A Probabilistic Approach to Rumor Source Detection and Graph-based Message Passing Algorithms

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Motivation

Rumors

Source: Bloomberg

NAE GRAND CHALLENGES FOR ENGINEERING

All engineering approaches to achieving security must be accompanied by methods of monitoring and quickly detecting any security compromises. And then once problems are detected, technologies for taking countermeasures and for repair and recovery must be in place as well. Part of that process should be new forensics for finding and catching criminals who commit cybercrime or cyberterrorism.

Challenge No. 8: Secure Cyberspace

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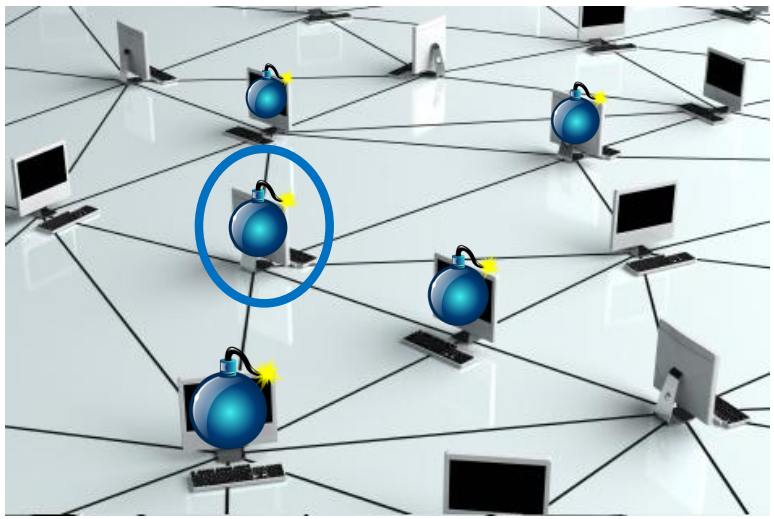
WHO IS THE CULPRIT?

■ Spread of computer virus



■ Tweeting and Retweeting in Twitter Network

- A dynamical process, e.g., rumor, virus, spreads on a network
- SI (Susceptible-Infectious) model [Kermack & McKendrick'1927]
- Observe prior suspect set and infected nodes
- Can we find the spreading source accurately and reliably?

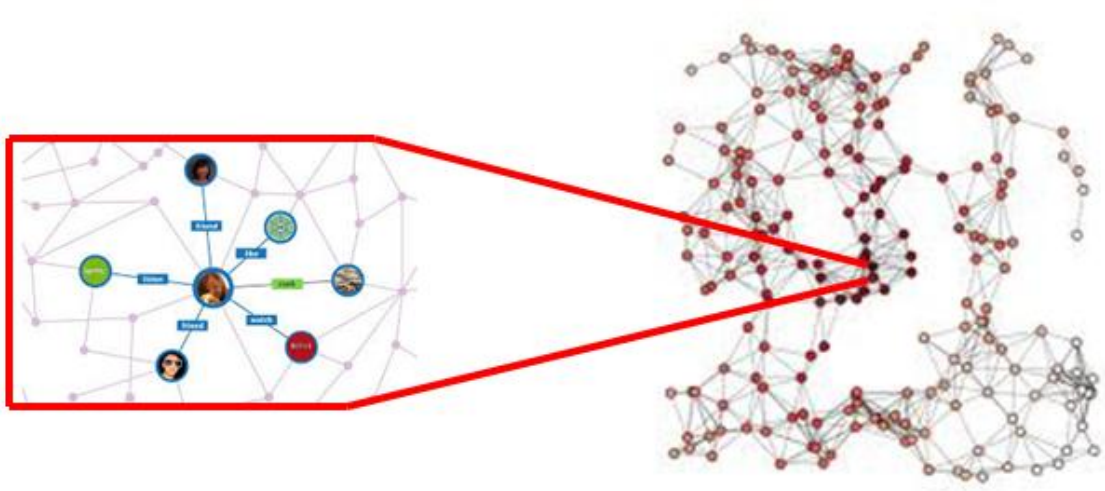
Rumor Source Estimator

Maximum likelihood (ML) estimator

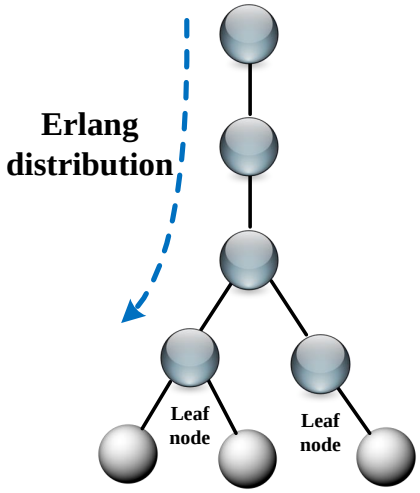
$$\hat{v} \in \arg\max_{v \in G_N} P(G_N \mid v, T),$$

where $P(G_N \mid v, T)$ is the probability of observing G_N at time T supposing that v is the rumor source.

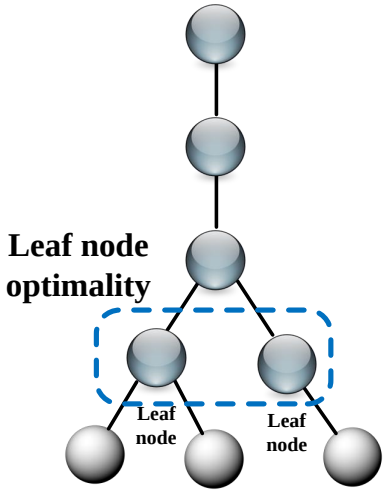
$\Rightarrow$ Most likely source is at the "center" of the network!



ML ESTIMATOR FOR TREE GRAPHS



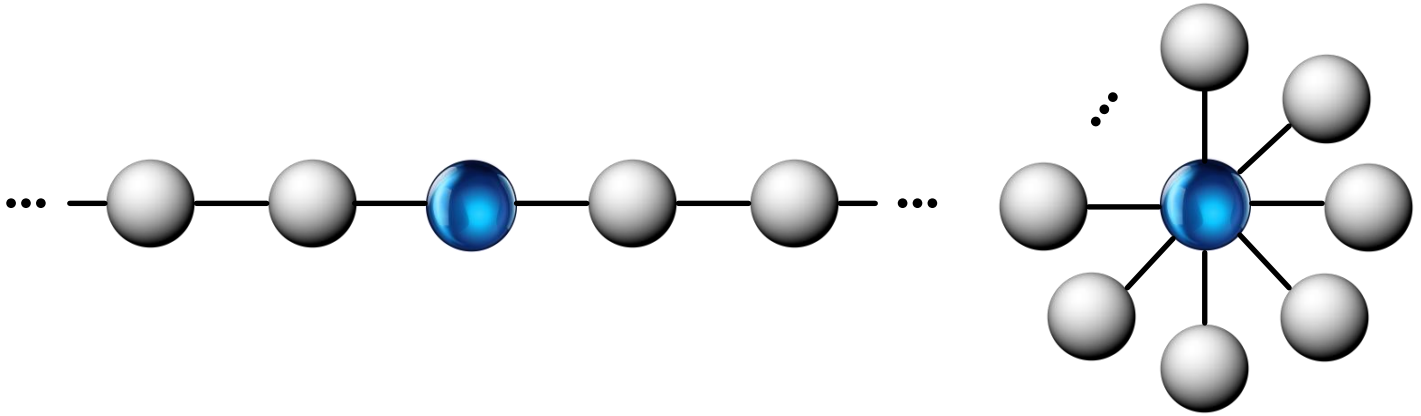
$$P\left(v_i \bigcap_{v_l \in \text{child}(v_i)}^{L} \bar{v}_l \,\middle|\, v_j\right) = \int_0^T \frac{t^{K_{ij}-1} e^{-t}}{(K_{ij}-1)!} e^{-(T-t)(d_i-1)} \mathrm{d}t$$



$$\hat{v} \in \arg\max_{v \in G_N} P(G_N \mid v, T)$$

$$= \arg\max_{v \in G_N} \prod_{v_i \in \text{leaf}(G_N|v)}^{L} P\left(v_i \bigcap_{v_l \in \text{child}(v_i)}^{L} \bar{v}_l \,\middle|\, v\right)$$

Special Optimality Condition

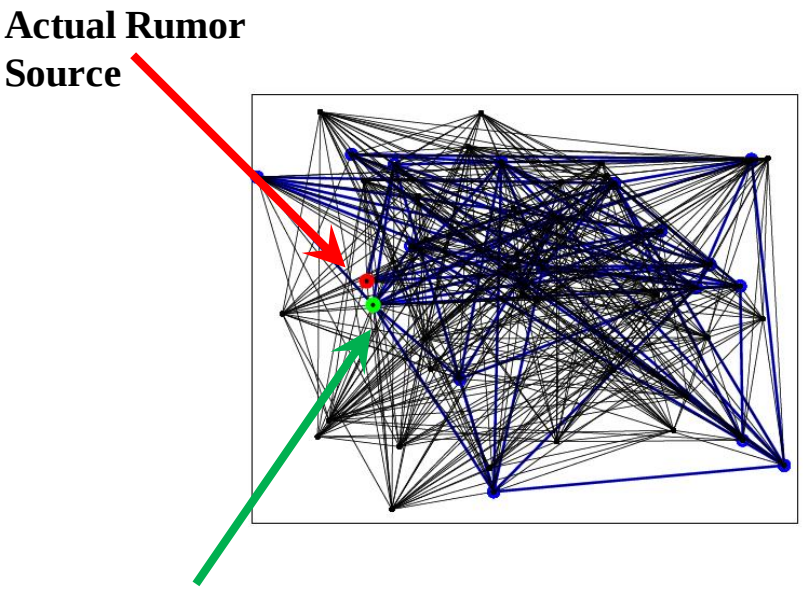


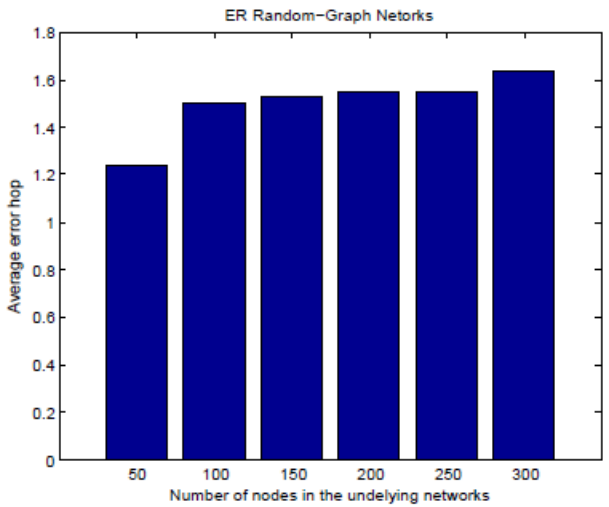
A line graph **A star graph**

Proposition 1: Leaf nodes are never the estimated rumor source when $N > 2$.
Proposition 2: The estimated rumor source of 2-degree regular tree is the node(s) in the middle of the line.
Proposition 3: The estimated rumor source of a star graph is the internal node.

Detection in Complex Networks

Erdos-Renyi random graph





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Thank you!

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