DIAL: A Distributed Adaptive-Learning Routing Method in VDTNs

Authors: Bo Wu, Haiying Shen and Kang Chen
Dept. of Electrical and Computer Engineering
Clemson University, SC, USA
Outline

- Background
- Trace data analysis
- Distributed Adaptive-Learning (DIAL) routing algorithm
- Evaluation
- Conclusion
Background

- **Delay tolerant network (DTN)**
  - Disruption and intermittent connectivity
  - Nodes move autonomously in the network

- **Vehicle Delay Tolerant Network (VDTN)**
  - Delay Tolerant Network consisting of vehicles

- **VDTN its own characteristics**
  - High vehicle mobility
  - Sparsity of vehicles
  - Short contact durations
Background

• **Routing algorithms**
  – Nodes communicate in a distributed manner without an infrastructure
  • Real-time traffic and emergency notification among vehicles
Background (cont.)

• Contact based algorithms [MC2R’03]
  – Select nodes with higher encounter frequency with target node for relaying packets.

• Centrality based algorithms [Infocom’10]
  – Select nodes with higher centrality for relaying packets.

• Location based algorithms [IPDPS’13]
  – Select nodes which will visit the locations that target node will visit for relaying packets.
Background (cont.)

• Not sufficiently efficient
  • Contact based algorithms
    – Low chance for a packet to encounter a suitable relay vehicle in a large-scale VDTN
  • Centrality based algorithms
    – The reachability of vehicles to different vehicles is not considered
  • Location based algorithms
    – Nodes close to the target may not move towards it
• Solution: adaptively choose the algorithm that performs the best
Our Work

• **Trace data analysis**
  – The performances of different routing algorithms can be different on different vehicle pairs
  – It is difficult to predict the performances of different routing algorithms based on vehicle features

• **Proposed method**: Choose the routing algorithm for individual vehicle pairs
Trace Data Analysis

- Measurements based on vehicle mobility traces
  - Taxi trajectory in Roma (Roma) [1]:
    - Size: 320 taxies
    - Period: from Feb. 1 to Mar. 2, 2014
    - Location: the center of Roma
  - Taxi trajectory in San Francisco (SanF) [2]:
    - Size: 500 taxies
    - Period: 30 days
    - Location: San Francisco Bay Area

Rationale (cont.)

The percentage of vehicle pairs that each routing algorithm performs the best:

Observation:
• Location > Centrality > Contact;
Rationale (cont.)

The top 50 vehicle pairs with the shortest delays of different routing algorithms:

Observations:
- When it comes to specific pairs of vehicles, it is difficult to predict the performances of different routing algorithms.
Rationale (cont.)

Contact based routing vs. other routings

Contact based routing
Centrality based routing
Location based routing

ICAR
Greenville
Clemson

With a contact utility of 0.1
Contact utility: 0.09
Centrality utility: 100
Location utility: 50 miles

With a centrality utility of 1000

With a location utility of 10 miles

With a location utility of 10 miles
Rationale (cont.)

Location based routing vs. other routings
Design of Distributed Adaptive Routing (DIAL)

- General idea:
  - Vehicle B chooses the most efficient routing method among multiple methods based on the personal information sent by vehicle A

- Two components:
  - Utility information collection
  - Adaptive-learning framework
Design of Distributed Adaptive Routing (DIAL)

- Setting thresholds for different utilities
Design of Distributed Adaptive Routing (DIAL)

- Utility information collection:
  - Record different utility information on each vehicle
- Record location and contact information on each vehicle

<table>
<thead>
<tr>
<th>Vehicle ID</th>
<th>Location</th>
<th>Contact</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>LTable 1</td>
<td>CTable 1</td>
</tr>
<tr>
<td>2</td>
<td>LTable 2</td>
<td>CTable 2</td>
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<tr>
<td>3</td>
<td>LTable 3</td>
<td>CTable 3</td>
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<tr>
<td>4</td>
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<td>CTable 4</td>
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<table>
<thead>
<tr>
<th>Location</th>
<th>Visited frequency</th>
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<tbody>
<tr>
<td>Road a</td>
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<tr>
<td>Road b</td>
<td>1</td>
</tr>
<tr>
<td>Road c</td>
<td>2</td>
</tr>
<tr>
<td>Road d</td>
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<table>
<thead>
<tr>
<th>Vehicle ID</th>
<th>Encounter frequency</th>
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<tbody>
<tr>
<td>7</td>
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<tr>
<td>8</td>
<td>0.3</td>
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<tr>
<td>9</td>
<td>0.2</td>
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<tr>
<td>10</td>
<td>0.4</td>
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Design of Distributed Adaptive Routing (DIAL)

- **Adaptive-learning framework**:  
  - Different routing algorithms  
  - Count success rate  
  - Adjust the thresholds of different algorithms  
    - A higher threshold means the corresponding routing method is less suitable for the vehicle pair
Design of Distributed Adaptive Routing (DIAL)

<table>
<thead>
<tr>
<th>Vehicle ID</th>
<th>Thresholds</th>
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<tr>
<td></td>
<td>Contact</td>
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<tr>
<td>B</td>
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<tr>
<td>C</td>
<td>0.4</td>
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<tr>
<td>D</td>
<td>0.2</td>
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</tbody>
</table>

- Routing algorithms for different vehicles
Design of Distributed Adaptive Routing (DIAL)

- Count success rate
Design of Distributed Adaptive Routing (DIAL)

• Adjust the thresholds of different routing:
  
  – When vehicle A sends a packet to vehicle B, vehicle A records the number of copies sent out by different methods;
  
  – When vehicle B receives the copies of the packet sent by A, vehicle B records the numbers of copies successfully delivered to itself by different methods;
  
  – When vehicle A receives the feedback sent by vehicle B, vehicle A adjusts the thresholds of different methods.
Performance Evaluation

• Simulation
• Data: Roma & SanF
• Metrics for the evaluation
  – **Success rate:** The percentage of packets that successfully arrive at their target vehicles.
  – **Average delay:** The average time per packet for successfully delivered packets to reach their target vehicles.
• Performance vs. the following factors:
  – **The # of copies:** The number of copies of each packet for routing.
  – **Memory size:** The memory size of each vehicle for storing packets.

Performance Evaluation (cont.)

• Compared methods
  – Location based algorithm
    • AAR [1]
  – Centrality based algorithm
    • PeopleRank [2]
  – Contact based algorithm
    • PROPHET [3]

Experiment with Different # of Copies

Success rate: DIAL > AAR > PeopleRank > PROPHET

Average delay: DIAL < AAR < PeopleRank < PROPHET
Experiment with Different Memory Size

**Roma**

*Sensitivities:* PeopleRank > AAR > DIAL > PROPHET

**SanF**

*Average delay:* DIAL < AAR < PeopleRank < PROPHET
Conclusion

• Distributed Adaptive Routing (DIAL)

• Trace-driven experiments
  – High success rate
  – Low average delay

• Future work
  – Pre-locate target vehicles’ positions to improve routing efficiency
Thank you!
Questions & Comments?

Haiying Shen
shenh@clemson.edu
Associate Professor
Electrical and Computer Engineering
Clemson University