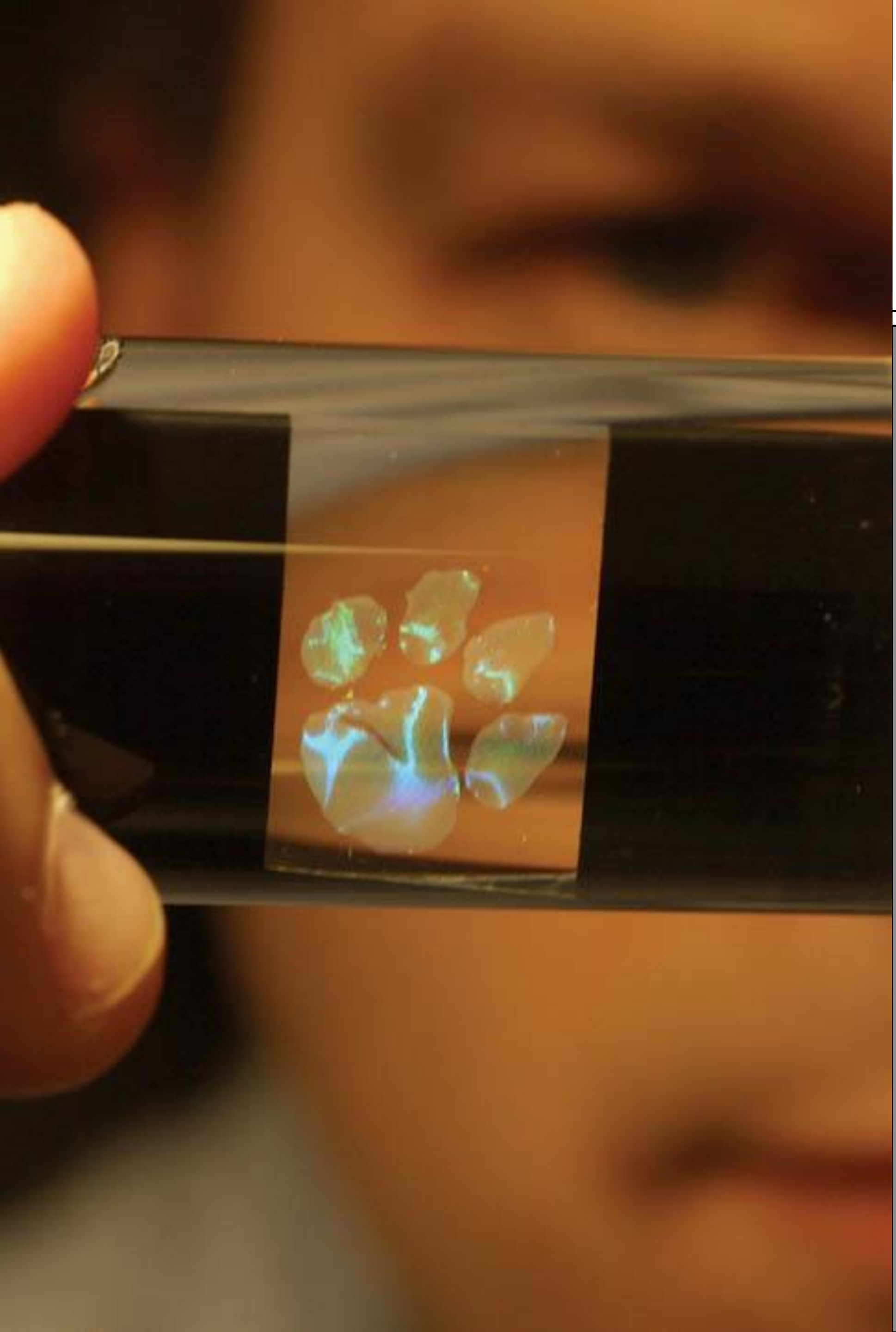

TSearch: Target-Oriented Low-Delay Node Searching in DTNs with Social Network Properties

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Outline

- Introduction
- Related work
- Rationale of TSearch design
- System design of TSearch
- Evaluation
- Conclusion

Introduction

- Nodes form delay tolerant networks in distributed manner
  - Without infrastructure for communication
- Nodes move autonomously in the network
  - Example 1: malfunctioning sensors on animals
  - Example 2: malicious nodes in the network
  - Example 3: mobile devices held by people on campus

Introduction (cont.)

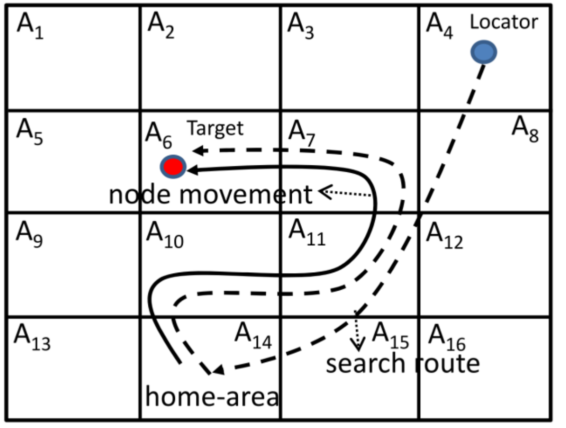
- Node searching is **important**
  - Find a node carrying a malfunctioning device
  - Locate malicious nodes timely
  - Enable the search of device holders
- Node searching is also **non-trivial**
  - No central controller to guide node movement
  - No infrastructure to collect node location information
  - Information transmission follows the “delay tolerant” manner

Related Work

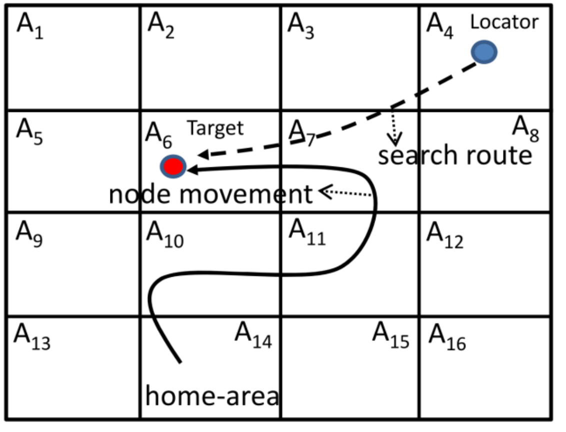
- Infrastructure-based methods [SIGCOMM'07, ICNP'13]
  - Rely on infrastructure to collect node mobility information
  - Drawbacks:
    - Not applicable to the DTN scenario
- DTN routing methods [SIGCOMM'07, INFOCOM'10]
  - Can achieve node searching
  - Drawbacks:
    - Low efficiency due to hop-by-hop routing
- DTN node searching methods [INFOCOM'14]
  - Summarize node mobility information
  - Let nodes store & distribute mobility information in the network for node searching

Related Work (cont.)

- DTN node searching methods [INFOCOM’14]
  - Drawbacks:
    - Tracing target along its movement is not sufficiently efficient



- Proposed method
  - Locators move to the most recent location of target
  - Use nodes’ preference in specific locations for search
  - Use nodes’ friends for search



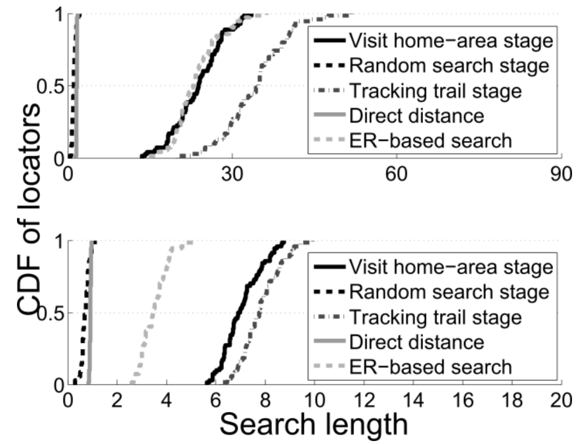
Rationale of TSearch Design

- Real traces for analysis
  - Dartmouth trace (DART) [1]:
    - A 119-day record for wireless devices carried by students on Dartmouth College campus
    - Initial period: 30 days
    - 70 locators were generated periodically (1 day) for 90 times
  - DieselNet trace (DNET) [2]:
    - A 20-day record for WiFi nodes attached to the buses in the downtown area of UMass college town
    - Initial period: 2.5 days
    - 70 locators were generated periodically (4 hours) for 90 times

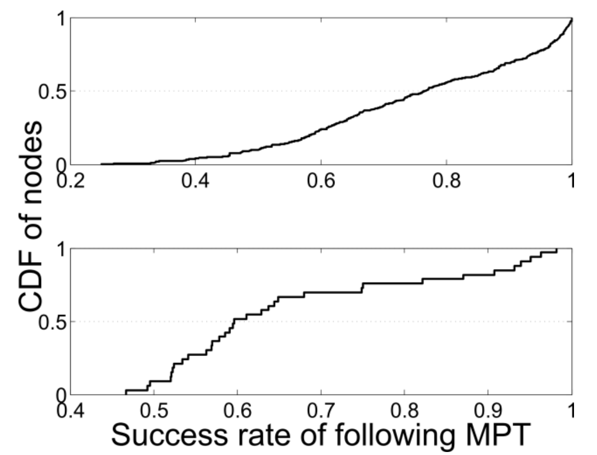
[1] T. Henderson, etc. "The changing usage of a mature campus-wide wireless network," in Proc. of MobiCom, 2004.
[2] X. Zhang, etc. "Study of a bus-based disruption-tolerant network: mobility modeling and impact on routing," in Proc. of MobiCom, 2007.

Rationale of TSearch Design

- Drawback of DSearch
  - Long distances to the home-area and movement trail of the target node
  - Solution: let locator move directly to the most recent locations of the targets.

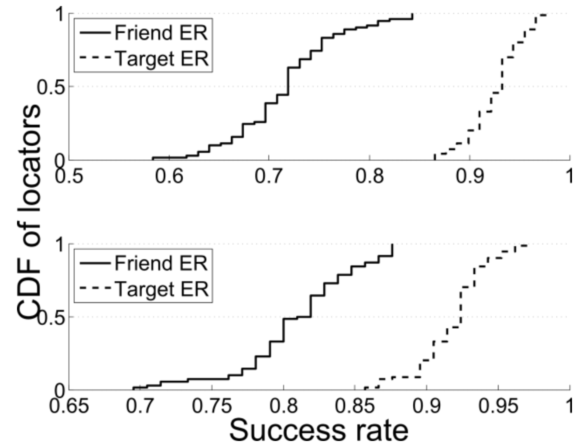


- Effectiveness of preferred locations on searching
  - Nodes have preference on multiple locations

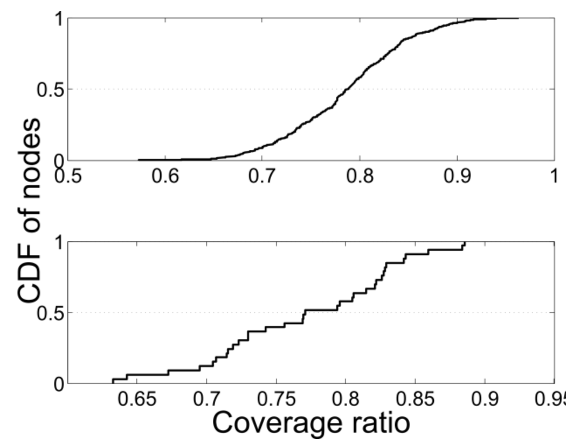


Rationale of TSearch Design (cont.)

- Friends
  - Each node has certain frequently meeting nodes
  - ERs of the target's friends can be used as complementary method for node searching.

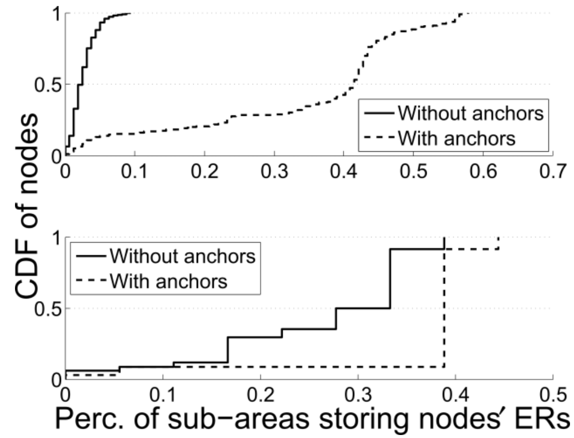


- Search range constraint
  - Nodes' possible locations can be determined based on the normal node velocity and the time and location in the nodes' latest ER

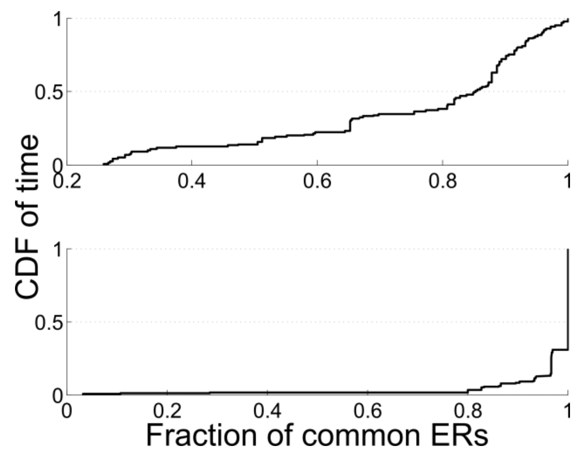


Rationale of TSearch Design (cont.)

- Information dissemination
  - Anchors: nodes that stay in certain sub-area for a long time
  - Anchors store mobility information of nodes for easy access.



  - Ambassadors: nodes that frequently transit between two sub-areas
  - Ambassadors help maintain consistency of mobility information among anchors



Design: Problem Definition

- A DTN with n nodes
  - $N_i,\ i = 1,2,3,\cdots,n$
- Whole DTN is split into sub-areas
  - Each sub-area contains one landmark, e.g., a popular place
  - The area between two landmarks is evenly split
  - No overlap among sub-areas
- Node searching
  - Enabling the locator to find the sub-area where the target node resides in

Design: Info. for Searching

- Encounter record (ER)
  - Generated when nodes encounter with each other
  - Shows a historical location of the node

$$< N_i, N_j, L_{ij}, T_{ij} >$$

  - N_i and N_j represent the two encountering nodes
  - L_{ij} and T_{ij} represent the current sub-area and the current time, respectively

- Purpose of ER
  - Providing the information on recent locations of the target

Design: Info. for Searching

- Friends and preferred locations
  - **Friends:** nodes that take up at least a high percentage (60%) of all contacts with the node
  - **Preferred locations:** The top ranked sub-areas that constitute 60% of visiting frequency of the target node.
- Purpose of friends and preferred locations
  - Providing the information on target's preference in meeting nodes and visiting sub-areas

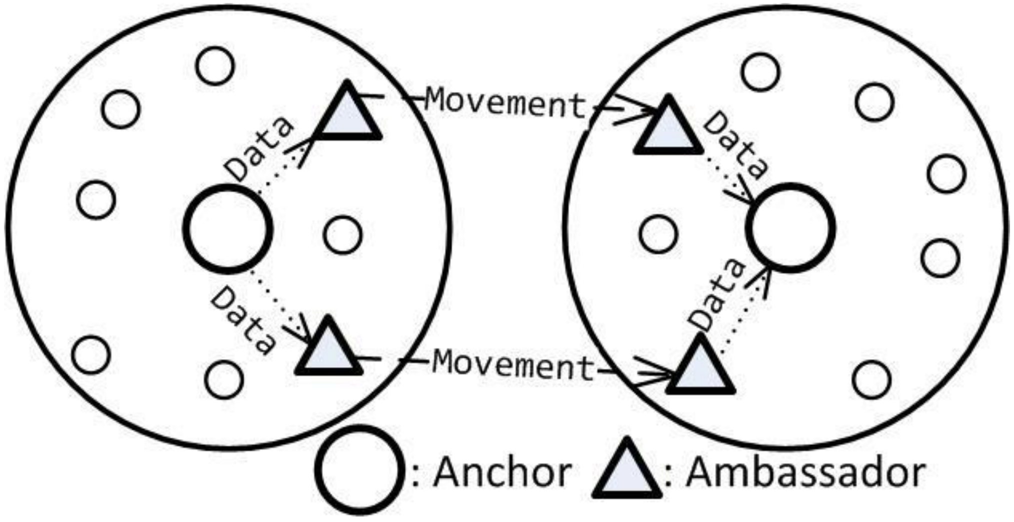
Node	Friends	Meeting prob.	Preferred locations	Visiting prob.
N_1	N_3	0.9	A_3	0.95
	N_4	0.8	A_4	0.8
	N_6	0.7	A_5	0.75

Design: Distribute Mobility Info.

- Anchor
  - Stable node with high storage and computing capacity
  - Collect ERs, friends and preferred locations of nodes
  - Once locator moves into a sub-area, it can quickly access the information of nodes that once visited the sub-area from the anchors of the sub-area
- Ambassador
  - Nodes frequently transiting between two sub-areas
  - Maintain the consistency of information among anchors

Design: Distribute Mobility Info.

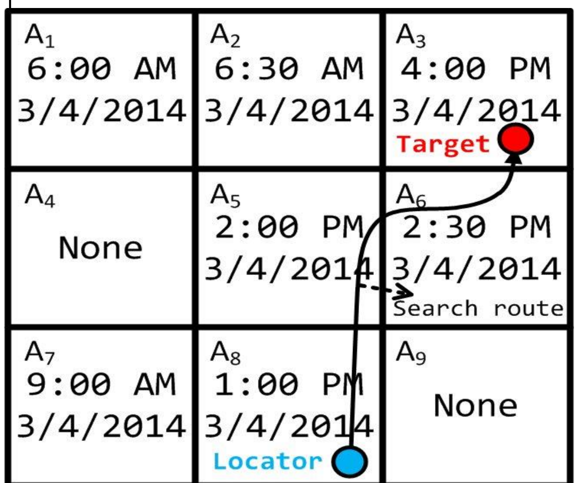
- Role determination
  - Anchor: staying probability of a node is larger than a threshold
  - Ambassador: frequency of transiting between two sub-areas is higher than a threshold



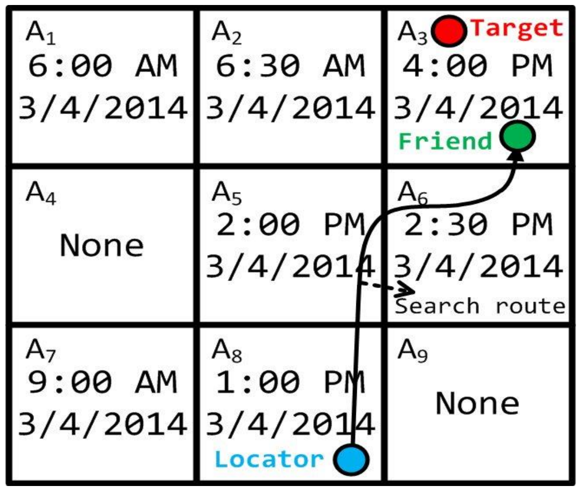
Design: Node Searching

- Node searching based on ERs
  - Locator moves to the location in the ER
  - Changes destination if newer ER is found
- Node searching based on friends' ERs
  - Locator moves to the location in the ER of the friend that has the highest meeting probability with the target
- Node searching based on target's preferred locations
  - Locator moves to the nearest preferred location
  - Locator relies on M nodes (as agents) to search the next top M preferred locations
  - Agents have common preferred locations with the target
  - If an agent finds the target, it uses a routing algorithm to notify the locator

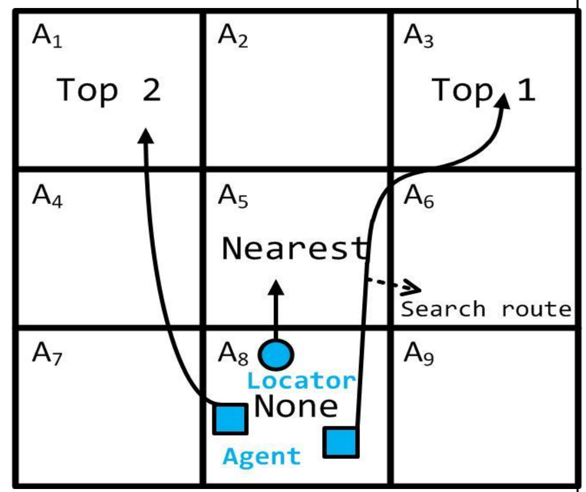
Design: Node Searching



Based on ERs



Based on friends' ERs



Based on preferred locations

Performance Evaluation

- Simulator
  - Event driven simulator
- Node Mobility Traces
  - Dartmouth trace (DART): records of mobile devices on campus [1]
  - DieselNet trace (DNET): records of buses in a college town [2]
- Comparison Methods
  - TS*: TSearch with ER exchange
  - TS: TSearch without ER exchange
  - DS: DSearch distributed node searching [INFOCOM 14']
  - Routing: a routing based method [SIGMOBILE 03']
  - ER: TSearch using ER only

[1] T. Henderson, etc. "The changing usage of a mature campus-wide wireless network," in Proc. of MobiCom, 2004.
[2] X. Zhang, etc. "Study of a bus-based disruption-tolerant network: mobility modeling and impact on routing," in Proc. of MobiCom, 2007.

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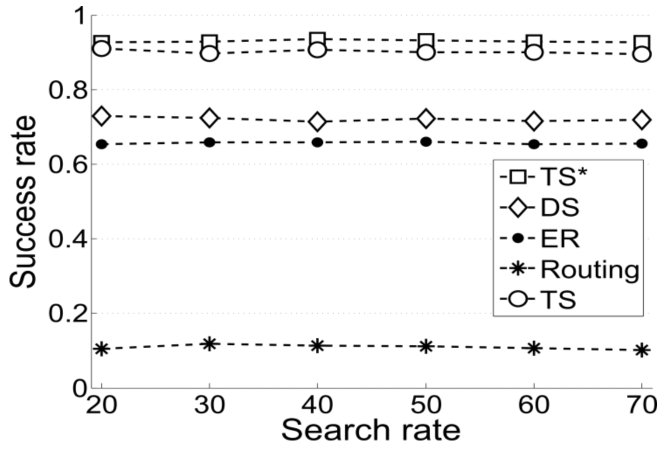
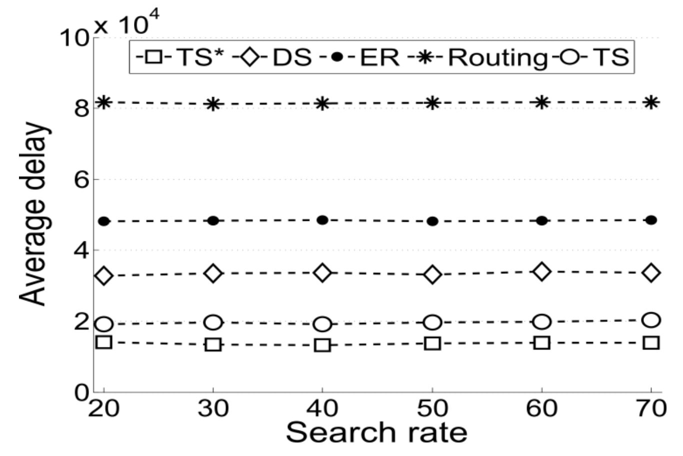
Metrics

- Success rate
  - The percentage of locators that can successfully locate the target nodes within the TTL
- Average delay
  - The average time used by successful locators
- Average transmission overhead
  - The average number of all packets transmitted among nodes
- Average node memory usage
  - The average number of memory units used by each node

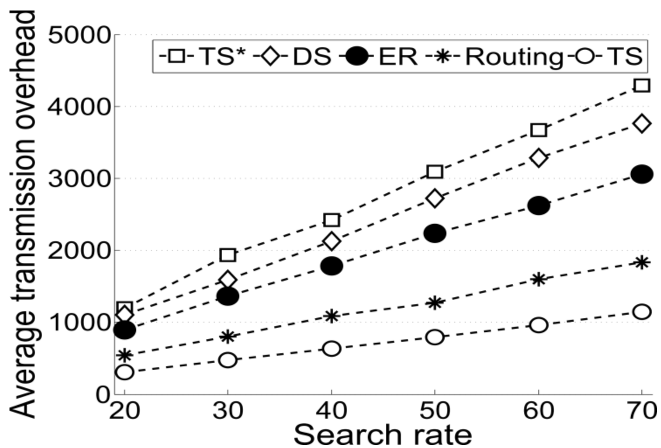
Experiment with Different Search Rates (DART)



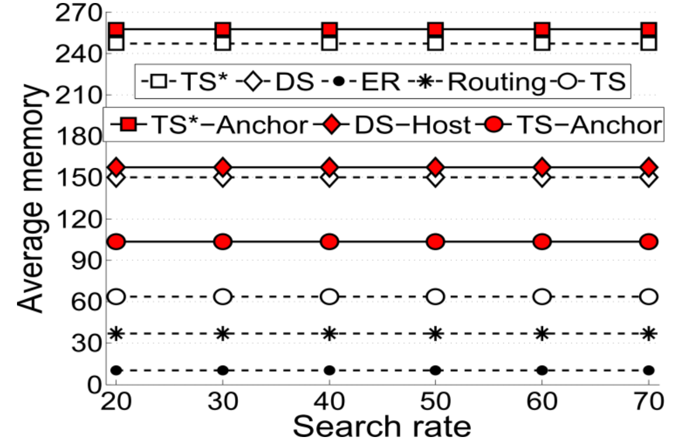
Success rate: TS*>TS>DS>ER>>Routing



Ave. delay: TS*<TS<DS<ER<<Routing

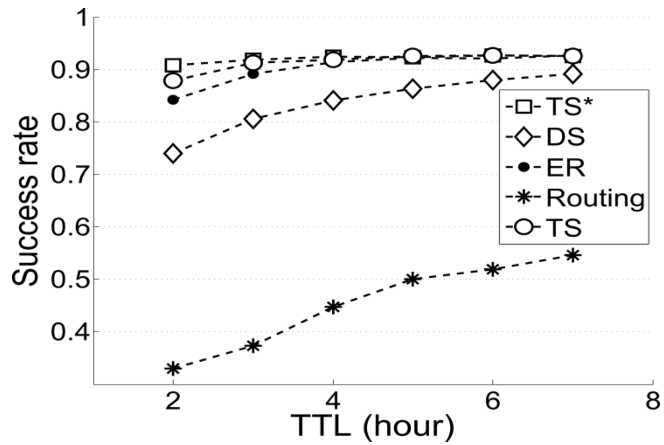


Ave. trans. overhead: TS<Routing<ER<DS<TS*

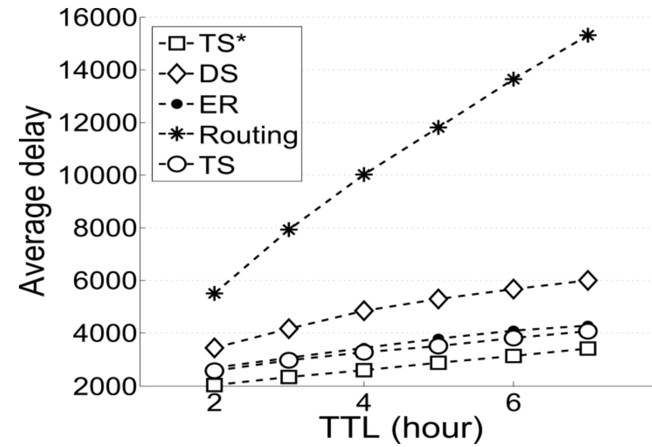


Ave. memo. usage: ER<Routing<TS<DS<TS*

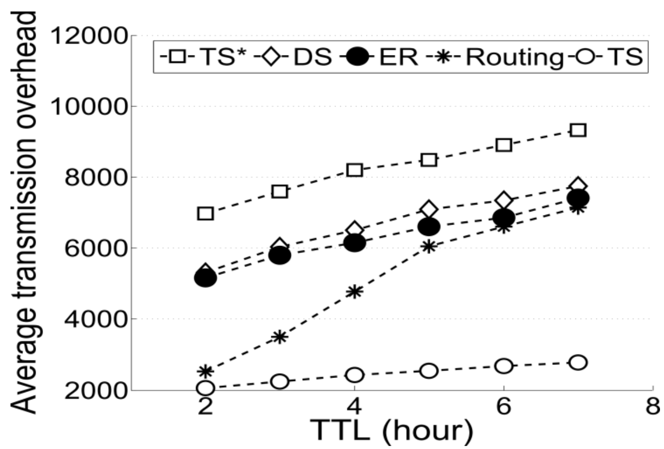
Experiment with Different TTLs (DNET)



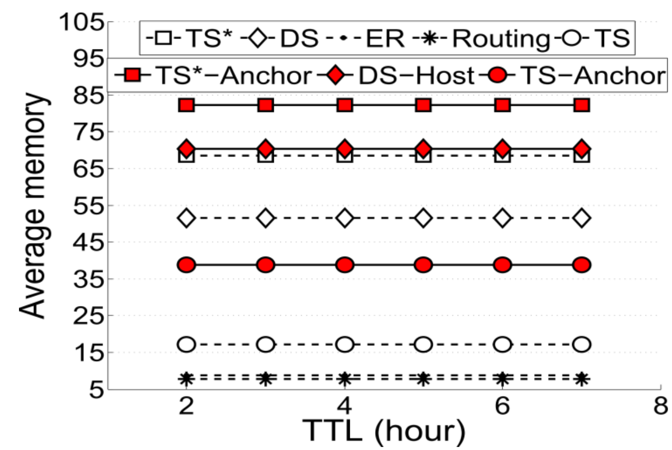
Success rate: TS*>TS>DS>ER>>Routing



Ave. delay: TS*<TS<DS<ER<<Routing



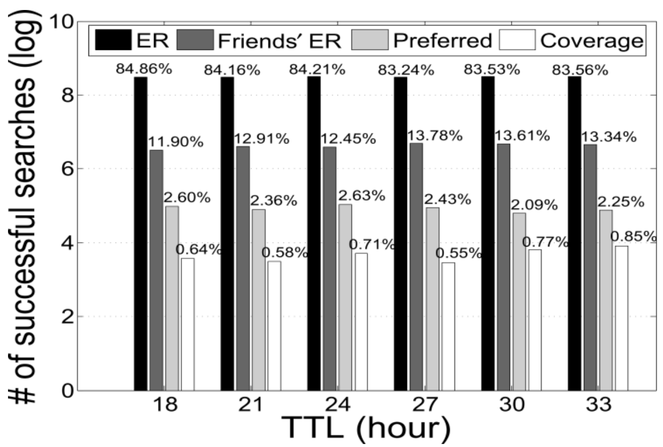
Ave. trans. overhead: TS<Routing<ER<DS<TS*



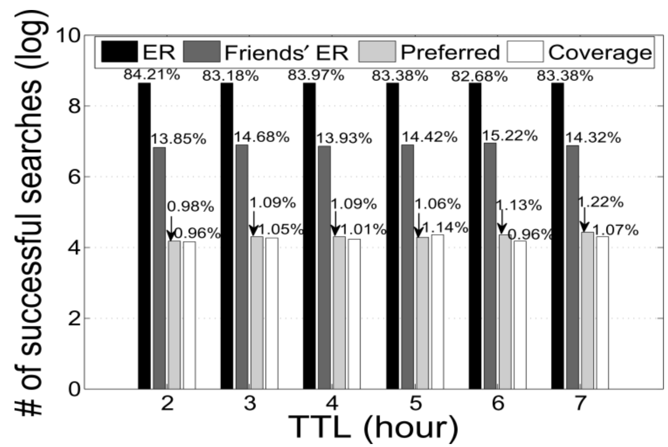
Ave. memo. usage: ER<Routing<TS<DS<TS*

Contribution of Different Stages in TSearch

- Most of the successful searches are achieved by following the target's ERs.
- The ERs of the target's friends have the second highest contribution on the success rate.
- The target's preferred location information has the third highest contribution on success rate.



DART



DNET

Conclusions

- Our real trace analysis confirms the drawbacks of previous node searching methods in DTNs
- We proposed TSearch, it
  - enables a locator to always move to the target's latest appearance place known by itself
  - enables a locator to find the target through its friends
  - enables a locator to ask a limited number of nodes that share common preferred locations with the target to assist node searching
- In our future work, we plan to further exploit nodes' social network properties to reduce node searching delay and overhead.

Thank you!

Questions & Comments?

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