On the Effects of Cooperation in DTNs

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Reference: http://cgi.di.uoa.gr/~ioannis/publications/2007COMSWARE.pvs.pdf

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Peculiarities of Delay Tolerant Networks

- No guaranteed connectivity
- Low frequency of node encounters

DTN Routing algorithms
- Mobility-assisted
- No route-establishment

DTN routing

Single-copy strategies
- Only one message copy in the network
- Forwarding based on a rule:
  - -maximization of a utility function
  - -probabilistic

Multiple-copy strategies
- Limited or unlimited message copies allowed
- Spreading based on:
  - -the number of copies allowed to be spread
  - -the number of copies available at each node

Performance of routing

Investigated w.r.t. the impact of:
- Environment characteristics
  - -network size
  - -node density
  - -message spreading rules
- Node behaviour
  - -mobility

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Assumption: Fully cooperative environment!

In this paper …

- A non-cooperative DTN environment is considered:
  - The copy is dropped or forwarded probabilistically
- 3 routing algorithms are studied in terms of the:
  - Induced delay
  - Transmission overhead
- A simple strategy for non-cooperative environments is investigated

Cooperation in DTNs

Shaped by the willingness (due to node misbehavior), or ability (due to buffer or energy limitations) of the node to participate in spreading.

2 types of cooperation considered:

-**Type I**: the node drops the message with probability P_{drop} (cooperation degree = $1-P_{drop}$)

- **Type II**: the node maintains the copy and forwards it with probability $P_{forward}$ (cooperation degree = $P_{forward}$)

The 3 routing algorithms

- **Epidemic routing**: (unlimited copies)
  - At each node encounter, all copies are exchanged
  - Minimum message delivery delay but high buffer occupancy and bandwidth utilization in fully cooperative environments

- **Two-hop routing**: (limited copies)
  - The source forwards one of its copies to the node (with no copy) it encounters
  - Only the source node forwards copies to others than the destination

- **Binary spray-and-wait routing (BSW)**: (limited copies)
  - Every one gives half its copies to a node (with no copy) it encounters
  - Faster than two-hop relaying when all cooperate

Metrics

- Delay until delivery of the message

- Overhead in terms of number of transmissions

The *Total* overhead has two components:

- Till delivery: Transmissions required until message delivery
- Additional: Transmissions wasted after the message delivery, affected by spreading process termination (*)

Spreading process termination

The spreading process is naturally terminated if all the potential spreaders of a copy are eventually informed of the message delivery or all copies are already spread.

Expedite natural termination through a delivery notification mechanism, activated upon message delivery: (*)

- A node that becomes aware of the message delivery becomes as notifier.
- Every node that contacts a notifier is informed of the message delivery and becomes a notifier itself.

Protocol sensitivity to cooperation degree

Two checks are used, by comparing performance for a certain degree of cooperation with that achieved

a. in a fully cooperative environment

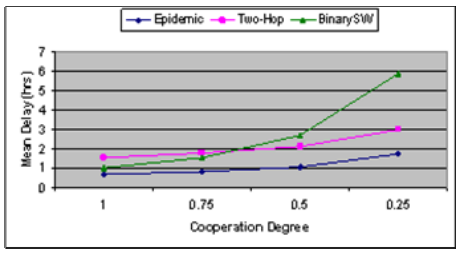
b. in the *Fully Cooperative Equivalent (FCE) network* (only for Type I)

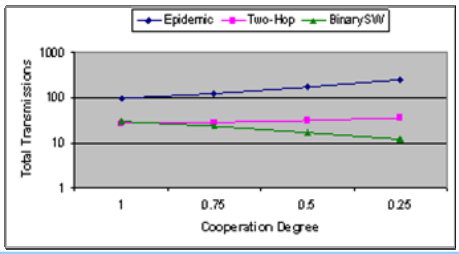
The FCE network of N nodes is defined as a network of N' fully cooperative nodes, where $N'=N(1-P_{drop})$.

Non-cooperative environment

Simulations: up to 100 nodes uniformly distributed in 8km x 8km area;
Mobility: Random Direction Model with a speed of 3m/sec;
Transmission Range: 200m;
All results were averaged values over 10000 runs.

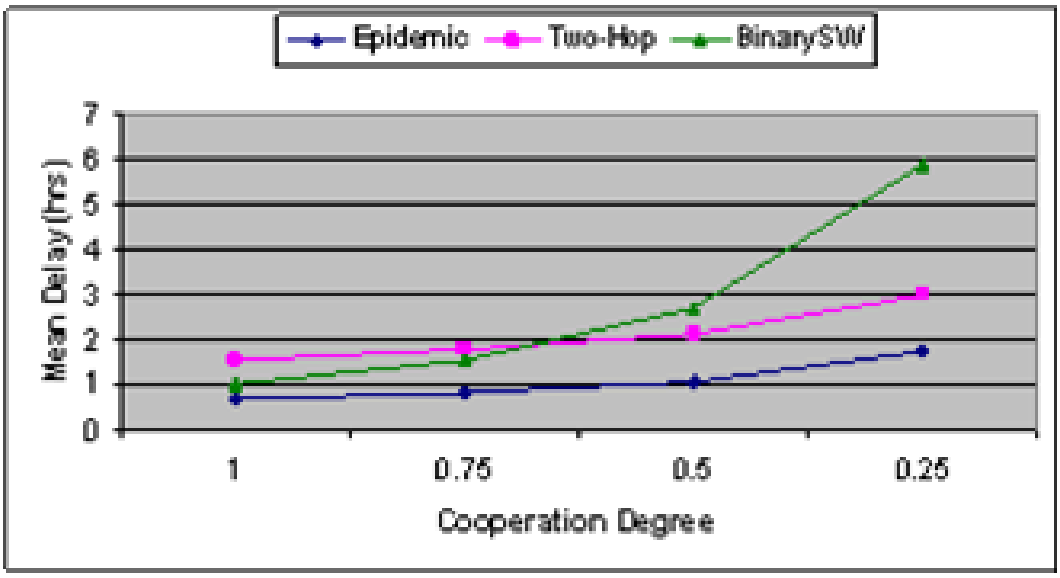
- Epidemic always provides for minimum delivery delay at the expense of significantly more transmissions in all environments.
- BSW achieves lower delivery delay in fully cooperative environments than two-hop; the rate at which the delivery delay achieved by two-hop increases in non-cooperative environment is lower than that of BSW.
- The overhead induced by BSW decreases in less cooperative environments contrary to what observed in two-hop.



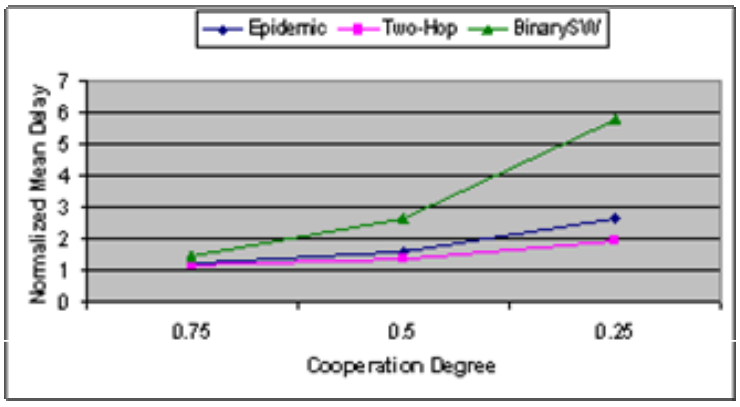


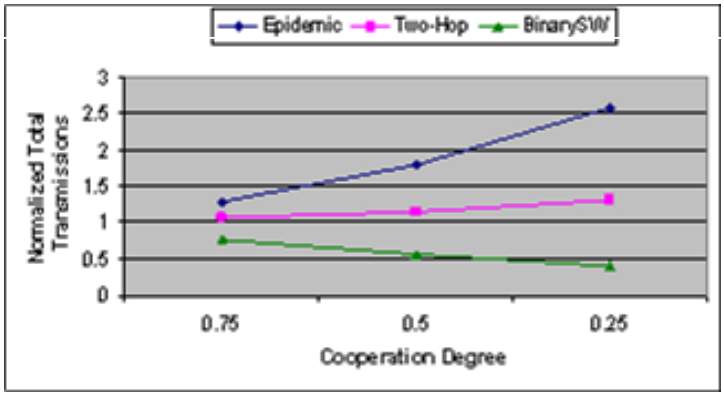
Observation 1:

2-hop: outperforms BSW for low cooperation



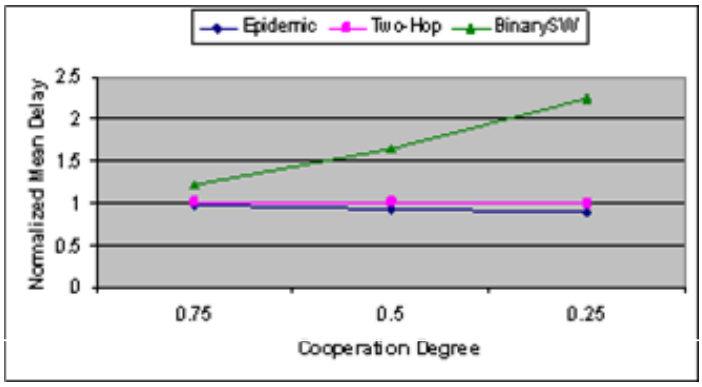
Sensitivity check I (wrt fullly coop Net)

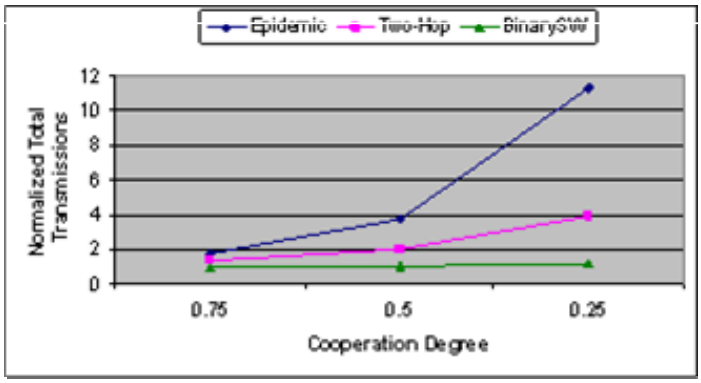




- Epidemic is the most sensitive wrt total transmissions
- BSW is the most sensitive one wrt delivery delay
- Two-hop is the least sensitive one concerning both metrics

Sensitivity check II (wrt FCE)





- Epidemic is the most sensitive concerning total transmissions
- BSW is the most sensitive wrt delay
- Two-hop and BSW are the least sensitive wrt delay and total transmissions, respectively

Reaction to non-cooperation

Assume that the cooperation degree is known to other nodes (e.g. through a reputation mechanism)

Strategy: Forward a copy only to most cooperative nodes (with cooperation degree above a threshold)

need to balance the potential waste of a precious copy (due to the non-cooperativeness of the current encounter) with the potential delay in forwarding this copy by the next encounter if the current encounter meant to cooperate.

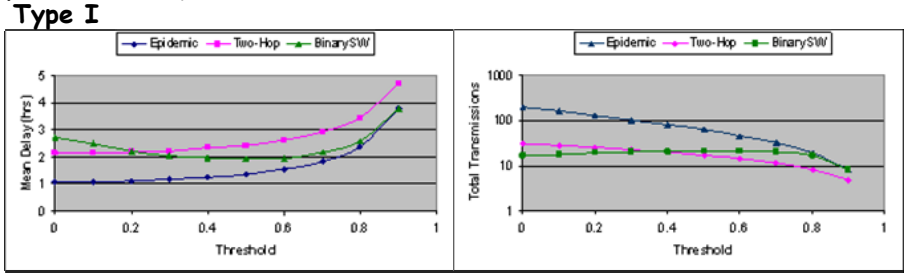
Reaction to non-cooperation

We employ a simple mechanism where each node is assumed to have knowledge of the degree of cooperation of the nodes it encounters. The message copy is spread only to the most cooperative nodes according to the applied threshold. (Here, the results refer to 100 nodes with mean degree of cooperation equal to 0.5)

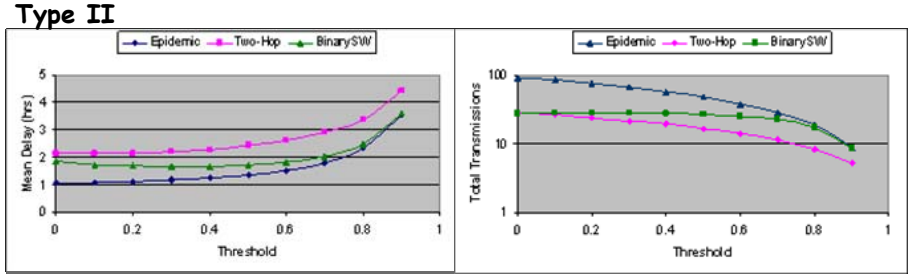
- For both types of cooperation, the behaviour the employment of forwarding threshold leads to a significant reduction in the number of transmissions at the cost of a small increase in the delivery delay (at least for a threshold, less than the average degree).

- For Type I, there is a threshold value below which two-hop achieves a lower delivery delay or/and induces more transmissions than BSW and vice versa above that threshold.

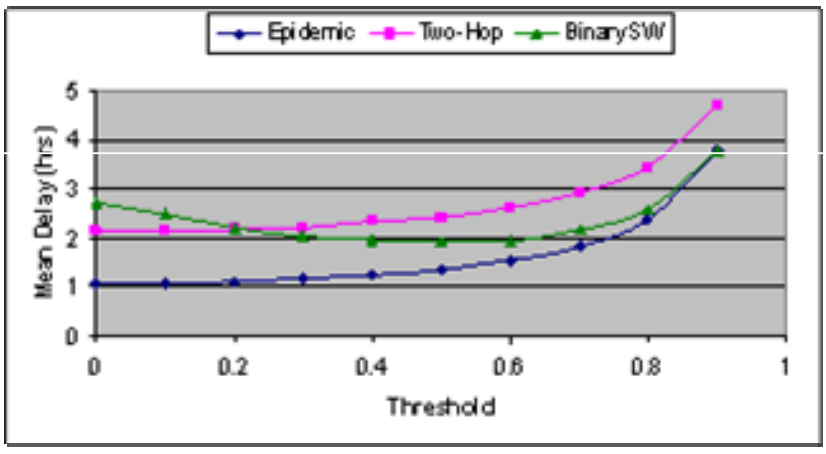
Type I

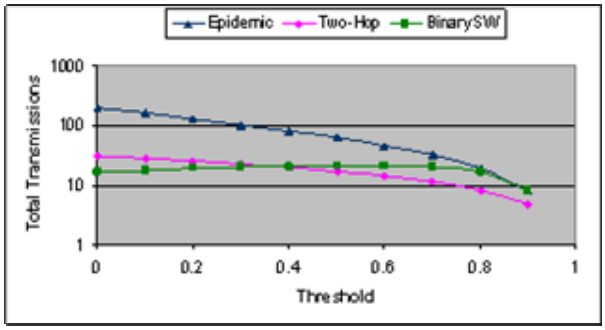


Type II



Reaction to non-cooperation





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Conclusions

The degree of cooperation may change the performance order of DTN protocols

- It is shown that epidemic routing, which seems to outperform the others w.r.t. the achieved delivery delay at the cost of significantly increased transmissions, is the most sensitive wrt the induced number of transmissions.
- BSW is the most sensitive wrt the mean delay.
- Two-hop is the least sensitive and seems as a good candidate for non-cooperative environments.
- The performance of routing may be improved by applying and fine-tuning a simple mechanism that utilizes knowledge of the cooperation degree of the nodes.