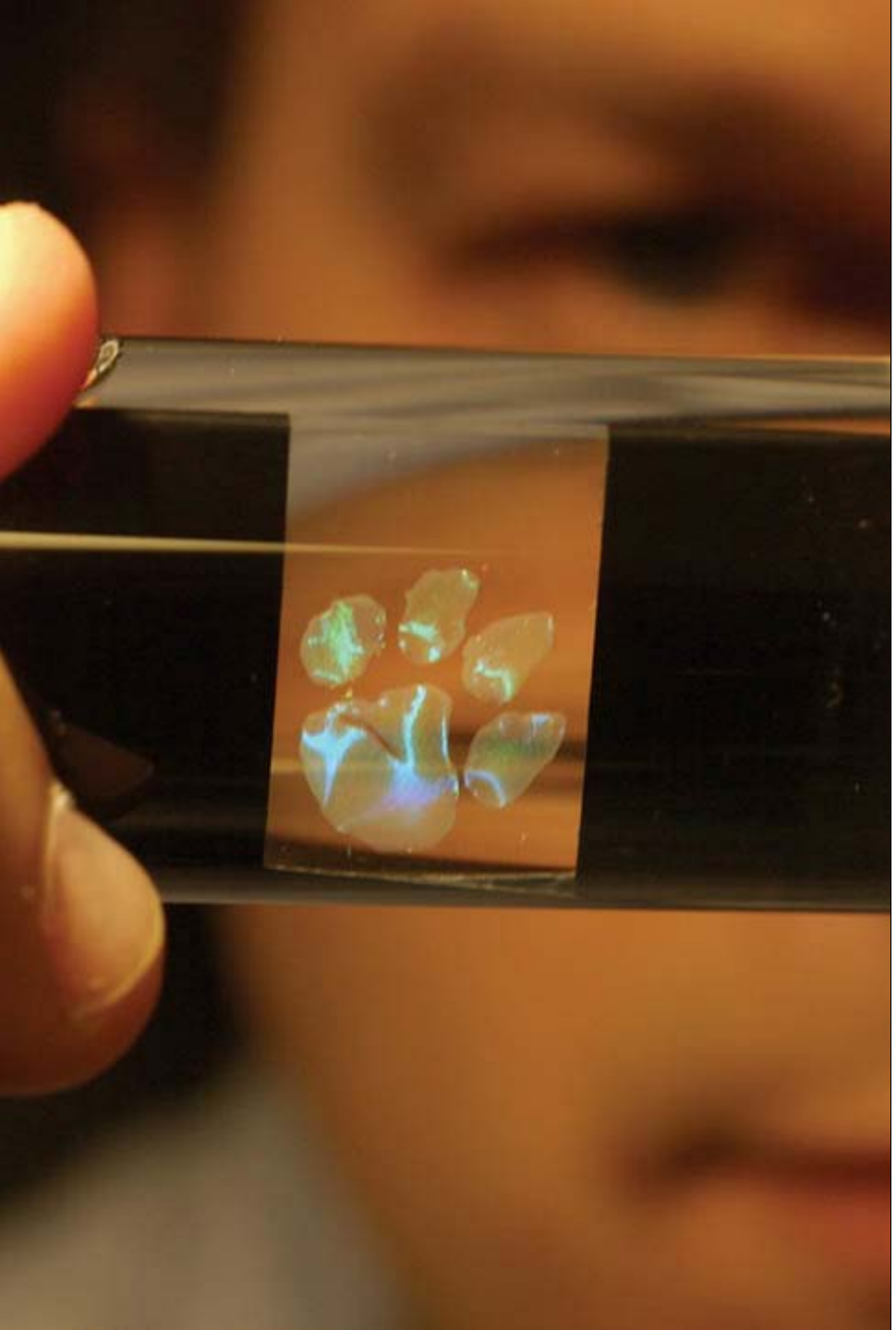


CLEMSON UNIVERSITY

Exploiting Active Sub-areas for Multi-copy Routing in VDTNs

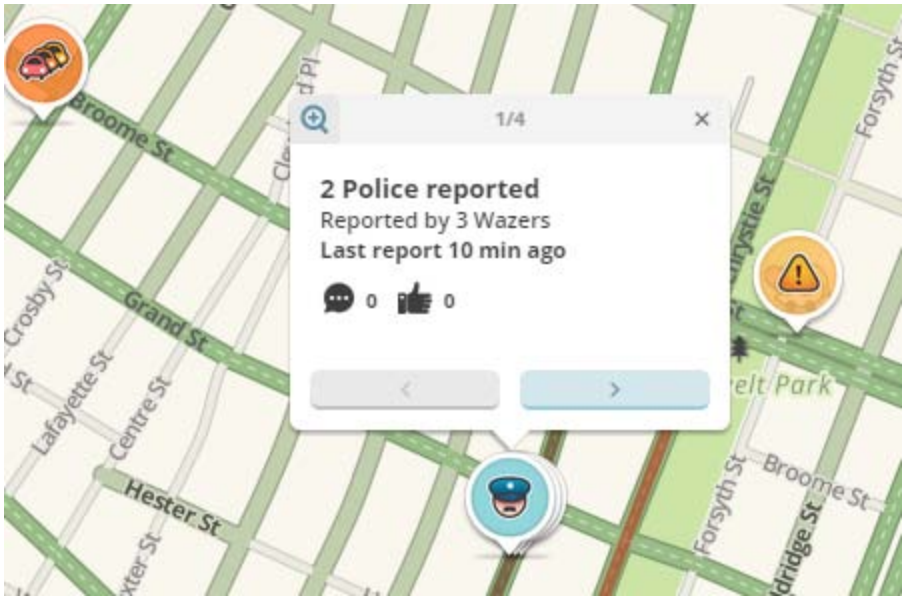
Authors: Bo Wu, Haiying Shen and Kang Chen
Dept. of Electrical and Computer Engineering
Clemson University, SC, USA

Outline

- Background
- Measurement
- Active Area Routing (AAR) System design
- Evaluation
- Conclusion

Background

- Nodes form delay tolerant networks in distributed manner
  - Without infrastructure for communication
- Nodes move autonomously in the network
  - Real time traffic and emergency notification among vehicles

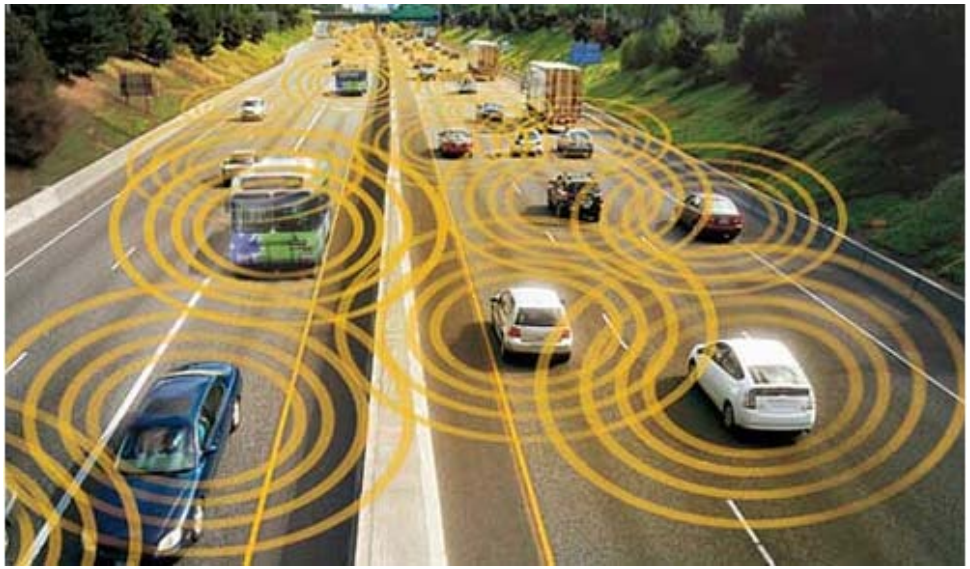


Background (cont.)

- Contact based methods [MC2R'03]
  - Select nodes with higher encounter frequency with target node for relaying packets.
- Centrality based methods [Infocom'10]
  - Select nodes with higher centrality for relaying packets.
- Location based methods [IPDPS'13]
  - Select nodes which will visit the locations target nodes will visit for relaying packets.

Background (cont.)

- We call Delay Tolerant Network which consists of vehicles as Vehicle Delay Tolerant Network (VDTN).



- Some of the characters of VDTN are similar as other DTNs, while some others are different.

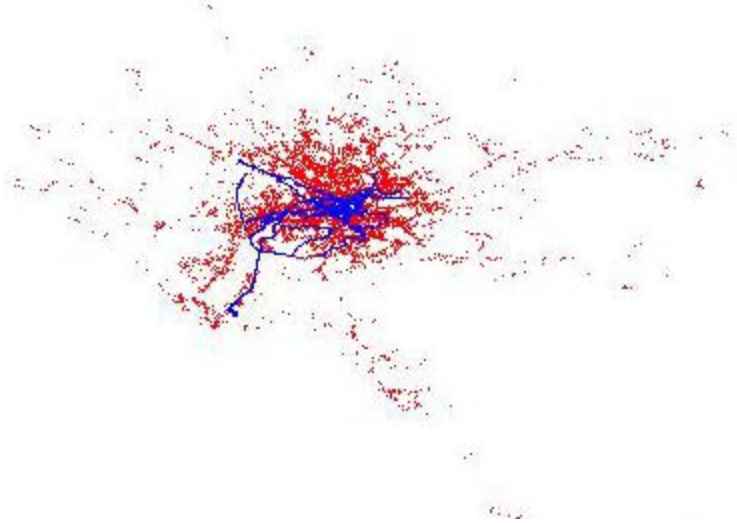
Measurement

- Node 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

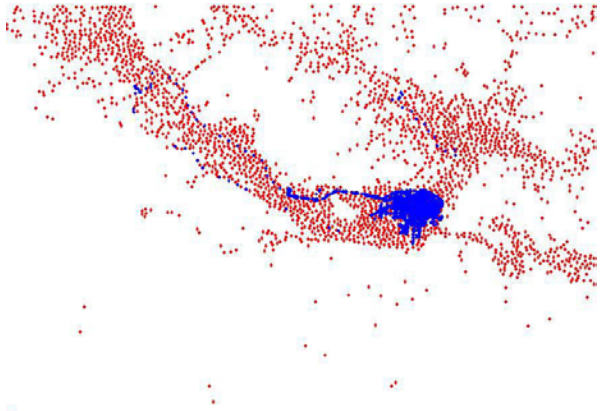
[1] T. Henderson, etc. “The changing usage of a mature campus-wide wireless network,” in Proc. of MobiCom, 2004.
[2] X. Zhang, etc. “Study of a bus-based disruption-tolerant network: mobility modeling and impact on routing,” in Proc. of MobiCom, 2007.

Measurement (cont.)

The trajectories of two random vehicles (Blue points denote the roads vehicles visited and red points denote the rest of the roads):



Roma



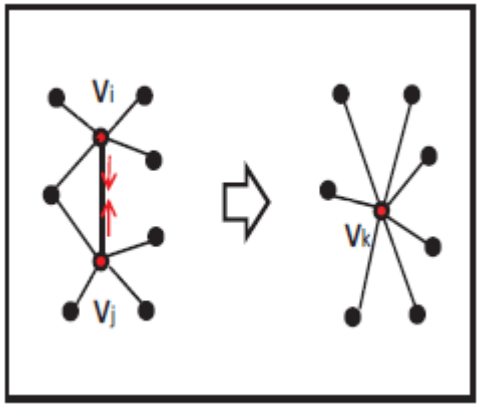
SanF

Observation:

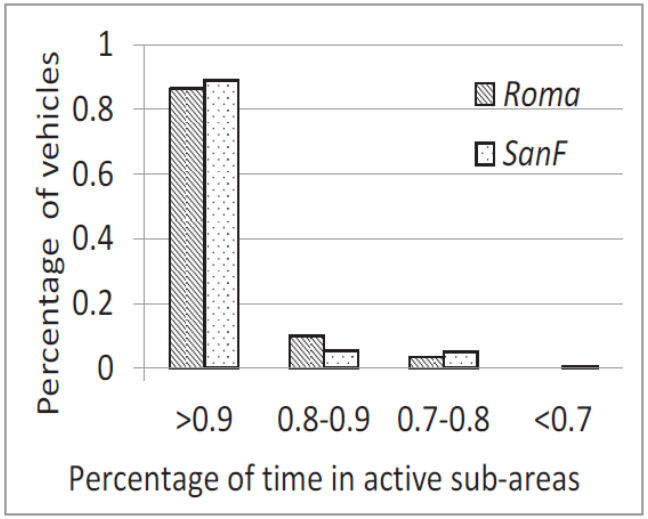
- Each vehicle is only active in very small area comparing with the whole VDTN map.

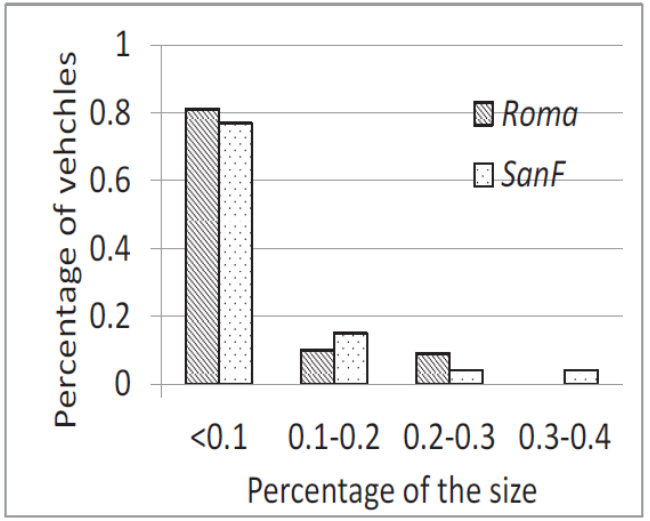
Measurement (cont.)

- Preprocess
  - Define road sections:
    - A road section is a section of road without any intersections on it.
  - Define active road sections of a vehicle v:
    - The road sections vehicle v visited more than r times are called active road sections of vehicle v.
  - Define active sub-areas of a vehicle v:
    - A set of connected active road sections are calledvehicle v is called active sub-area of vehicle v.
    - There may be multiple active sub-areas for vehicle v.
    - Active sub-areas are identified by merging connected active road sections recursively.



Measurement (cont.)



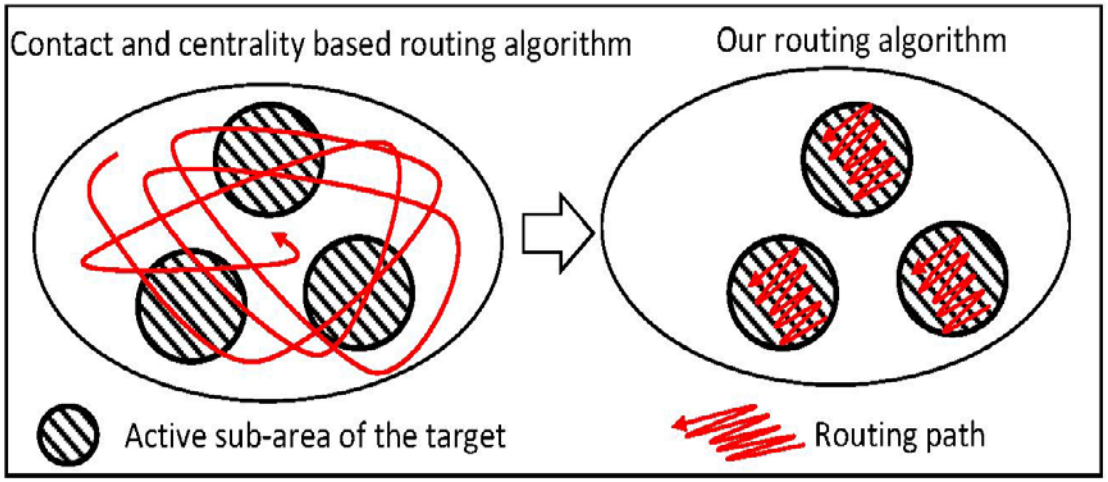


Observations:

- Most vehicles spend most of their time in their active sub-areas.
- The sizes of active sub-areas are relatively very small comparing with the whole map.

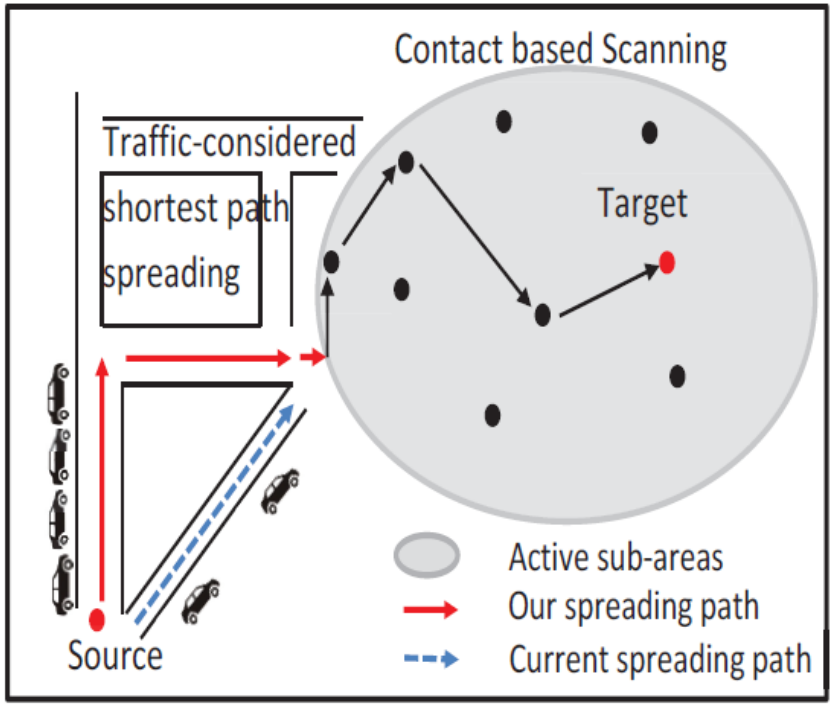
Design of Active Area Routing(AAR)

- General idea:



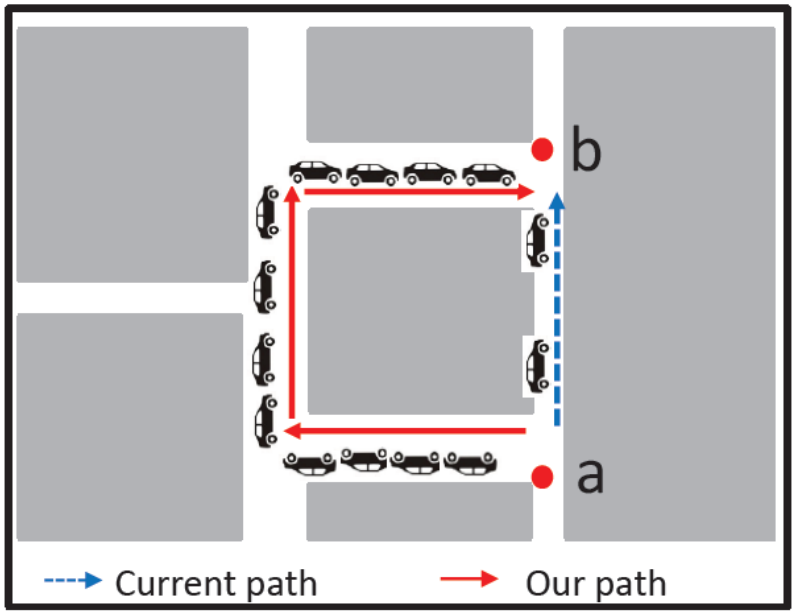
- **Two steps:**
  - Try to spread copies of a packet to different active sub-areas of the target vehicle.
  - Search the target vehicle in each active sub-area, respectively.

Design of Active Area Routing(AAR)



- Design: Traffic-considered shortest path spreading.
- Design: Contact based scanning in active sub-areas.

Design: Traffic-considered shortest path spreading algorithm



- Traffic vs. Shortest path.
- Compute traffic in each road section dynamically with the assistance of road units.

Design: Traffic-considered shortest path spreading algorithm

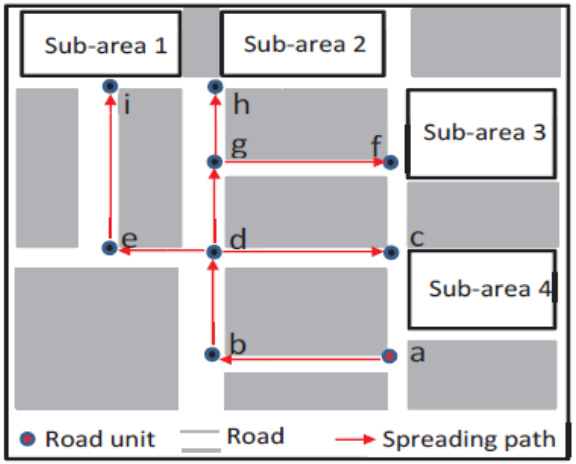
Computing traffic condition dynamically :

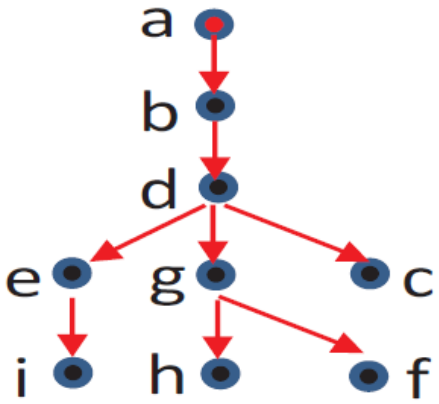
- Each road section is allocated with a road unit.
- Dynamically computing traffic condition of different road sections by road unites.
- By taking advantage of vehicle mobility, we spread the updated traffic condition of road sections among different road units. Therefore, each road unit can has the traffic condition information of the whole map. At the same time, vehicles update their own traffic condition information of the whole map.
- At the same time, each vehicle updates the weighted distance map.

[1] A. Lindgren, A. Doria, and O. Scheln, “Probabilistic routing in intermittently connected networks.” Mobile Computing and Communications Review, 2003.

Design: Traffic-considered shortest path spreading algorithm

- An example of group spreading path to different active sub-areas:





Design: Contact based Scanning in Active Sub-areas

Three strategies of contact based scanning:

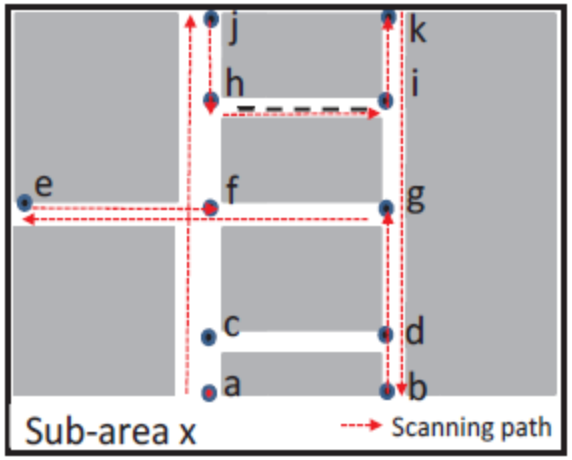
- Uniformly scan the active sub-area one road section by one road section if there is no vehicles with high encounter frequency.
  - Scanning table
- Relay packets to vehicles with high encounter frequency with target vehicles if possible.
  - Contact utility calculation [1]
- The routing area of each packet is restricted to its corresponding active sub-area only.

[1] A. Lindgren, A. Doria, and O. Scheln, “Probabilistic routing in intermittently connected networks.” Mobile Computing and Communications Review, 2003.

Design: Contact based Scanning in Active Sub-areas

- An example of scanning in an active sub-area:

Road section	Time stamp	Road section	Time stamp
ac	1:01	fg	1:14
bd	1:12	fh	1:03
cd	0:00	gi	1:09
cf	1:02	hi	1:06
dg	1:13	hj	1:05
ef	1:16	ik	1:08



Performance Evaluation

- Simulator
  - Event driven simulator
- Data:
  - Roma
  - SanF

[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

- 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.

- 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.

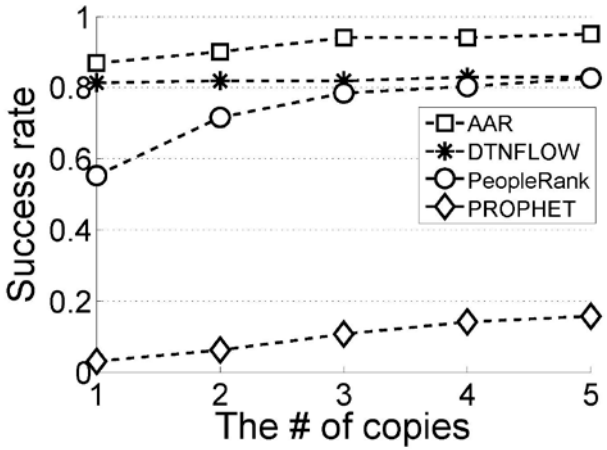
Performance Evaluation (cont.)

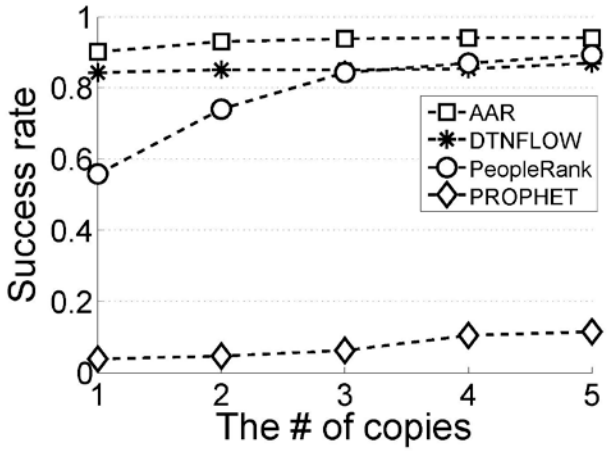
- Compared methods
  - Location based method
    - DTNFLOW[1]
  - Centrality based method
    - PeopleRank[2]
  - Contact based method
    - PROPHET[3]

[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

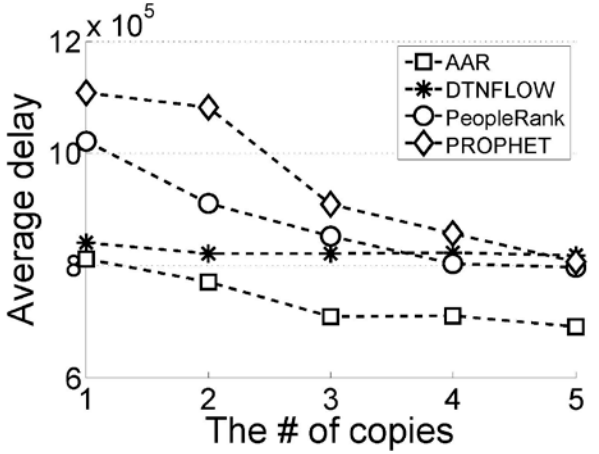
Roma

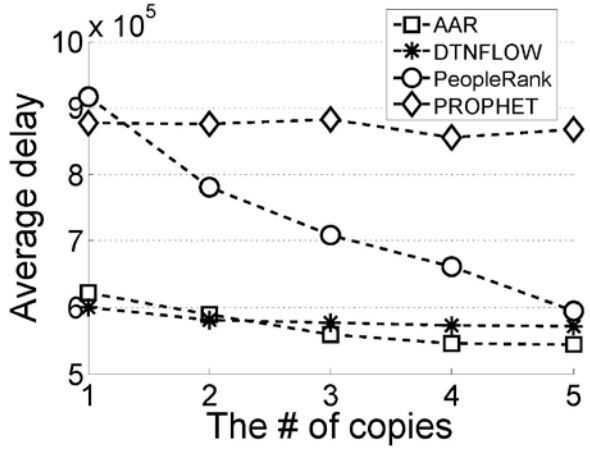




SanF

Success rate : AAR > DTNFLOW > PeopleRank > PROPHET

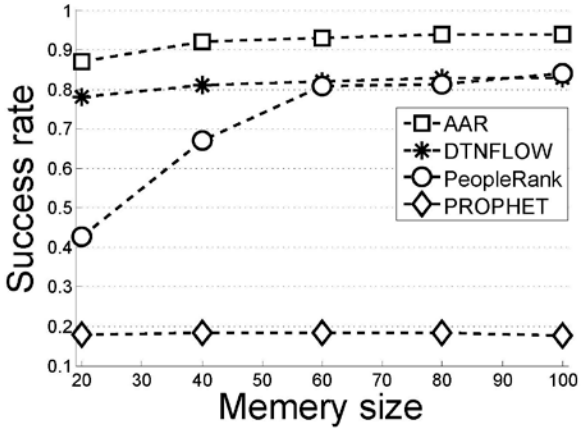


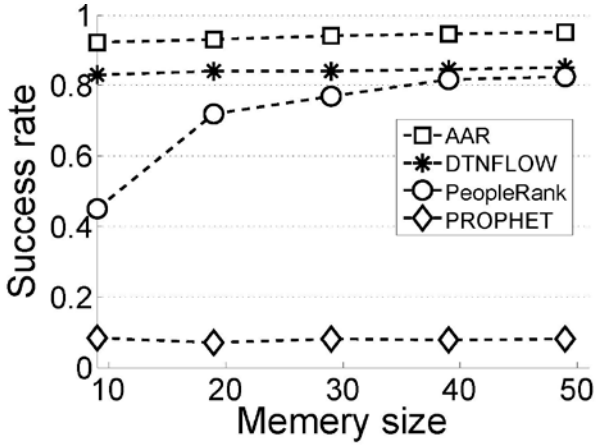


Average delay: AAR < DTNFLOW > PeopleRank > PROPHET

Experiment with Different Memory Size

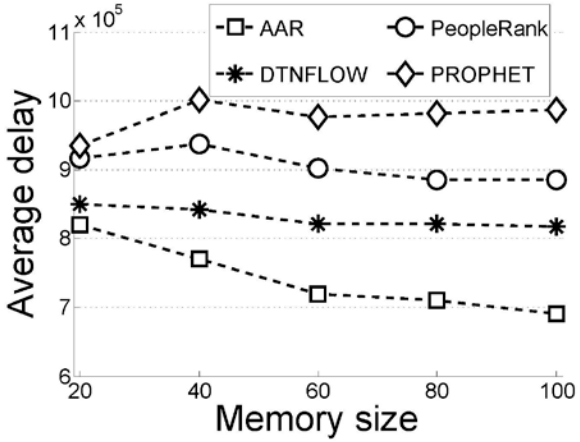
Roma

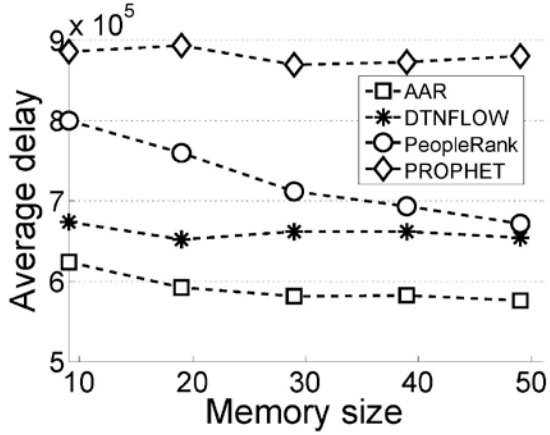




SanF

Sensitivities: PeopleRank > AAR > DTNFLOW > PROPHET





Conclusions

- We proposed AAR, it
  - Restrain the searching area of packets to their active sub-areas which significantly reduces the inefficient searching time.
  - Count the traffic information in spreading the packets.
  - Find a scanning solution for the contact based method in each active sub-area.
- In our future work, we will discuss the possibility of decreasing the sensitivity of AAR to memory size of relay vehicles.

Thank you!

Questions & Comments?

Bo Wu, PhD Candidate

bwu2@clemson.edu

Pervasive Communication Laboratory

Clemson University