Metadata-Conscious Anonymous Messaging

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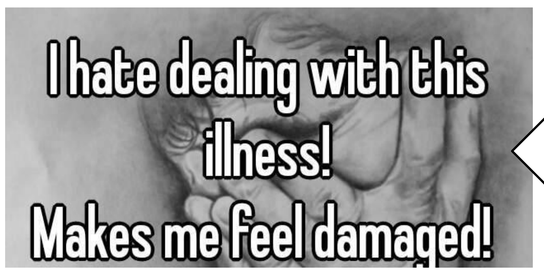
Anonymity matters



Personal Confessions ⟷ Political Activism

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How can we empower people to speak without fear of social or political retribution?

The problem

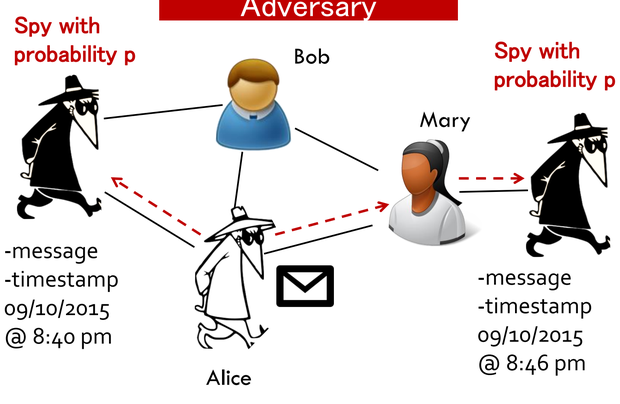
Design a distributed messaging algorithm that:

a) Prevents a powerful adversary from identifying the true message source,

b) Spreads content quickly over contact graphs.

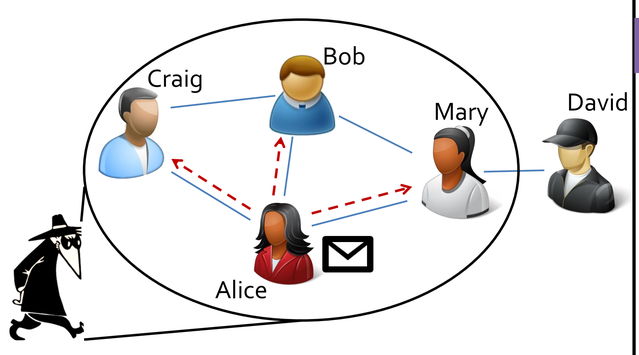
The adversaries

Spy-based Adversary



Colluding "spies" share message contents, metadata, and underlying graph structure to infer message authorship.

Snapshot Adversary



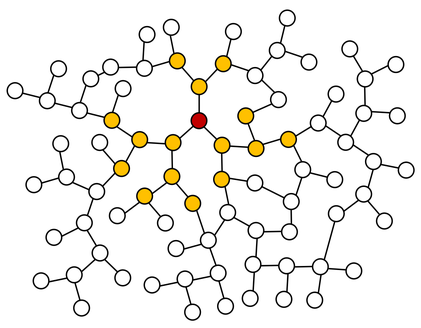
Adversary knows the underlying graph and can con collect a snapshot containing information about who got the message.

Information flow in social networks

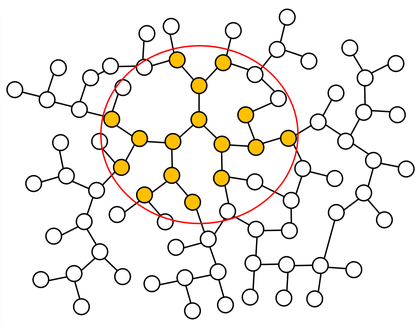
Most social networks spread content symmetrically based on user input.

(user approves message → message gets passed to friends)

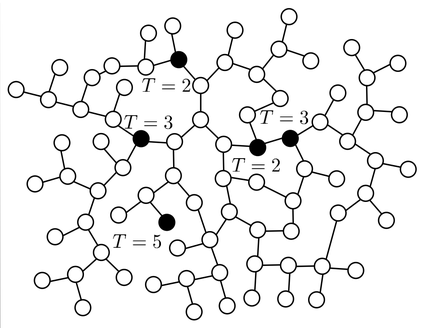
Spreading Pattern



Snapshot Adversary

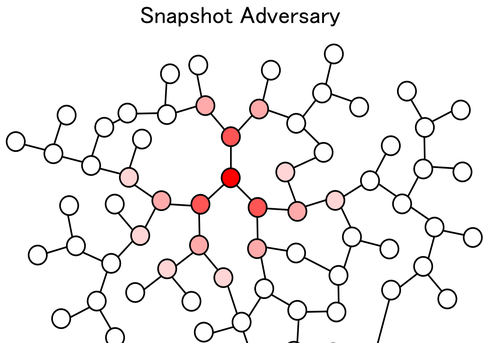


Spy-based Adversary



This spreading model is known as the **diffusion model.** Messages flow in all directions at the same rate. With high probability, diffusion places the **true source in the center** of the graph. This helps adversaries infer the source. [Shah & Zaman 2011, Pinto et. al. 2012]

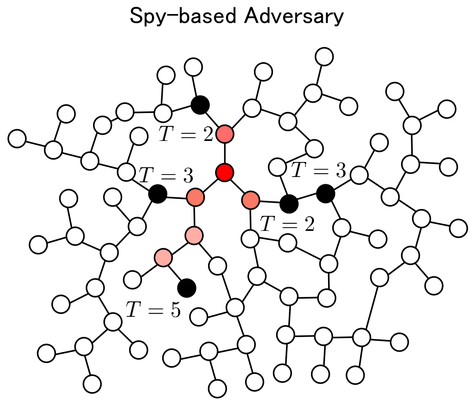
Snapshot Adversary



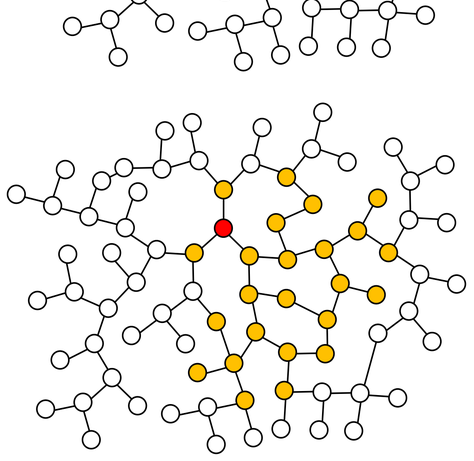
high likelihood

low likelihood

Spy-based Adversary



Intuition: Break the symmetry around the center. Spread in a way such that the source is always on the boundary of the information spread.



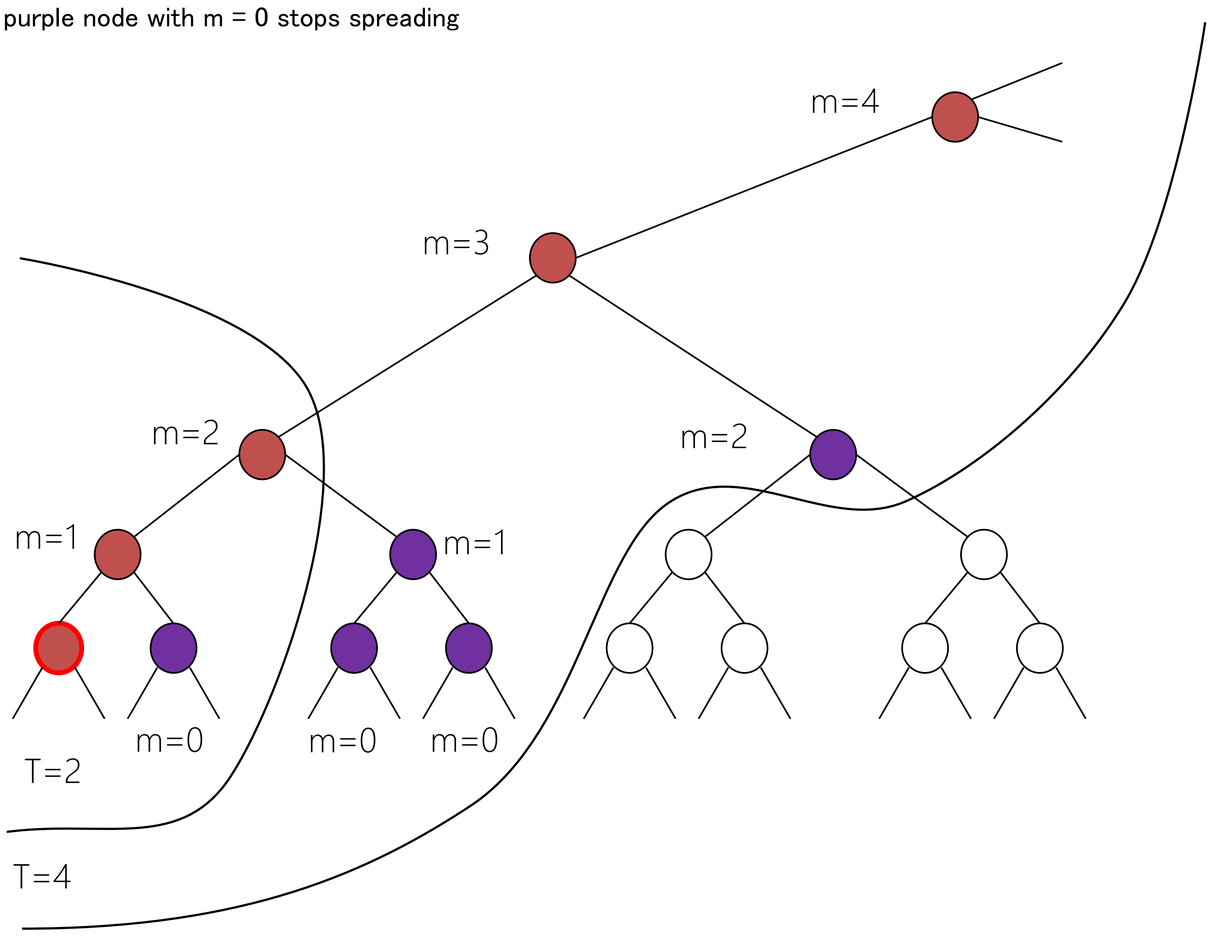
Adaptive Diffusion

Adaptive diffusion breaks symmetry to provide strong anonymity.

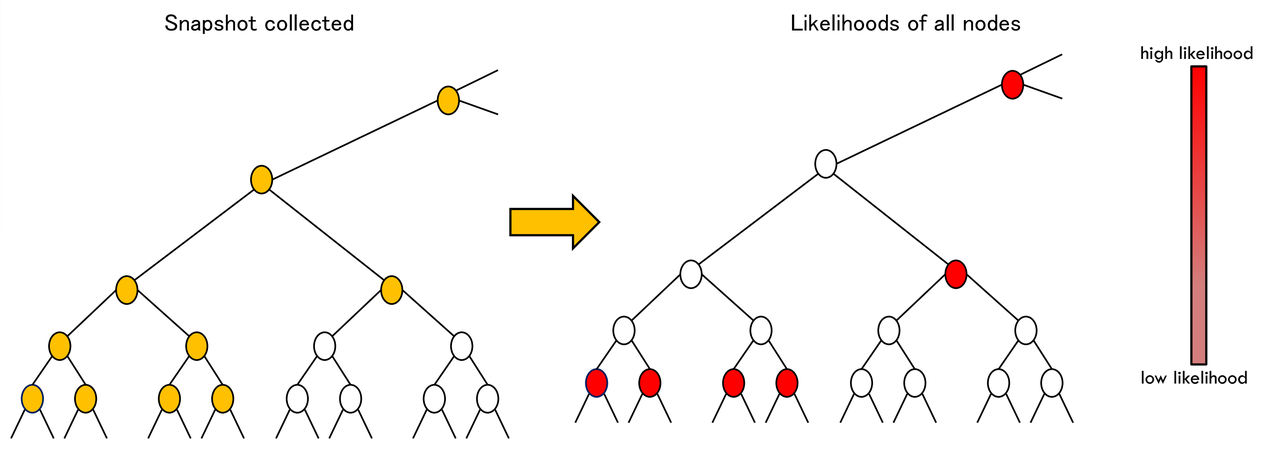
Intuition: carefully adapt the information flow rate and direction

Adaptive diffusion protocol:

1. The source node chooses a neighbor at random, and passes the message to it with **m = 1 & color = orange**
2. An orange node
   1. passes the message to a randomly chosen neighbor with an **incremented m & color = orange**,
   2. and then to all other neighbors with a **decremented m & color = purple.**
3. A purple node with m > 1 passes the message to all its neighbors with a **decremented m & color = purple**
4. A purple node with m = 0 stops spreading

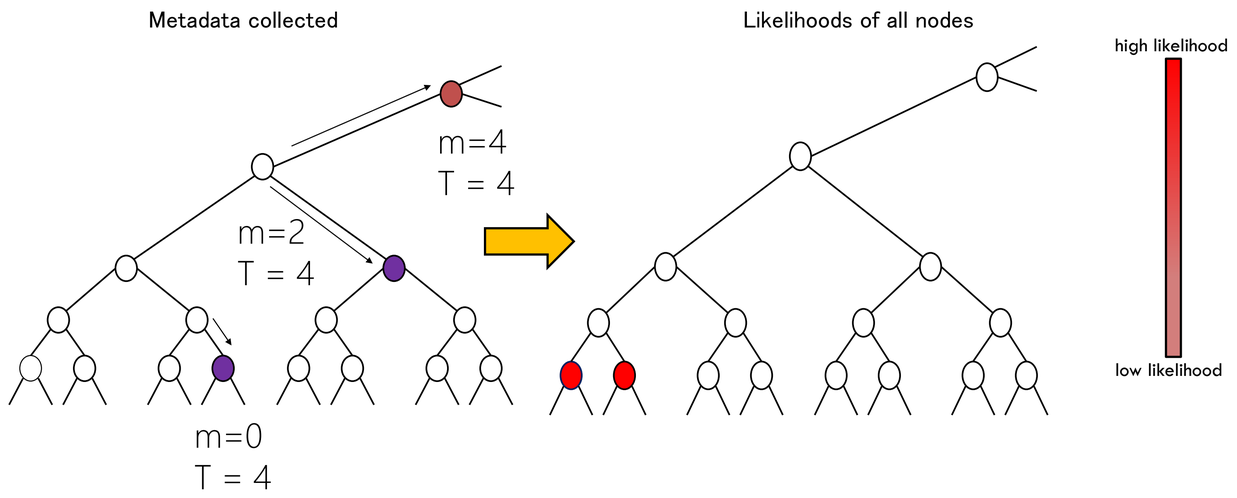


Regular Trees: snapshot adversary



Theorem: On regular trees, adaptive diffusion hides the source **in all the leaf nodes** and spreads the message **exponentially quickly**. Therefore, the probability of rumor source detection is inversely proportional to the number of noes with the message.

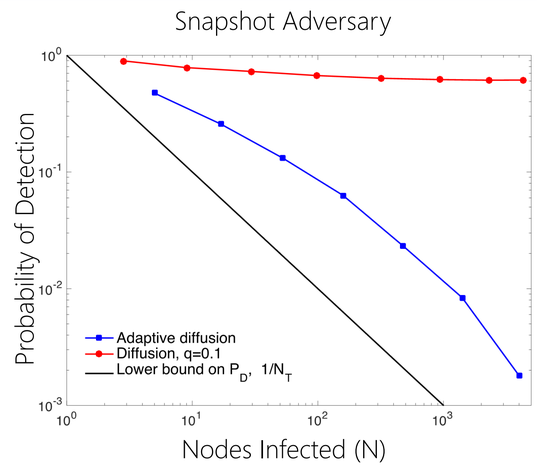
Regular Trees: spy-based adversary



Theorem: On regular trees, the probability of detection is always greater than or equal to p. Moreover, the probability of detection under adaptive diffusion is p + o(p). The limit of the probability of detection, as the degree of the tree goes to infinity, is equal to p.

Adaptive Diffusion on Real Graphs

Snapshot Adversary



Spy-based Adversary