GZ06 – Mobile & Adaptive Systems

Presentation by:

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on

Social Network Analysis for Routing in Disconnected Delay-Tolerant MANETs

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Contents

- Introduction
- Concepts
- SimBet Routing
- Results
- Conclusion

Key Points

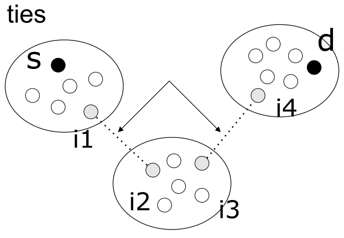
1. Routing in sparse DTN MANETs .
2. Social Network Analysis and graph theory .
3. Performance comparison with PRoPHET & Epidemic.

Related Work

- DTN MANETs treated in class:
  - CarTel
  - ZebraNet
  - Predictive Publish Subscribe for DTN
- Epidemic
- ProPHET

Social Network Analysis Techniques

- Exploited in order to:
  - Identify bridging ties
    - Centrality
  - Identify clusters
    - Similarity



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SimBet Routing Distinction

- Metric comprised of both a node's centrality and social similarity.
- For unknown destinations, message routed to a 'more central' node to increase potential of finding suitable carrier.
- No assumptions of:
  - Node movement control
  - Knowledge of future movements
  - Message multi-copies (leading to a conservation of network resources).
- Improves on encounter-based strategies where direct or indirect encounters may be available.

Contents

Centrality

- Originally developed to measure the importance of a person in a social network.
- Important people typically have a strong capability of connecting other network members.
- Located at the centre of a network and act as a connection between clusters.
- Made up of three components.

Centrality Metrics [Freeman 1977,1979]

- Degree centrality
  - popular nodes in the network

$$C_D(p_i) = \sum_{k=1}^{N} a(p_i, p_k)$$

- Closeness centrality
  - the distance of a given node to each node in the network

$$C_C(p_i) = \frac{N-1}{\sum_{k=1}^{N} d(p_i, p_k)}$$

- Betweenness centrality
  - the extent to which a node can facilitate communication to other nodes in the network

$$C_B(p_i) = \sum_{j=1}^{N} \sum_{k=1}^{j-1} \frac{g_{jk}(p_i)}{g_{jk}}$$

Ego-Networks

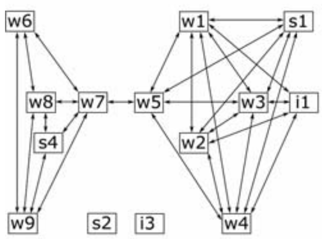
- Can't use Freeman centrality metrics, as it requires knowledge of the total network.
- Ego-Networks consist of a single actor (ego), the actors it is connected to (alters) and the links between them.
- Analysis can be performed locally.
- Centrality metrics introduced by Marsden.

Ego-Networks Metrics

- Centrality-Degree
  - Easy to measure locally
  - Number of contacts
- Centrality-Closeness
  - Not existent, since all links are direct
- Centrality-Betweenness
  - Does not perfectly correspond to sociocentric measure, but ranking is the same.

Ego-Networks Metrics

- Centrality-Betweenness



Node	Sociocentric betweenness	Egocentric betweenness
w1	3.75	0.83
w2	0.25	0.25
w3	3.75	0.83
w4	3.75	0.83
w5	30	4
w6	0	0
w7	28.33	4.33
w8	0.33	0.33
w9	0.33	0.33
s1	1.5	0.25
s2	0	0
s4	0	0
i1	0	0
i3	0	0

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SIMILARITY

- Based on high transitivity in social networks
- Separation can be measured by the ratio of common neighbours between individuals
- Therefore nodes with a low degree of separation are good for routing
- Newman analysed past collaborations to predict future collaborations.
- Liebel-Nowel and Kleinberg explored this theory.

$$P(x, y) = |N(x) \cap N(y)|$$

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Betweenness Utility Calculation

- Node contacts represented by symmetric adjacency matrix A ***nxn***, (***n*** # contacts a node has encountered) with elements

$$A_{ij} = \begin{cases} 1 & \text{if there is a contact between } i \text{ and } j \\ 0 & \text{otherwise} \end{cases}$$

w8 =

	w8	w6	w7	w9	s4
w8	0	1	1	1	1
w6	1	0	1	1	0
w7	1	1	0	1	1
w9	1	1	1	0	1
s4	1	0	1	1	0

- Contacts bidirectional
- Ego betweenness is given as the sum of the reciprocals of

$$A^2 [1 - A]_{ij}$$

w8²[1-w8] =

	w8	w6	w7	w9	s4
w8	*	*	*	*	*
w6	*	*	*	*	3
w7	*	*	*	*	*
w9	*	*	*	*	*
s4	*	*	*	*	*

[Everett and Borgatti 2005]

Similarity Utility Calculation

- Node similarity is a simple count of common neighbours
- Indirect Node contacts learnt during a node encounter is represented in and additional matrix

w8 =

	w8	w6	w7	w9	s4	w5
w8	0	1	1	1	1	0
w6	1	0	1	1	0	0
w7	1	1	0	1	1	1
w9	1	1	1	0	1	0
s4	1	0	1	1	0	0

SimBet Utility Calculation

- Goal: to select node that represents the best trade off across both attributes

$$SimUtil_n(d) = \frac{Sim_n(d)}{Sim_n(d) + Sim_m(d)}$$

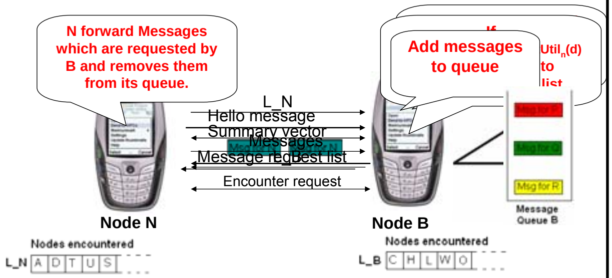
$$BetUtil_n = \frac{Bet_n}{Bet_n + Bet_m}$$

- Combined:

$$SimBetUtil_n(d) = \alpha SimUtil_n + \beta BetUtil_n$$

$$\alpha + \beta = 1$$

SimBet Routing



SimBet Routing Algorithm

Algorithm 1 SimBet Routing Algorithm, pseudo-code of node *n*

```
upon reception of Hello message h from node m do
 if newNeighbour(m) == true
   if msgQueue.hasMsgsForDest(m) == true
     deliverMsgs(m)
   requestEncounters(m)

upon reception of encounter vector ev from node m do
addNodeEncounters(m, ev)
updateBetweenness()
updateSimilarity()
exchangeSummaryVector(m)

upon reception of summary vector sv from node m do
  Vector requestMsgs
  for all destinations є sv do
    if m.simBet(d) < simBet(d)
      requestMsgs.add(d)
  sendMsgRequest(m, requestMsgs)

upon reception of message request vector mrv from node m
do
Vector transferMsgs
for all messages є mrv do
  transferMsgs.add(msgQueue.getMsgs(d))
sendTransferMsgs(m, transferMsgs)

upon reception of transfer message tm from node m do
  msgQueue.add(tm)
```

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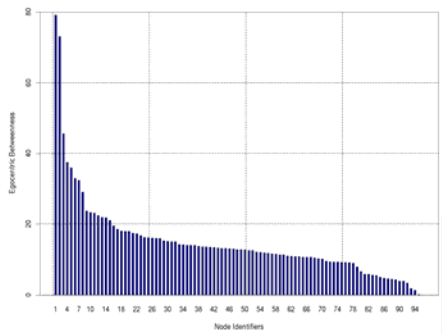
Simulation

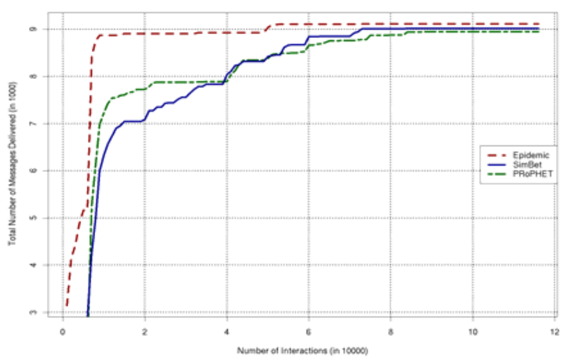
- Simulation based on trace from MIT Reality Mining project
  - 100 users carrying smartphones for 9 months
  - Bluetooth sightings = opportunity for data exchange
- Compared results to:
  - Epidemic Routing [Vahdat and Becker 2000]
  - PRoPHET [Lindgren, Doria and Schelén 2004]

Egocentric Betweenness

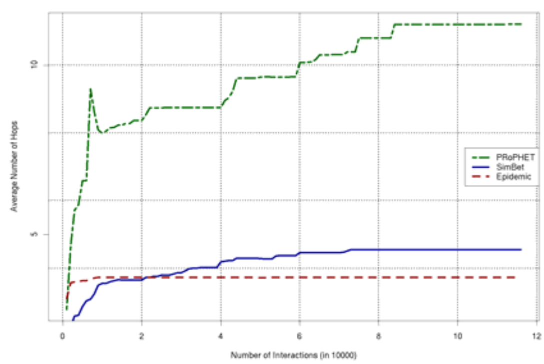


Friendship network
Eagle and Pentland

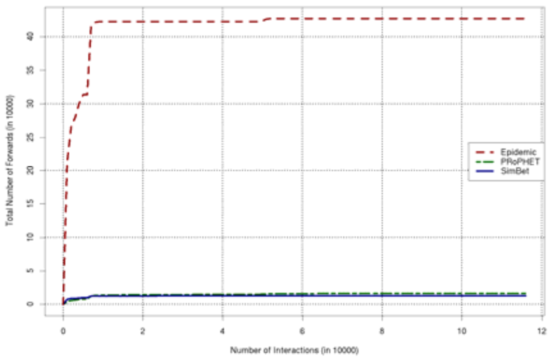
Total number of messages delivered



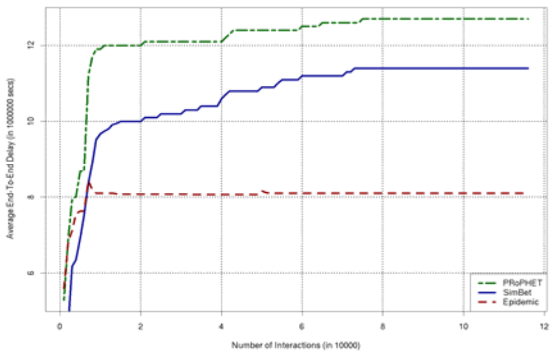
Average Number of Hops



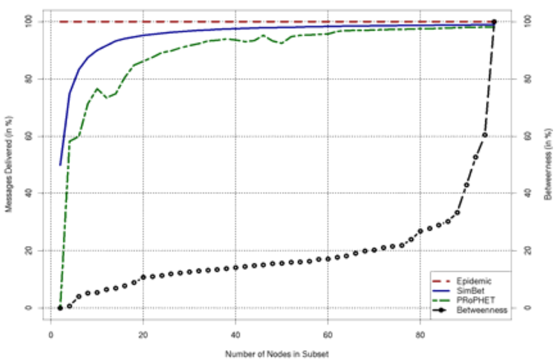
Total Number of Forwards



Average End-To-End Delay



Delivery Performance between least connected nodes



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Conclusion

- Simple metrics for capturing network social structure suitable for disconnected delay-tolerant MANETs
  - Egocentric Betweenness
  - Centrality Similarity
- Achieves similar performance to Epidemic routing without the overhead
- Finds shorter paths than Prophet
  - Lower average end-to-end delay
- Achieves delivery performance between least connected nodes

Criticism

1. Assumption of bi-directional communication of nodes.
2. No investigation into effects of varying α and β parameters in experiment.
3. No hint on real-life application.
4. Other metrics could have been included in the utility function.
5. Large end-to-end delay – spans up to months!