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

Presenter: Fangming Liu

Authors: Li Yan, Haiying Shen and Kang Chen
Dept. of Electrical and Computer Engineering
Clemson University, SC, USA
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

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
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
  - $N_i$, $i = 1, 2, 3, \ldots, n$

- 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

<table>
<thead>
<tr>
<th>Node</th>
<th>Friends</th>
<th>Meeting prob.</th>
<th>Preferred locations</th>
<th>Visiting prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_1$</td>
<td>$N_3$</td>
<td>0.9</td>
<td>$A_3$</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>$N_4$</td>
<td>0.8</td>
<td>$A_4$</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>$N_6$</td>
<td>0.7</td>
<td>$A_5$</td>
<td>0.75</td>
</tr>
</tbody>
</table>
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

[Diagram showing anchor and ambassador nodes with movement and data exchange.]
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

<table>
<thead>
<tr>
<th>A_1</th>
<th>A_2</th>
<th>A_3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Target</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A_4</th>
<th>A_5</th>
<th>A_6</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2:00 PM 3/4/2014</td>
<td>2:30 PM 3/4/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Search route</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A_7</th>
<th>A_8</th>
<th>A_9</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 AM 3/4/2014</td>
<td>1:00 PM 3/4/2014</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locator</td>
</tr>
</tbody>
</table>

Based on friends’ ERs

<table>
<thead>
<tr>
<th>A_1</th>
<th>A_2</th>
<th>A_3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Target</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A_4</th>
<th>A_5</th>
<th>A_6</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>2:00 PM 3/4/2014</td>
<td>2:30 PM 3/4/2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Search route</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A_7</th>
<th>A_8</th>
<th>A_9</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 AM 3/4/2014</td>
<td>1:00 PM 3/4/2014</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locator</td>
</tr>
</tbody>
</table>

Based on preferred locations

<table>
<thead>
<tr>
<th>A_1</th>
<th>A_2</th>
<th>A_3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Top 1</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A_4</th>
<th>A_5</th>
<th>A_6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Search route</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A_7</th>
<th>A_8</th>
<th>A_9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Locator</td>
<td>Agent</td>
</tr>
<tr>
<td></td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

17
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

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: $\text{TS}^* > \text{TS} > \text{DS} > \text{ER} >> \text{Routing}$

Ave. delay: $\text{TS}^* < \text{TS} < \text{DS} < \text{ER} < \text{Routing}$

Ave. trans. overhead: $\text{TS} < \text{Routing} < \text{ER} < \text{DS} < \text{TS}^*$

Ave. memo. usage: $\text{ER} < \text{Routing} < \text{TS} < \text{DS} < \text{TS}^*$
Experiment with Different TTLs (DNET)

Success rate: $\text{TS}^* > \text{TS} > \text{DS} > \text{ER} > \text{Routing}$

Ave. delay: $\text{TS}^* < \text{TS} < \text{DS} < \text{ER} < \text{Routing}$

Ave. trans. overhead: $\text{TS} < \text{Routing} < \text{ER} < \text{DS} < \text{TS}^*$

Ave. memo. usage: $\text{ER} < \text{Routing} < \text{TS} < \text{DS} < \text{TS}^*$
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.
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?

Li Yan, PhD Candidate
lyan@clemson.edu
Pervasive Communication Laboratory
Clemson University