Heterogeneous Community-based Routing in Opportunistic Mobile Social Networks

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Outline

- Opportunistic Mobile Social Networks
- Heterogeneous Community-based Routing
  - Forwarding Set Selection
  - Recursive 2-Hop Routing
- Simulation Results
- Conclusion

Opportunistic Mobile Social Networks

- ***Opportunistic mobile social networks*** (OMSNs) are designed to operate without the supports of preset infrastructures and guaranteed network connectivity.

Challenges

- Frequent disruptions and delays
- Intermittent connectivity environment
- Insecure communication

Social-aware Single-copy Routing

- Social Information
  - Internal Social Features
    - Low Overhead to Obtain
- Single-copy Scenario
  - Priorities of the Social Features

Transition Probability

- Transition Probability (T): average contact probability of two groups of nodes in a social feature dimension

$$T_i = \frac{1}{f_i}$$

where f_i is the number of different distinct values in social feature dimension i.

  – Male and Female: ***0.5*** (Gender)

Two-Hop Routing

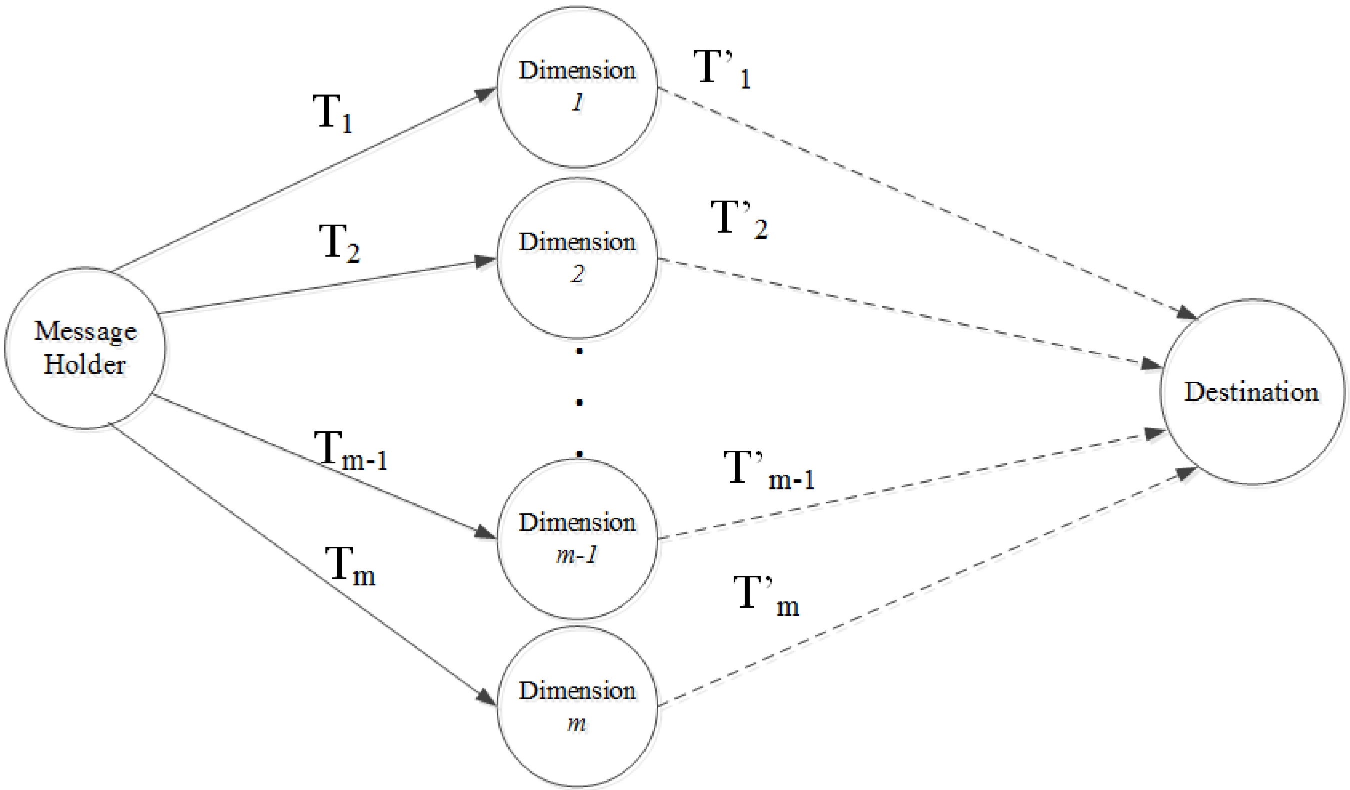
- Uses *local* network information.
- Achieves a high delivery ratio through *mobility* [1].
- Each message copy will be forwarded at most twice, resulting in the advantage of the bounded resource (e.g., energy and buffer) consumption.

[1] M. Grossglauser and D. Tse, "Mobility increases the capacity of ad-hoc wireless networks," IEEE/ACM Trans. Netw., vol. 10, pp. 477–486, Aug. 2002.

Different Dimension Set & Forwarding Set

- **Different Dimension Set** (*D*): the different social feature dimensions to the destination
- **Forwarding Set** (*F*): a set of next relay dimensions that can reduce the expected delivery delay based on the transition probabilities

Link-state Graph



Link-state Graph Cont'd

- The first hop from the message holder to a relay node in social feature dimension d_i, has a transition probability T_i.
- The second hop is a virtual hop from the relay node to the final destination. which can be estimated as

$$T_i' = (|D| - 1)! \times \prod_{j \in D - d_i} T_j$$

where D is the dimension difference set between the message holder and the destination. ($|D|$ – 1)! shows the possible combination of the sequences.

Expected Delay

- The probability density function (PDF) of the message delivery delay is

$$h(t) = \sum_{i \in F} \frac{T_i \times T_i'}{\lambda - T_i'} \left[e^{-T_i' t} - e^{-\lambda t} \right], \qquad (2)$$

where $\lambda = \sum_{i \in F} T_i$.

- The expected delay

$$E = \int_0^\infty h(t) \cdot t dt = \frac{1}{\lambda} \left[1 + \sum_{i \in F} \frac{T_i}{T_i'} \right]. \qquad (3)$$

Forwarding Set Selection

- The optimal forwarding set, F^*, should minimize the corresponding expected delay E.

Algorithm 1 Forwarding Set Selection

Input: The link-stat graph

Sort all virtual paths by T'_i, $T'_1 > T'_2 > ... > T'_m$;
Set $F = \emptyset$, $E = \infty$, and $j = 1$;
while $T'_j > \frac{1}{E}$ and $j \leq m$ **do**
    Add social feature dimension f_j to F;
    Update E according to Eq. 3;
    $j = j + 1$;
end while
return $F^* = F$.

- The virtual links have a higher probability than $1/E$ will be selected into the forwarding set.

Recursive 2-Hop Routing

- Opportunistic forwarding:
  - The message will be forwarded to the first encountered relay node who has the same social feature in the forwarding set F.
- After each step, the resolved social feature dimension will be deleted from the dimension set.
- The social feature resolve process is a recursive 2-hop routing process.

Shortcut

- If there are multiple social feature dimensions in the forwarding set, we can extend the basic scheme by shortcuts, which means that more than one social feature distance can be resolved at one step.
- These social feature dimensions will be deleted from the dimension forwarding set.

Extension: Multi-Copy

- The source node will partition the message copies to its encountered nodes.
- *m*-D space with *C* copies
- Each qualified relay node will receive one copy.
- In order to increase the delivery efficiency, the forwarding paths of these *C* copies should be *C* node-disjoint paths from the source to the destination.

Node-Disjointness

- The node-disjointness means that these C paths are parallel without overlap, which can control the overhead, and at the same time, increase the efficiency.

Greedy Algorithm

- Estimate the expected delay from source to the destination based on the transition probability.
- Select the best sequence with the smallest expected delay.
- Use this sequence to find *C* paths.

Coordinate Sequence

- D^0: $<1,2,\ldots,k>$ is defined as the ***coordinate sequence*** from a given *D*. (D^0 is the best sequence).
- D^0 determines how a path is constructed based on the resolution order of dimension differences given in *D*.

Coordinate Sequence Cont'd

- D^i: i circular left shifts of D^0.
- k node-disjoint shortest paths:
- *Path* 1 generated by D^0 : *<1,2,…,k> ;*
- *Path* 2 generated by D^1 : *<2,3,…,k,1> ;*
- …
- *Path* k generated by D^k : *<k,1,…,k-2,k-1>.*

C best paths selection

- Once we have *k* coordinate sequence paths, we need to select the best *C* paths since we only have *C* copies of message.
- The *C* best paths selection process is the smallest expected delay paths selection process

Simulation

- Infocom 2006 trace: a conference contact trace (6 social features) ;
- MIT reality mining trace: a campus communication trace (6 social features) .

- Synthetic trace: a 100-node network with 8 social features.

Comparison Schemes

- Heterogeneous Community-based Routing
- Random Forwarding
- SimBet [2]

[2] E. M. Daly and M. Haahr. Social network analysis for routing in disconnected delay-tolerant manets. In *Proc. of ACM MobiHoc*, pages 32–40, 2007.

Comparison Parameters

- Latency
- Delivery Rate
- Number of Forwardings

Results 1

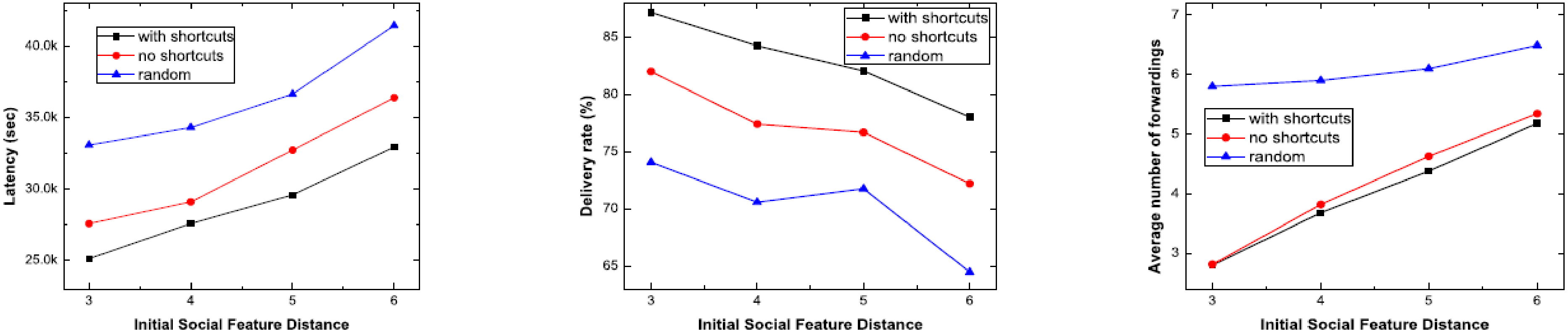


Fig. 2. Simulation results in the Infocom trace.

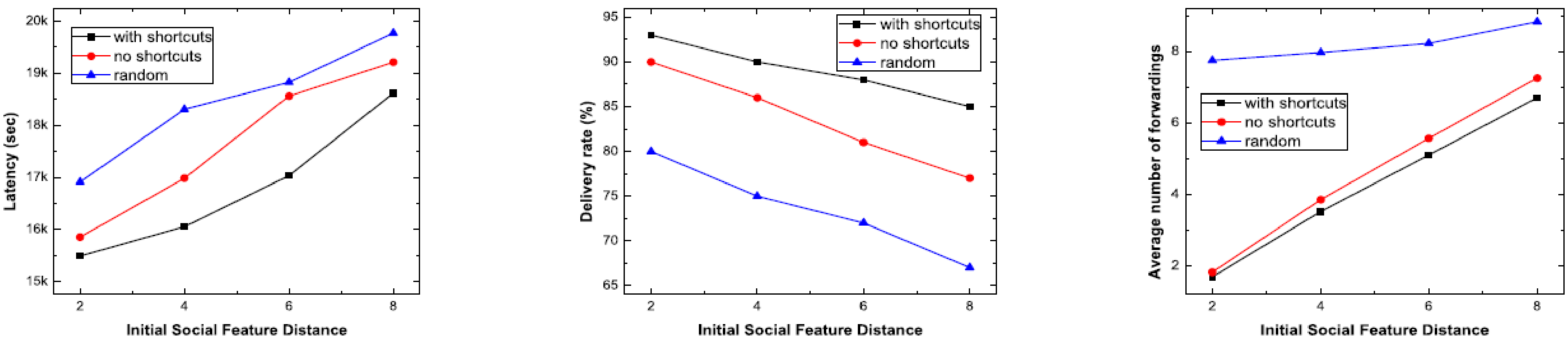


Fig. 3. Simulation results in the synthetic trace.

Results 2

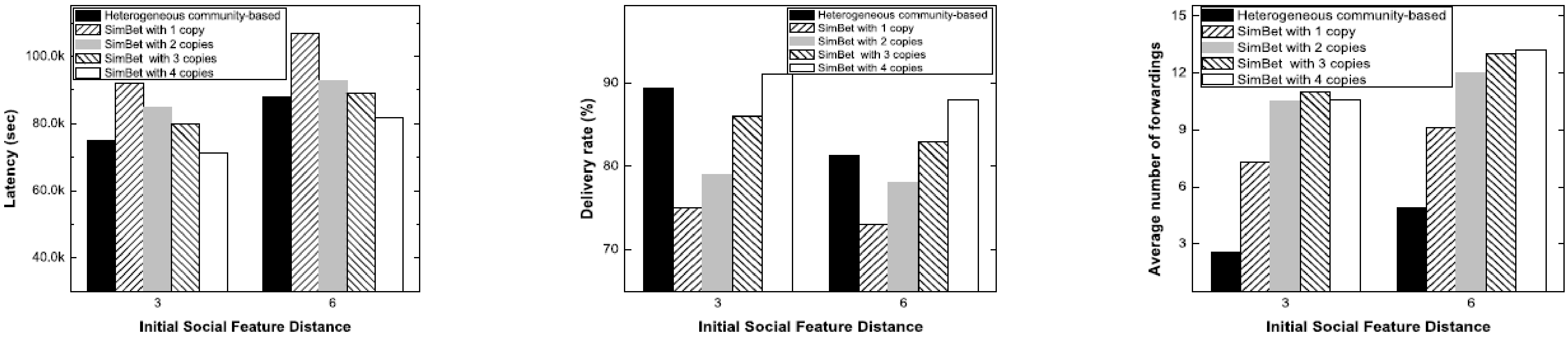


Fig. 4. Comparison with SimBet scheme in the MIT reality trace.

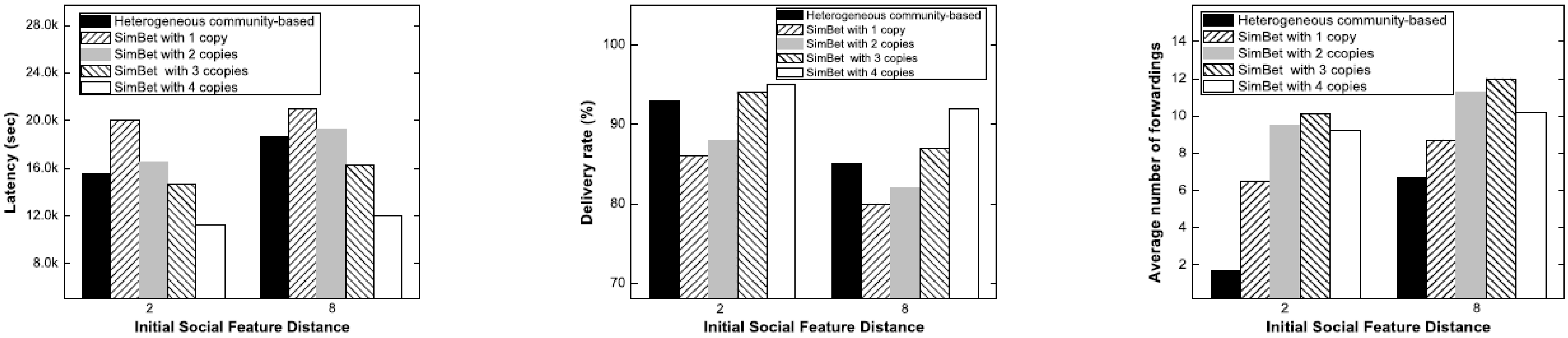


Fig. 5. Comparison with SimBet scheme in the synthetic trace.

Conclusion

- Heterogeneous Community-based Routing
  - Forwarding Set Selection
  - Recursive 2-Hop Routing
- Single Copy vs Multi-Copy

Thank You