A General Data and Acknowledgement Dissemination Scheme in Mobile Social Networks

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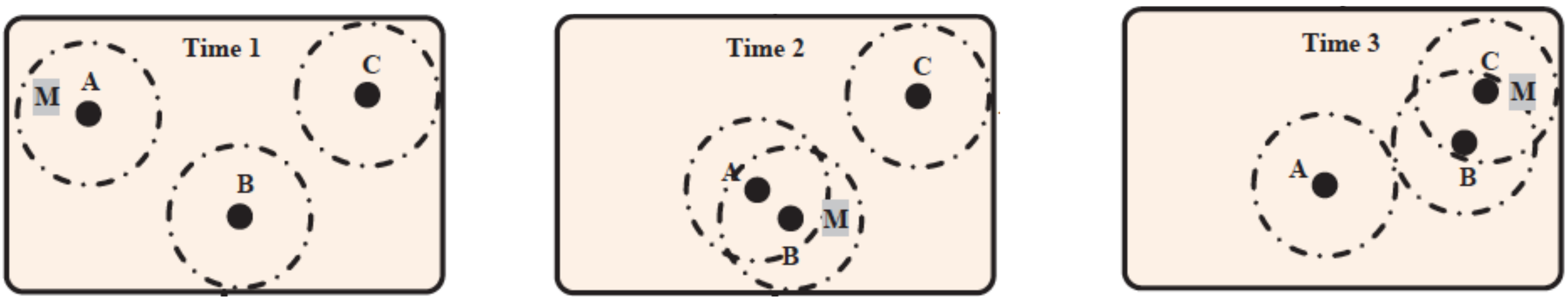
Mobile Social Networks

Concept of mobile social networks (MSNs):

- People walk around with smartphones and communicate with each other via Bluetooth or Wi-Fi when they are within transmission range of each other.

Characters:

- No end-to-end connectivity
- Using store-carry-forward design
- Exploiting node's mobility



Content dissemination in MSNs

- Two main problems:
  - Information dissemination
    - Mobile ad, News, Twitter, ……
  - Acknowledgement dissemination
    - Mobile trade, incentive mechanism

Content dissemination in MSNs

- A scenario (mobile ad dissemination)

Information dissemination:

The merchant node would like to send the message (ads) to the potential receivers (customers) soon.

Acknowledgement dissemination:

After the receiver gets the message, it would send back a receipt (ack.) to the sender. If the merchant receives this ack., it might pay some money for relays.

The relay nodes would like to send the ack. to the merchant node soon.

Content dissemination in MSNs

- A scenario (mobile ad dissemination)

Data and ack. dissemination problem:

We hope to find a scheme so that the ads can soon be sent to the receiver. At the same time, the relay can get the reward soon.

Network model

- Message (data and acknowledgement):
  - Single-copy unicast scenario.
  - Time-to-live (TTL) is assigned.
- Nodes:
  - Buffer is limited.

Msg	Data1	Ack1	Ack2	Ack3	idle
TTL	2	5	30	70	

Node a's buffer

Msg	Data2	Data3	Ack4	idle
TTL	50	15	10	

Node b's buffer

Problem formulation

- Priority buffer exchange problem:

  Suppose two nodes encounter with limited contact opportunity: how should we design a buffer exchange scheme with local information so that:

  - It can satisfy the data and ack. delivery objective.
  - For example:
    - maximize the delivery ratio of data and ack.
    - minimize the delivery delay of data and ack.

Challenges

- How can we use the local information to evaluate each node's ability?
  - keeping the message vs. exchanging the message
- What's the buffer exchange priority each time?
  - Which one should be exchanged first?
  - Data and ack. have different priorities.

Ideas

- Relay selection criteria:
  - Strongly connected relationship with destination.
  - Weakly connected relationship with destination.
- Priority buffer exchange:
  - Message should reach the destination before the deadline.
  - Combine the expected delivery time and TTL to assign priority.
  - Assign data and ack. different priorities.

Agenda

- Relay selection criteria
- Priority buffer exchange
- Simulation

Relay selection Criteria

- Two kinds of relationships:
  - Contact probability:
    - The encounter probability between node a and b is denoted as $p_a(b)$. (One-hop information).
  - Social status:
    - The centrality of a node in the network.

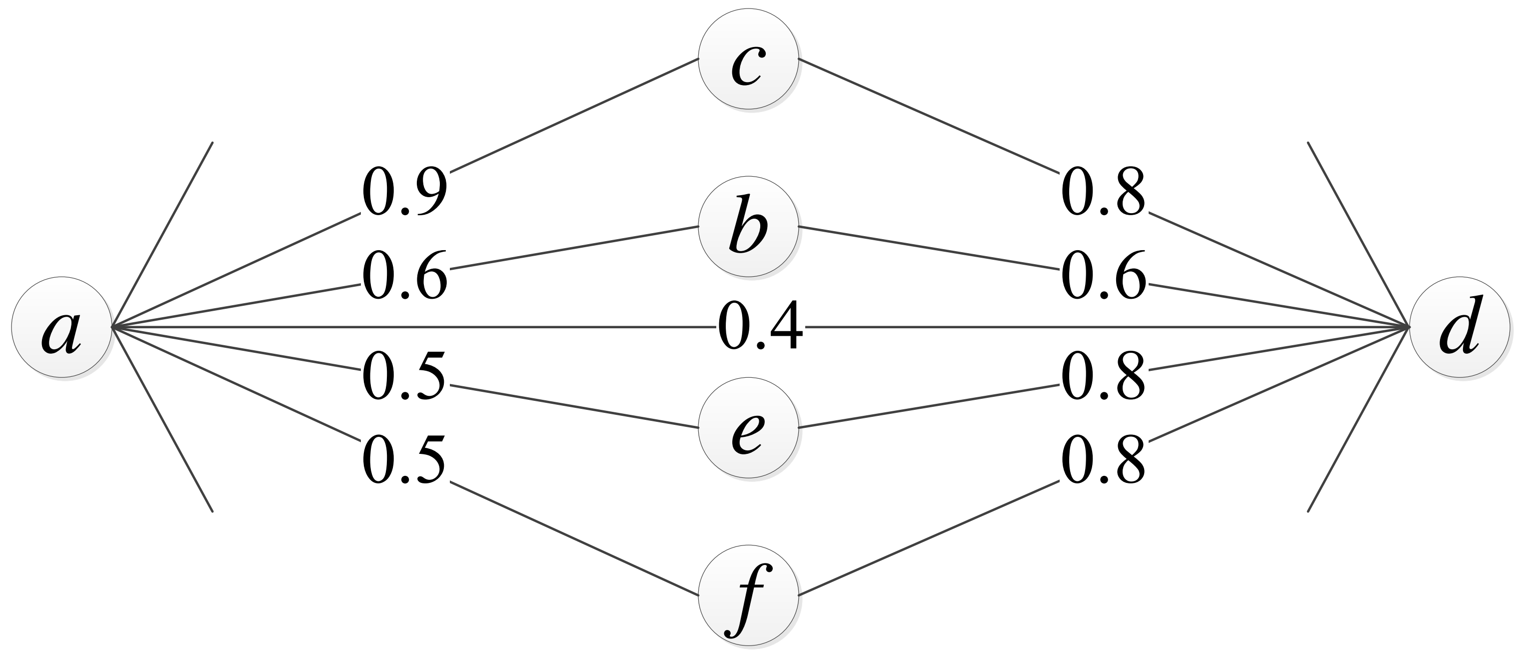
      (Multi-hop estimation).

$$S(a) = \sum_{b \in N(a)} p_a(b)$$

N(a) denotes node a 's neighbor set

Relay selection Criteria

- Is node b better than node a as a relay?
  - Contact probability: $p_a(d) < p_b(d)$
  - Transitive contact probability: $p_a(c)\, p_c(d) > p_b(d)$
  - Two-hop probability: 0.75 > 0.6
  - Multi-hop probability: larger than 0.75 > 0.6



Relay selection Criteria

- Compare operation:
  - Idea: social status has an influence on relay selection.
    - Order the messages based on the contact probability.
    - Only the m-k messages can be exchanged in each contact.

$$k = \lceil \frac{S(a)}{S(a)+S(b)} \times m \rceil$$

m is the number of messages in node a's butter

The higher the social status, the less the contact probability matters

Relay selection Criteria

- Compare operation (cont'd)
  - An illustration about compare operation

$$a \xleftrightarrow{\text{encounter}} b$$

Destination set	$\{d_1, d_2, \ldots, d_m\}$	
Contact probability	$\{p_a(d_1), p_a(d_2), \ldots, p_a(d_m)\}$	$\{p_b(d_1), p_b(d_2), \ldots, p_b(d_m)\}$
Probability difference vector	$\{\Delta_1, \Delta_2, \ldots, \Delta_m\}$	$\Delta_i = p_a(d_i) - p_b(d_i)$

*k*th element partition $\Downarrow$

Destination set	$\{d_1', d_2', \ldots, d_k'\}$	$\{d_{(k+1)}', d_{(k+2)}', \ldots, d_m'\}$

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Relay selection Criteria

- An example about the compare operation

Destination set	$\{d_1, d_2, d_3, d_4, d_5\}$	
Social status	6	9

- From node a's view:

$$k = \lceil \frac{6}{6+9} \rceil \cdot 5 = 2$$

Destination set	$\{d_1, d_2, d_3, d_4, d_5\}$	
Social status	6	9
Contact probability	{0.6, 0.2, 0.7, 0.4, 0.7}	{0.4, 1, 0.4, 0.5, 0.6}
Probability difference vector	{0.2, -0.8, 0.3, -0.1, 0.1}	
Partition	{1, 3}	{2, 4, 5}

Priority buffer exchange

- Within one type of message:
  - Estimate the expected delay
    - The effect of contact probability and social status:

$$E_a(d) = \frac{1}{S(a) \times p_a(d)}$$

  - Priority setting
    - Balance the expected delay and remaining time.

$$P(a) = \begin{cases} \frac{E_a(d)}{\tau_a - t} & (\tau_a - t) > E_a(d) \\ 0 & (\tau_a - t) < E_a(d) \end{cases}$$

Priority buffer exchange

- Between two types of messages:
  - The relative important factor is considered as α
    - In different scenarios, we have different α
    - The delivery cost, such as message size, can also be embedded into α
  - Two typical scenarios:
    - Data-first: $\alpha P(a) > P(b)$
    - Acknowledgement-first: $\alpha P(a) < P(b)$

Priority buffer exchange

- An example

Destination set	$\{d_1, d_2, d_3, d_4, d_5\}$	
Partition	{1, 3}	{2, 4, 5}
Priority of the data	{5, 4, 3, 2, 1}	
Priority of the acknowledgement	{0, 0.5, 1, 1.5, 0}	

- Buffer size of a node is 4. The number under the destination is the number of messages for that destination respectively.

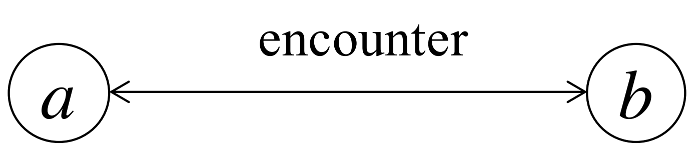
$$a \xleftrightarrow{\text{encounter}} b$$

Dest.	1	2	3	4	5
Data	1	1	0	0	0
Ack.	0	1	0	1	0

Dest.	1	2	3	4	5
Data	0	0	1	1	1
Ack.	0	0	1	0	0

Priority buffer exchange

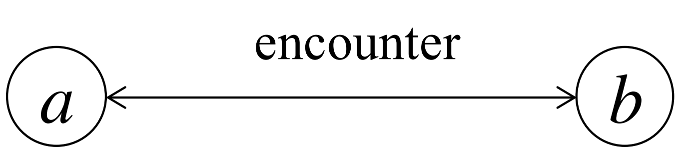
- An example (cont'd)



Dest.	1	2	3	4	5
Data	1	1	0	0	0
Ack.	0	1	0	1	0

Dest.	1	2	3	4	5
Data	0	0	1	1	1
Ack.	0	0	1	0	0

Before buffer exchange



Dest.	1	2	3	4	5
Data	1	0	1	0	0
Ack.	0	1	1	0	0

Dest.	1	2	3	4	5
Data	0	1	0	1	1
Ack.	0	0	0	1	0

After buffer exchange

Sum of delivery probability

Node a: 1.4
Node b: 1.9

Sum of delivery probability

Node a: 2.2
Node b: 2.6

Extension

- Multiple-copy single destination
  - Difference: A node can see the duplicated message many times.
  - Idea: Priority decreases as the encounter time increases.
  - Solution: The priority of data i is determined by a tuple <times, P(i)>.

Agenda

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Simulation setting

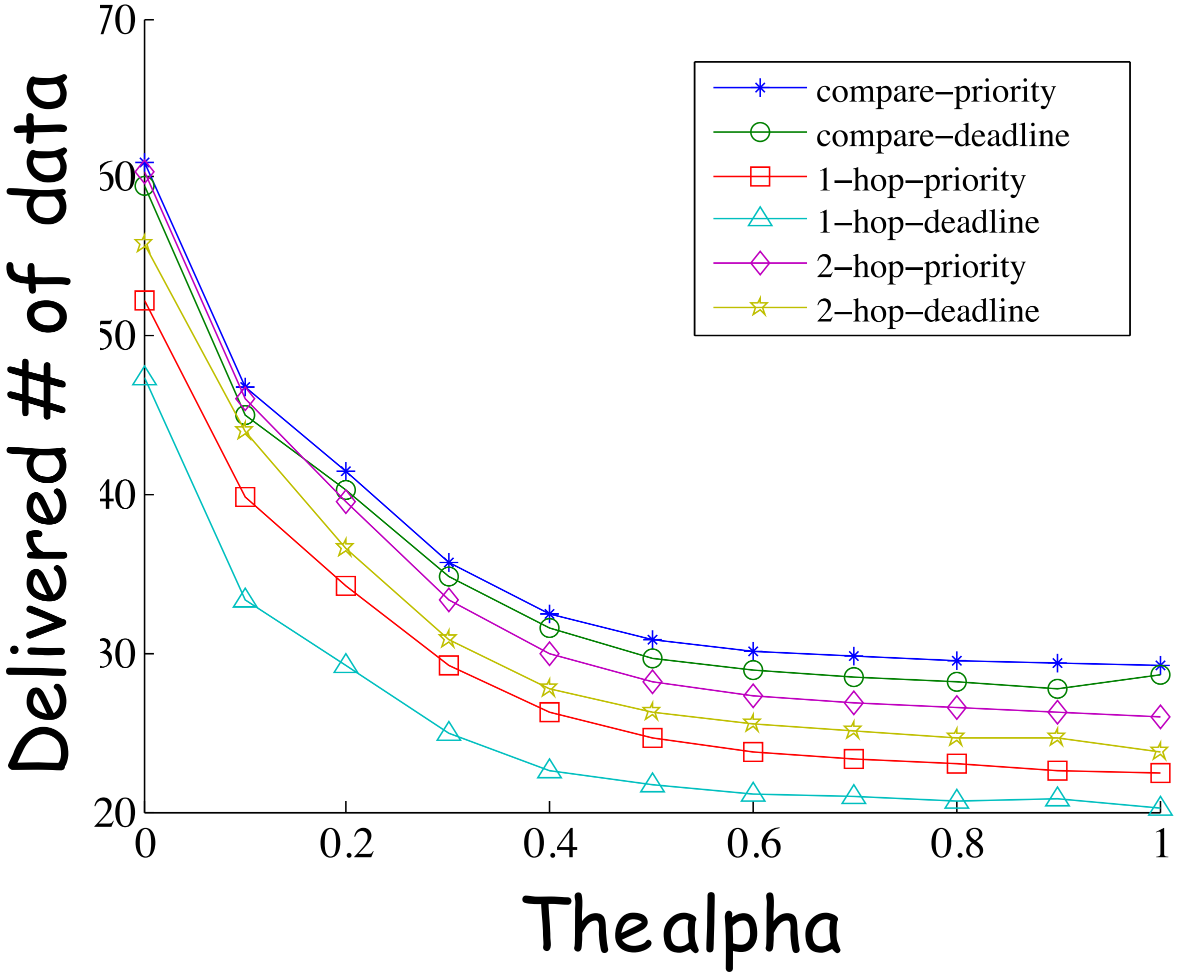
- Synthetic dataset
  - 20 nodes
  - Uniform mobility distribution
  - 5 source nodes and 5 destination nodes.
- Real trace (Infocom2006):
  - 78 mobile nodes + 20 stable nodes
  - 10 source nodes and 10 destination nodes.

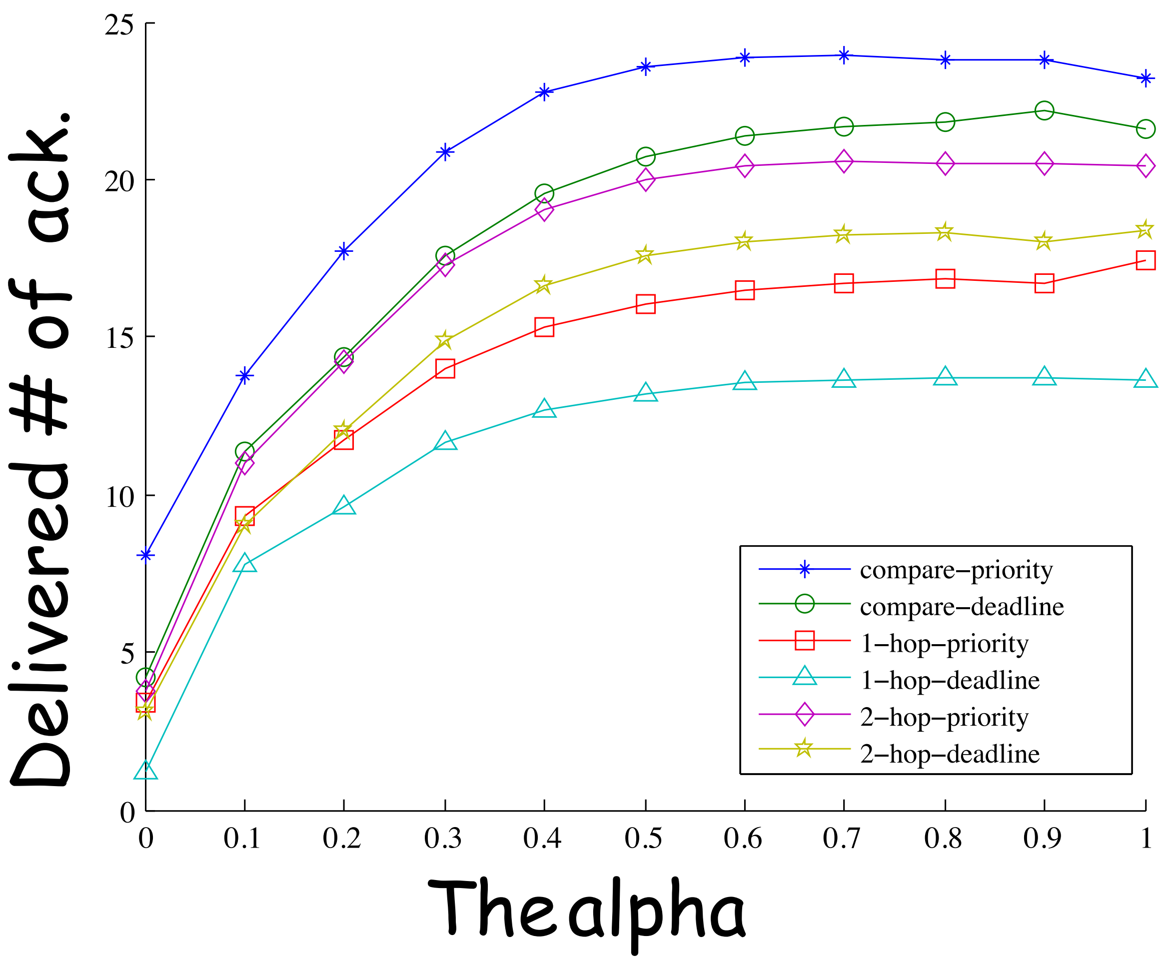
Algorithm comparison

- Algorithms:
  - As for relay selection, we compare our algorithm with 1-hop and 2-hop routing.
  - As for the priority, we compare our method with the deadline

The combination from above is 6 algorithms.

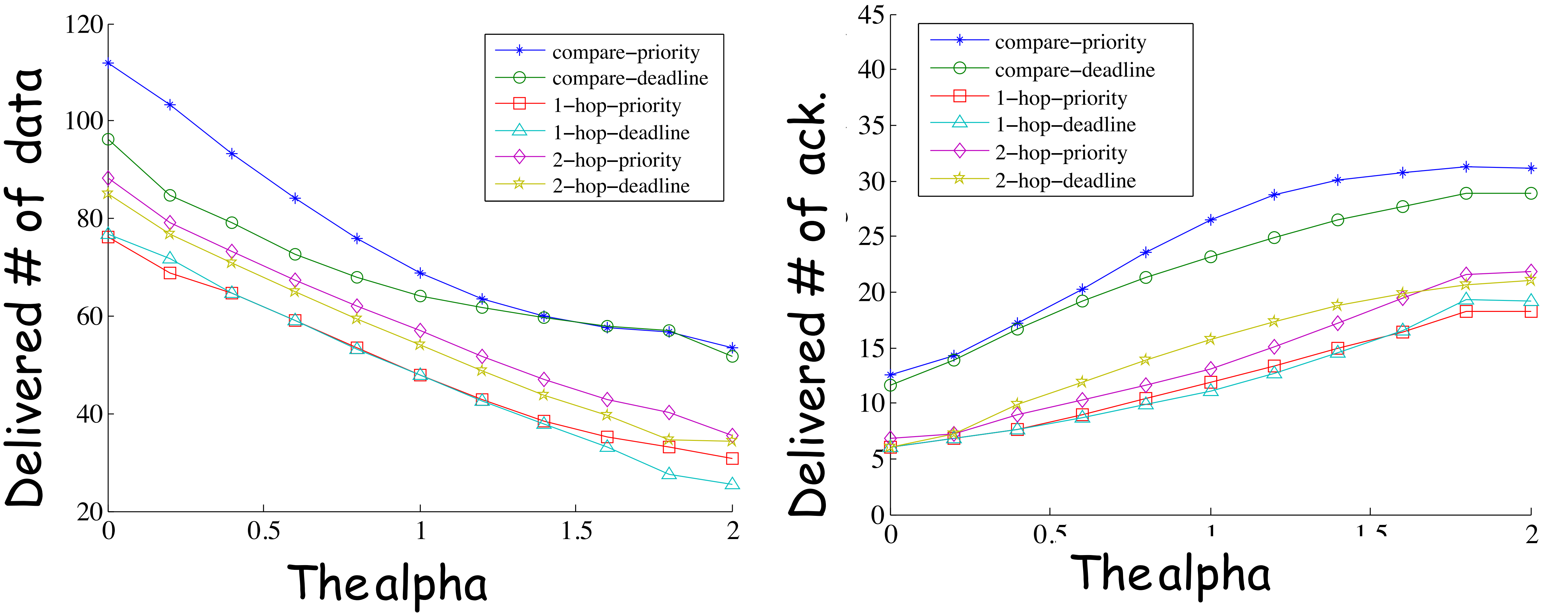
Synthetic dataset





- Along with the increase of alpha, the message delivery ratio decreases, and the ack. delivery ratio increases.
- Our proposed algorithm achieves the highest delivery ratio

Real trace



- Along with the increase of alpha, the message delivery ratio decreases, and the ack. delivery ratio increases.
- Our proposed algorithm achieves the highest delivery ratio

Simulation summary

- Simulation results:
  - Delivered ratio increase with TTL.
  - The factor alpha can adjust the priority well.
- Algorithm:
  - Relay selection
    - Proposed scheme > 2-hop > 1-hop
  - Priority setting
    - Proposed scheme > deadline driven scheme

Conclusions

- We investigate a general scheme for the message dissemination problem in MSNs, considering the time constraint and buffer constraint.
- A novel localized buffer exchange scheme is proposed to maximize the achievable objective.
  - Two dimensions are jointly considered to evaluate the relay
  - The message type, expected delivery time, and deadline are considered to assign priority.

Thank you, any Questions?

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