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

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

\downarrow

Complexity Theory

Network

Can a Computer Solve Problem $P$ in Time $t$?
Complexity Theory

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

Distributed Network

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

Each round:
1. send msgs
2. rcv msgs
3. compute
An Example

each round:
every node:
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2. rcv msgs
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How Many Nodes in Network?

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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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Diameter of Network?

- **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 $\Rightarrow \Omega(n)$ time!

[Frischknecht, Holzer, W, 2012]
Distributed Complexity Classification

1 \quad \log^* n \quad \text{polylog } n \quad D \quad \text{poly } n

e.g., dominating set approximation in planar graphs

MIS, approx. of dominating set, vertex cover, ...

diameter, MST, verification of e.g. spanning tree, ...

various problems in growth-bounded graphs

count, sum, spanning tree, ...

e.g., [Kuhn, Moscibroda, W, 2014]
Sublinear Algorithms
Self-Stabilization
Distributed Complexity
Applications e.g. Multi-Core
Dynamic Networks
Self-Assembly

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Science: Still Interesting in 100 Years

Engineering: Interesting Right Now!
Bitcoin
Spending Money
Moving Money

Transaction

Source | Destination | Amount
Distributing the Bank
Double-spending

TX

Source

Destination Amount

TX'

Source

Destination Amount
Double-spending in the Network
Distributing the Bank

I am the leader
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?
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

[Decker, W, Arxiv, in submission]
WHERE ARE THE $500M, DUDE?
Summary

IS NETWORK SCIENCE...

...A SCIENCE?

EITHER OR
Thank You!
Questions & Comments?

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Silvio Frischknecht
Stephan Holzer

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