Performance of a fixed reward incentive scheme for two-hop Delay Tolerant Networks with competing relays

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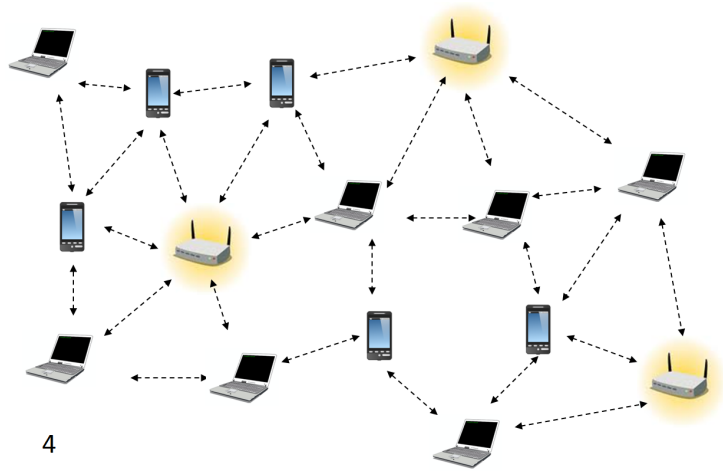
Outline

Broad classification of networks

Infrastructure-based

Self-organizing, ad hoc . . .



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Example of participative networks

✔ Nodes contribute resources and in return get to use resources in the network

- Peer-to-peer file sharing 

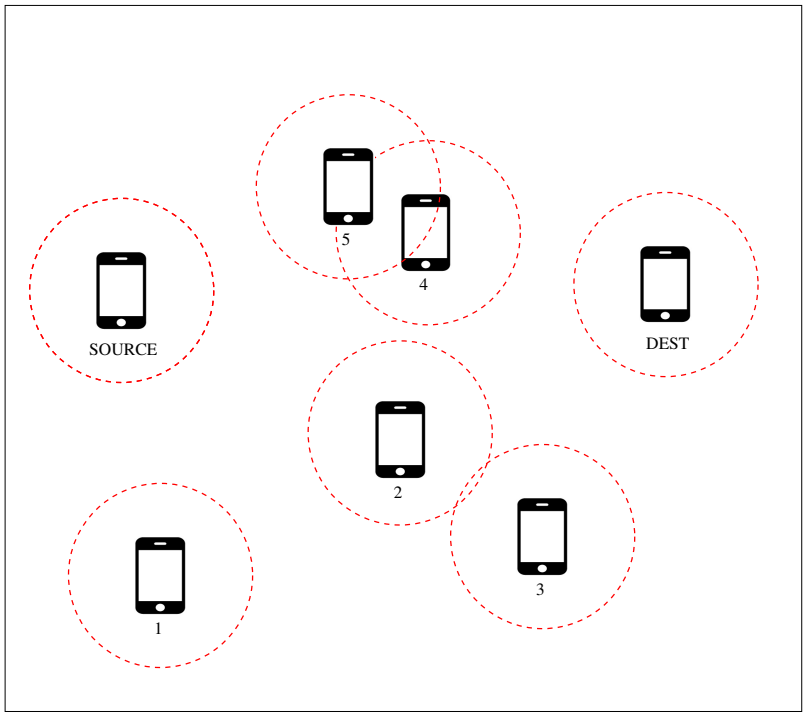
- P2P multicast
- FON WiFi 

- Q&A sites 

- Linux, Wikipedia, . . .
- Delay Tolerant Networks (DTN)

Delay Tolerant Networks

- Wireless nodes moving randomly in a given area



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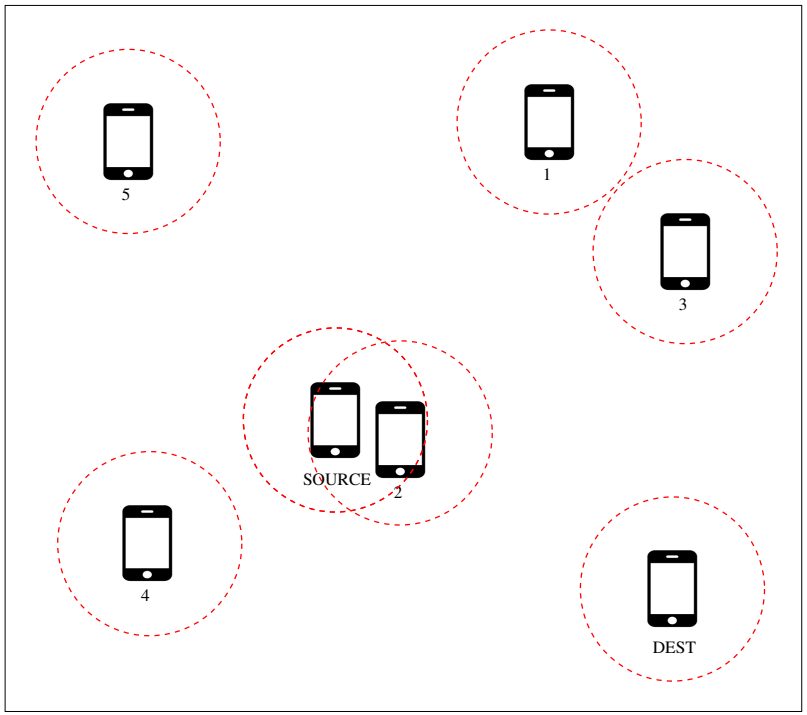
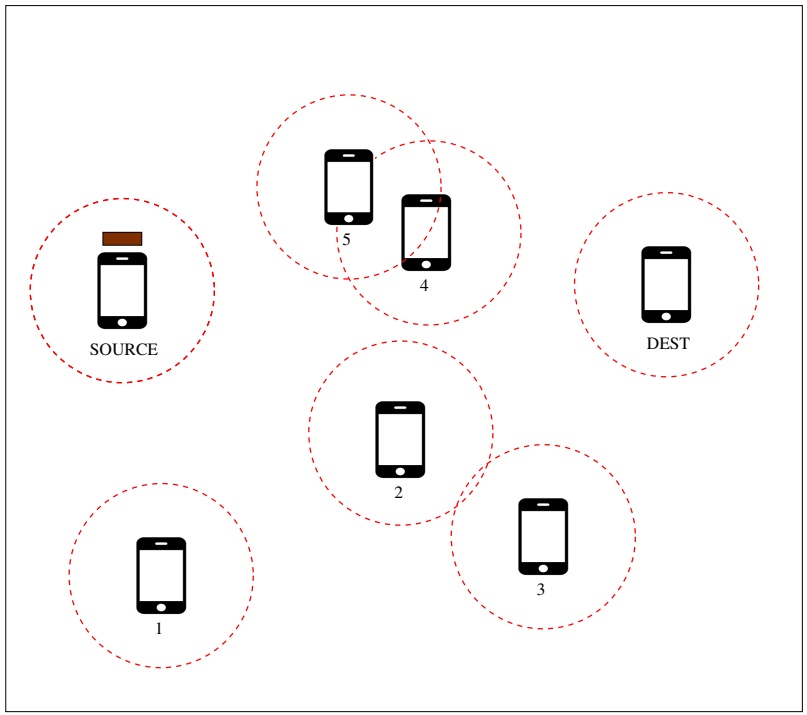


- Time-varying topology: lack of continuous network connectivity.
- Potentially large delays

Delay Tolerant Networks: store-and-forward principle

- Message is incrementally moved and stored throughout the network.



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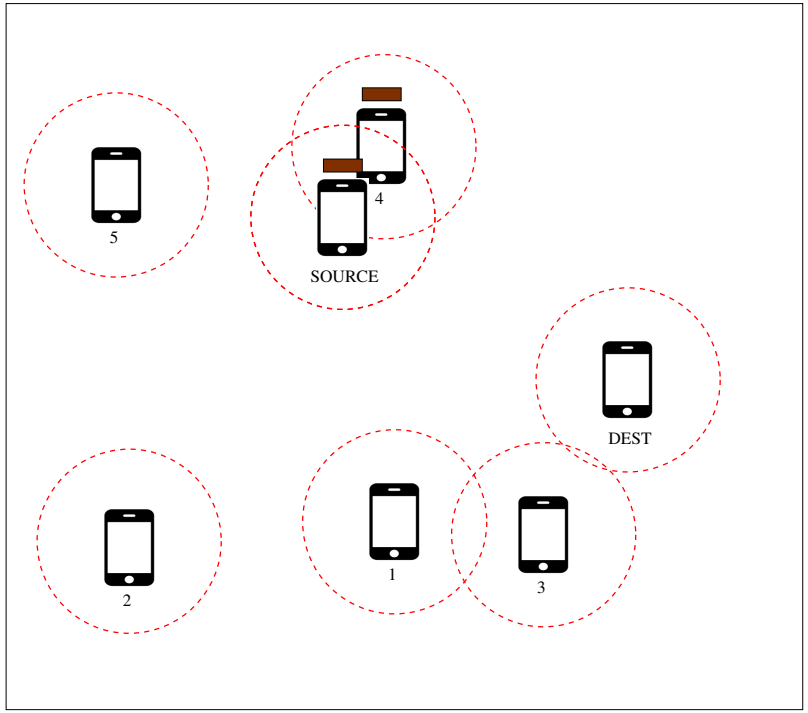

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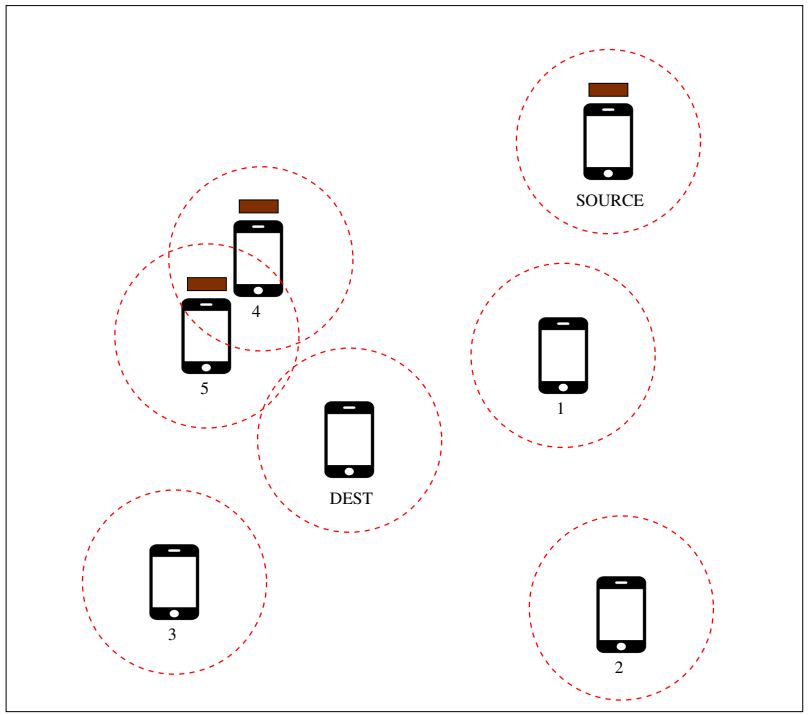

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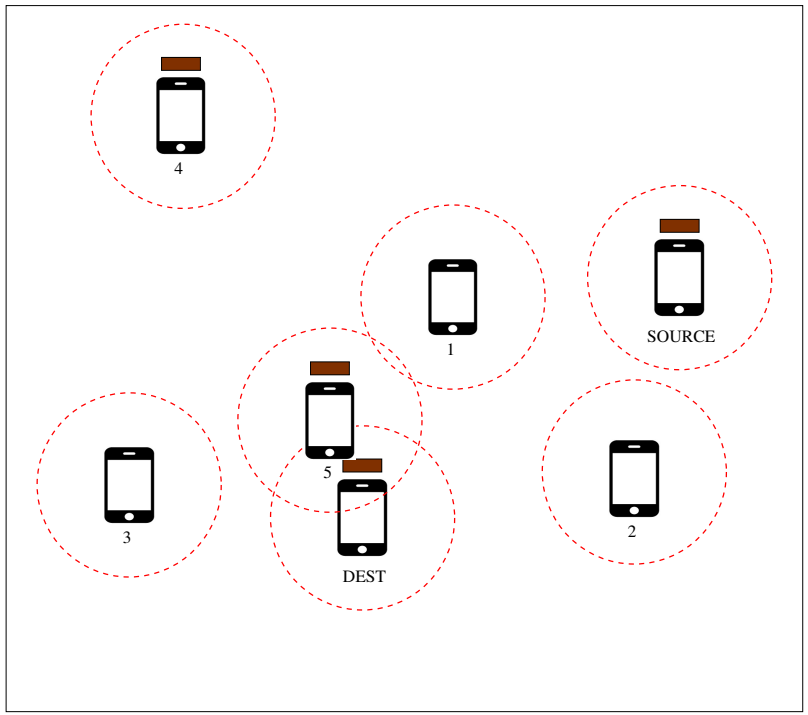

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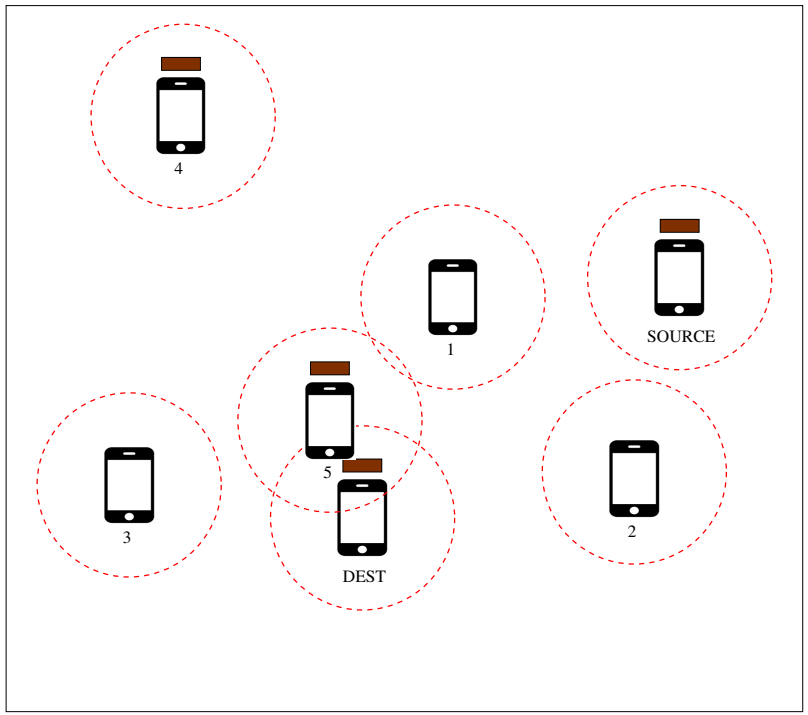

- Finite message lifetime to avoid too many copies.

The need for incentive

- Participative networks rely on node-participation to function

✔ Design mechanisms to coerce users to participate

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- Participation involves costs : bandwidth (P2P), energy (wireless networks)
- Free-rider problem : nodes use resources but do not provide anything; temptation for free lunch

✔ Design mechanisms to coerce users to participate

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    ✖ Drawbacks : computing trust, collusion; (e.g., services to improve PageRank)
  - Fixed contribution : each node contributes a fixed amount of resources and can use other's resources (e.g., FON, Grille 5000)
    - easy to configure; solves free riding problem
    - might not work well if resources are not homogeneous.
    - Tragedy of commons

Types of Incentive mechanisms

✔ *Monetary-based* : money (or some virtual currency) is given in exchange for a service

- Cereus : uses English auction bidding for resources
- Nuglets (Buttyan and Hubaux) : a virtual currency for self-orgranized networks
  - Packet Purse model : add an amount of currency to be shared between the forwarding nodes
    "...it is difficult to estimate the number of nuglets required to reach a given destination."
    ✖ Nuglets are lost if packet is dropped

Two-Hop network

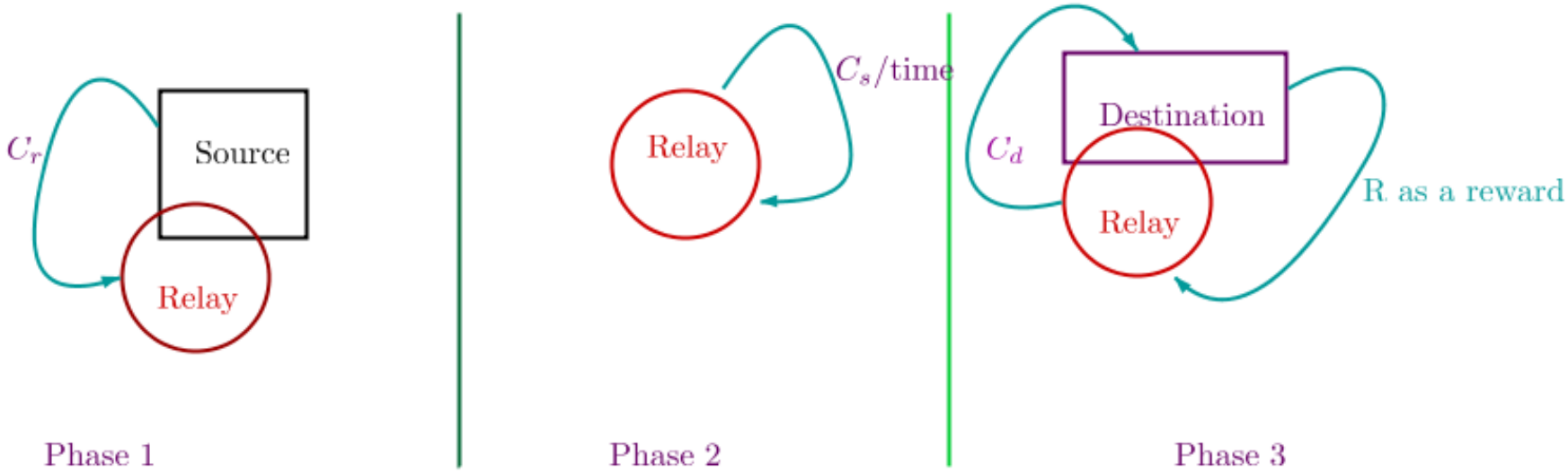

Figure: Two-Hop network

Objective of the research

Consider an incentive mechanism

- Promises a reward for the first successfully delivery relay, e.g E-check.
- Fixed reward.

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- How money is distributed.
- The probability of success of the source as well as the relays.
- The expected time to delivery the message.

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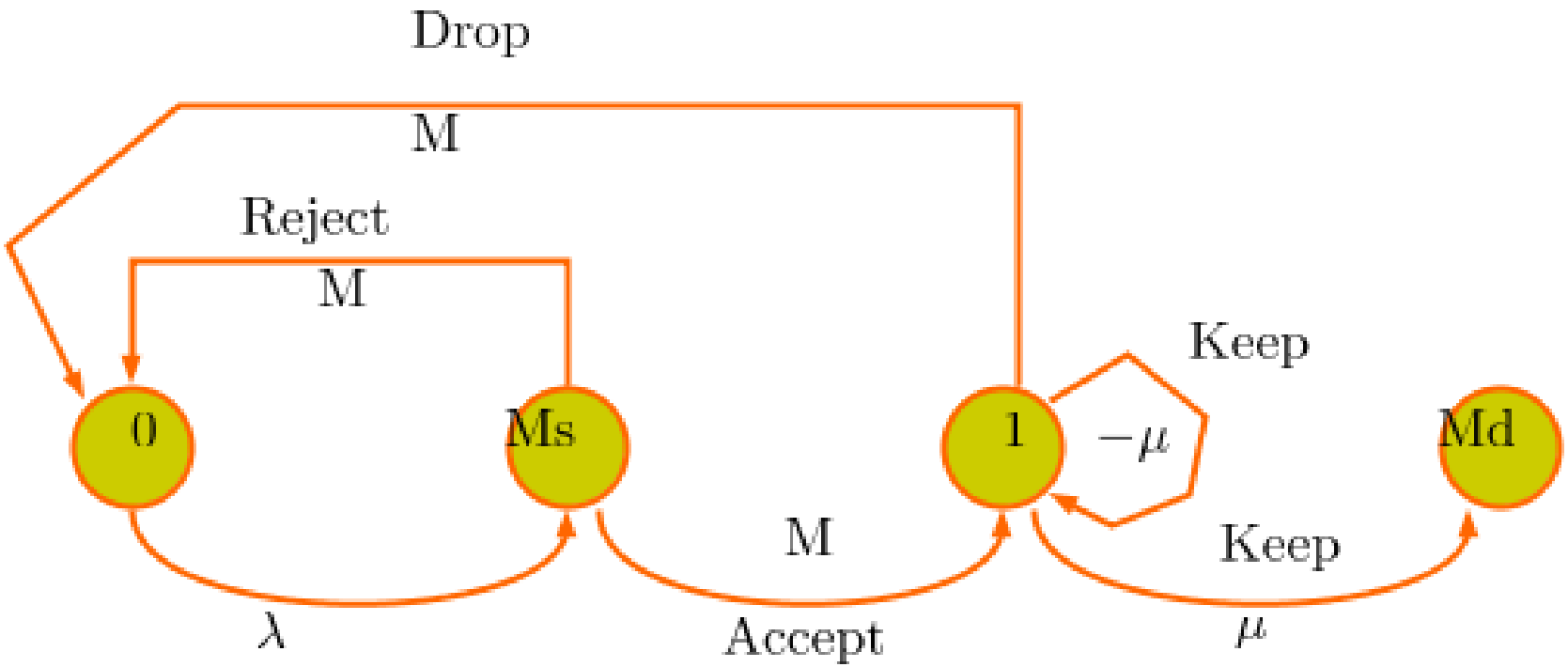
$\Longrightarrow$ Stochastic games, stochastic modeling.

Current work

- Fixed reward.
- One source and one destination.
- Inter-contact time follows Exponential distribution.
- Relay cannot forward message to others.



Model

- *The source has many messages to send, and it proposes them one by one.*
- *Cost: C_r, C_s, C_d.*
- *A relay can store only one message at a time.*
- *The relay can accept/reject and keep/drop.*
- *Two states: 1 for having the message and 0 otherwise.*

The expected total cost of keeping the message in the interval (a, b)

$$C_r + \int_a^b \mu e^{-\mu(t-a)}(C_s(t-a) + (C_d - R)p_k(t))dt + \exp(-\mu(b-a))C_s(b-a) =: C_r + G_k(a,b). \quad (1)$$

And

$$J_k^\pi(t;1) = \mathbb{E}[G_k(t, t+d) + \exp(-\mu d)J_k^\pi(t';0)],$$

where t' is the first epoch after $t + d$.

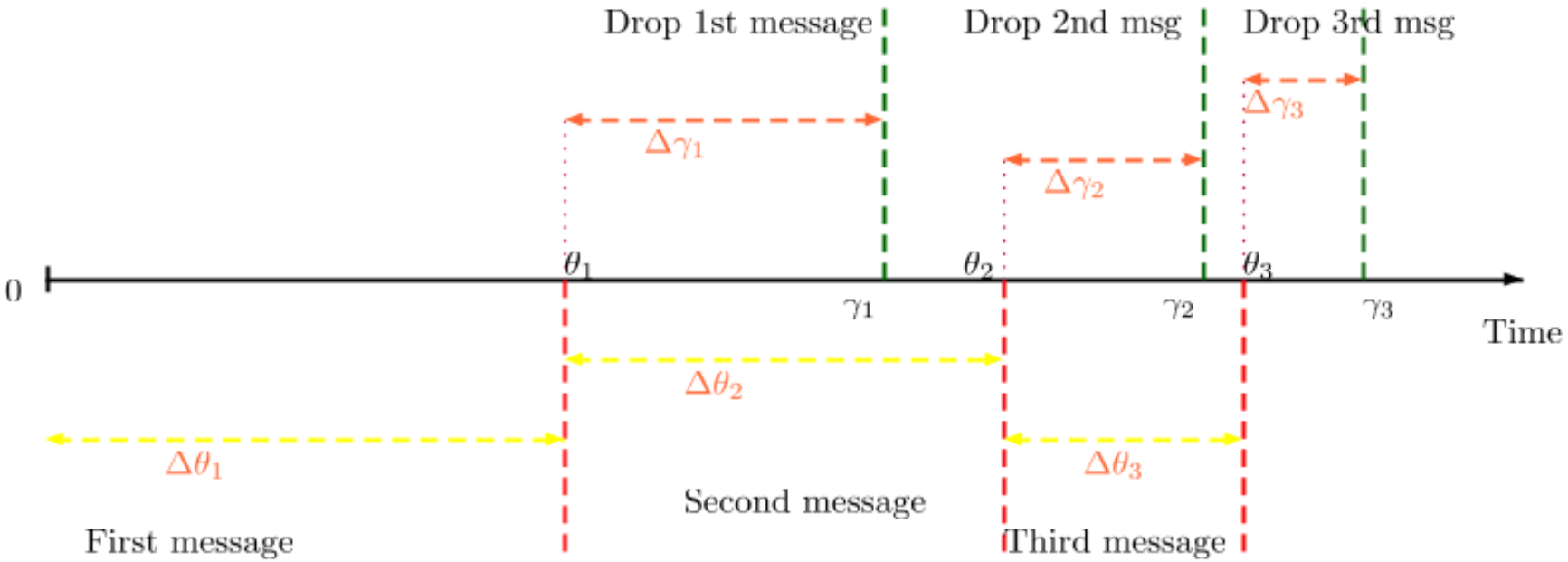
$$J_k^\pi(t;0) = \begin{cases} J_k^\pi(t+,0), & \text{if refuse;} \\ C_r + J_k^\pi(t+,1), & \text{if accept.} \end{cases} \quad (2)$$

$\Longrightarrow$ Find optimal strategy for relays which is

$$\Pi_k^*(t;s) = \underset{\pi}{argmin} \quad J_k^\pi(t;s).$$

Some results

- The optimal policy is of threshold type.
- Numerical method to compute the thresholds θ_k, γ_k.
- Analyze the stable state in symmetric cases.

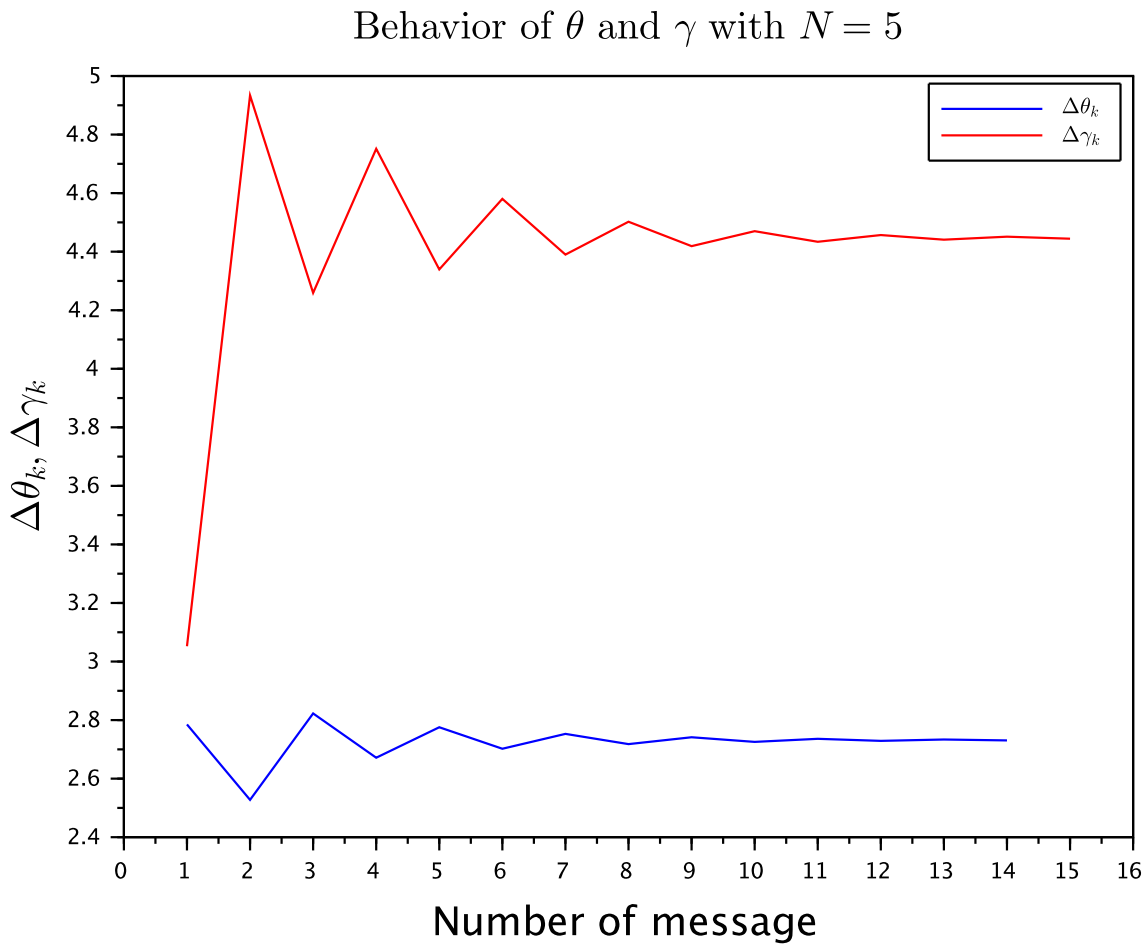


Thredhold policy illustration

Some results

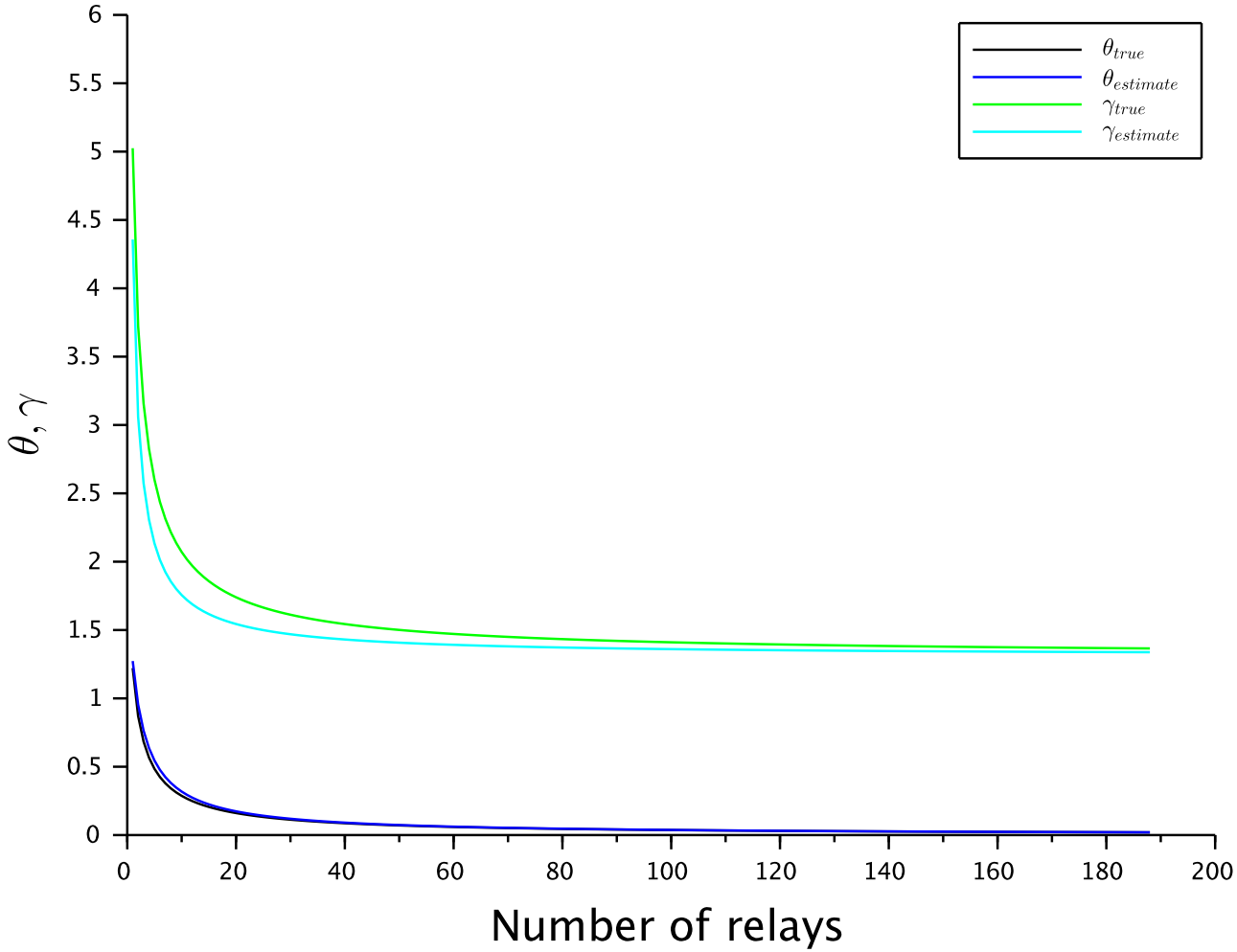
Take

$C_r = 4; C_s = 0.5; C_d = 4; \lambda = 0.8; \mu = 0.4; R = 7 \times (C_d + C_r + C_s/\mu).$



Some results

θ, γ with $k = 1$and the number of players changing.



Proposition

In stationarity ($k \to \infty$), we have

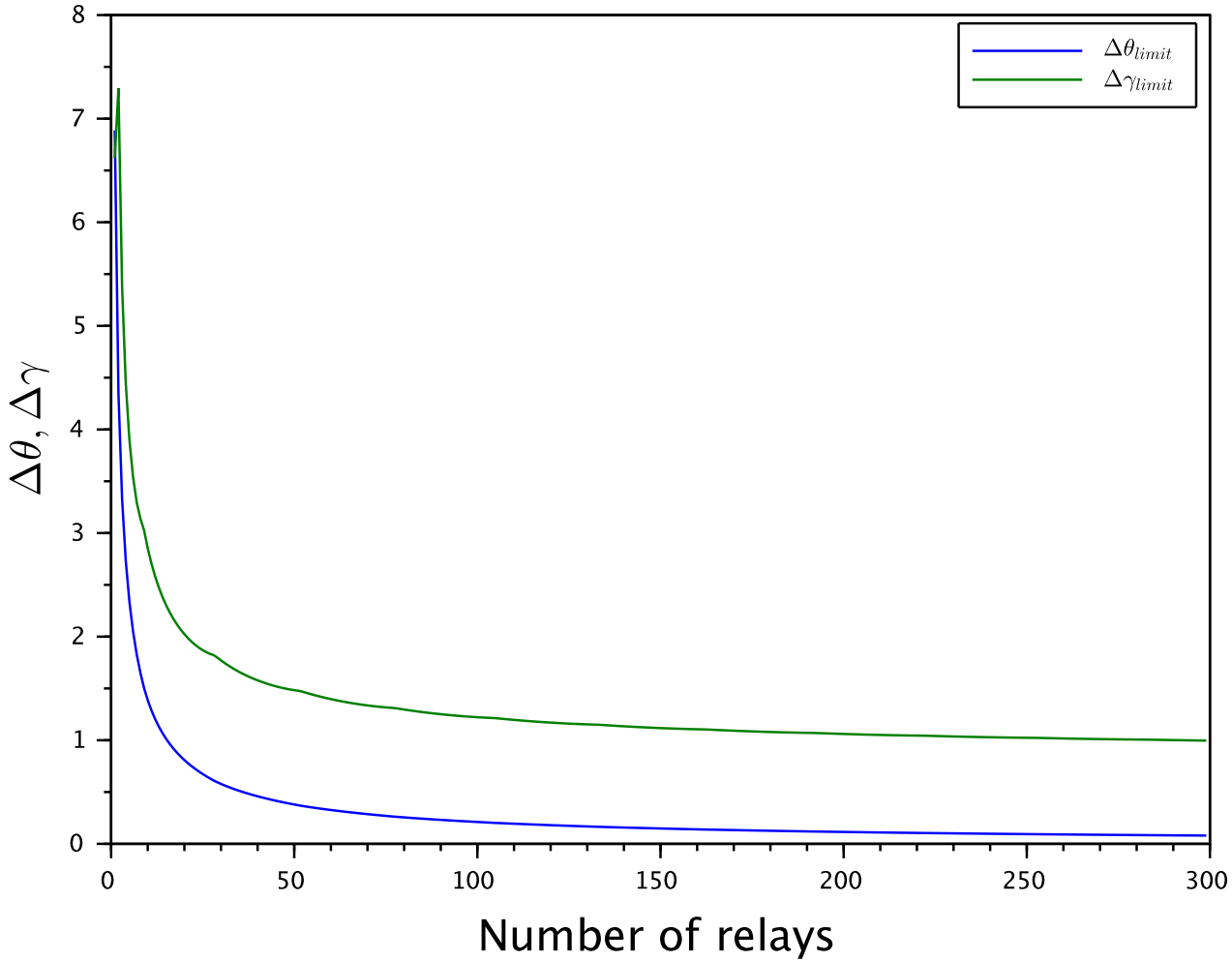
$$\Delta\gamma = -\frac{ln(1+B)}{\mu}, \tag{3}$$

$$\Delta a = \frac{-ln\left(\frac{-C_s}{\mu(C_d-R)}\right)}{(1-e^{-\mu\Delta\gamma})h_1\lambda}. \tag{4}$$

Where $B = \frac{C_r}{\frac{C_s}{\mu} - \frac{C_s/\mu + C_d - R}{ln\left(\frac{-C_s}{\mu(C_d-R)}\right)}}$.

Some results

The limitation of $\Delta\theta, \Delta\gamma$with the number of players changing.



Future work

- Extend to multiple sources and destinations.
- Allow relay to drop current message and accept others.
- The number of message and relays tend to infinite.

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