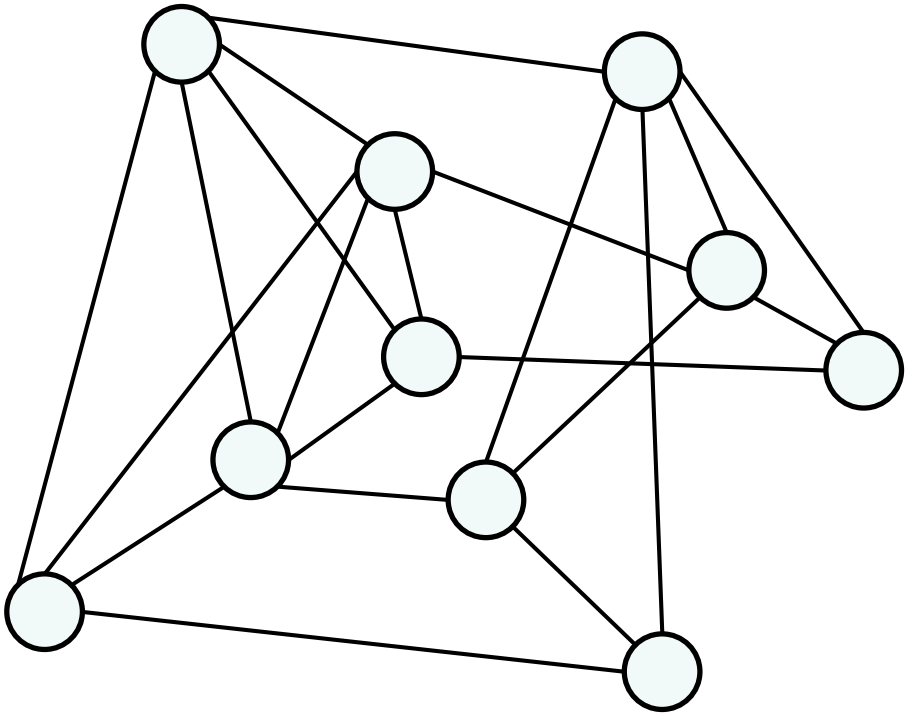
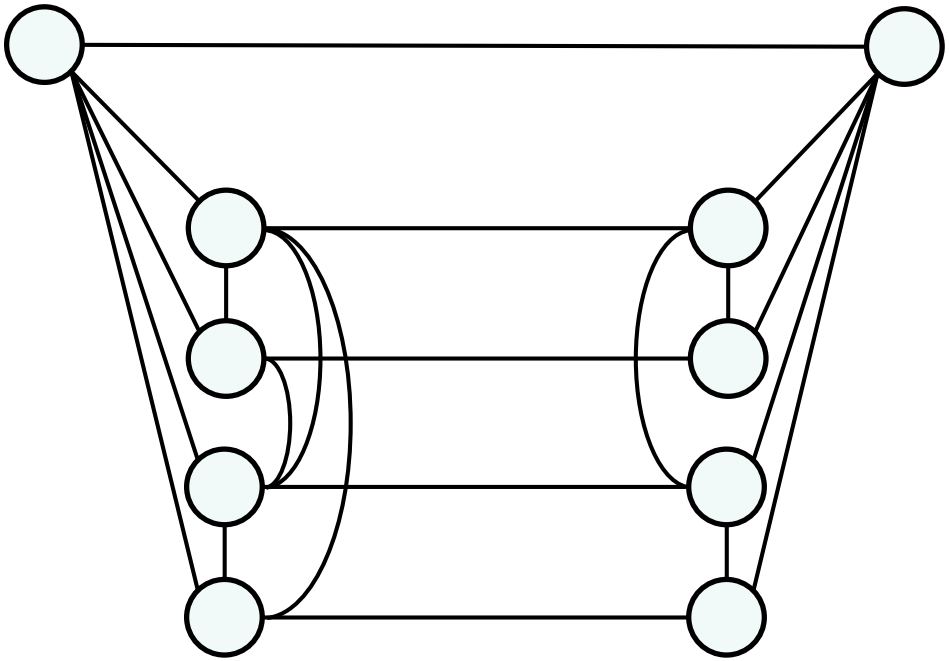
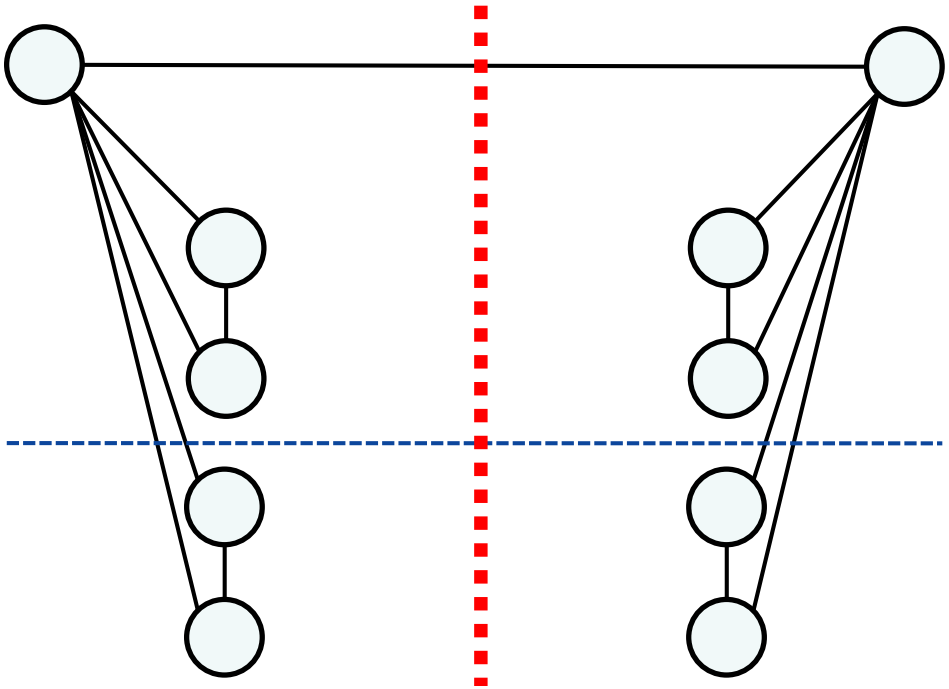


- Distance between two nodes = Number of hops of shortest path
- Diameter of network = Maximum distance, between any two nodes

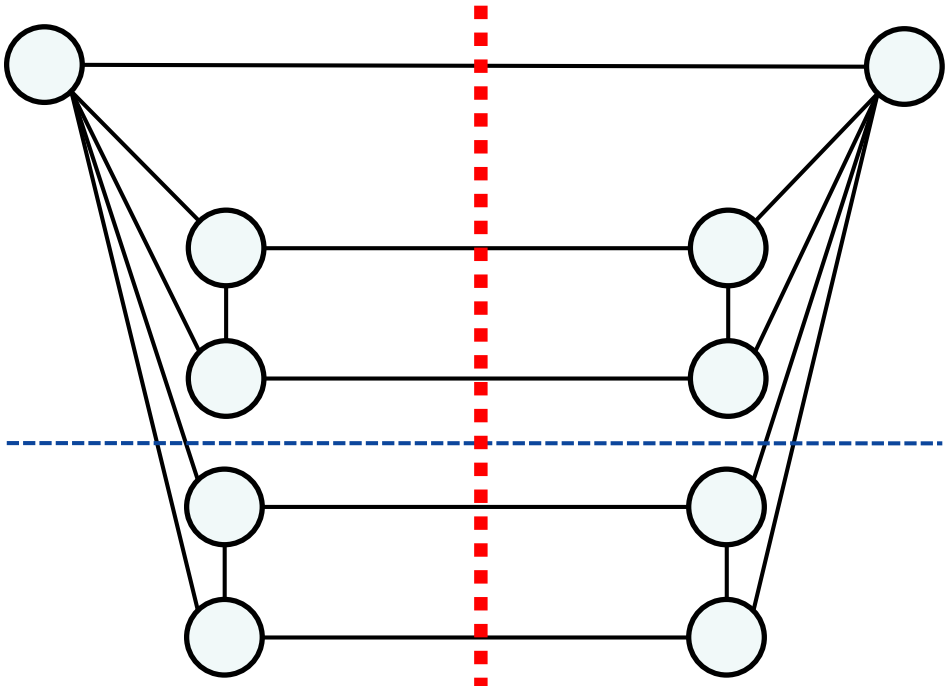
Diameter of Network?



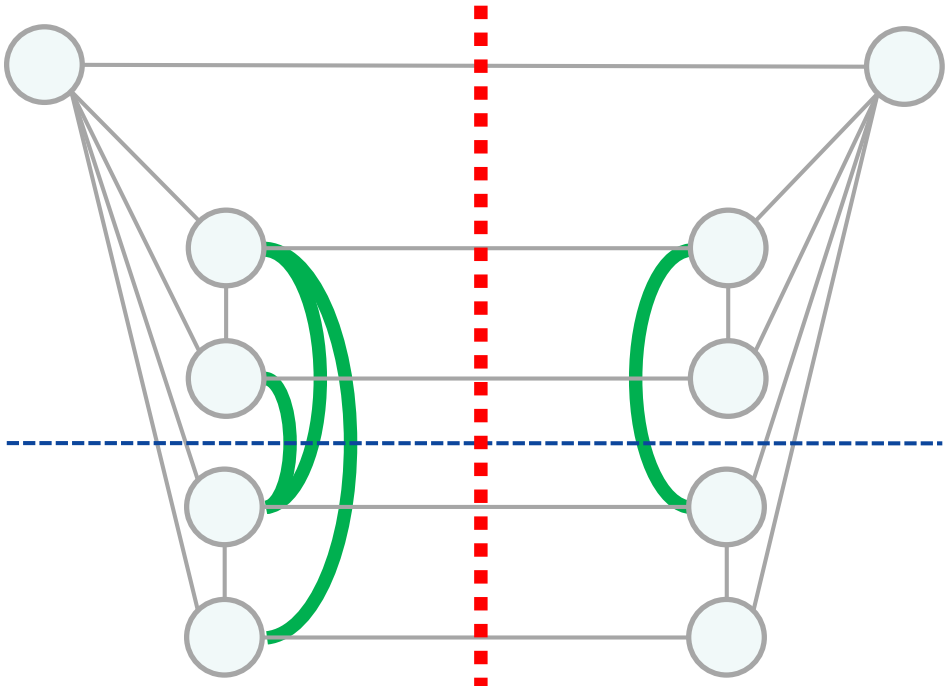
Diameter of Network?



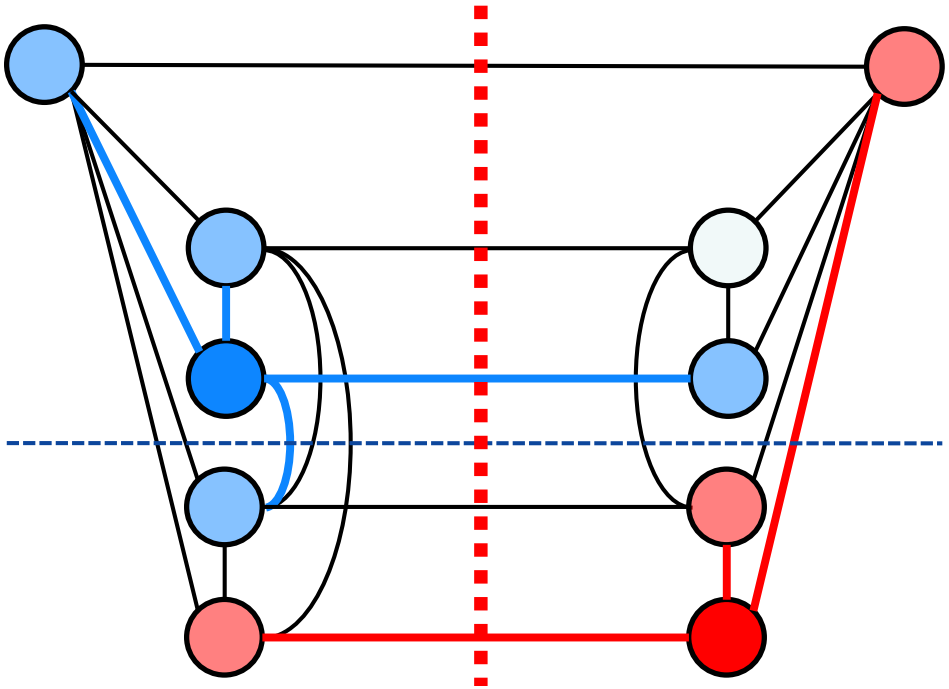
Diameter of Network?



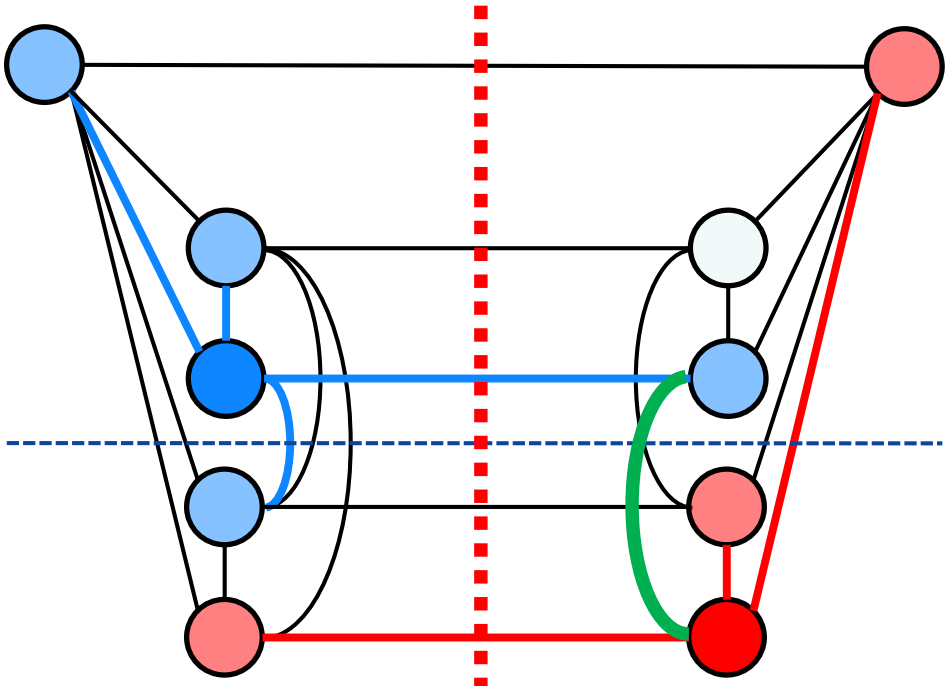
Diameter of Network?



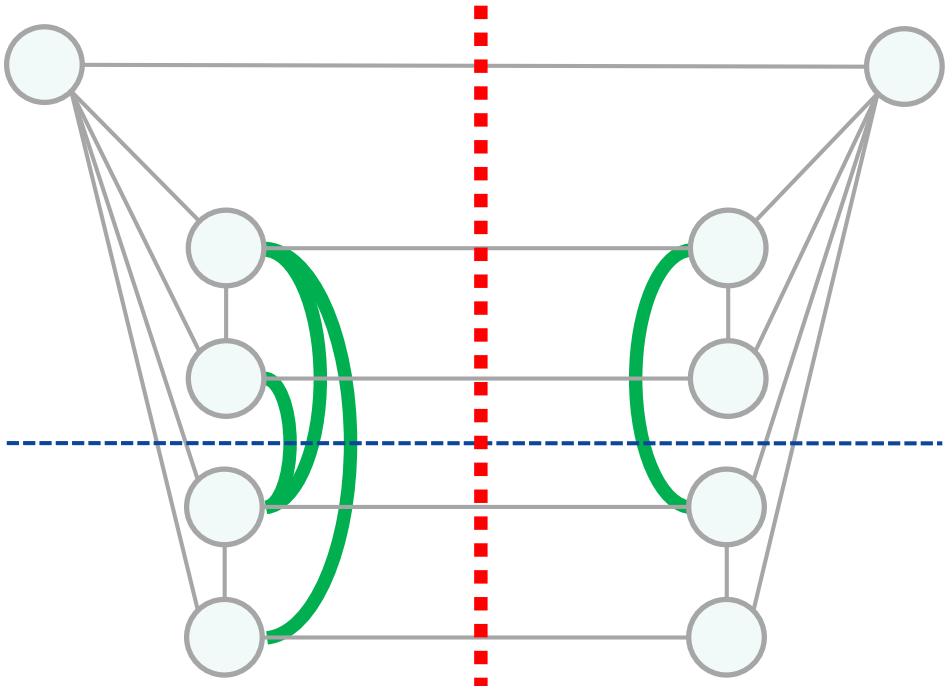
Diameter of Network?



Diameter of Network?

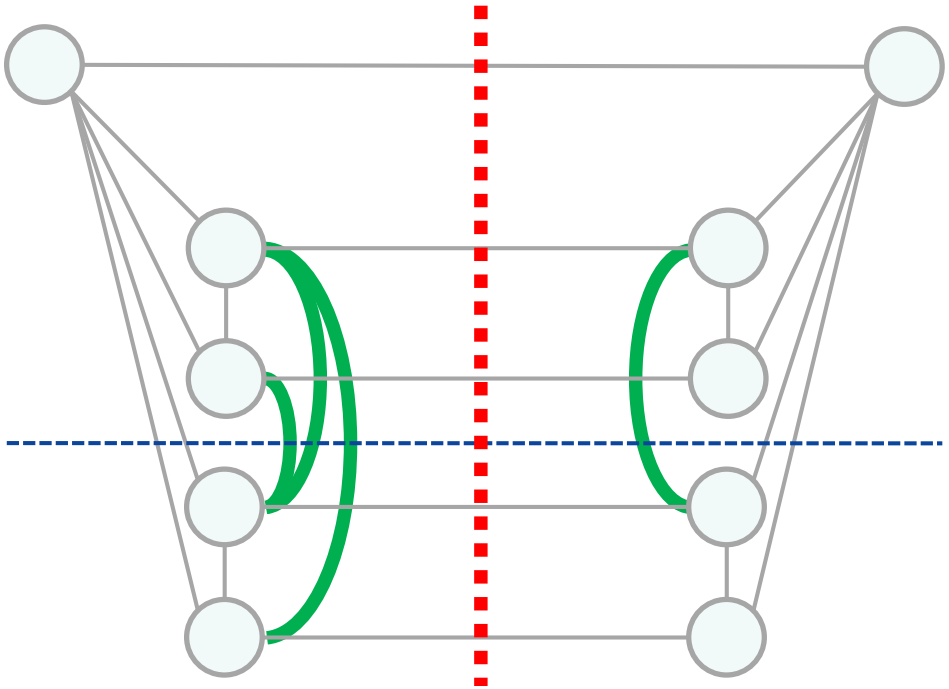


Diameter of Network?



Networks Cannot Compute Their Diameter in Sublinear Time!

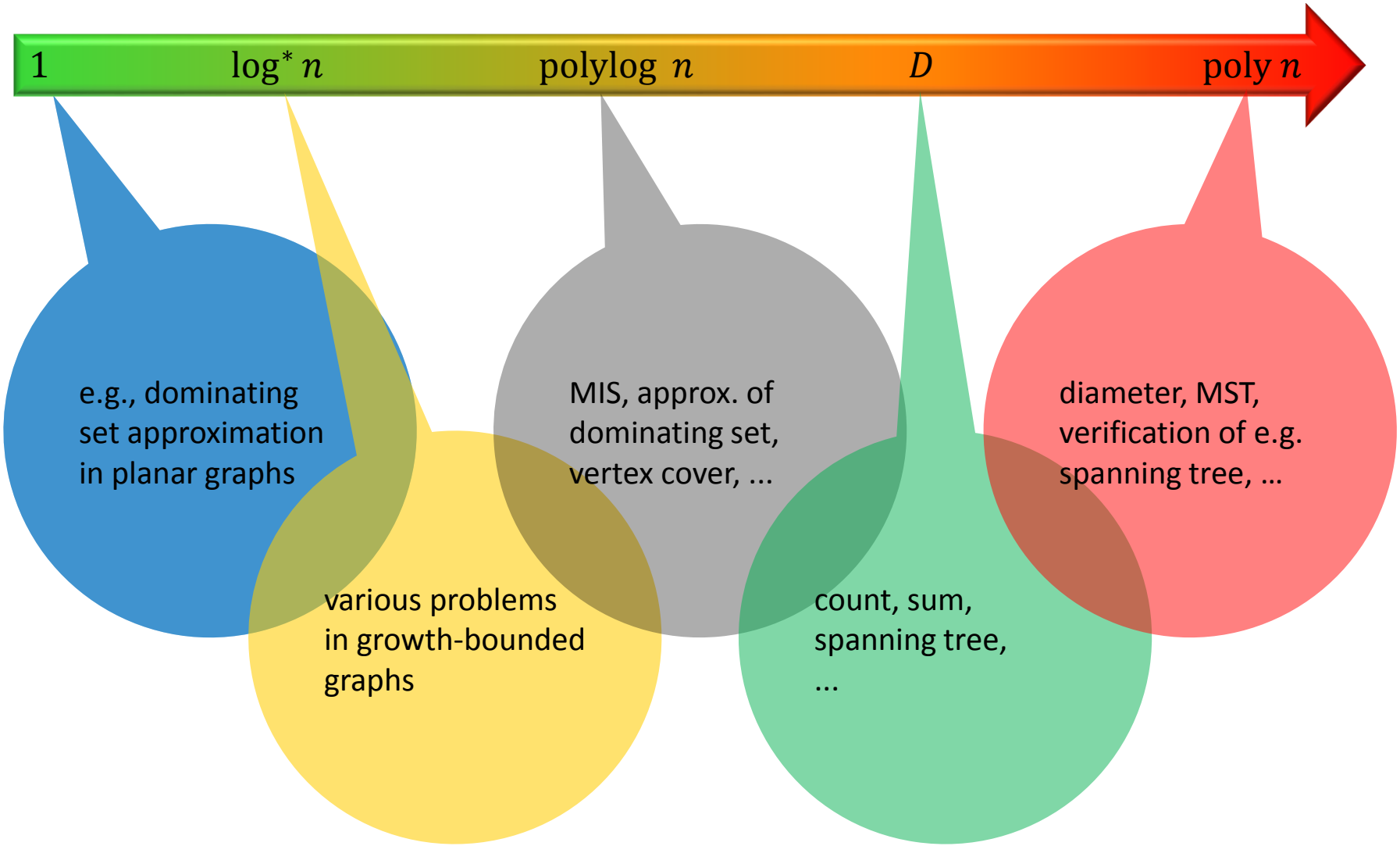
(even if diameter is just a small constant)



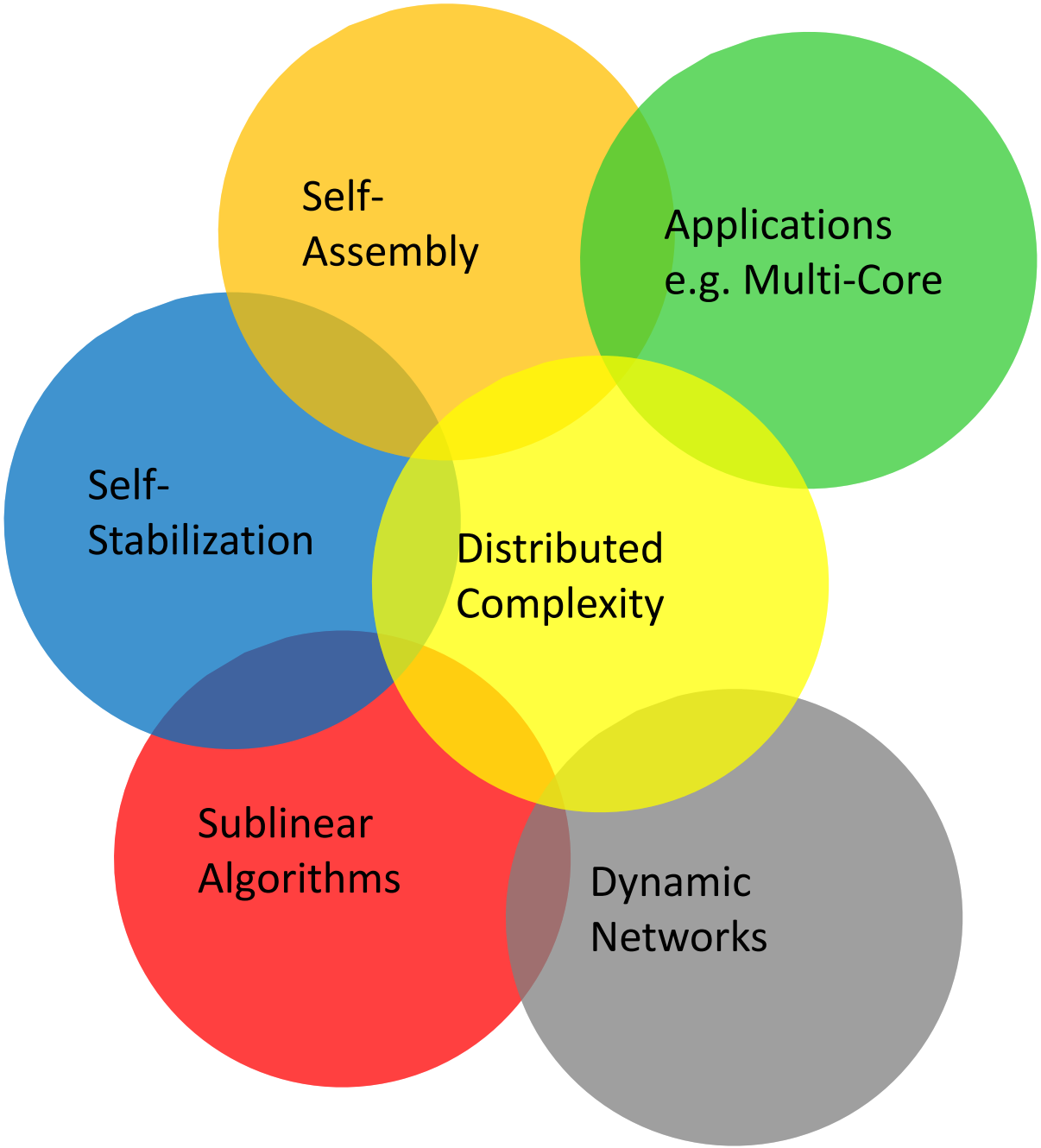
Pair of rows connected neither left nor right? Communication complexity:
Transmit $\Theta(n^2)$ information over $O(n)$ edges → $\Omega(n)$ time!

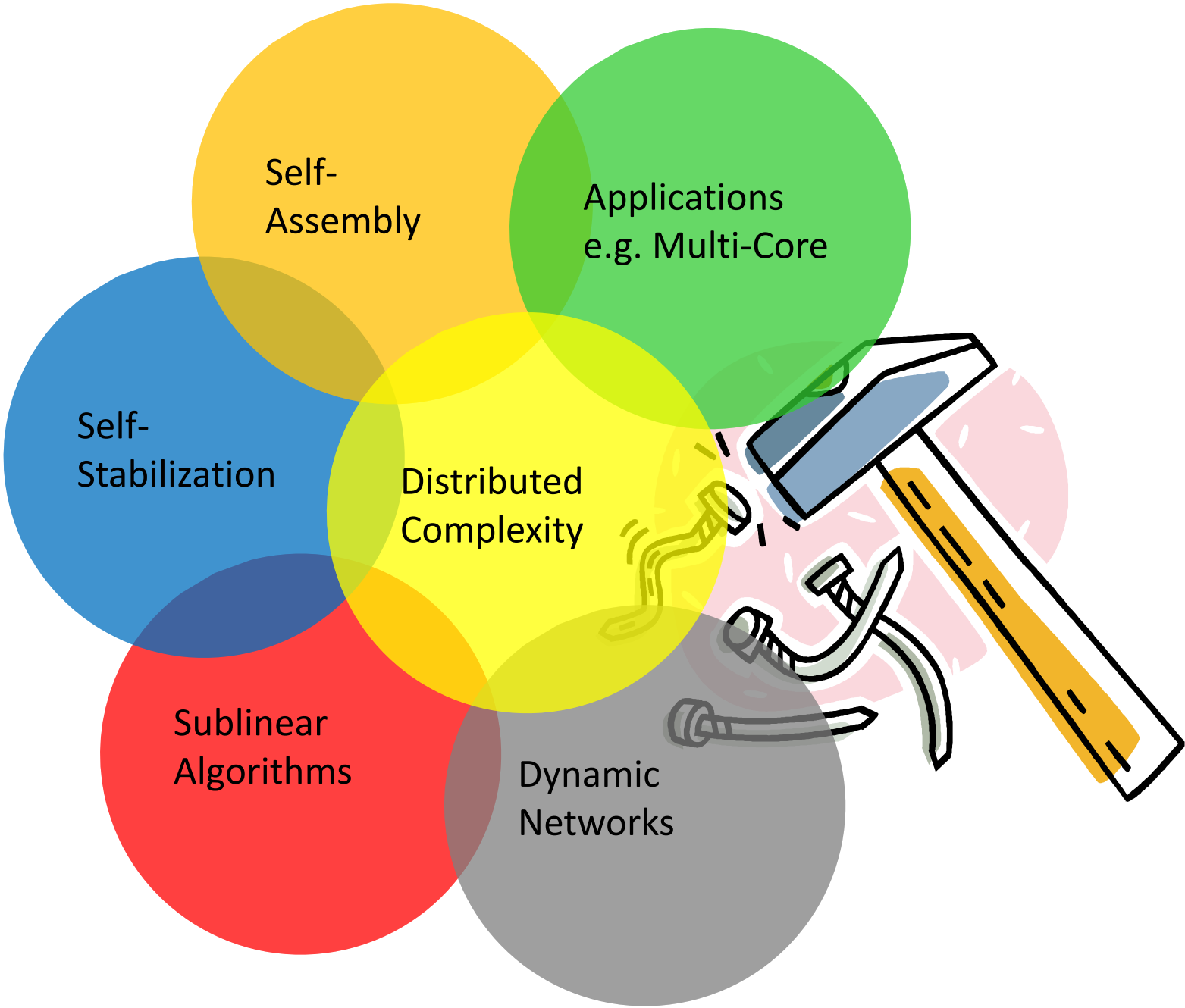
[Frischknecht, Holzer, W, 2012]

Distributed Complexity Classification



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


Self-
Assembly
Applications
e.g. Multi-Core
Self-
Stabilization
Distributed
Complexity
Sublinear
Algorithms
Dynamic
Networks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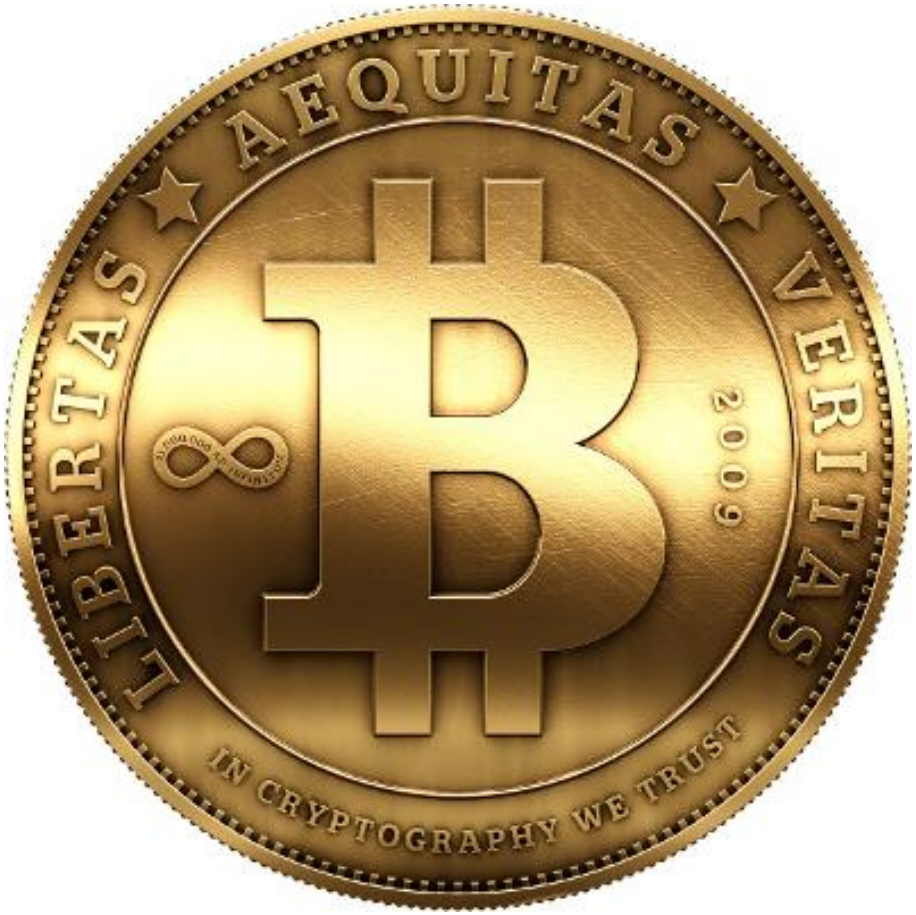
Science: Still Interesting in 100 Years

Engineering: Interesting Right Now!

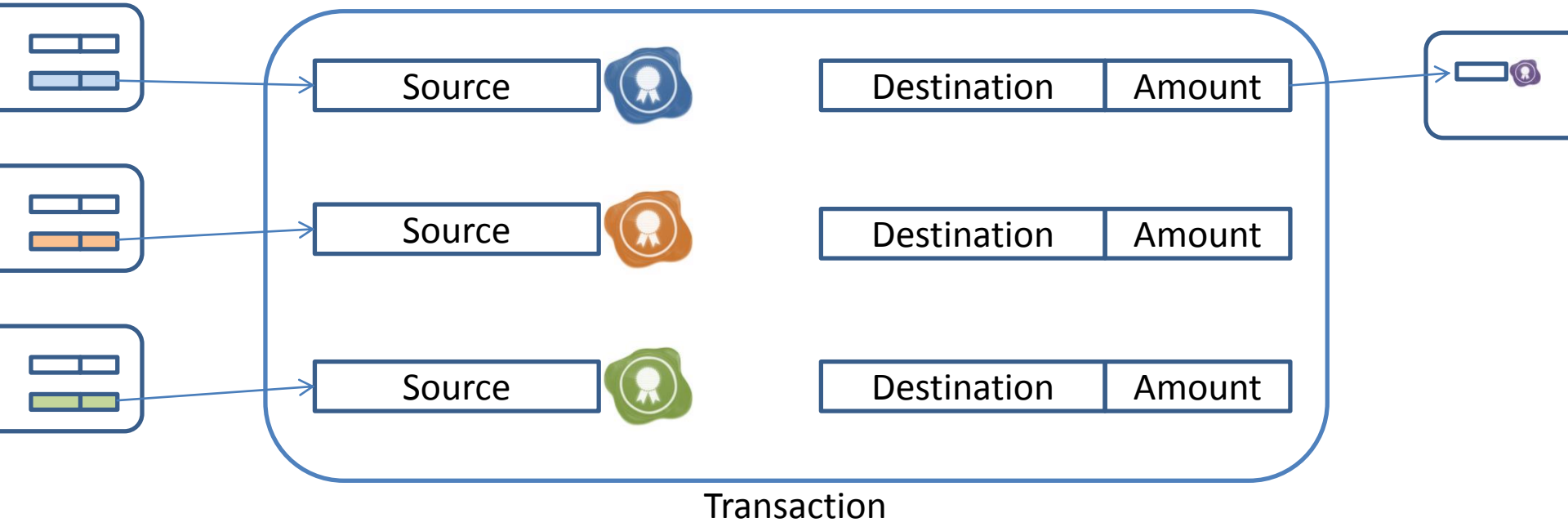


Bitcoin

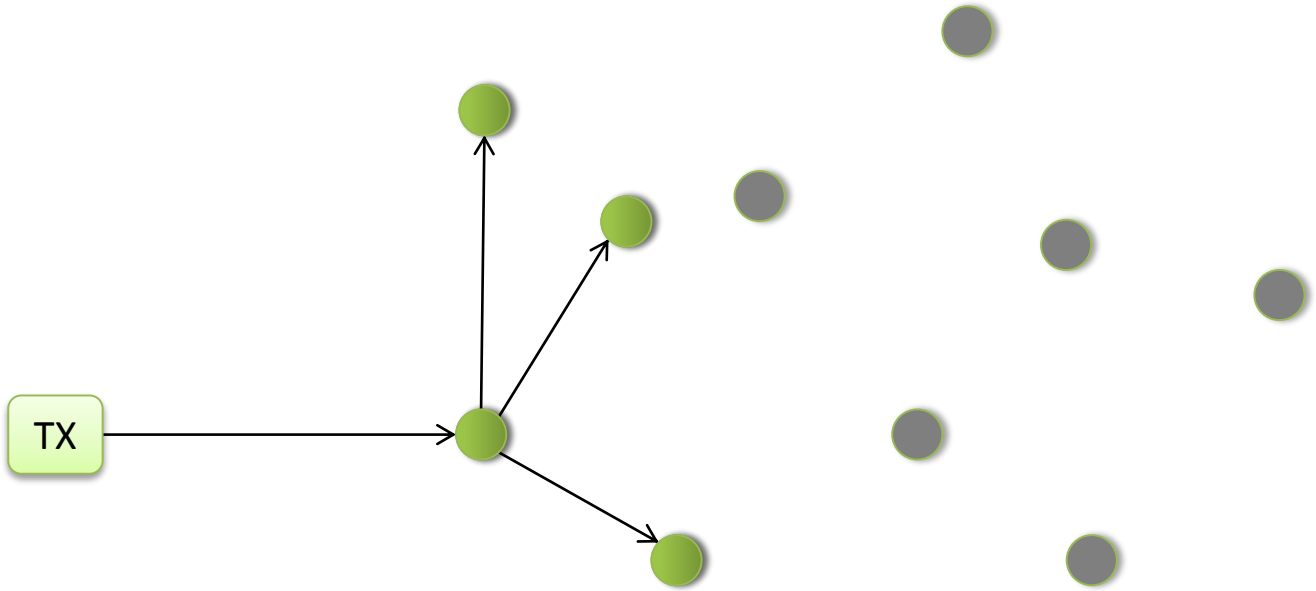
Bank of Bitcoin

Spending Money

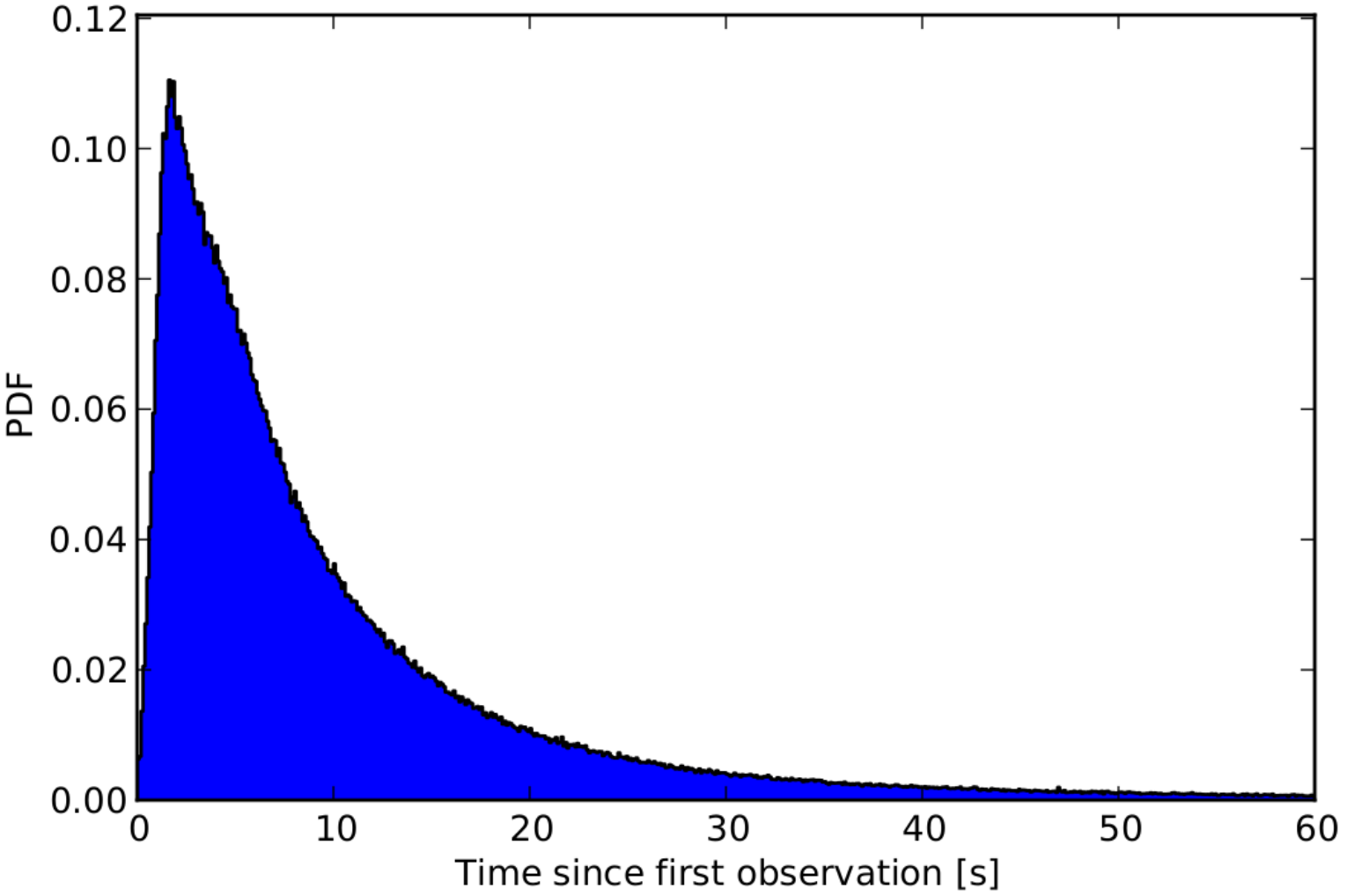
Moving Money



Distributing the Bank

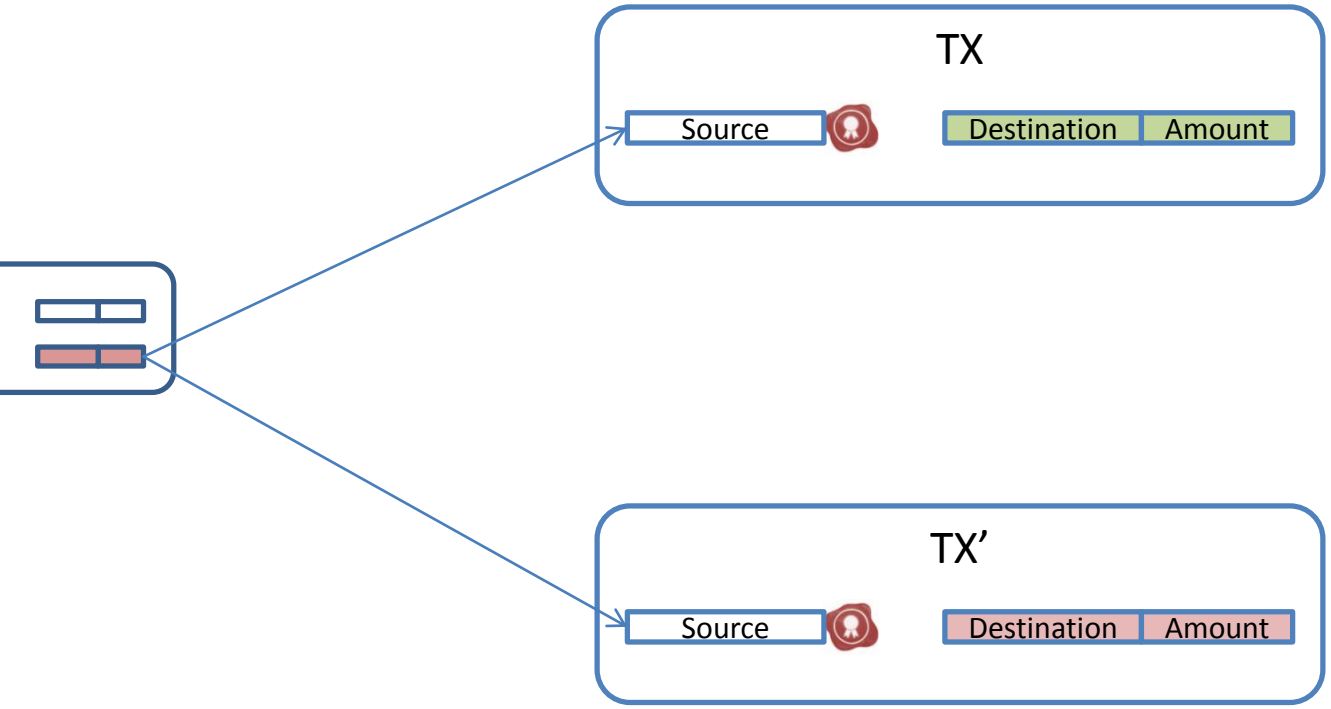


Propagation Time

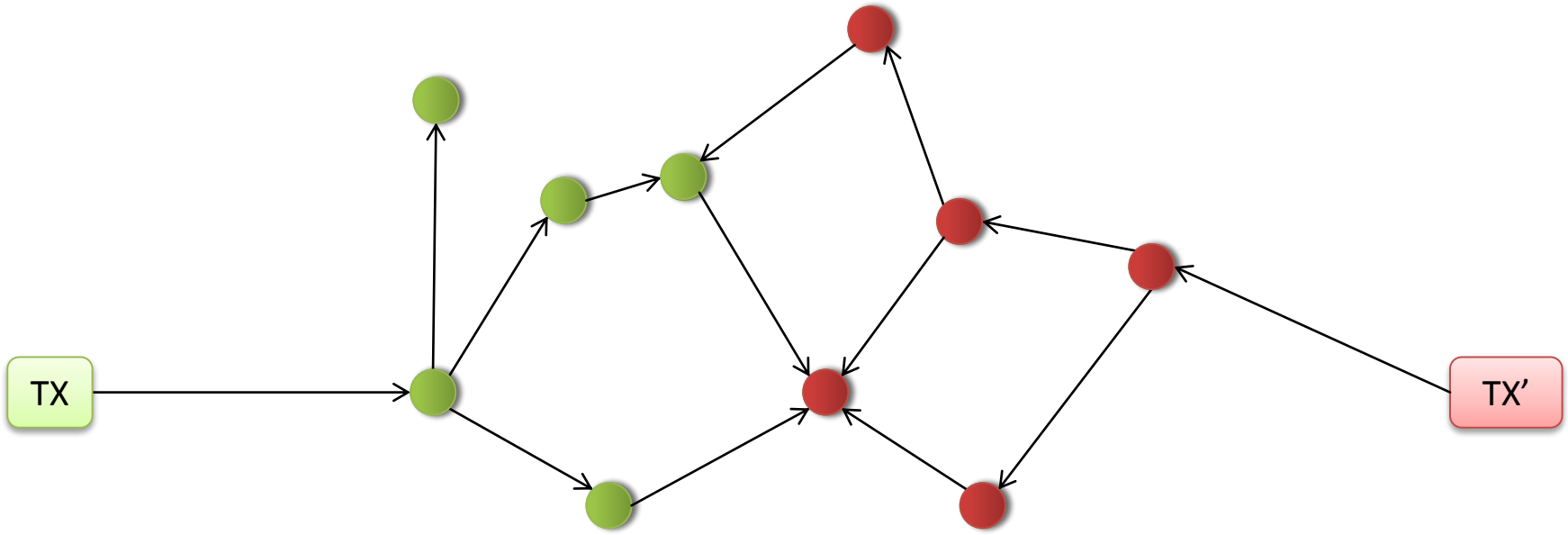


[Decker, W, 2013]

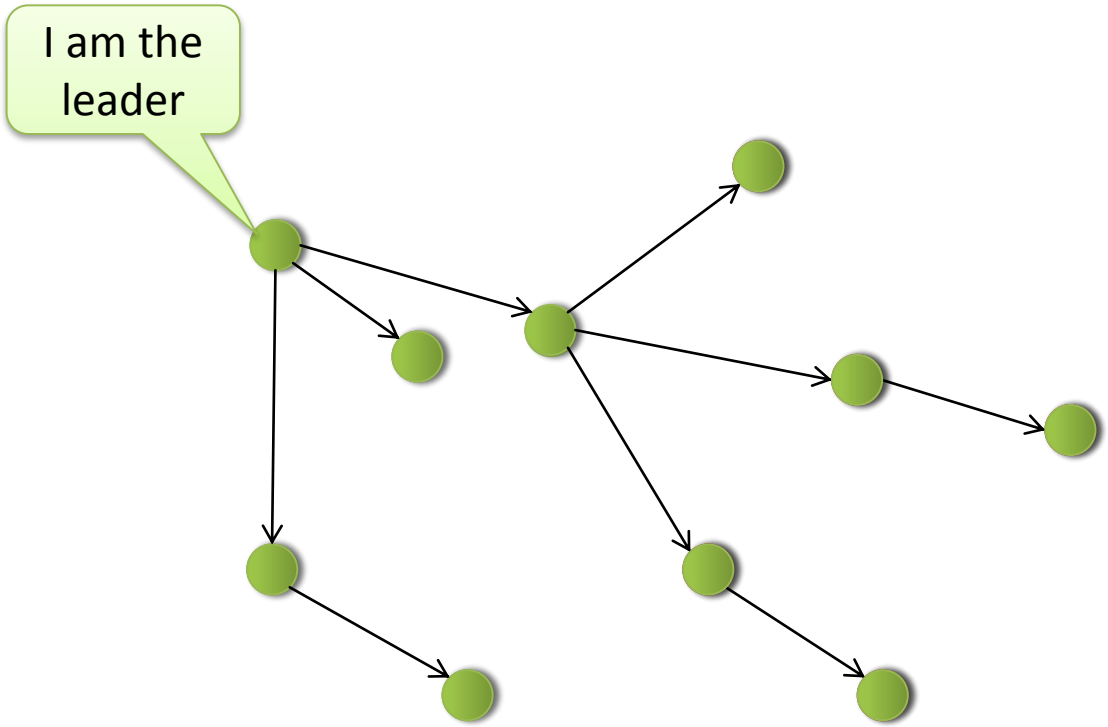
Double-spending



Double-spending in the Network



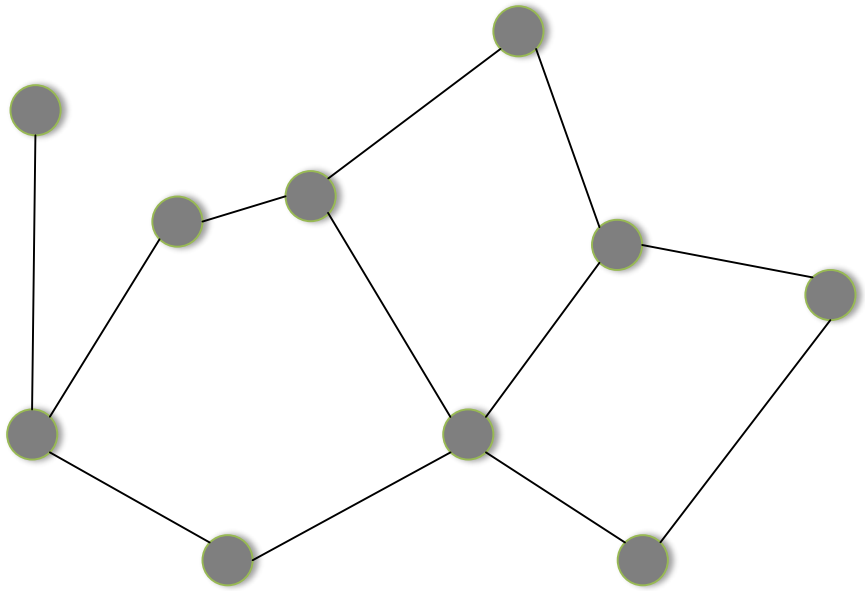
Distributing the Bank



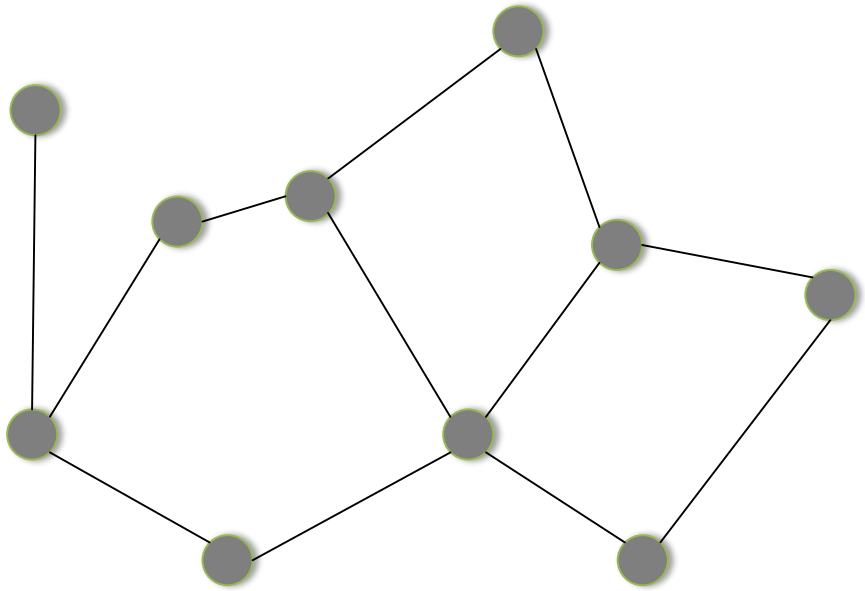
Double-spending in the Real World

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

Where would you inject your transaction?



Double-spending, the Theory

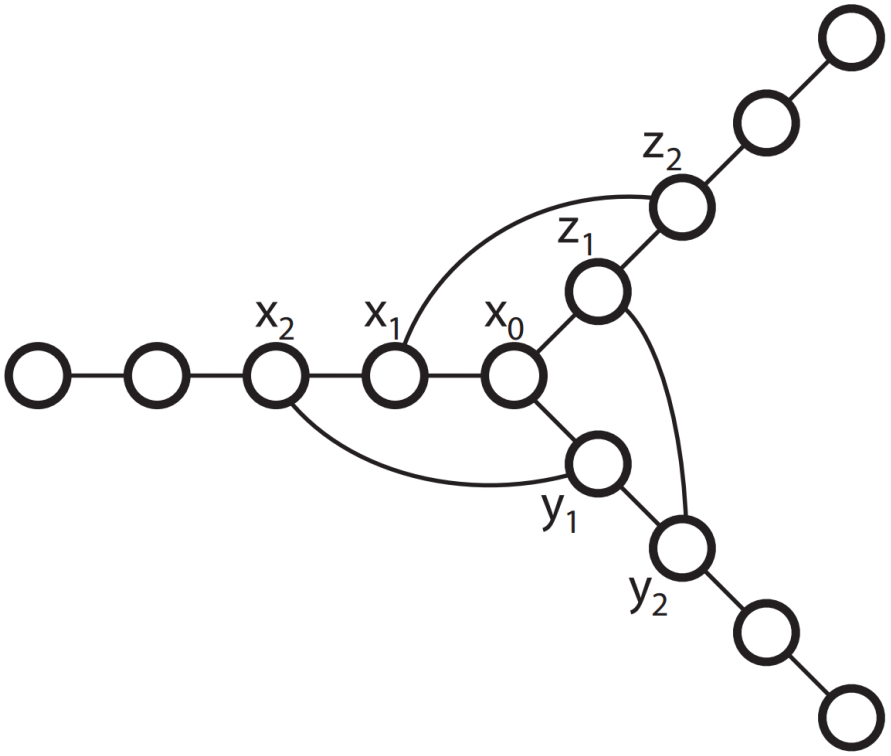


Player 1: Where to inject original transaction?
Player 2: Where to inject copy?


SECOND IS
THE FIRST
LOSER

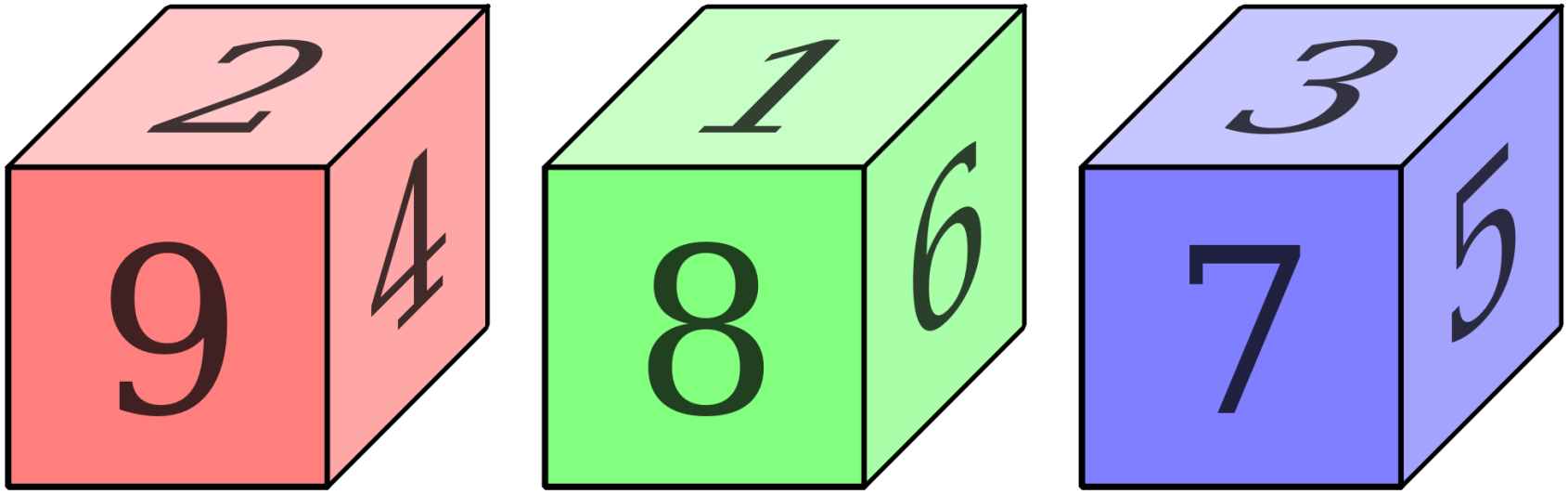
Really?

Sometimes, being second is better!



[Meier, Pignolet, Schmid, W, 2014]

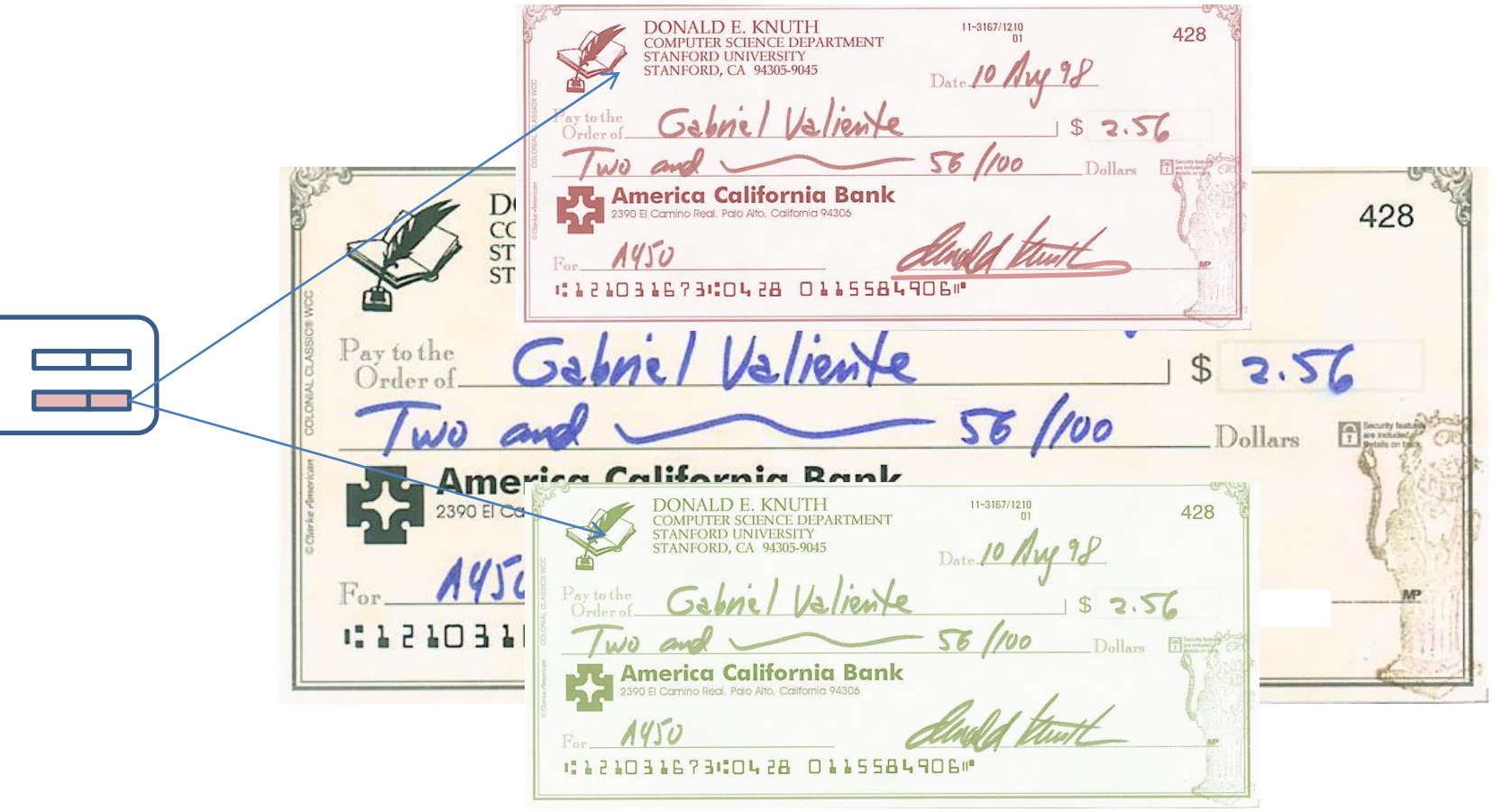
Another Example: Nontransitive Dice



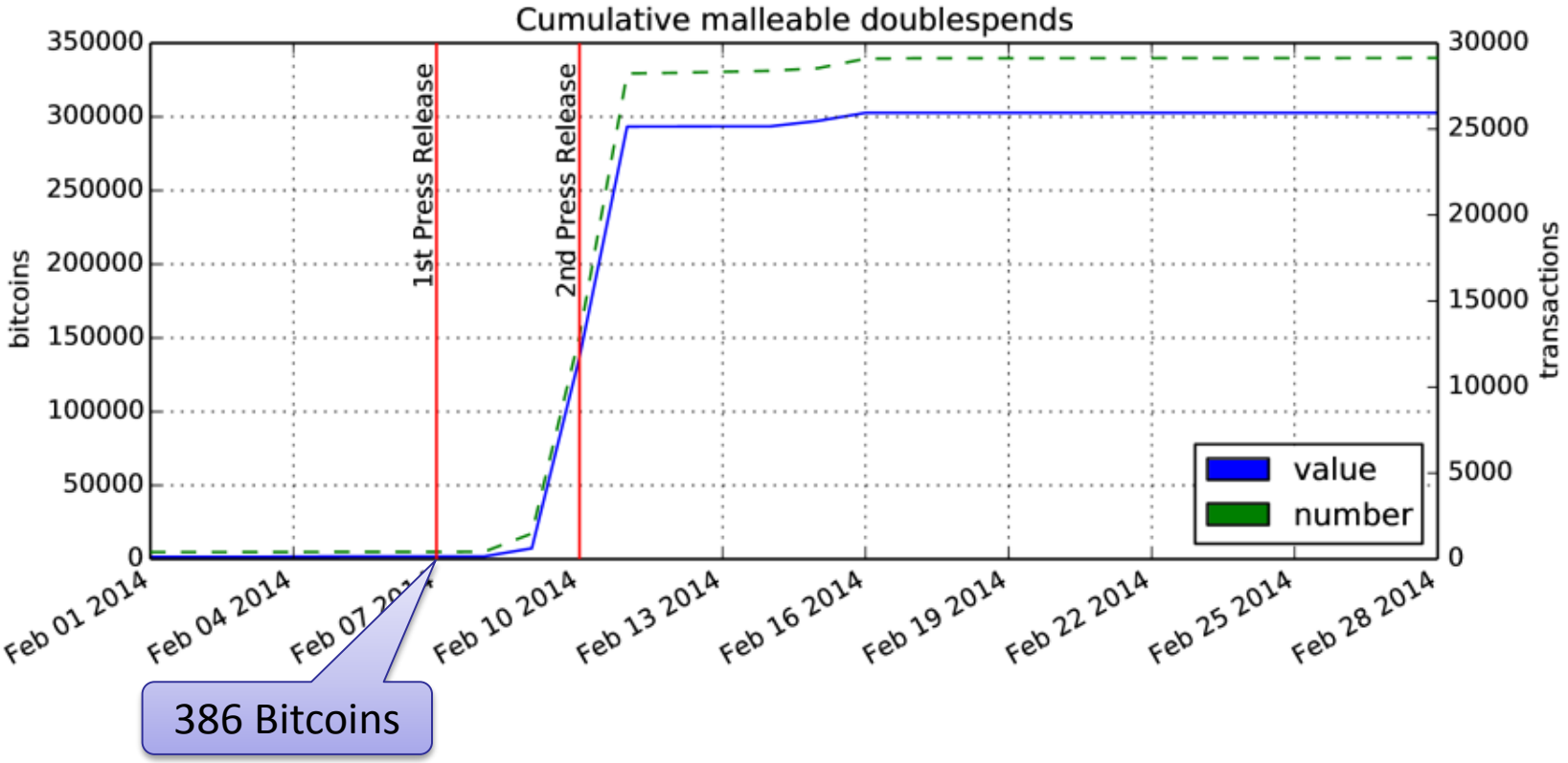
Transaction Malleability

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

Transaction Malleability



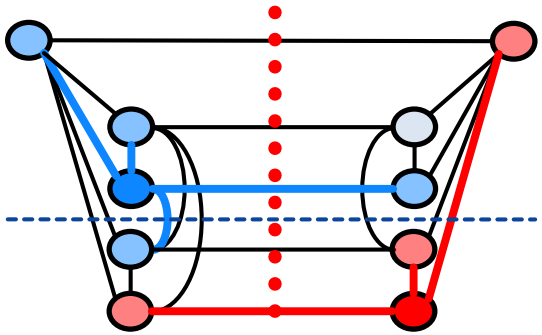
Transaction Malleability in Real Life

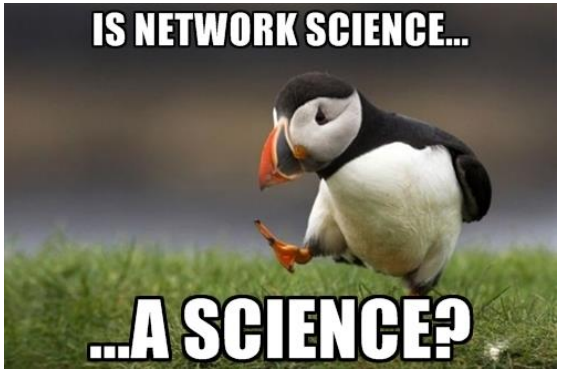


[Decker, W, Arxiv, in submission]


WHERE ARE THE
$500M, DUDE?

Summary



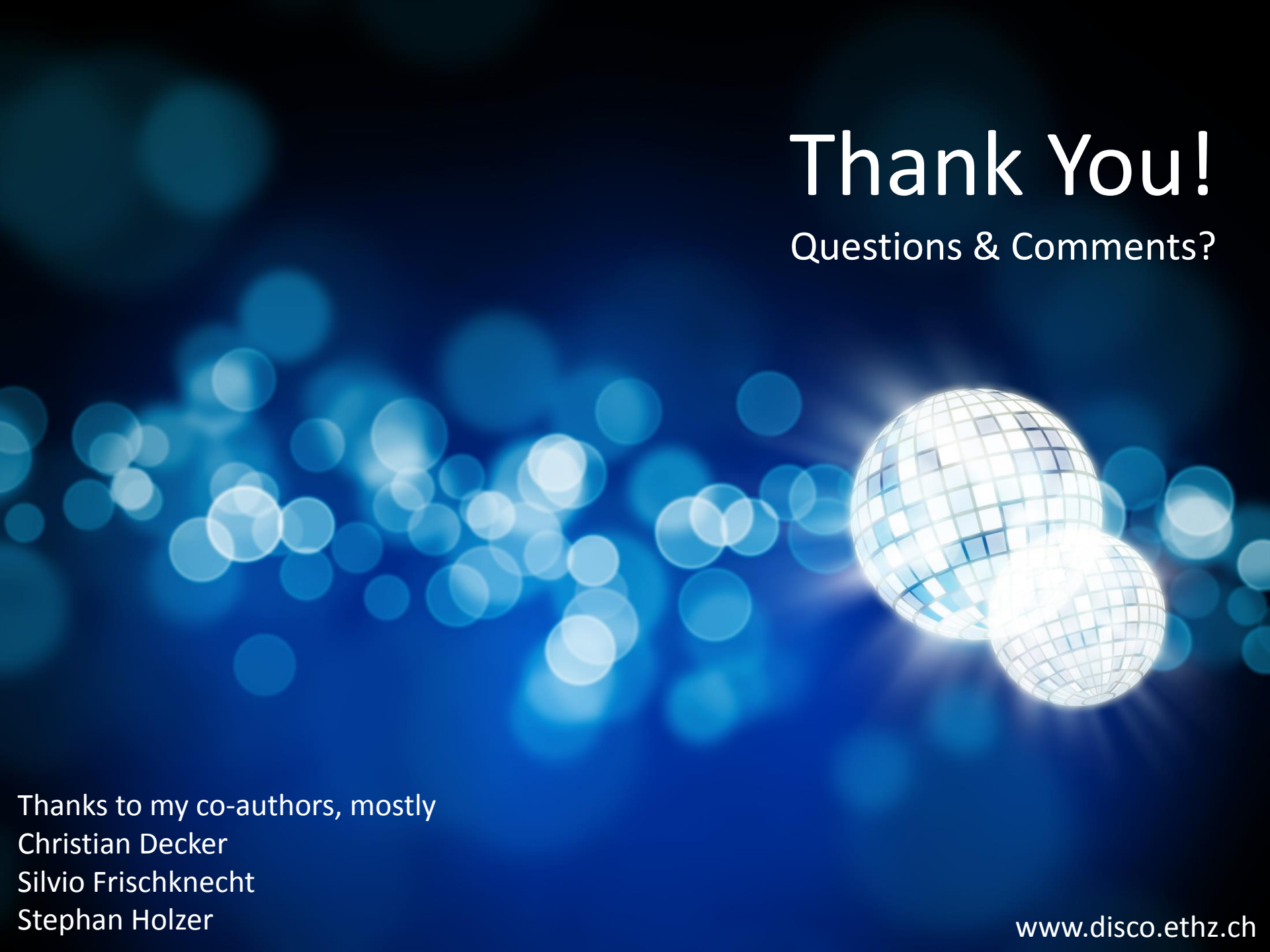

IS NETWORK SCIENCE...
...A SCIENCE?


LIBERTAS
AEQUITAS
VERITAS
2009
IN CRYPTOGRAPHY WE TRUST


EITHER
OR

Thank You!

Questions & Comments?



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

www.disco.ethz.ch