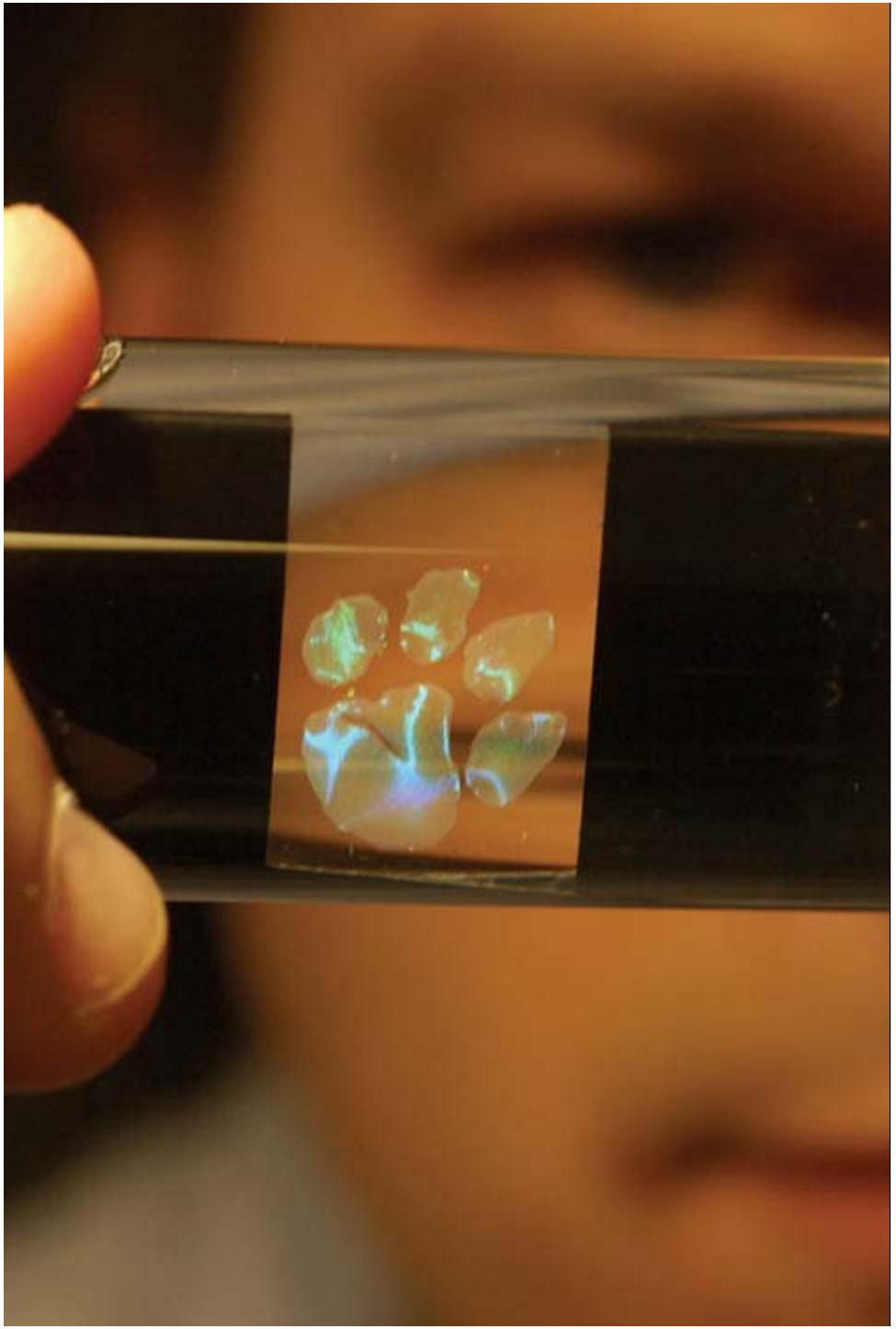

DIAL: A Distributed Adaptive-Learning Routing Method in VDTNs

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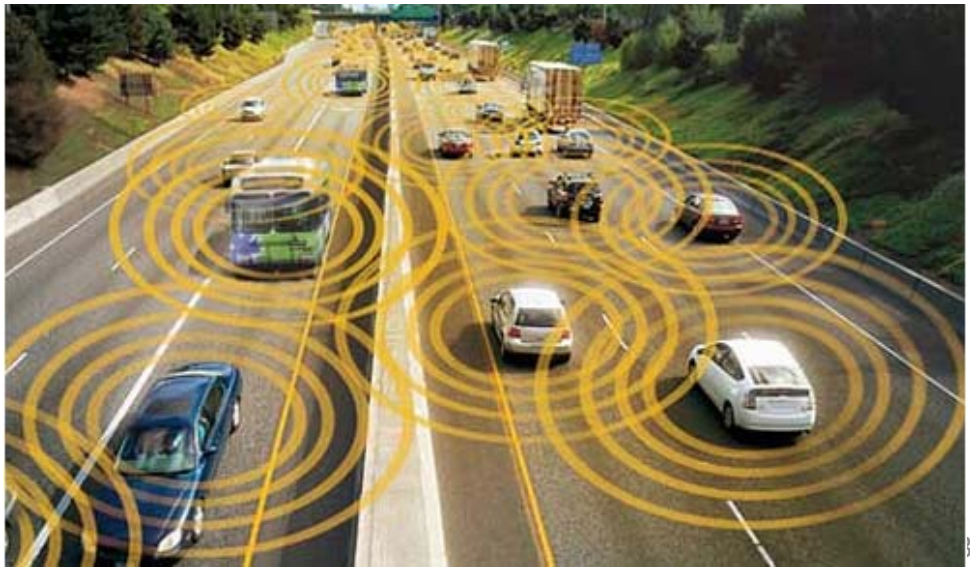
Outline

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

Background

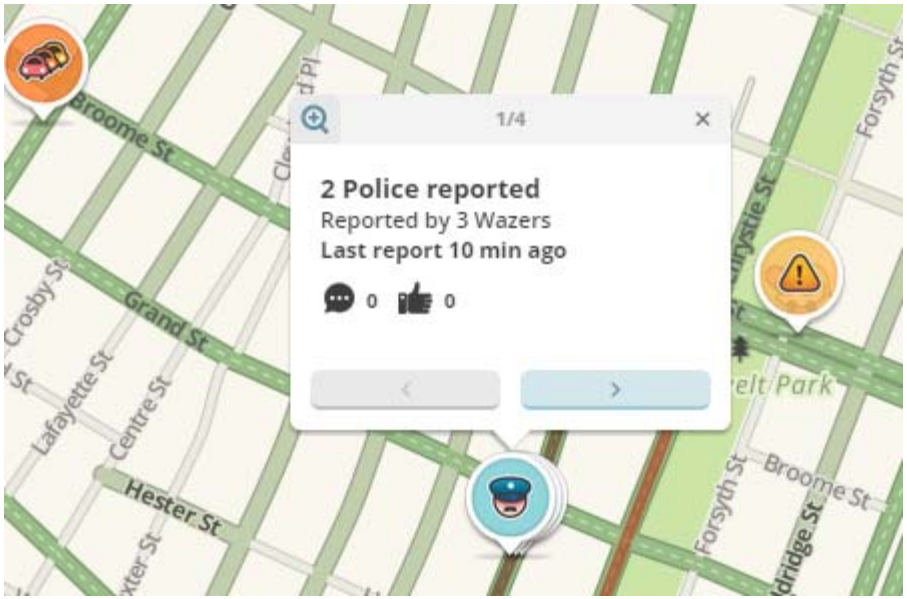
- Delay tolerant network (DTN)
  - Disruption and intermittent connectivity
  - Nodes move autonomously in the network
- Vehicle Delay Tolerant Network (VDTN)
  - Delay Tolerant Network consisting of vehicles
- VDTN its own characteristics
  - High vehicle mobility
  - Sparsity of vehicles
  - Short contact durations



Background

- Routing algorithms
  - Nodes communicate in a distributed manner without an infrastructure
    - Real time traffic and emergency notification among vehicles

Source Relay Relay Target



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

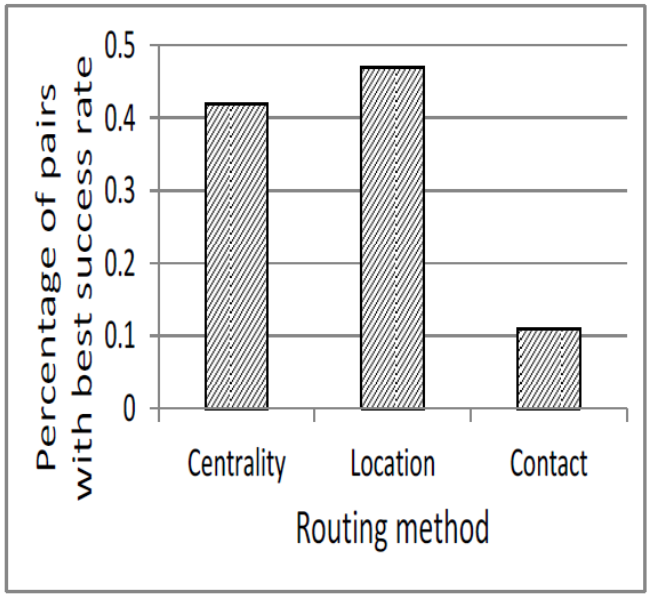
Trace Data Analysis

- 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

[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 (cont.)

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

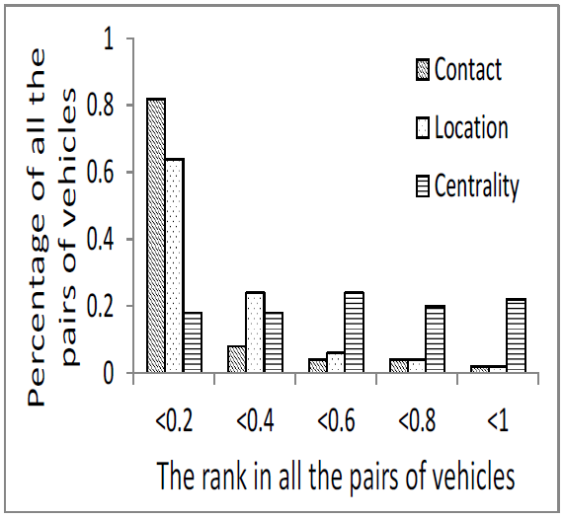


Observation:

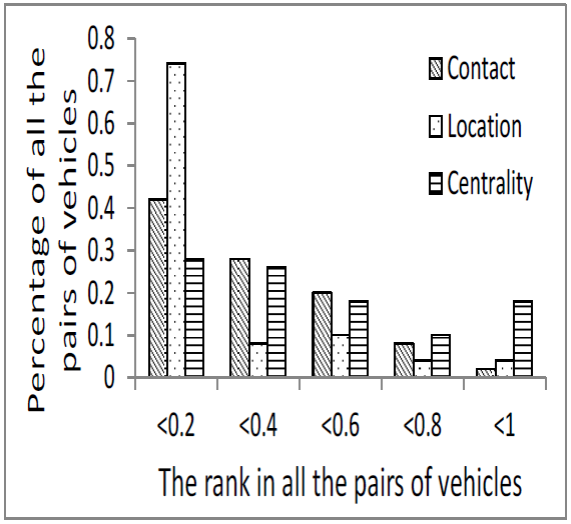
- Location>Centrality>Contact;

Rationale (cont.)

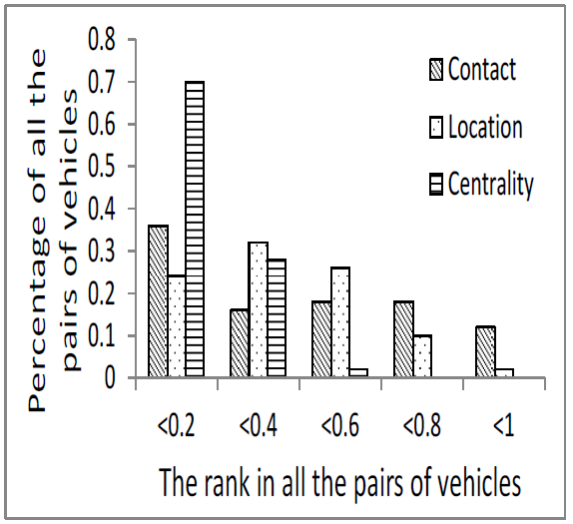
The top 50 vehicle pairs with the shortest delays of different routing algorithms:



Contact



Location

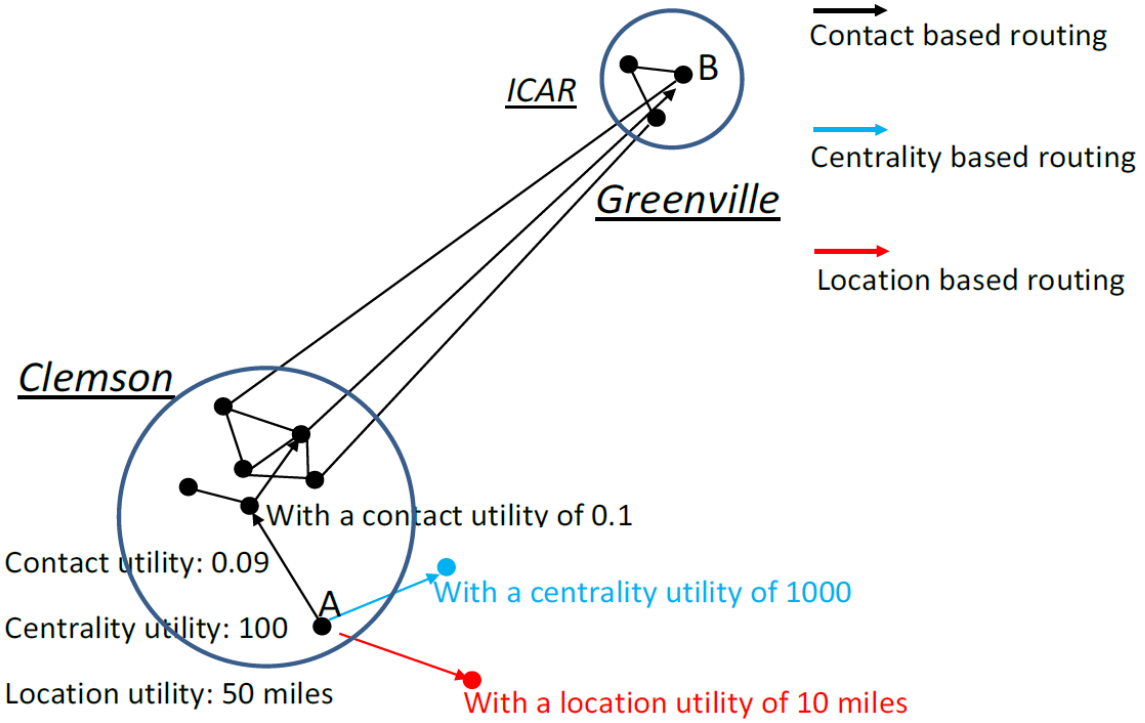


Centrality

Observations:

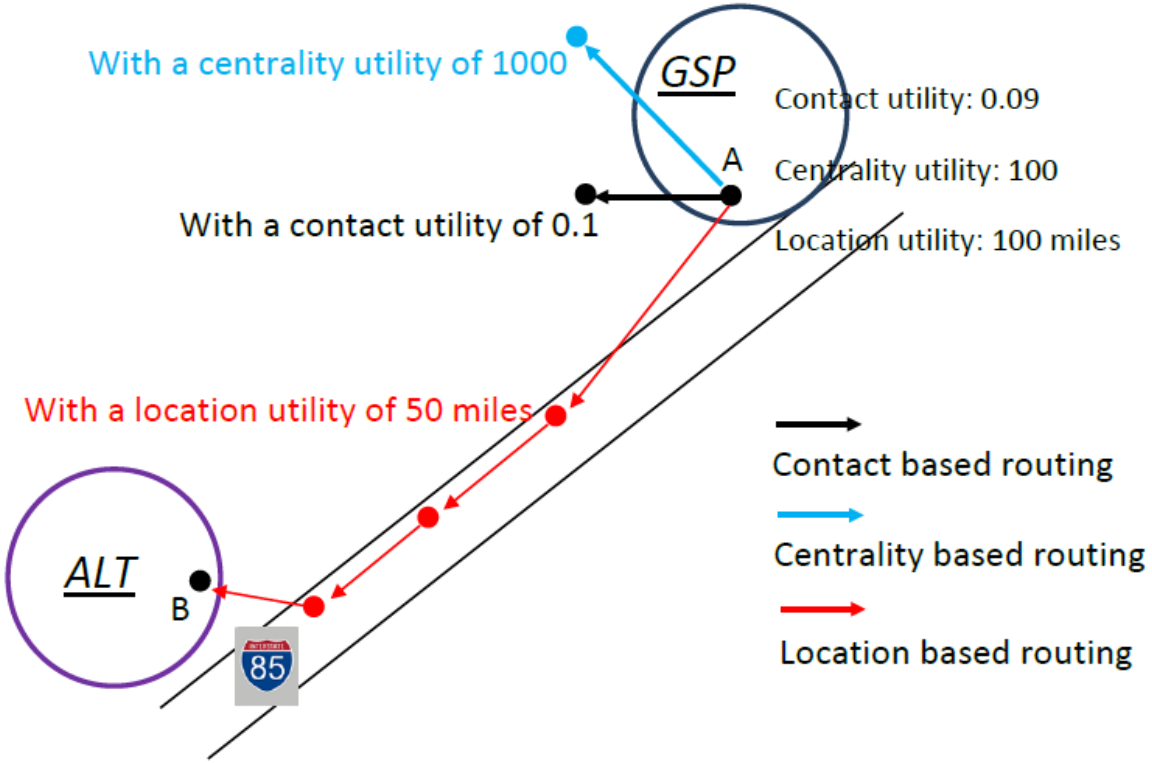
- When it comes to specific pairs of vehicles, it is difficult to predict the performances of different routing algorithms

Rationale (cont.)



Contact based routing vs. other routings

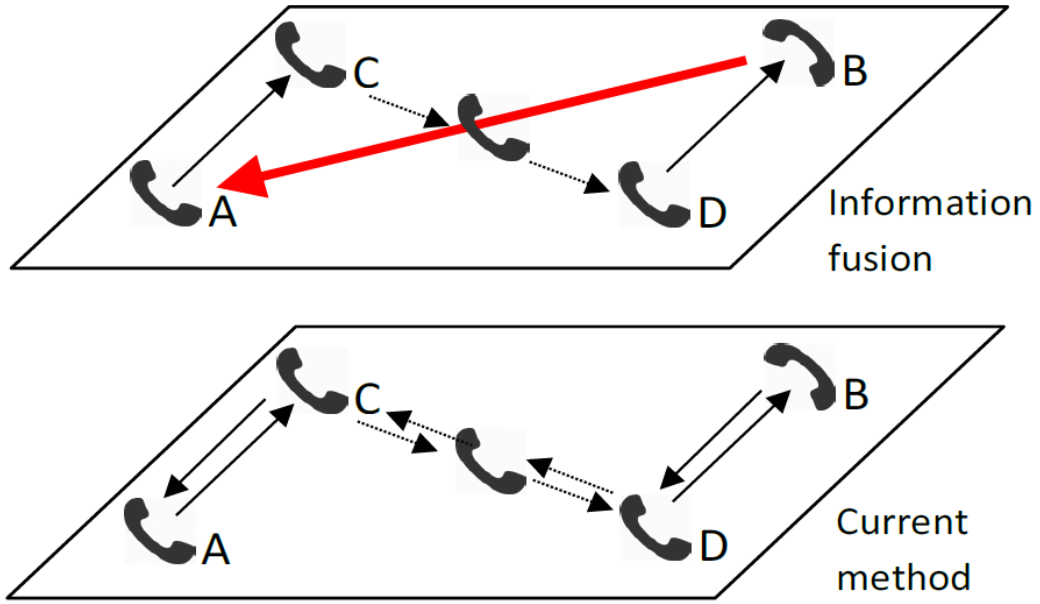
Rationale (cont.)



Location based routing vs. other routings

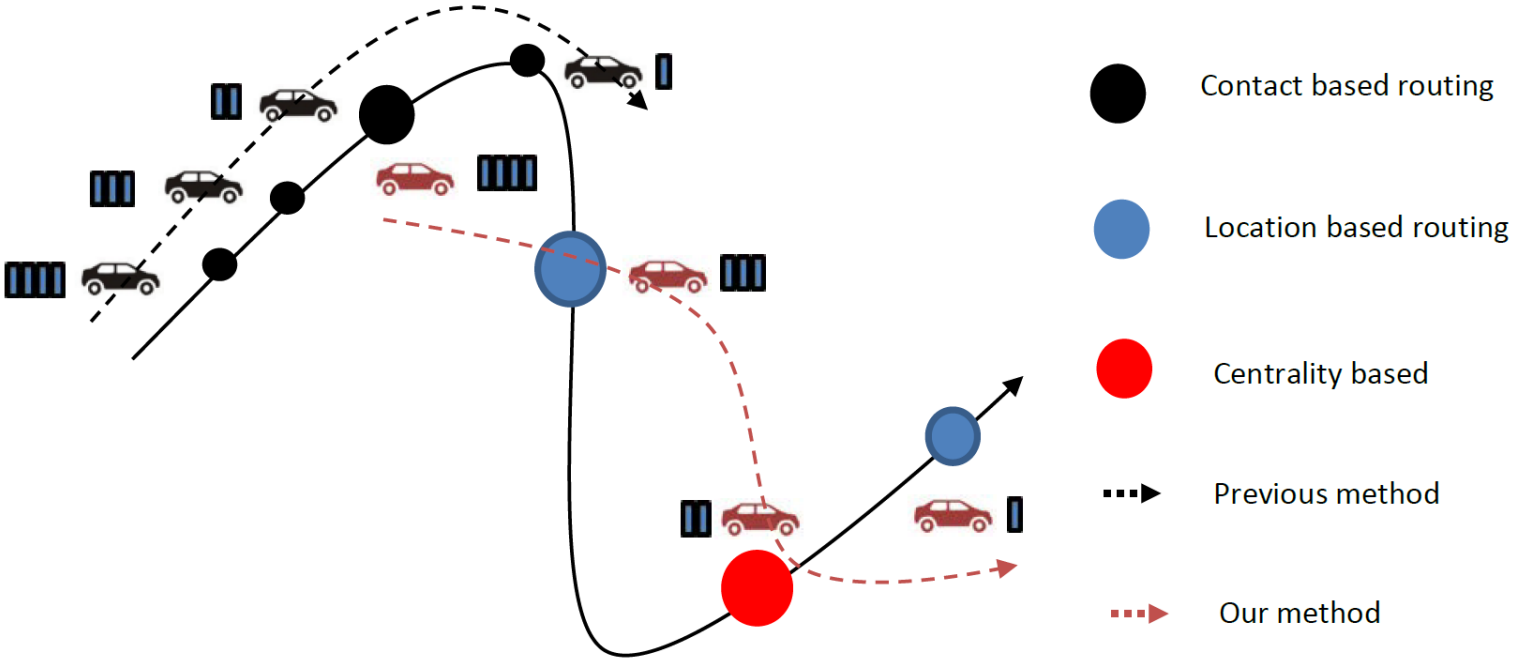
Design of Distributed Adaptive Routing (DIAL)

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



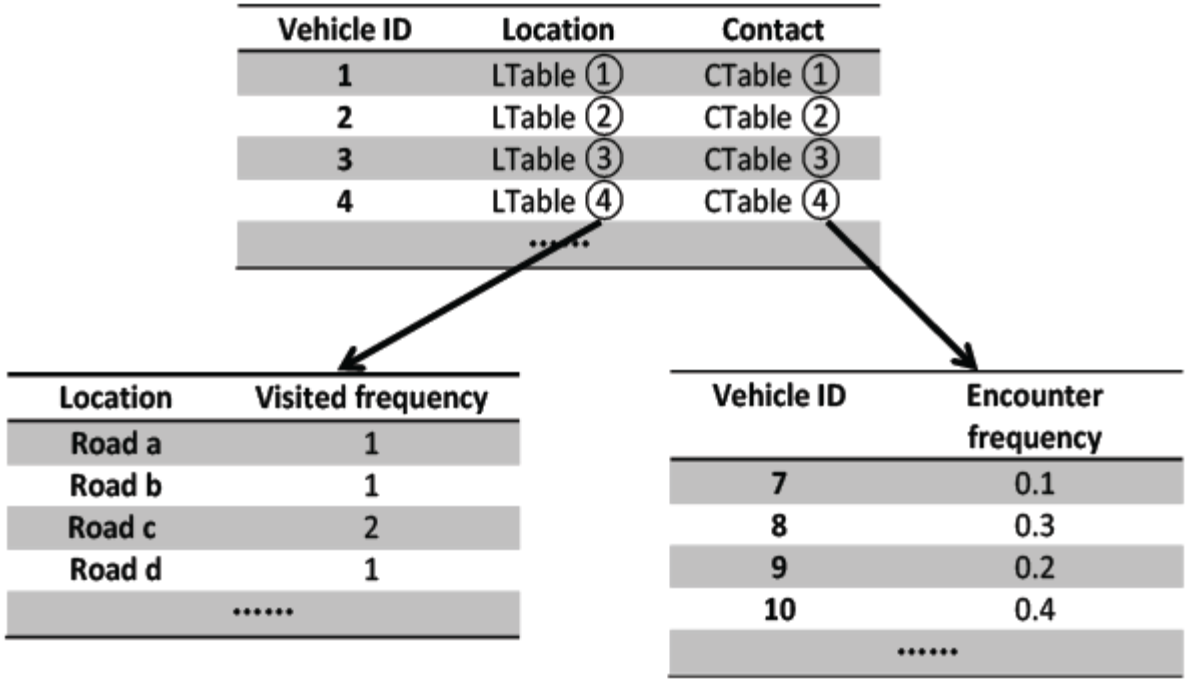
- Two components:
  - Utility information collection
  - Adaptive-learning framework

Design of Distributed Adaptive Routing (DIAL)



- Setting thresholds for different utilities

Design of Distributed Adaptive Routing (DIAL)



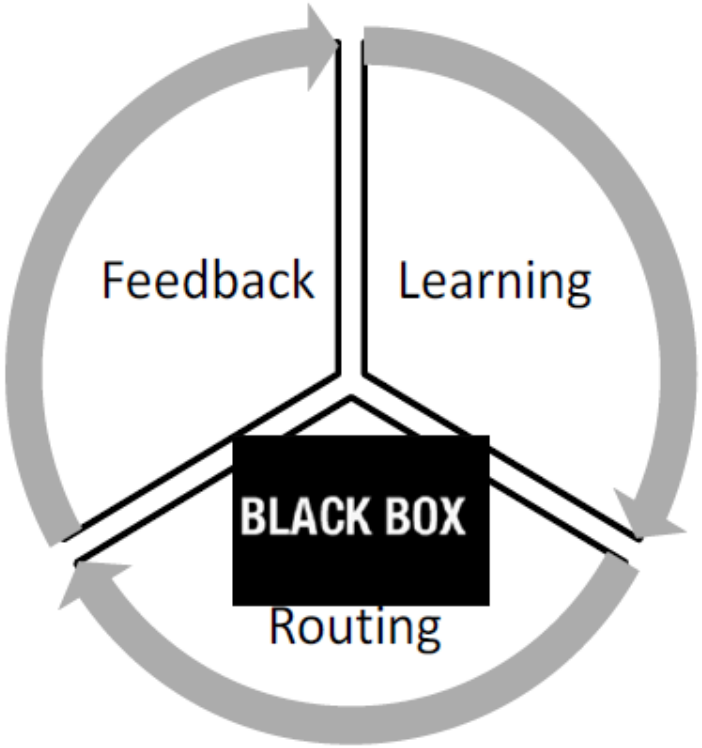
Vehicle ID	Location	Contact
1	LTable ①	CTable ①
2	LTable ②	CTable ②
3	LTable ③	CTable ③
4	LTable ④	CTable ④
.....		

Location	Visited frequency
Road a	1
Road b	1
Road c	2
Road d	1
.....	

Vehicle ID	Encounter frequency
7	0.1
8	0.3
9	0.2
10	0.4
.....	

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

Design of Distributed Adaptive Routing (DIAL)



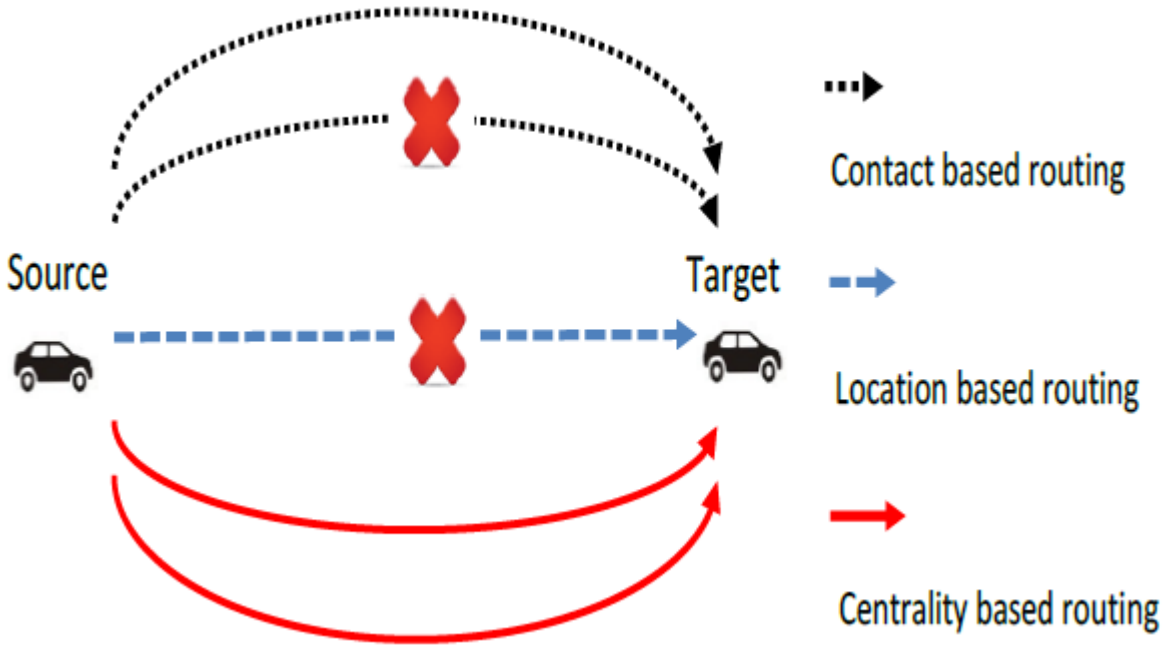
- Adaptive-learning framework:
  - Different routing algorithms
  - Count success rate
  - Adjust the thresholds of different algorithms
    - A higher threshold means the corresponding routing method is less suitable for the vehicle pair

Design of Distributed Adaptive Routing (DIAL)

Vehicle ID	Thresholds		
	Contact	Centrality	Location
B	0.1	1.7	5
C	0.4	2.5	7
D	0.2	1.6	3
	.....		

- 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.

[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.

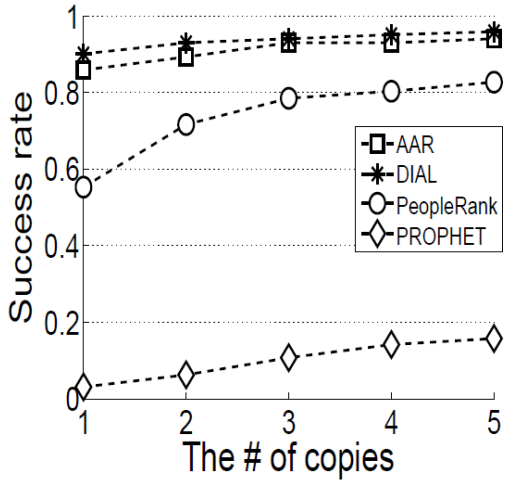
Performance Evaluation (cont.)

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

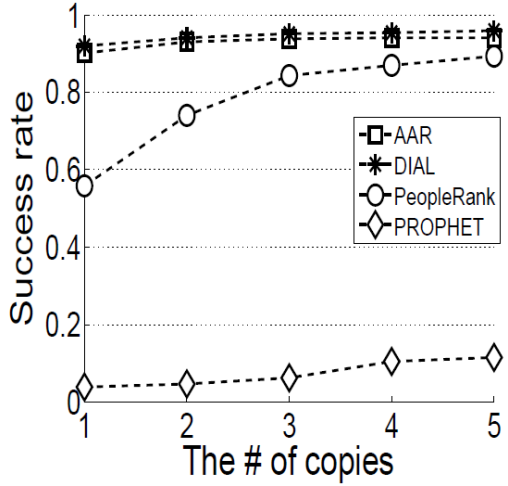
[1] A. Lindgren, A. Doria, and O. Scheln, “Probabilistic routing in intermittently connected networks.” Mobile Computing and Communications Review, 2003.
[2] A. Mtibaa, M. May, C. Diot, and M. H. Ammar, “Peoplerank: Social opportunistic forwarding.” in Proc. of INFOCOM, pp. 111–115, IEEE, 2010.
[3] K. Chen and H. Shen, “Dtn-flow: Inter-landmark data flow for high-throughput routing in dtns.” in Proc. Of IPDPS, pp. 726–737, IEEE, 2013.

Experiment with Different # of Copies

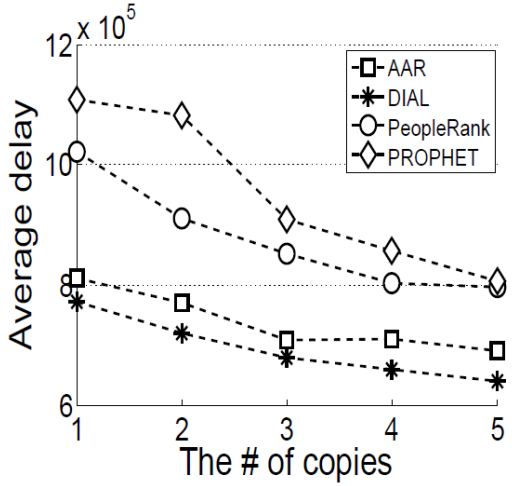
Roma

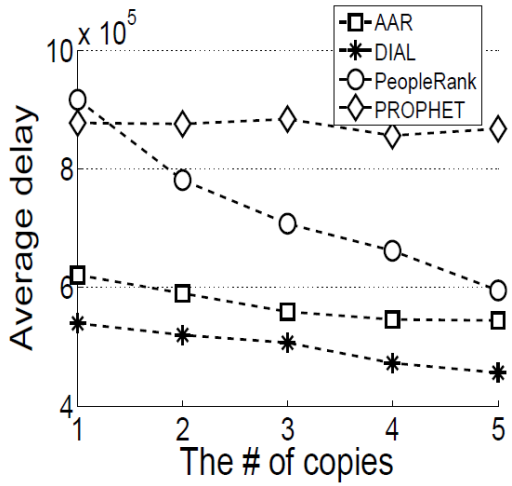


SanF



Success rate : DIAL > AAR > PeopleRank > PROPHET

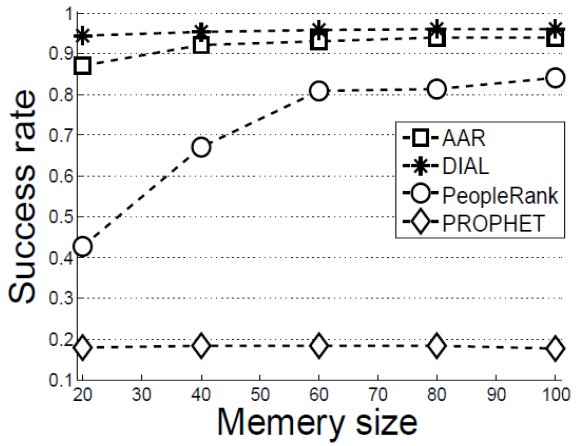


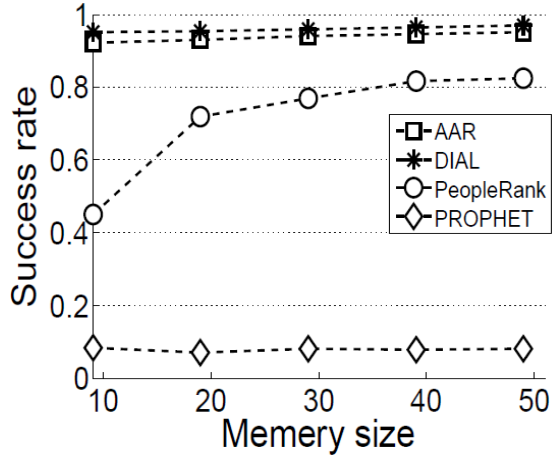


Average delay: DIAL < AAR < PeopleRank < PROPHET

Experiment with Different Memory Size

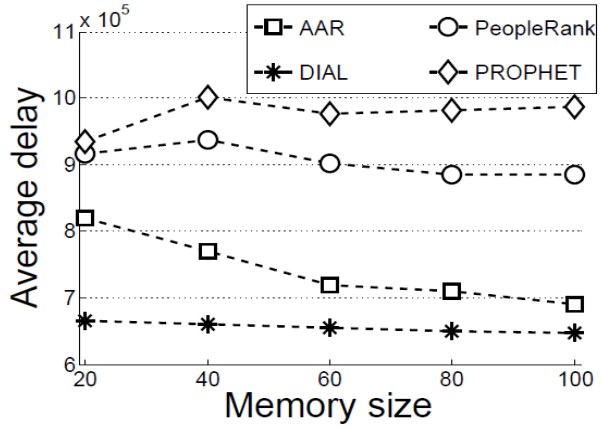
Roma

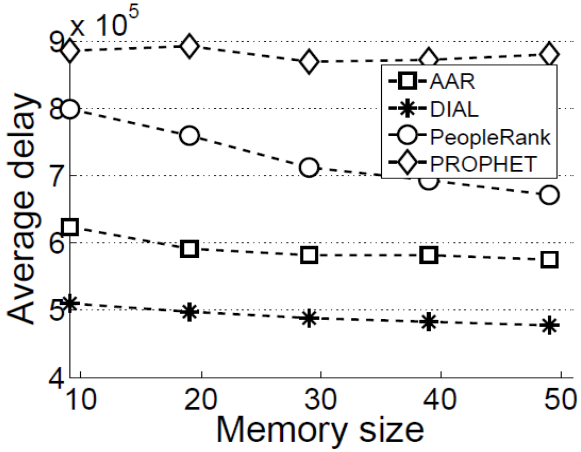




SanF

Sensitivities: PeopleRank > AAR > DIAL > PROPHET





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?

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