

Rumour Spreading in Social Networks

Alessandro Panconesi
Dipartimento di Informatica



SAPIENZA
UNIVERSITÀ DI ROMA

Joint work with Flavio Chierichetti and Silvio Lattanzi



Rumours spread quickly



We're Not
Gossiping.
We're Networking.



OUR GOAL

Argue in a rigorous way
that **rumours** spread **quickly**
in a **social network**

Social Networking



How to tackle the problem



How to tackle the problem





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OUR GOAL

Prove that **rumours** spread
quickly in a **social network**

Gossip: a very simple model



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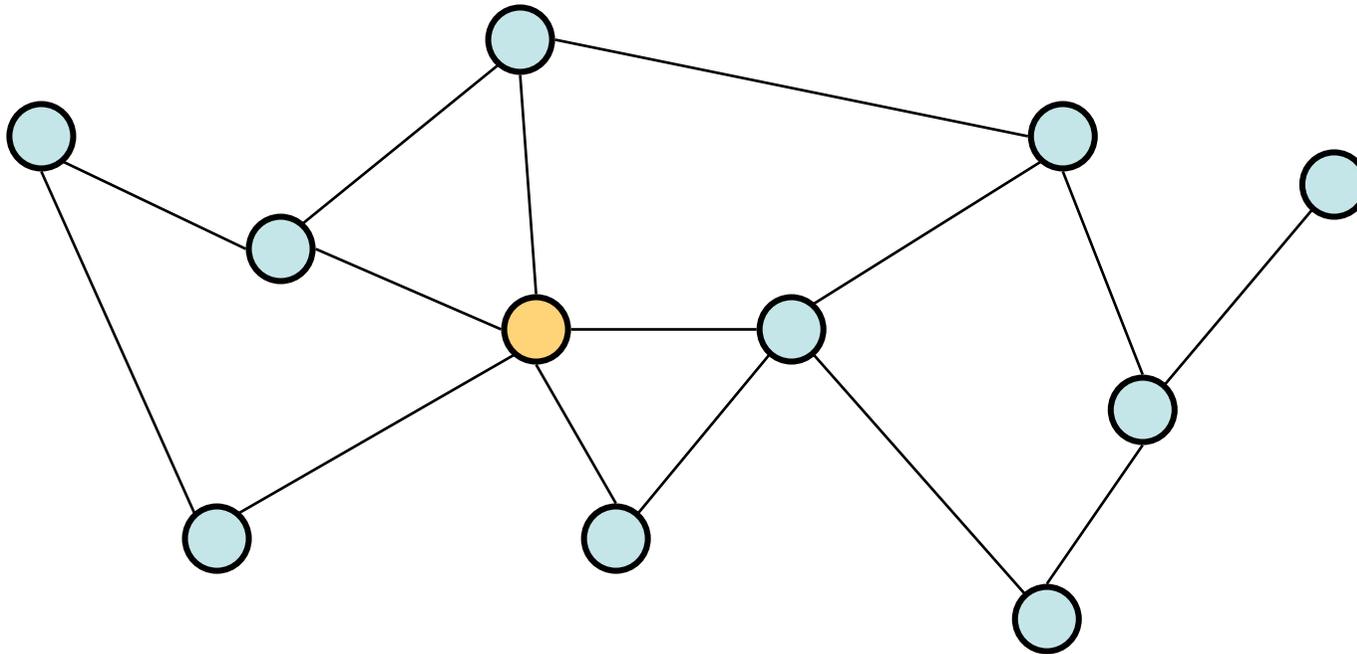




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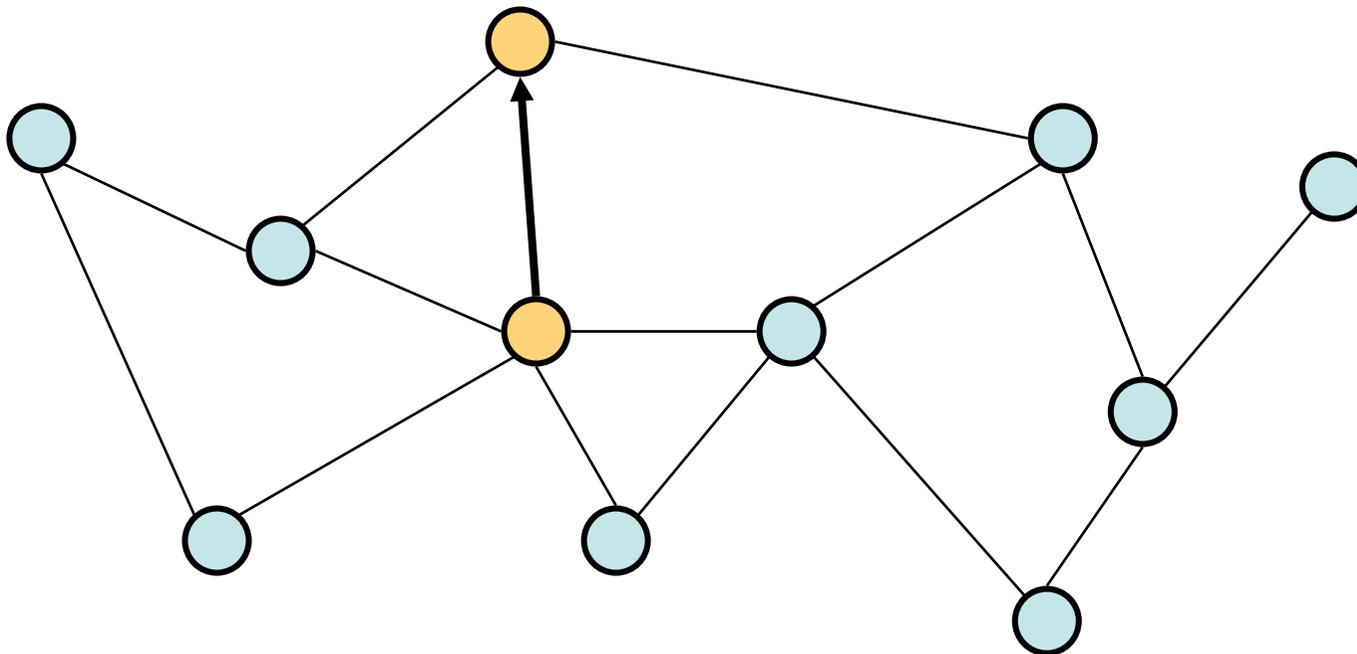




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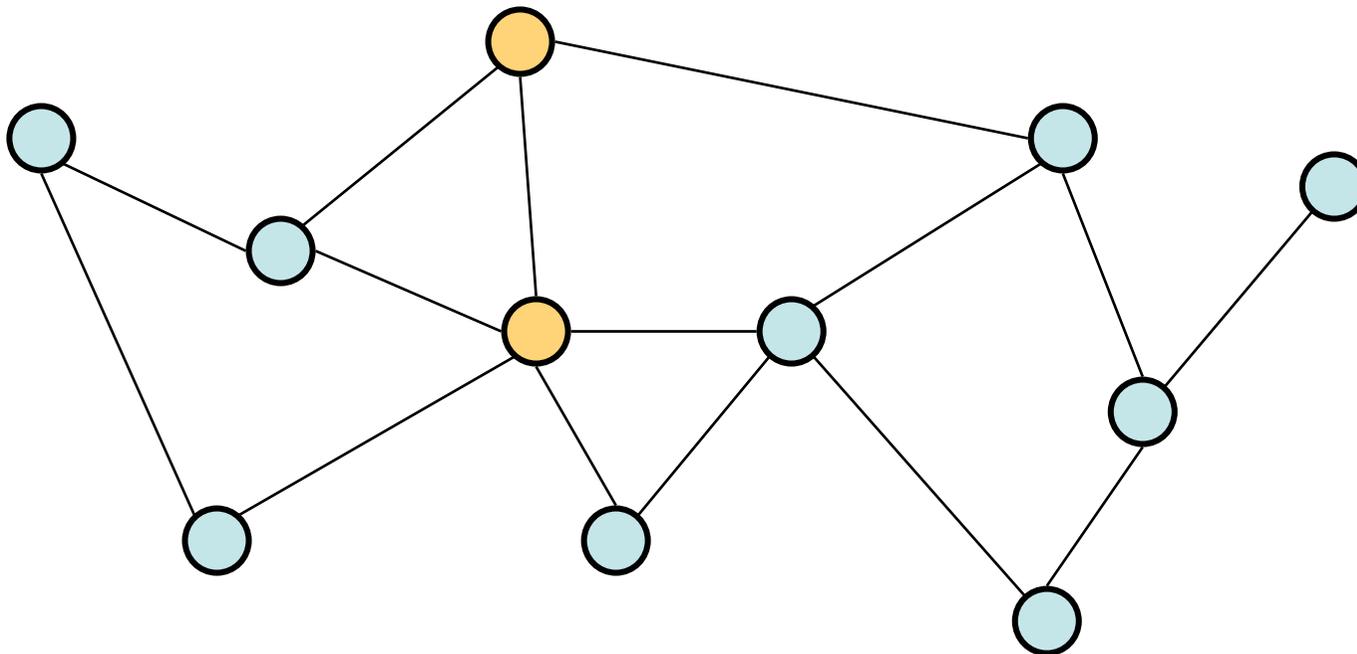




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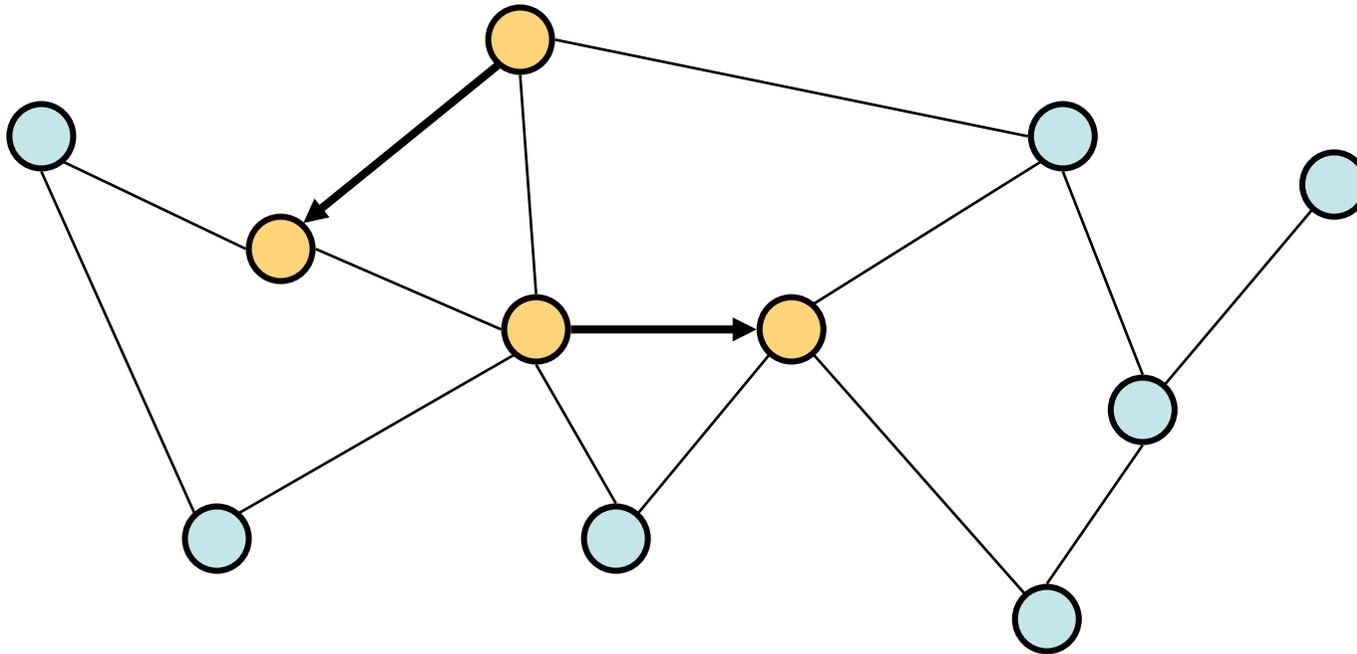




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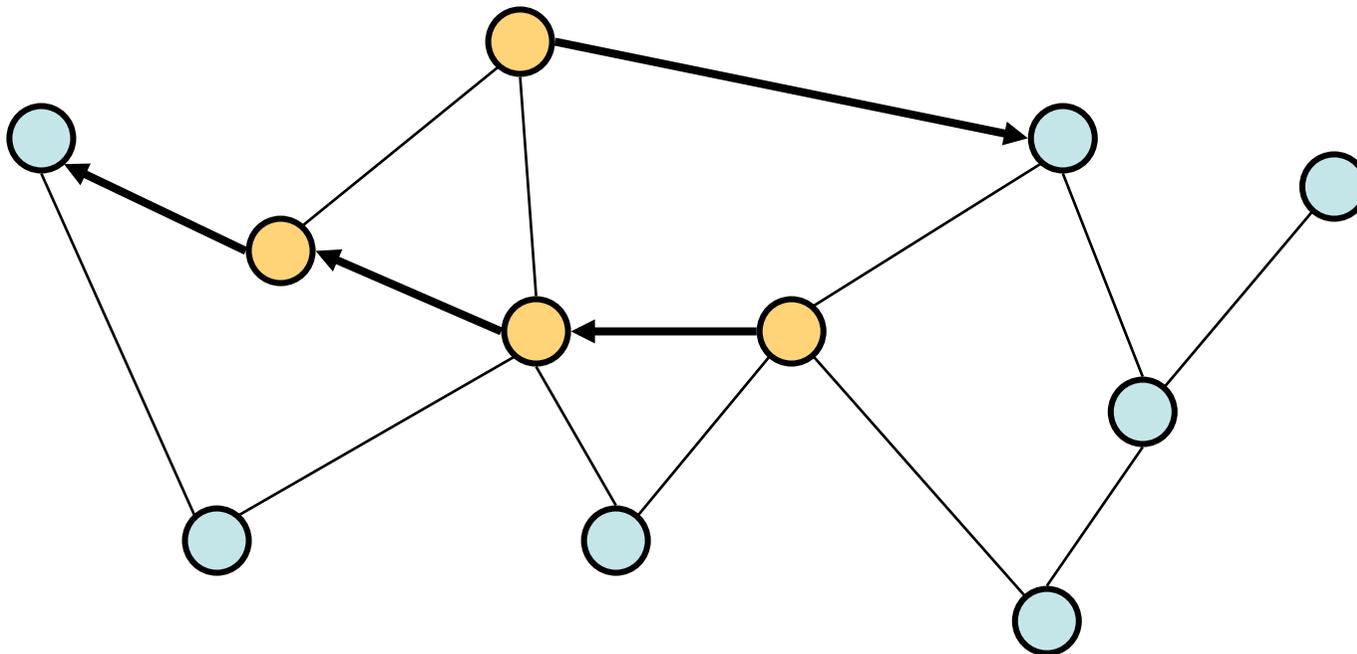




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Gossiping Variants



PUSH

Node with information sends to
a random neighbour



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Gossiping Variants



PUSH

Node with information sends to
a random neighbour



PULL

Node without
information asks a
random neighbour



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Gossiping Variants

PUSH-PULL



PUSH

Node with information sends to
a random neighbour



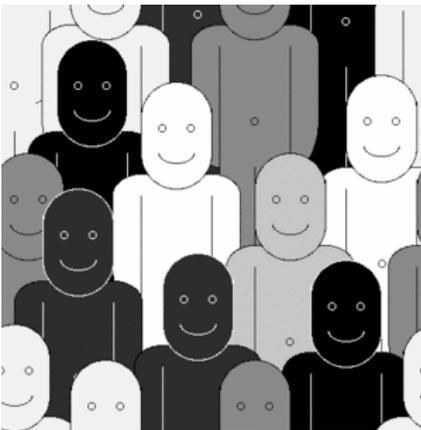
PULL

Node without
information asks a
random neighbour

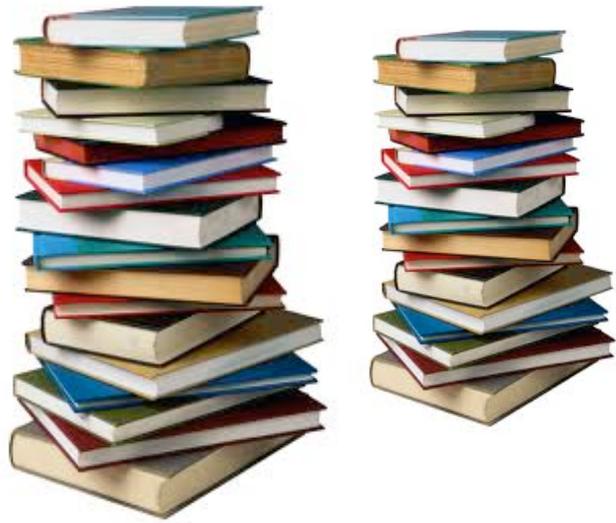
Motivation



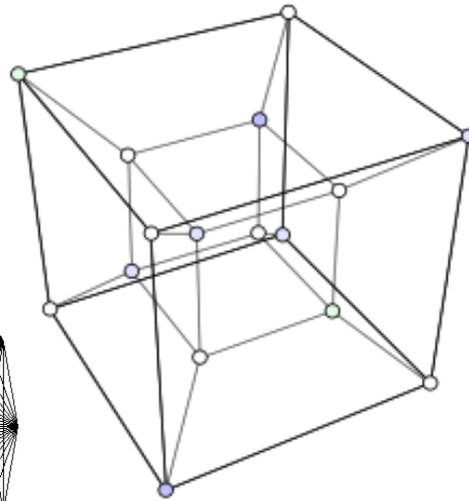
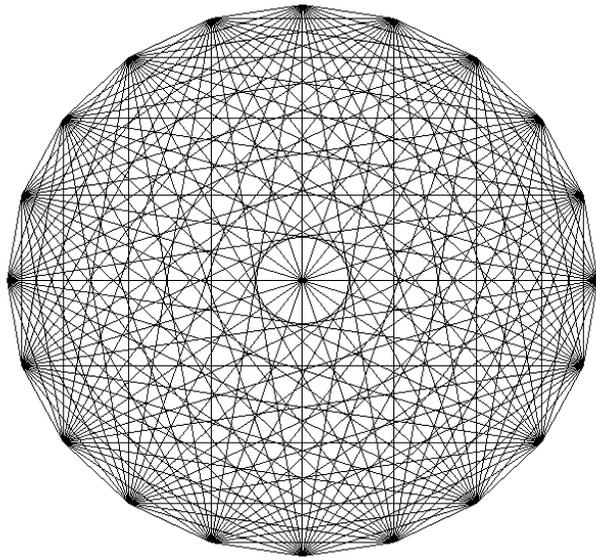
- **Technological:** Rumour spreading algorithms are widely used in communication networks which, more and more, are likely to exhibit a social dimension. This knowledge might be exploited for more efficient communication protocols

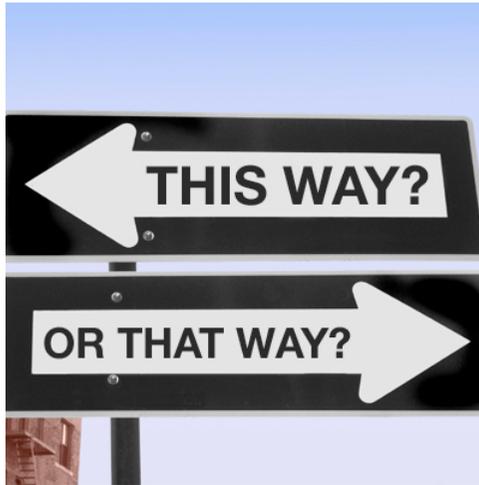


- **Sociological:** rumour spreading is a basic, simple form of a contagion dynamics. By studying it we hope to gain some insight into more complex diffusion phenomena



Previous Work





Different approach

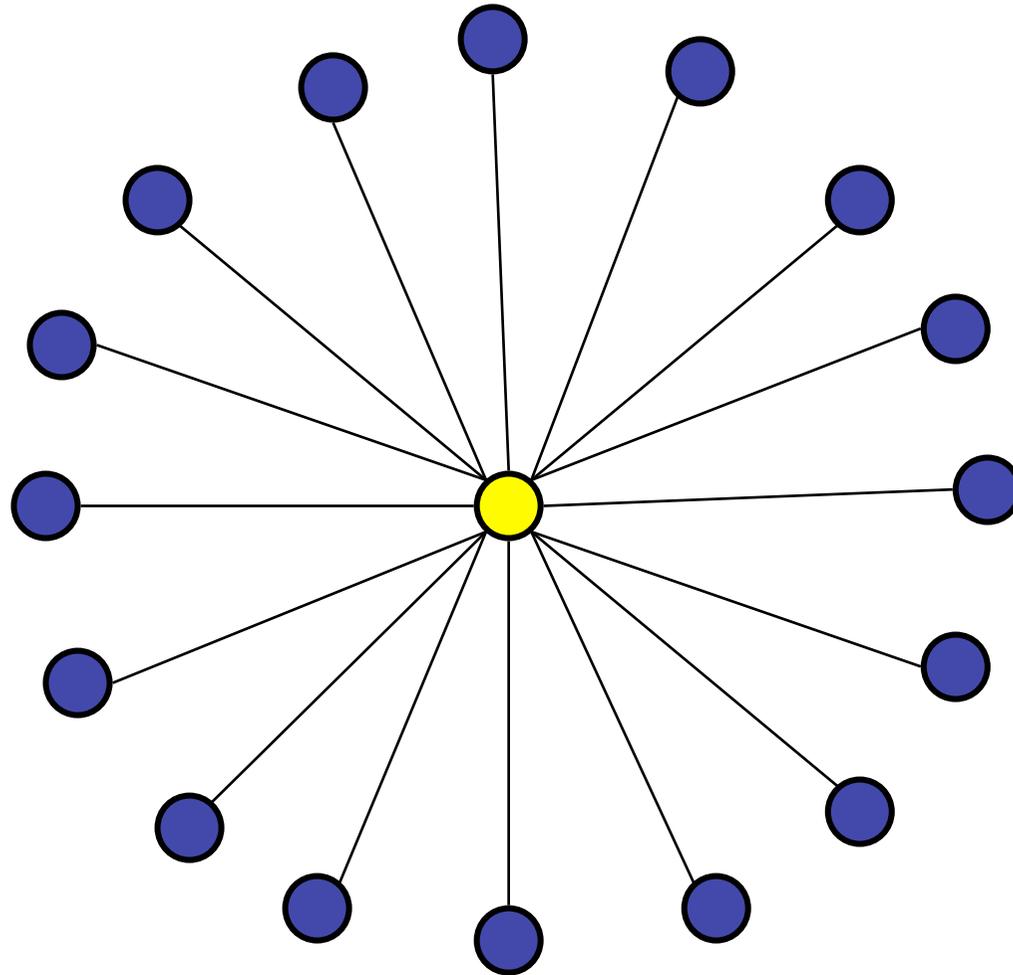
We are looking for necessary and/or sufficient conditions for rumour spreading to be fast in a given network



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Push

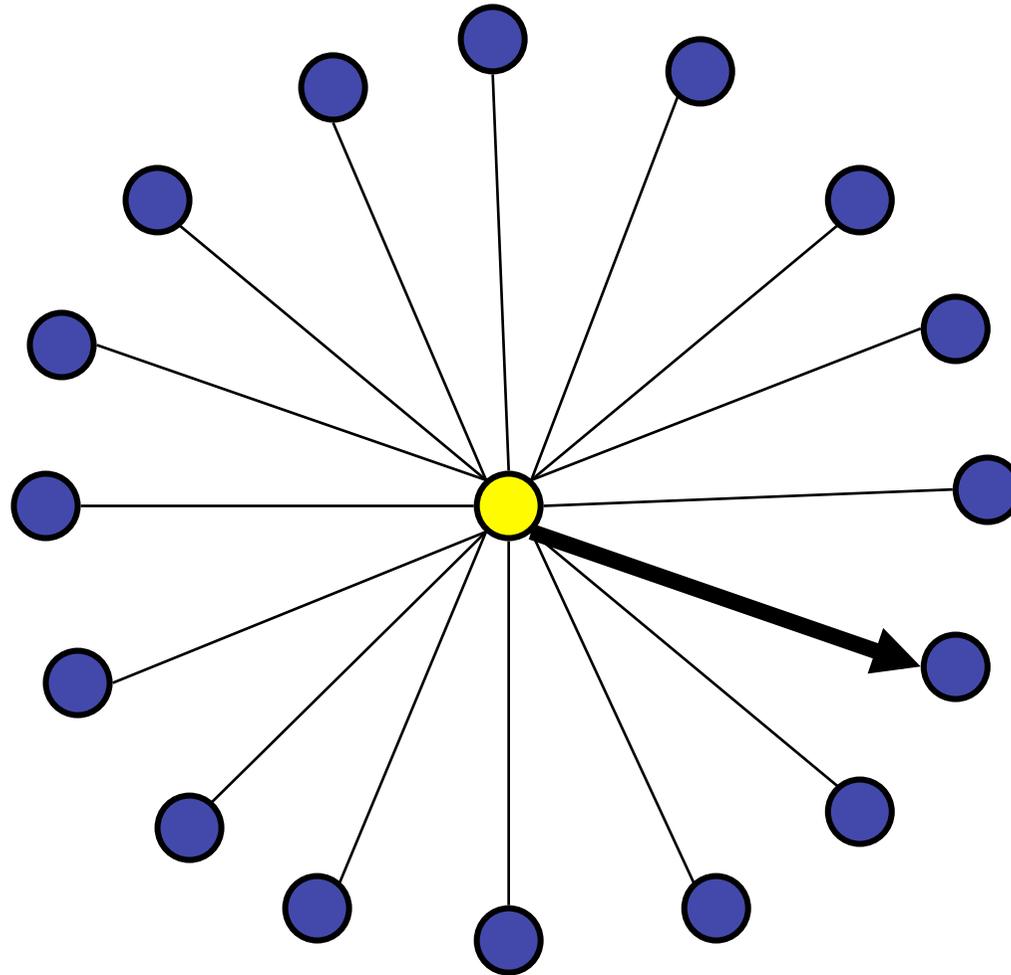




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Push

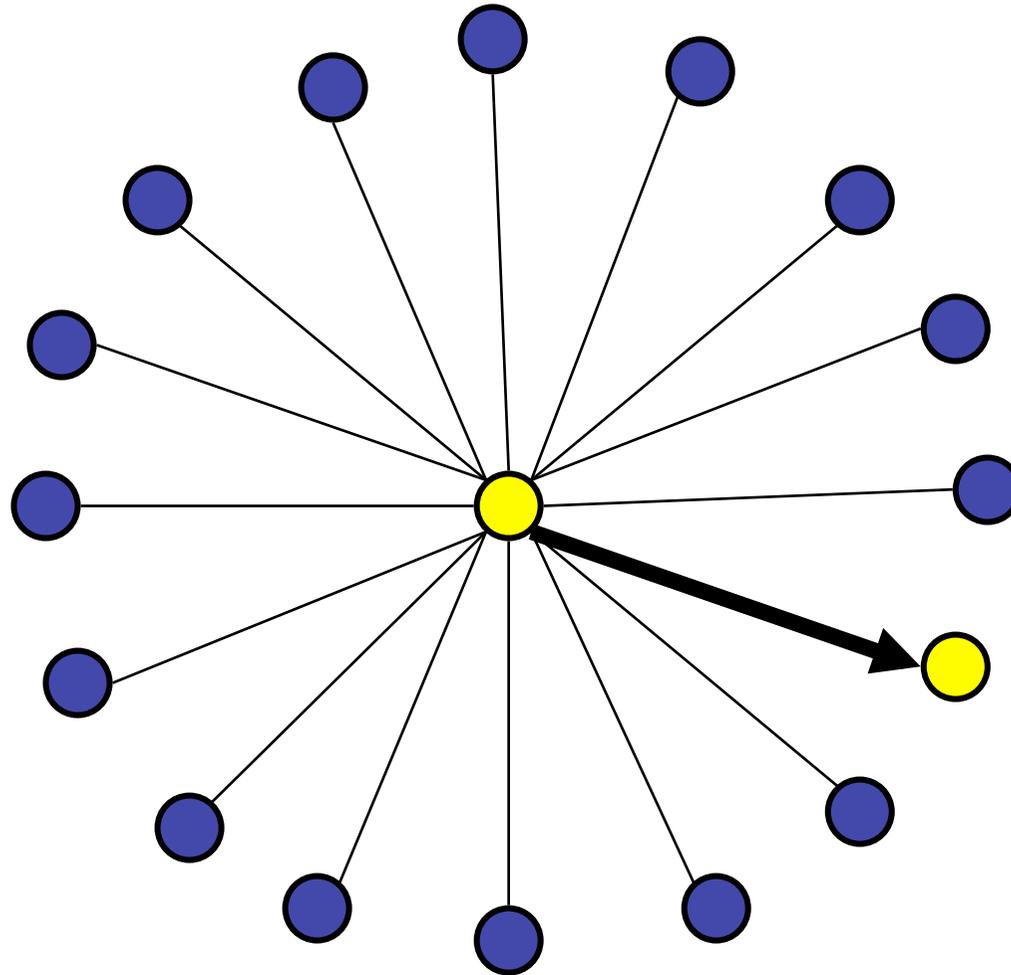




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Push

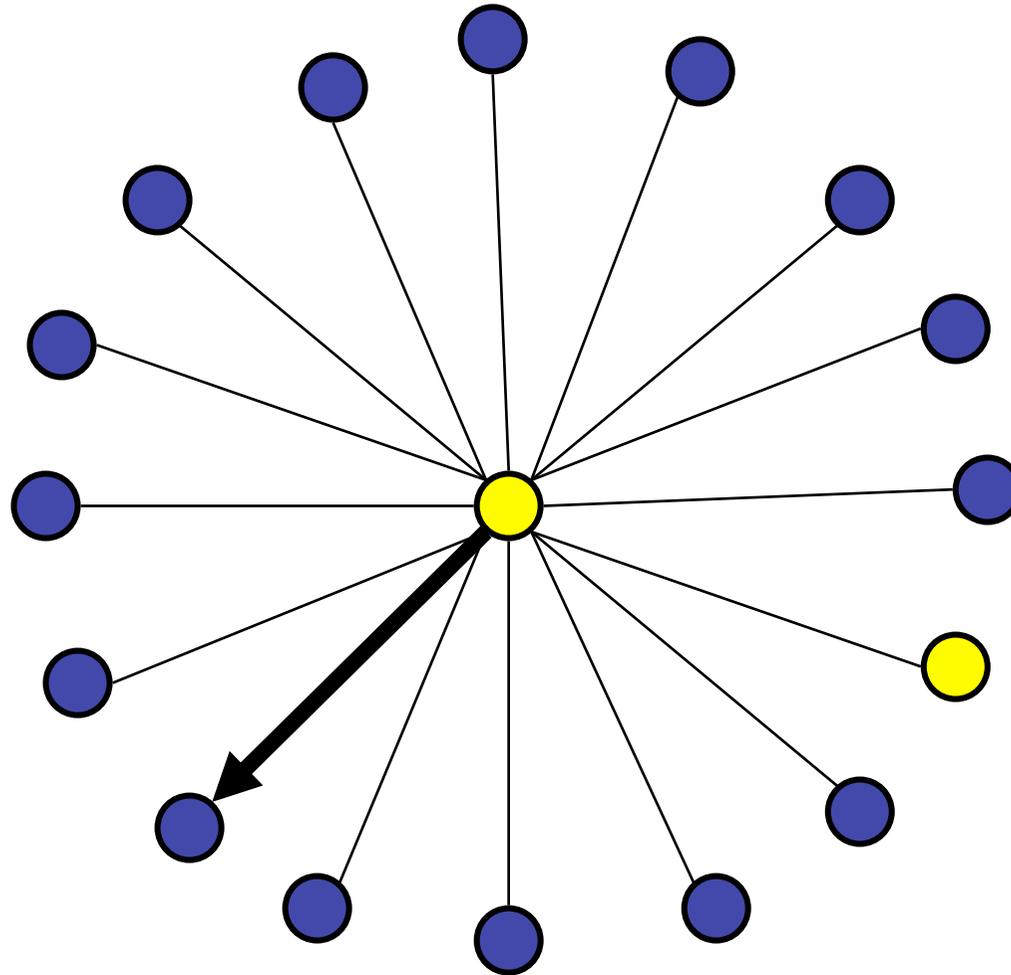




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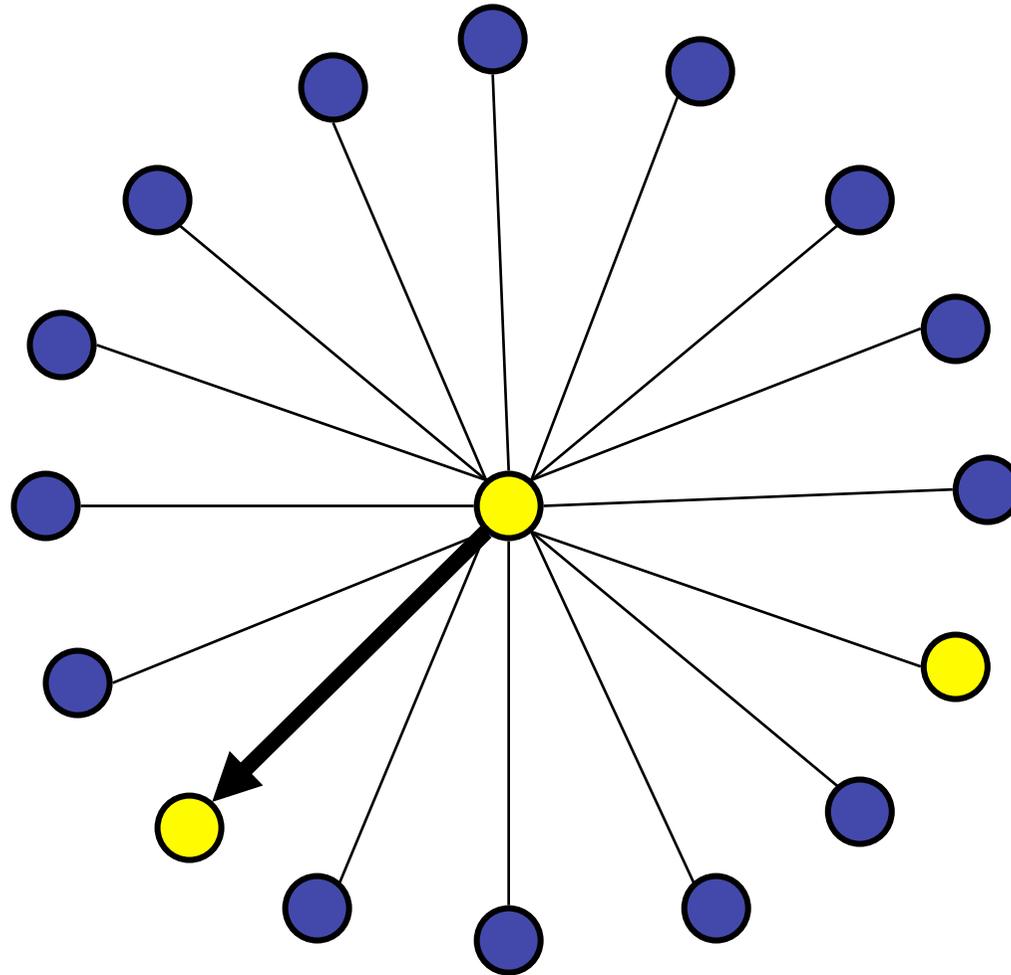




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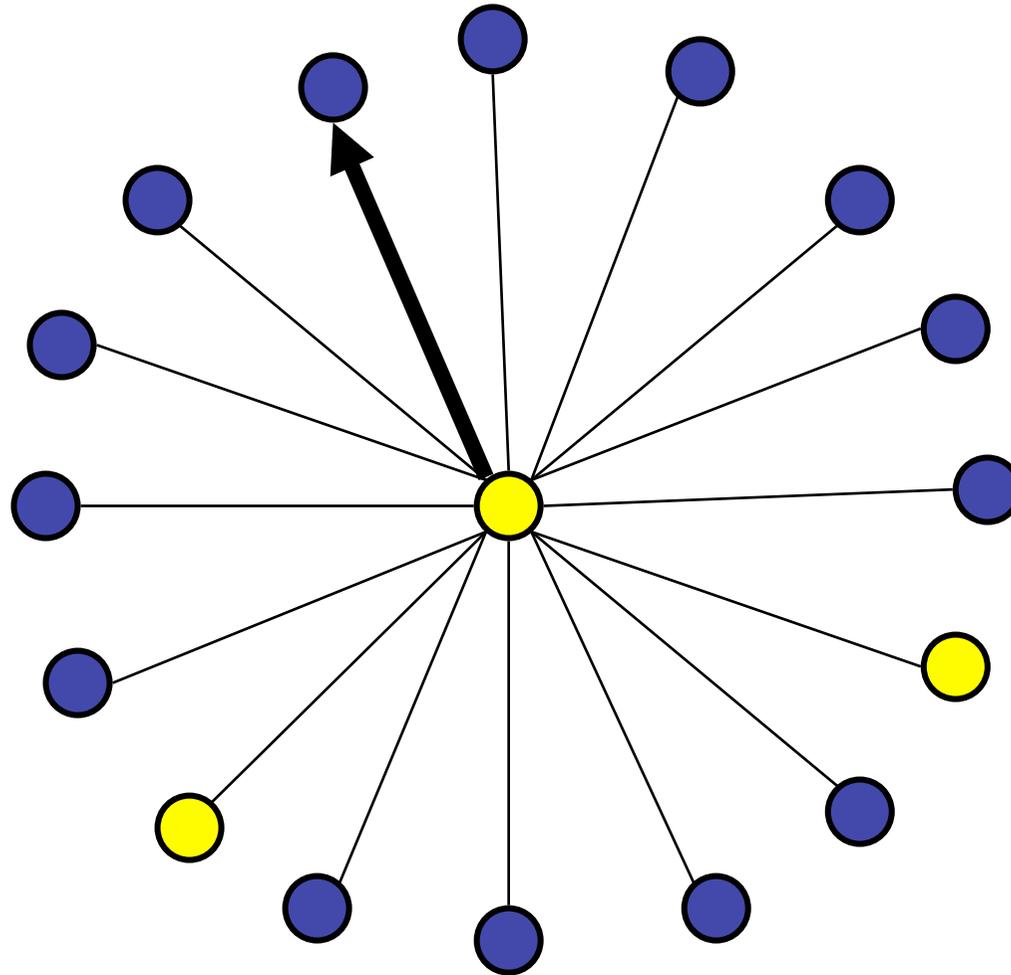




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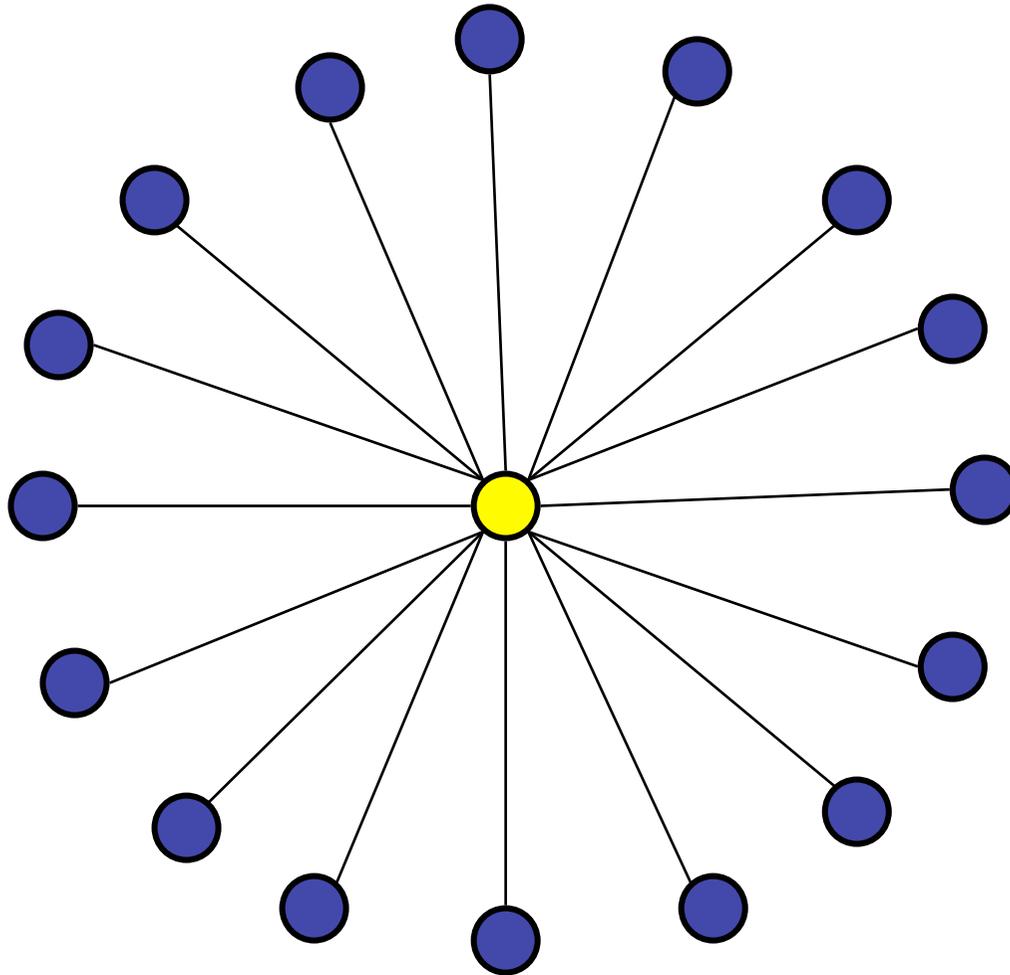




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Pull

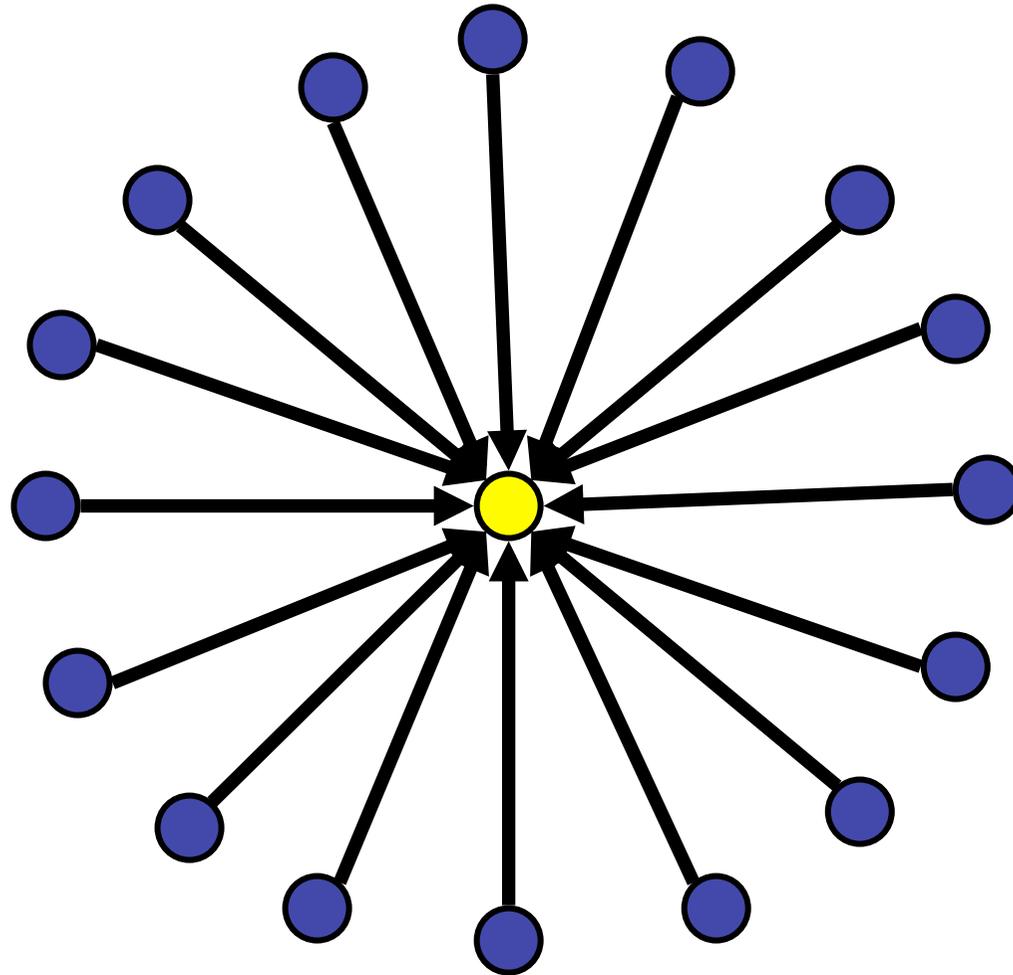




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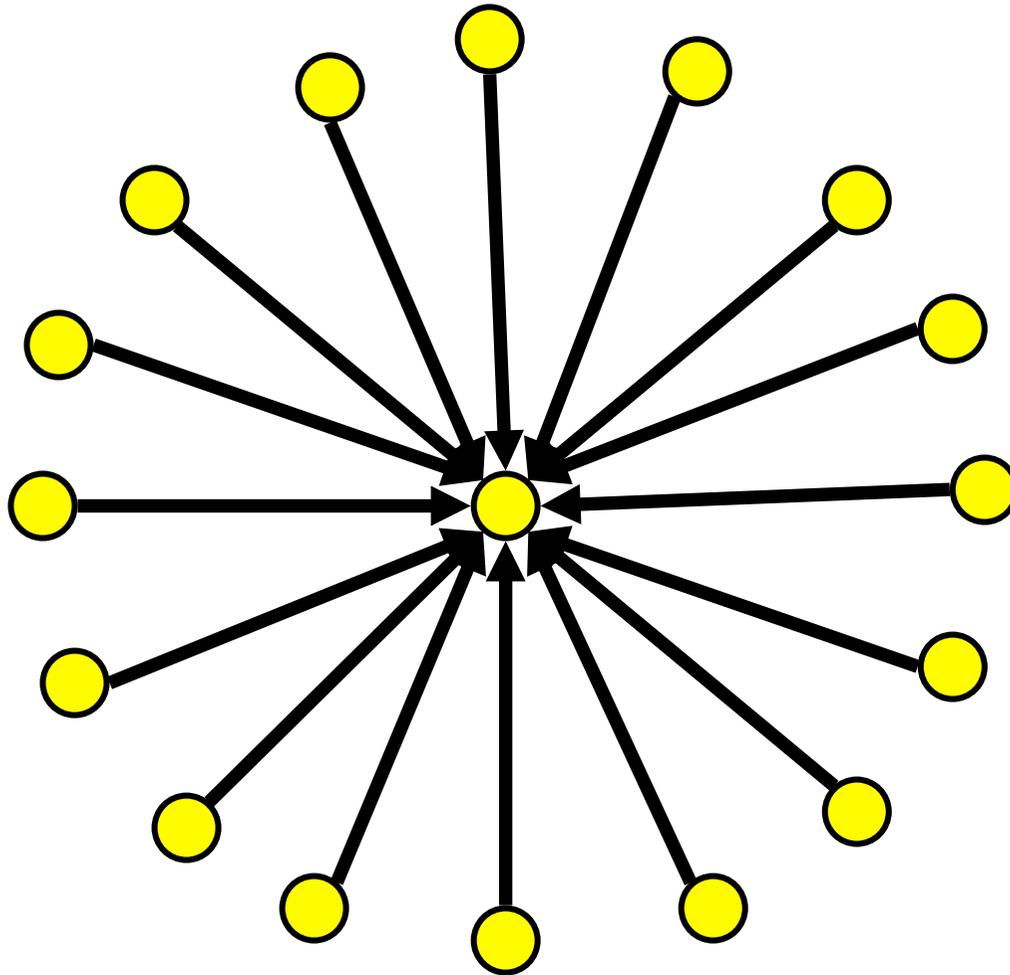




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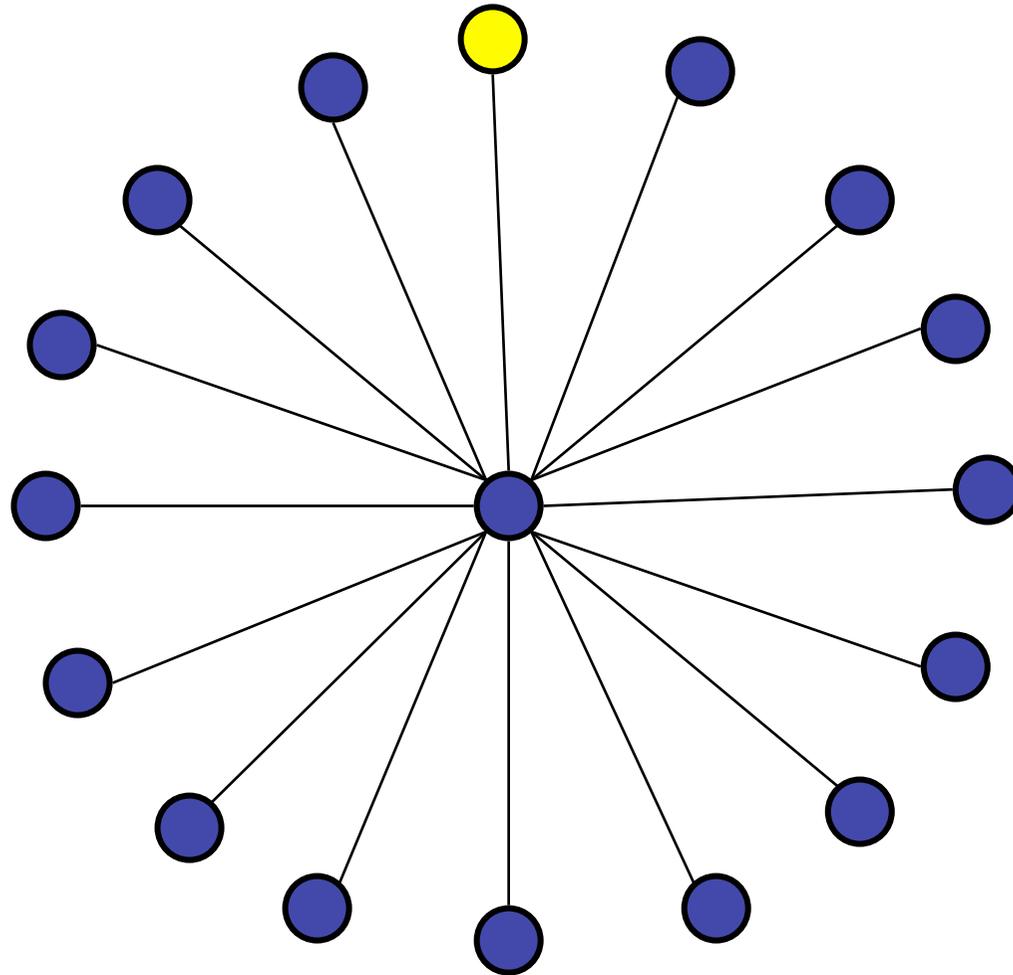




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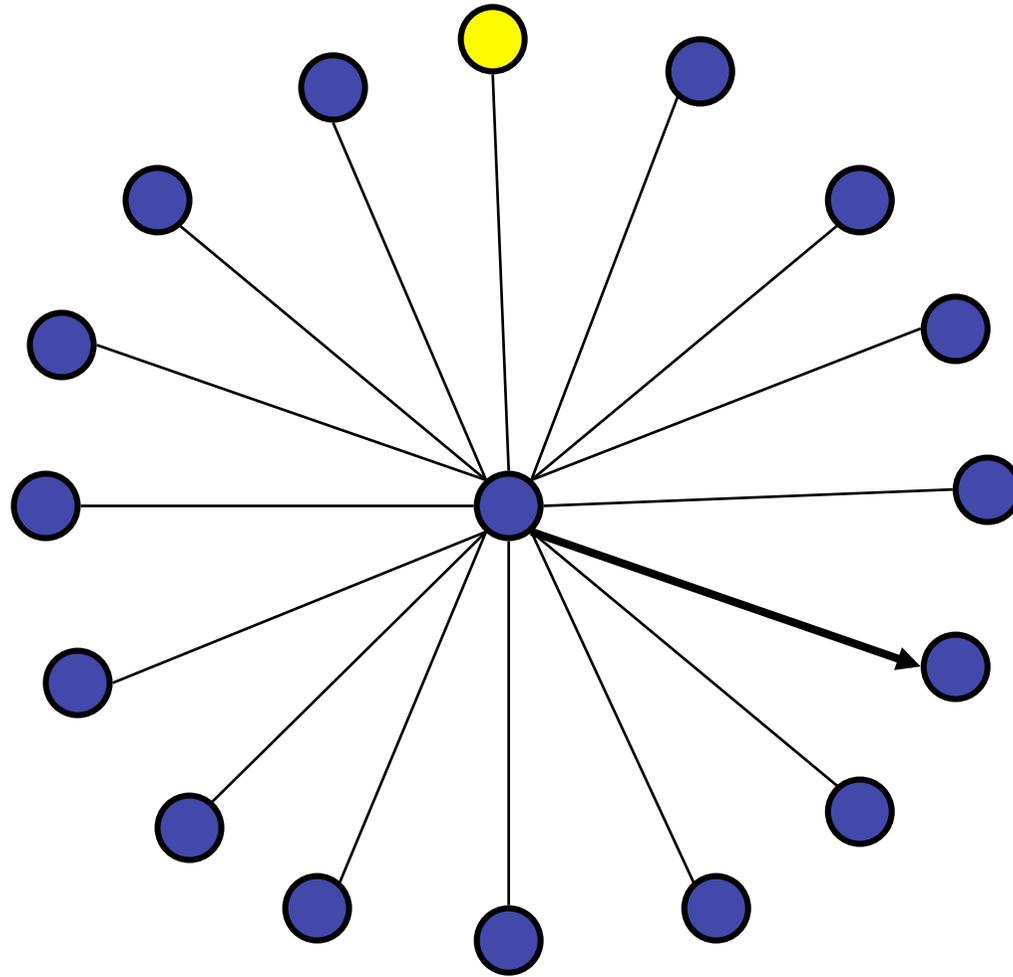




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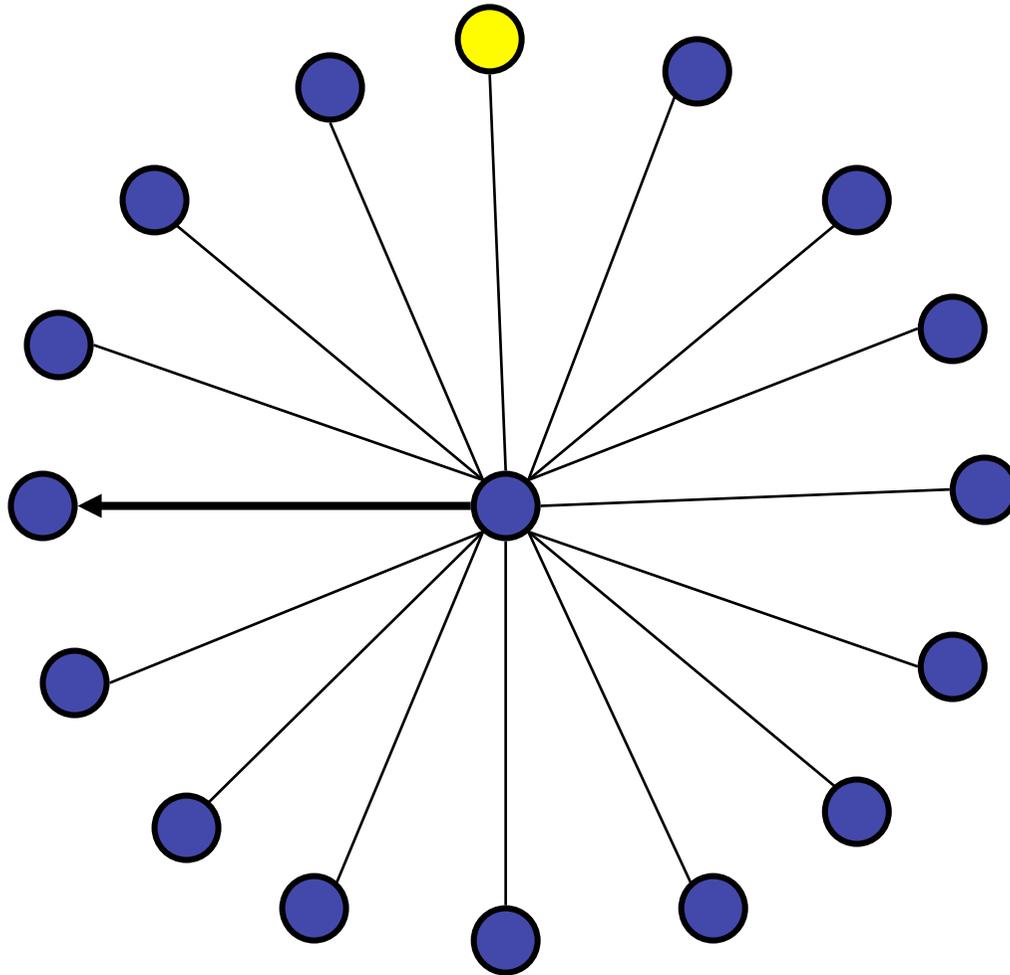


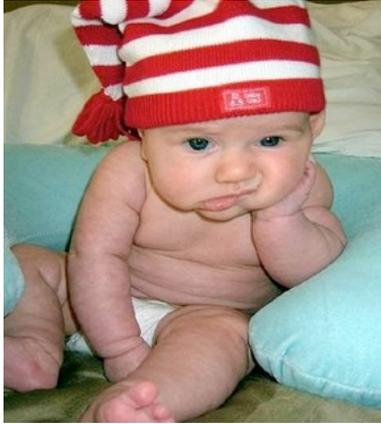


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Pull





Both Push and Pull are
hopeless



Therefore, we consider
Push-Pull, quite
appropriately in the Age of
the Internet

Push



Push



Pull



twitter

Push



Push-Pull

Pull



twitter



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OUR GOAL



Prove that **rumours** spread
quickly in a **social network**

Time is of the essence



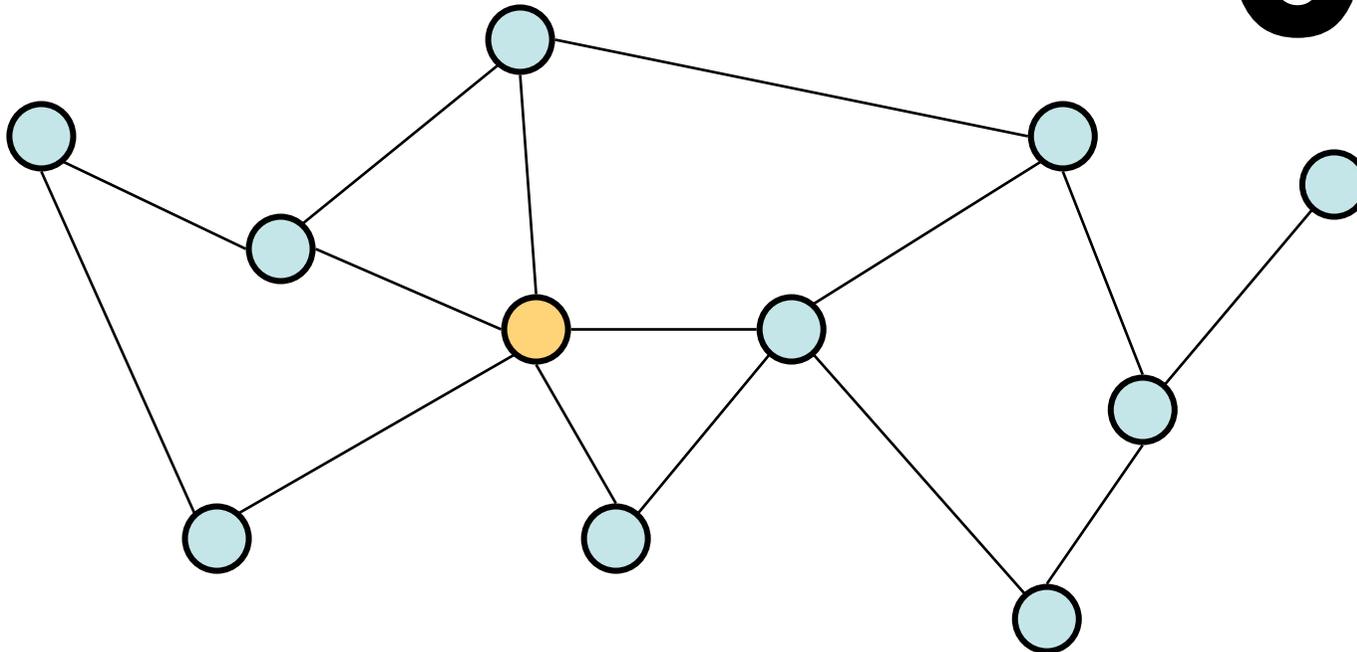


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Gossiping

0



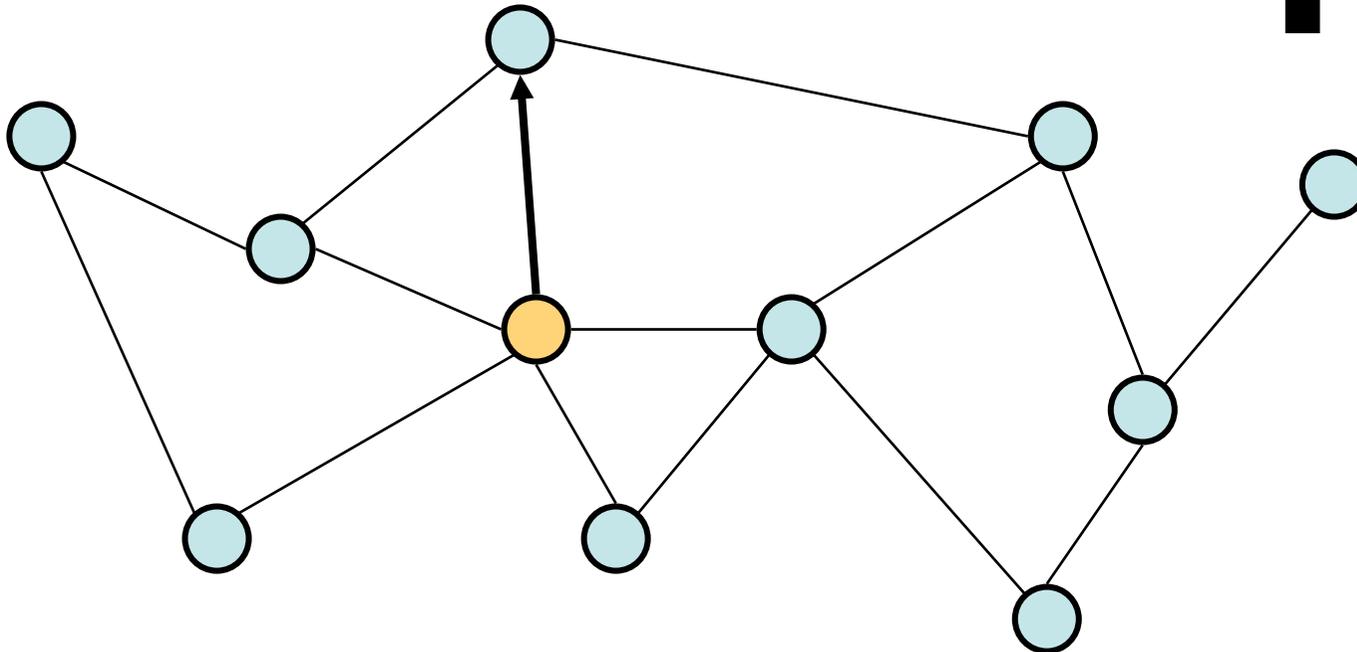


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Gossiping

1



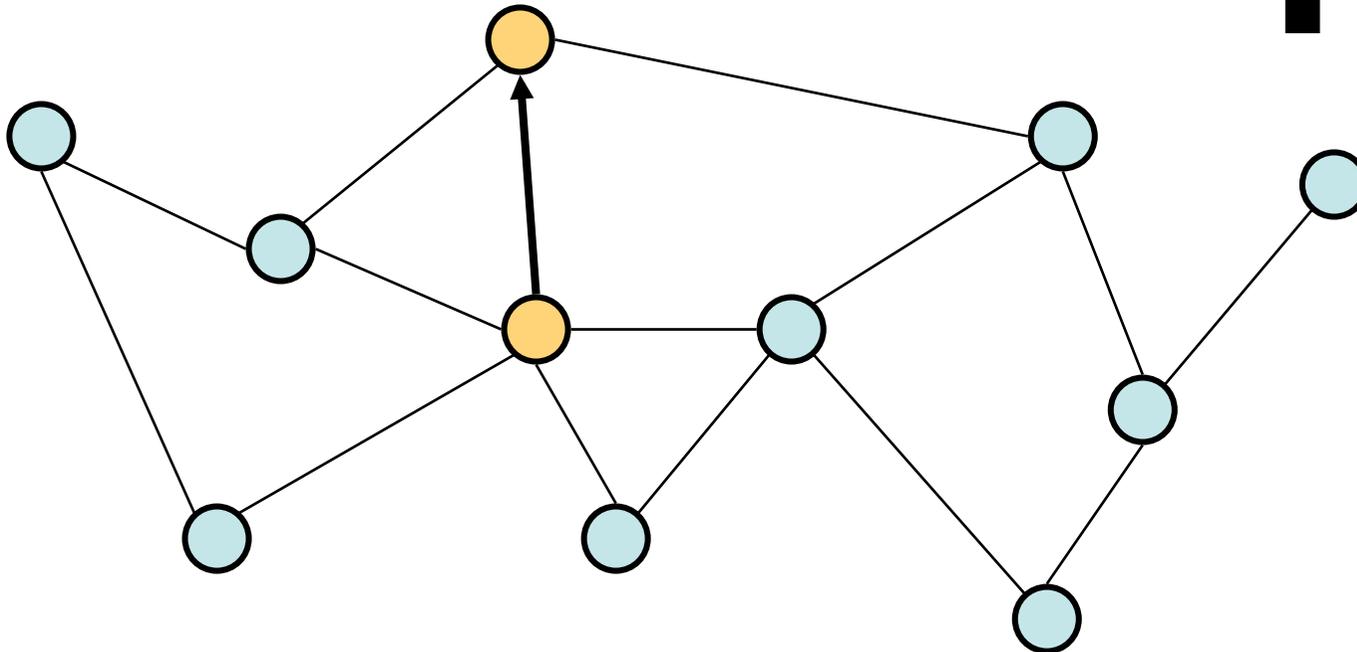


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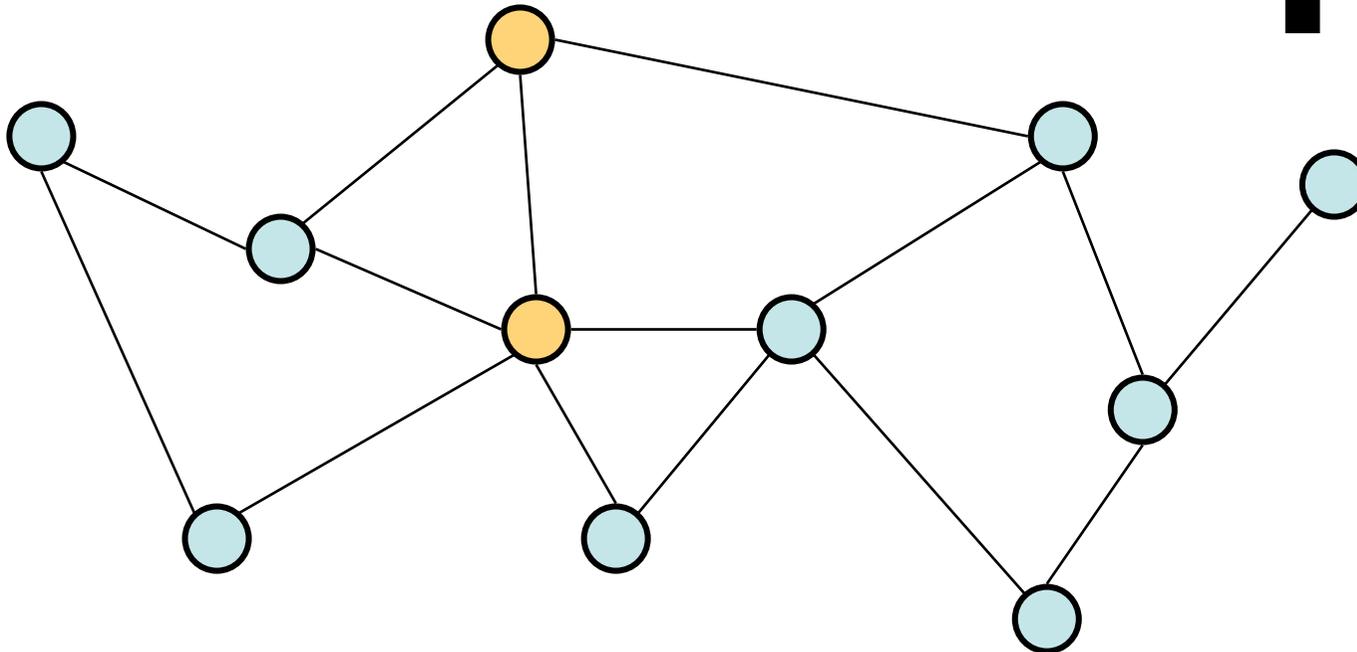


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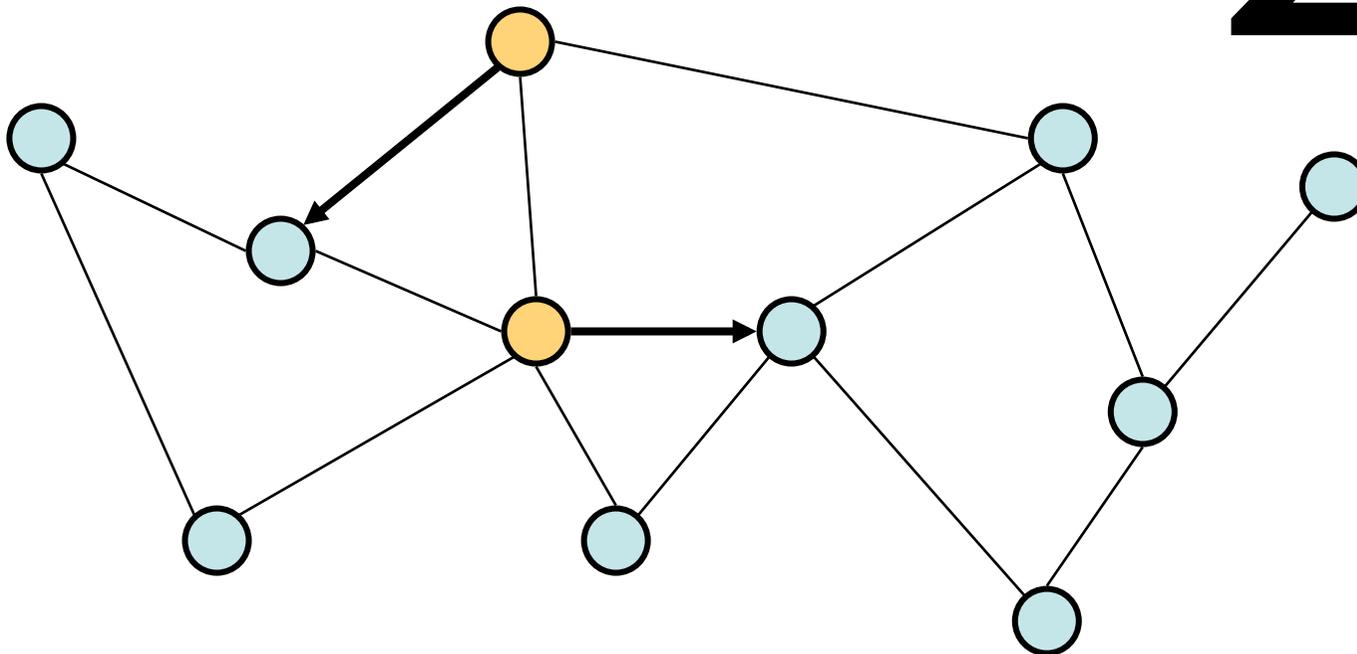


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2



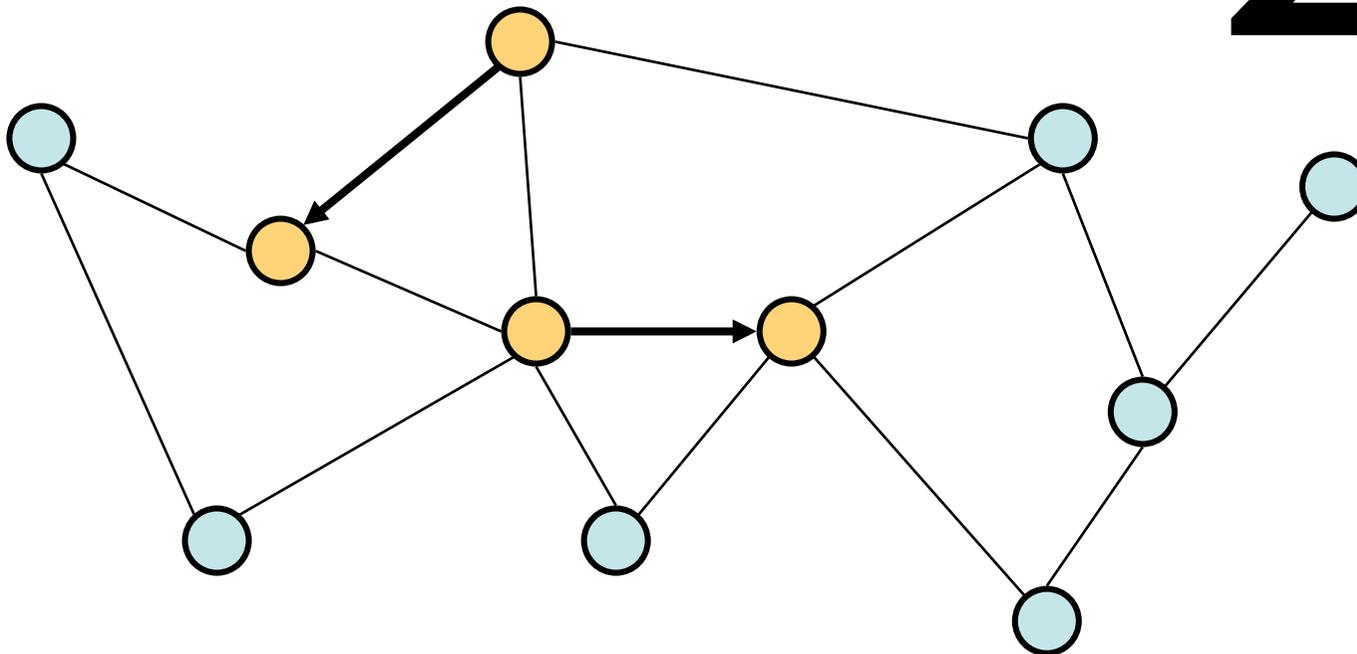


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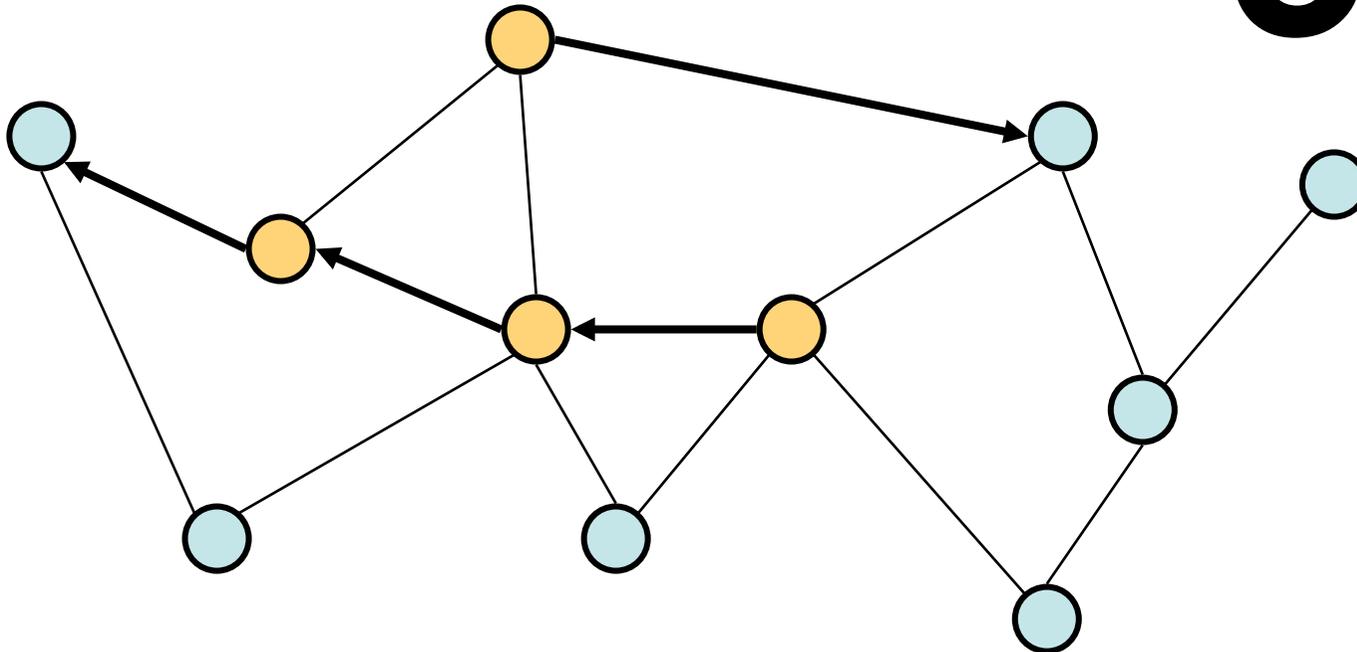


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Gossiping

3





Time is of the essence



Time = #rounds



Speed = Time is poly-logarithmic



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OUR GOAL

Prove that **rumours** spread
quickly in a **social network**



Recall our goal..

Prove that **rumours** spread
quickly in a **social network**

Problem formulation:

How many rounds will it take Push-Pull to broadcast
a message in a **social network**?

But..what is a social
network??

Argue about a model



Argue about a model



- **Chierichetti, Lattanzi, P [ICALP'09]**
Randomized broadcast is fast in PA graphs: with high probability, regardless of the source, push-pull broadcasts the message within $O(\log^2 N)$ many rounds

Argue about a model



- **Chierichetti, Lattanzi, P [ICALP'09]**
Randomized broadcast is fast in PA graphs: with high probability, regardless of the source, push-pull broadcasts the message within $O(\log^2 N)$ many rounds
- **Dörr, Fouz, Sauerwald [STOC'11]**
show optimal $\Theta(\log N)$ bound holds



Argue about a model

However, there is no accepted model for social networks...

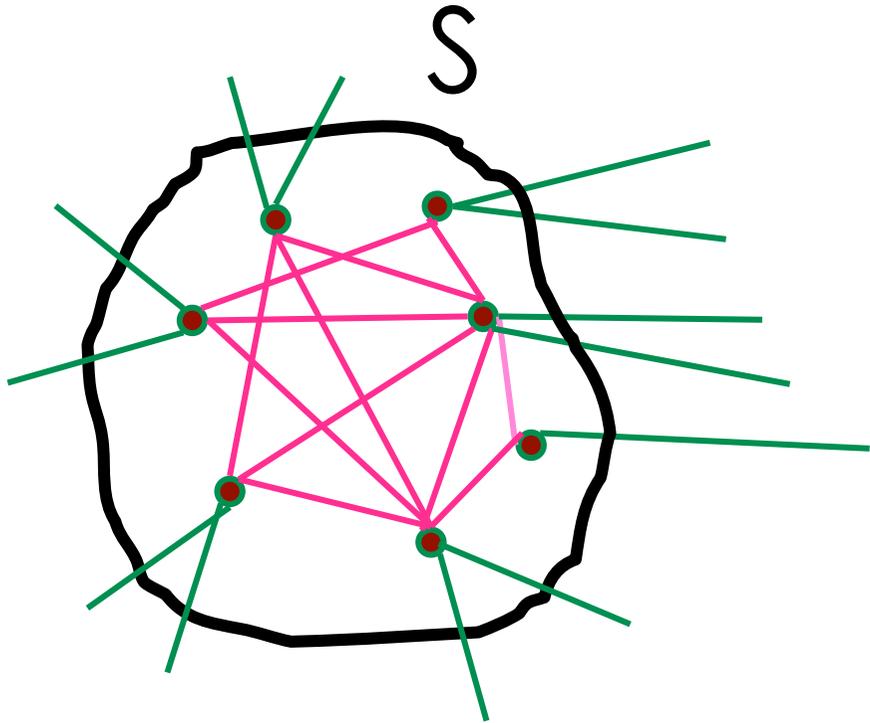




Empiricism to the rescue

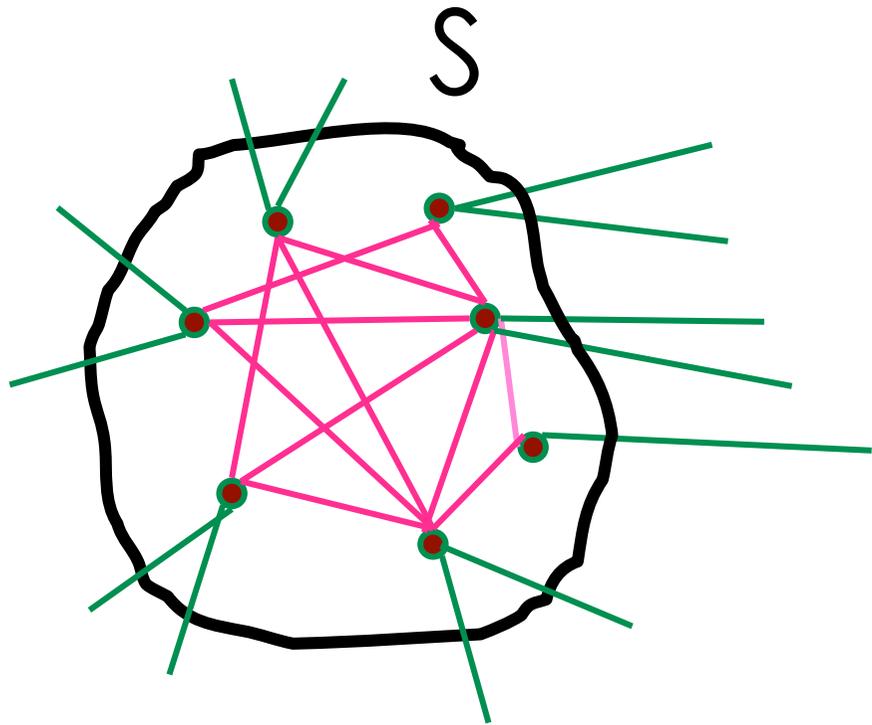
Leskovec et al [WWW'08] show that real-world networks (seem to) enjoy **high conductance** (in the order of $\log^{-1} N$)

Conductance



$$\text{vol}(S) = \sum_{v \in S} d_v = \text{green edges} + 2 \times \text{red edges}$$

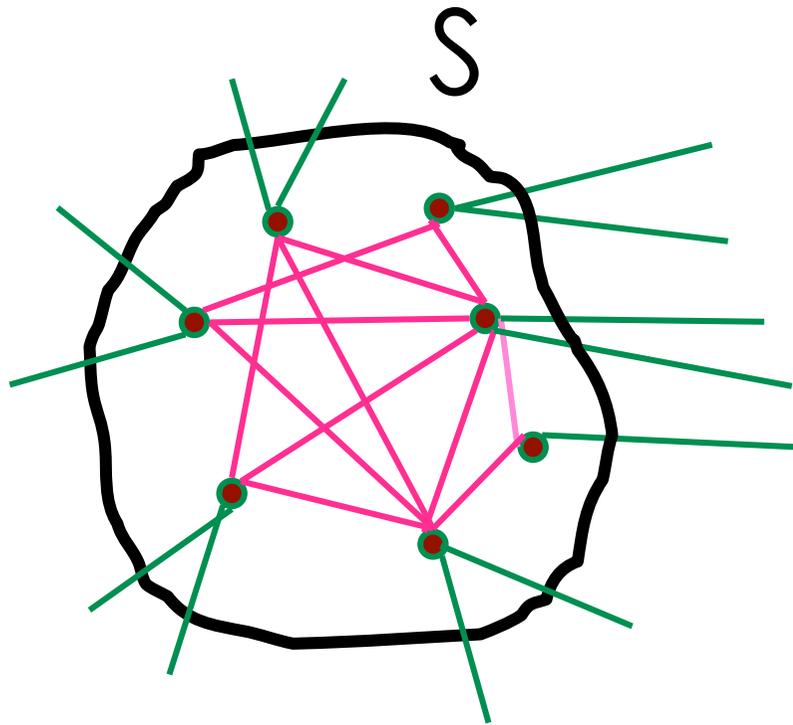
Conductance



$$\varphi(S) = \frac{\text{cut}(S)}{\text{vol}(S)}$$

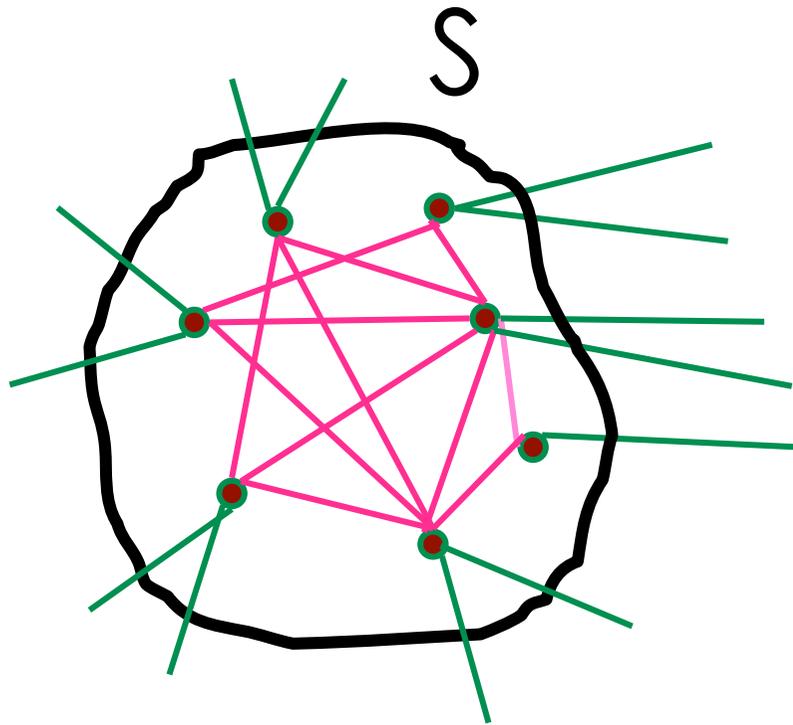
$$\text{vol}(S) = \sum_{v \in S} d_v = \text{green edges} + 2 \times \text{red edges}$$

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$$\varphi(G) := \min_S \varphi(S)$$

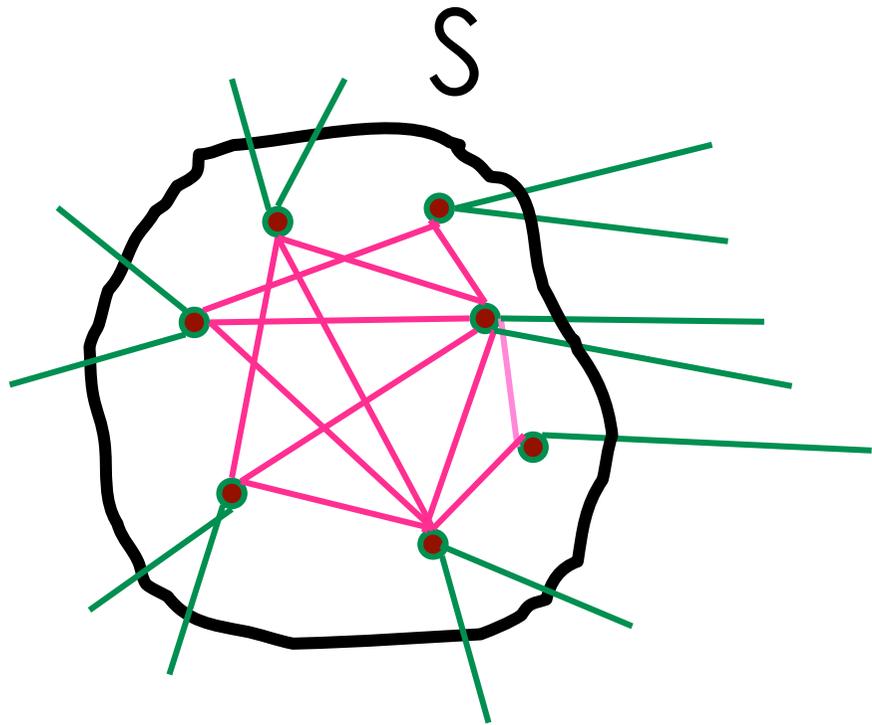
Conductance



$$\varphi(G) := \min_S \varphi(S)$$

$$\text{caveat: } \text{vol}(S) \leq \frac{1}{2} \text{vol}(V)$$

Conductance



$$\Pr(\text{pebble leaves } S | \text{pebble in } S) = \phi(S)$$



Our Goal finally
becomes..

**Prove that if a network has
high conductance then
rumours spread quickly**



Our Goal finally
becomes..

**Prove that if a network has
high conductance then
rumours spread quickly
assuming a worst case
source**



Results

Chierichetti, Lattanzi, P [SODA'10] With high probability, regardless of the source, push-pull broadcasts the message within

$$O(\log^4 N / \Phi^6)$$

many rounds



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Chierichetti, Lattanzi, P [STOC'10] Improved to $O(\Phi^{-1} \log N \log^2 \Phi^{-1})$



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Chierichetti, Lattanzi, P [STOC'10] Improved to $O(\Phi^{-1} \log N \log^2 \Phi^{-1})$

Giakkoupis [STACS'11] Improved to $O(\Phi^{-1} \log N)$



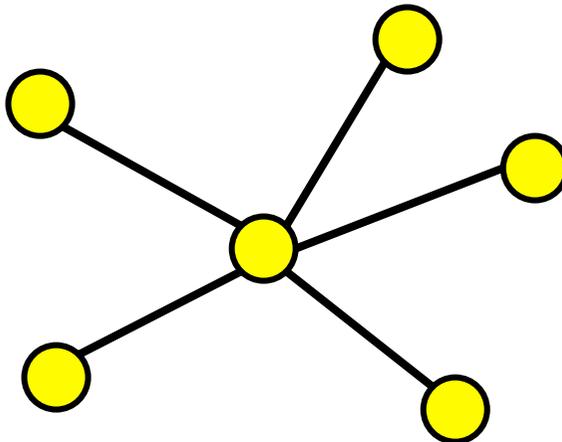
Results

$$\Theta(\Phi^{-1} \log N)$$



Variations on the theme

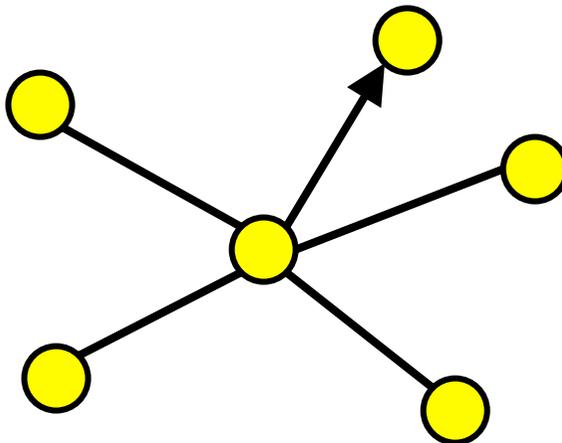
Dörr, Fouz, Sauerwald [STOC'11] Time for Push-Pull in PA graphs becomes $O(\log N / \log \log N)$ if random choice excludes last used neighbour





Variations on the theme

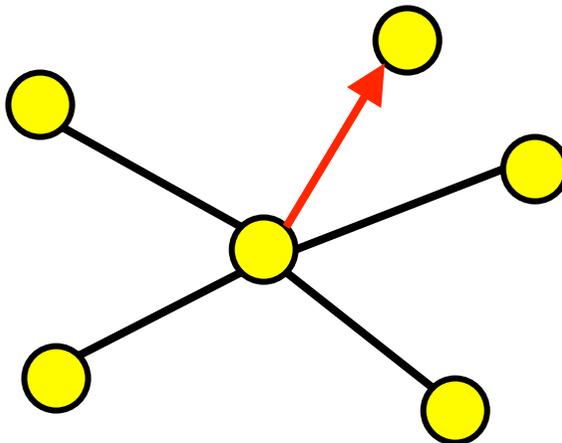
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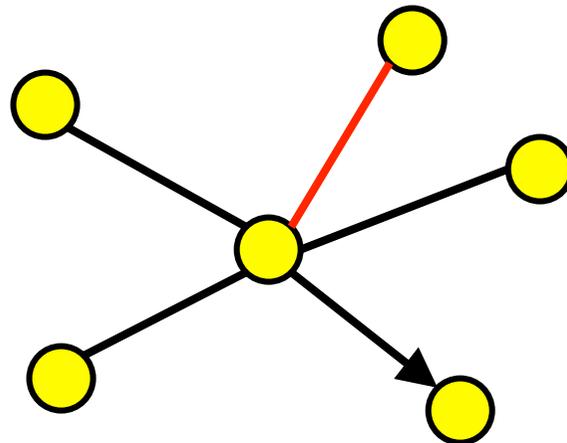
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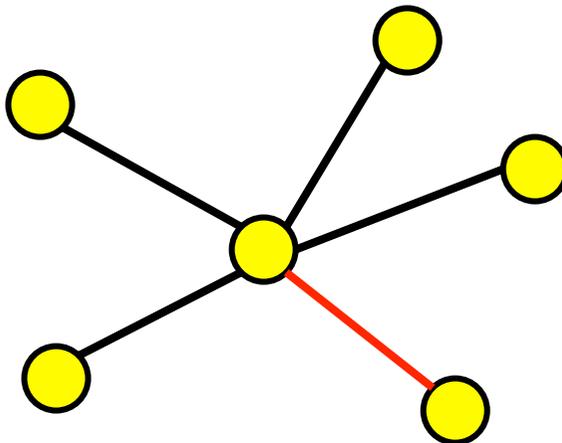
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Variations on the theme

Fountoulakis, Panagiotou, Sauerwald [SODA'12] In power law graphs (Chung-Lu)

- With $2 < \alpha < 3$ $O(\log \log N)$ rounds are sufficient, with high probability, for Push-Pull to reach a $(1-\epsilon)$ fraction of the network, starting from a random source
- If $\alpha > 3$ then $\Omega(\log N)$ rounds are necessary, with high probability



Variations on the theme

Giakkoupis, Sauerwald [STOC'11] For graphs with vertex expansion at least λ Push-Pull takes

- At most $O(\lambda \log^{5/2} N)$ rounds to reach every node, with high probability
- At least $\Omega(\lambda \log^2 N)$ rounds, with positive probability

To summarize

- There is a close connection between conductance (and other expansion properties) and rumour spreading
- Since social networks enjoy high conductance, this by itself ensures that rumours will spread fast



Things to come

- Rumour spreading without the network
- Rumour spreading in evolving graphs

THANKS

