VADD: Vehicle-Assisted Data Delivery in Vehicular Ad Hoc Networks

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Overview

1. Motivation
2. Background
3. Assumptions
4. The VADD Model
5. Results
6. Conclusions

Motivation

- Growing importance for vehicular Ad Hoc Networks

(FCC has allocated 75MHz of spectrum for dedicated short range communications)

- Problems posed by high mobility, frequent disconnections
- Previous work unsatisfactory in achieving results

=> efficient data delivery in vehicular ad hoc networks

Motivation (Application)

Wireless LAN (infostations):

- Delivery of advertisements or announcements
- Limited broadcast range
- Cheaper to set up and maintain than wireless infrastructure (e.g. 3G)
- Relay of request – response from a large distance
- Can tolerate seconds – even minutes of delay for non critical information

Background

- Most existing protocols assume that intermediate nodes can be found to set up and end-to-end connection
- Two types of protocols which use *carry and forward:*
  - Epidemic routing (Vadhat and Becker)
    - Mobility history brings marginal improvements, if at all
  - Controllable mobility

=> Either too much control or no control on mobility, thus not suitable for vehicular applications

Background (Cont'd)

- Greedy Perimeter Stateless Routing (GPSR):
  - routing protocol for wireless datagram networks
  - uses the positions of routers and a packet's destination for packet forwarding decisions.
  - greedy forwarding decisions using only information about a router's *immediate neighbors* in the network topology.
  - in a region where greedy forwarding is impossible, the algorithm recovers by routing around the perimeter of the region.
  - under mobility's frequent topology changes, GPSR can use *local topology* information to find correct new routes quickly.
  - scalability on densely deployed wireless networks.

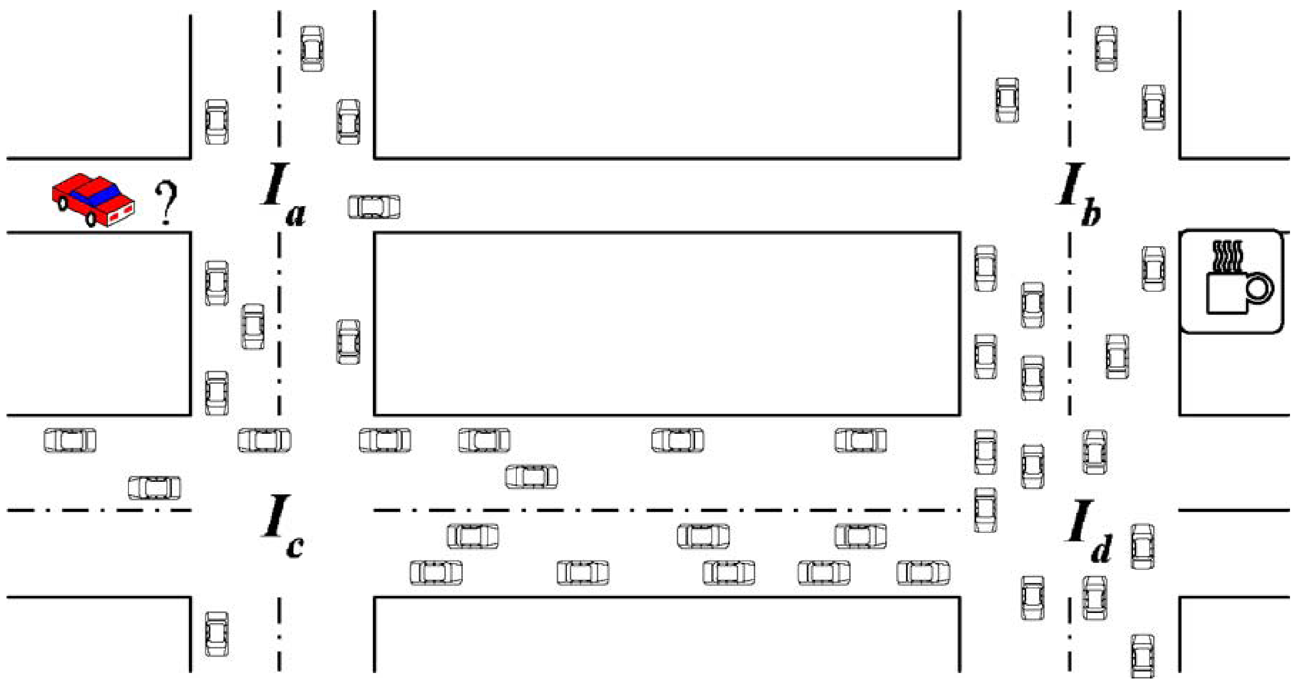
Assumptions

- Vehicle-to-vehicle short range wireless channel
- Packet delivery information specified by data source (source id, source location, packet generation time, destination location, expiration time, etc)
- Vehicles know their location (GPS, triangulation)
- Pre-loaded digital maps (street-level map and traffic statistics: traffic density, vehicle speeds at different times of the day)

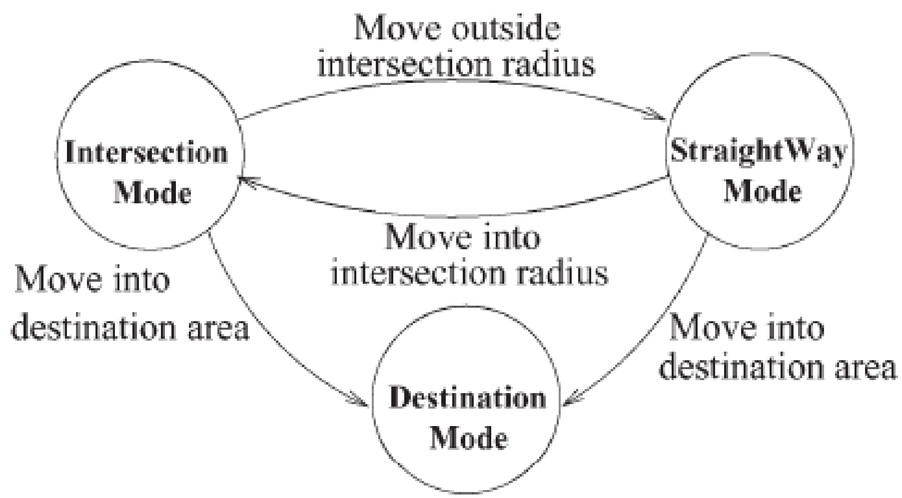
The VADD Model

- Problem : Find path from car to the coffee shop (deliver request from mobile source to fixed destination)

$I_a \rightarrow I_c$, $I_c \rightarrow I_d$, $I_d \rightarrow I_b$ faster than $I_a \rightarrow I_b$



The VADD Model (cont'd)



- Basic principles:

1. Transmit through wireless channels as much as possible
2. If roads need to be taken, choose the one with higher speed pattern
3. Dynamic path selection should continuously be executed throughout the packet forwarding process (performed by carrier)

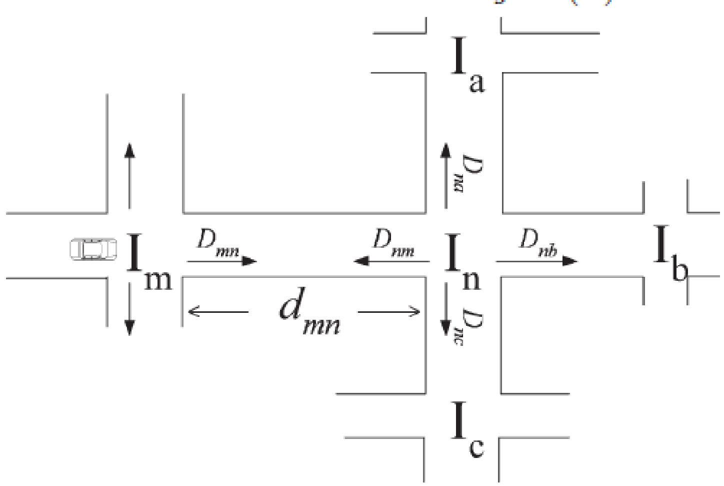
The VADD Model (cont'd)

- Expected packet forwarding delay:

$$d_{ij} = (1 - e^{-R \cdot \rho_{ij}}) \cdot \frac{l_{ij} \cdot c}{R} + e^{-R \cdot \rho_{ij}} \cdot \frac{l_{ij}}{v_{ij}}$$

- Expected delay through road r_{mn}:

$$D_{mn} = d_{mn} + \sum_{j \in N(n)} (P_{nj} \times D_{nj}).$$

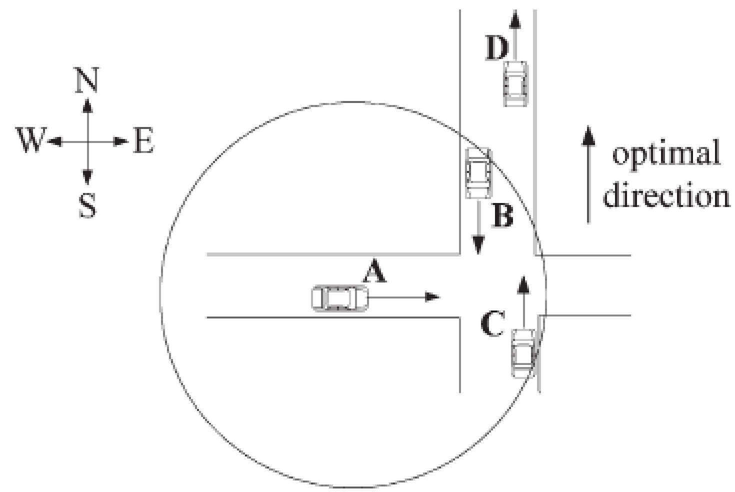


Example of the VADD delay model.

r_{ij}: the road from I_i to I_j;
l_{ij}: the Euclidean distance of r_{ij};
ρ_{ij}: the vehicle density on r_{ij};
v_{ij}: the average vehicle velocity on r_{ij};
d_{ij}: the expected packet-forwarding delay from I_i to I_j.
D_{ij}: the expected packet-delivery delay from I_i to the destination if the packet carrier at I_i chooses to deliver the packet following road r_{ij};
P_{ij}: the probability that the packet is forwarded through road r_{ij} at I_i;
$N(j)$: the set of neighboring intersections of I_j.

The VADD Model (Intersection Mode – L-VADD)

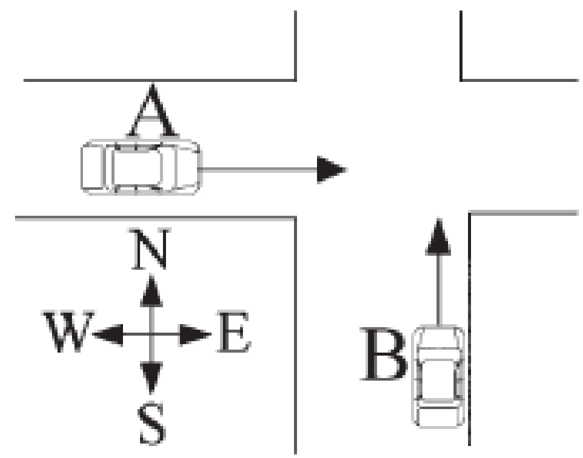
- Location-first probe:
  - Closest contact towards the preferred forwarding directio of a packet
  - Uses D_{ij} to select priorities (small D = high priority)
  - Attempts contact with next intersection from high to low priority
  - Stops when priority of next intersection is lower than the direction the carrier is going



The VADD Model (Intersection Mode – L-VADD)

- Problem: routing loops
  - Assume North has highest priority, followed by East
  - A finds nothing to North, B to East
  - B finds A to North

=> loop!



The VADD Model (Intersection Mode – D/MD-VADD)

- Direction First Probe:
  - Only probes vehicles whose direction priority is higher than or equal to the direction of the carrier
  - Free from routing loops
- Multi-Path Direction First Probe:
  - After passing a copy of the packet to a contact, carrier continues buffering the packet, making it SENT
  - If the carrier meets another contact in the same intersection with higher priority, pass the packet again
  - Remove from buffer only when leaving intersection mode or when highest priority direction contact is found

The VADD Model (Intersection Mode – H-VADD)

- Hybrid Probe:
  - Use L-VADD as long as no loop is detected
  - Apply loop detection mechanism (record previous hops when transmitting a packet)
  - If loop detected, switch to D-VADD (or MD-VADD) until vehicle exists intersection

The VADD Model (StraightWay Mode)

- Specify target location (next or previous intersection)
- If next instersection:
  - Apply geographically greedy forwarding (GPSR – Greedy Perimeter Stateless Routing for Wireless Networks) if vehicles available ahead
  - If no vehicles ahead, carrier continues to carry packet
- If previous intersection:
  - Carrier will forward message as soon as another vehicle is encountered on the other side of the road

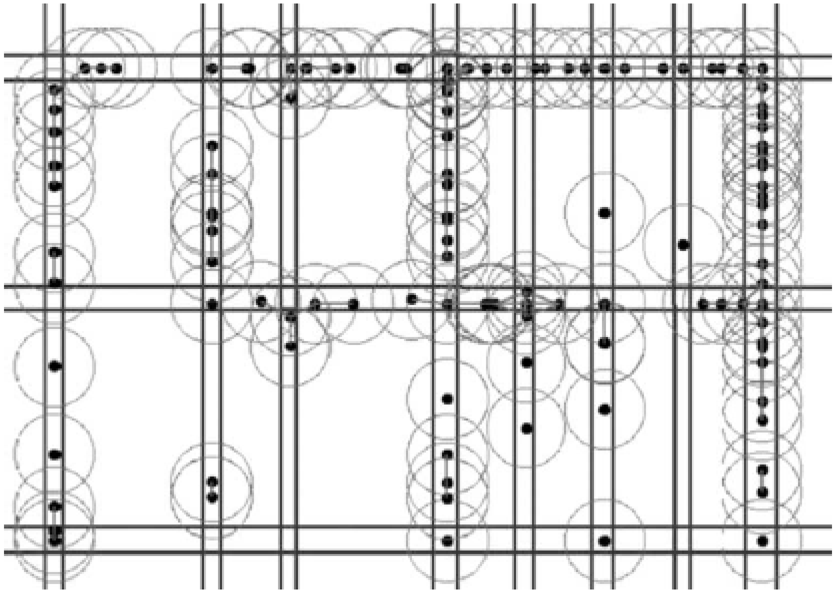
The VADD Model (Destination Mode)

- Distance to destination is below a certain threshold
- GPSR is used to deliver information to final target

The VADD Model
Response to Query

- Assume predictable vehicle path (GPS knows destination)
- Trajectory can be added to query packet to aid in finding the target
- Information server could bear the computational cost of estimating location of target
- Solution left for future work

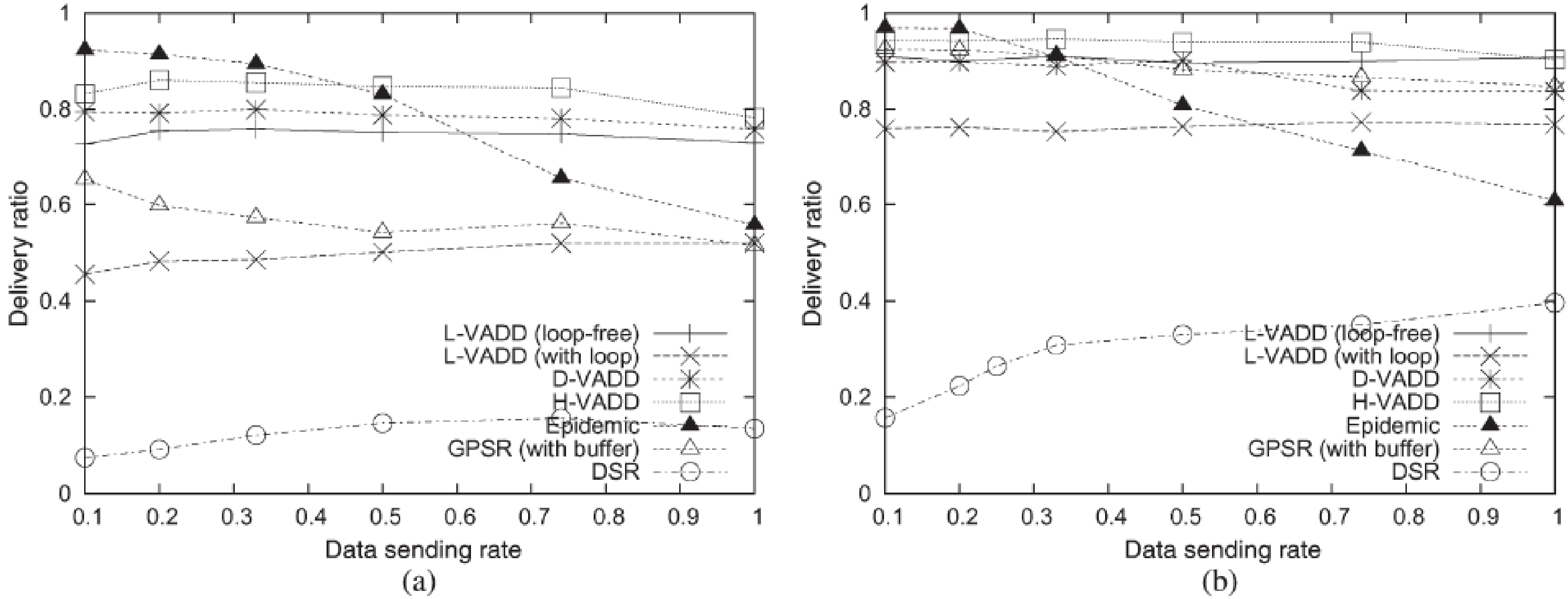
Results



SIMULATION SETUP

Parameter	Value
Simulation area	$4000m \times 3200m$
# of intersections	24
Intersection area radius	200m
Number of vehicles	150, 210
# of packet senders	15
Communication range	200m
Vehicle velocity	15 - 80 miles per hour
CBR rate	0.1 - 1 packet per second
Data packet size	10 B - 4 KB
Vehicle beacon interval	0.5 sec
Packet TTL	128 sec

Results



Data-delivery ratio as a function of the data-sending rate. (a) 150 nodes. (b) 210 nodes.

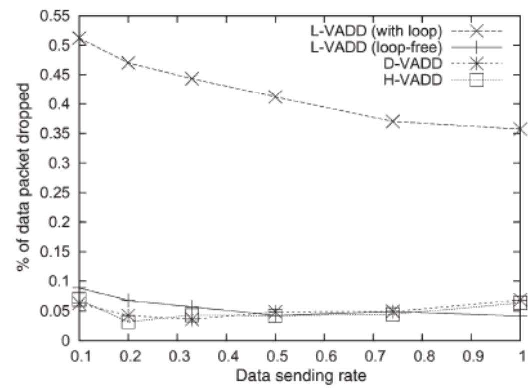
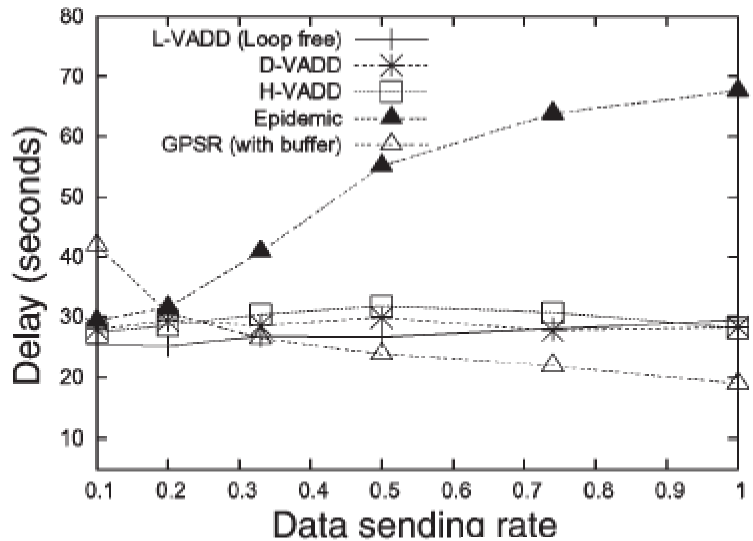
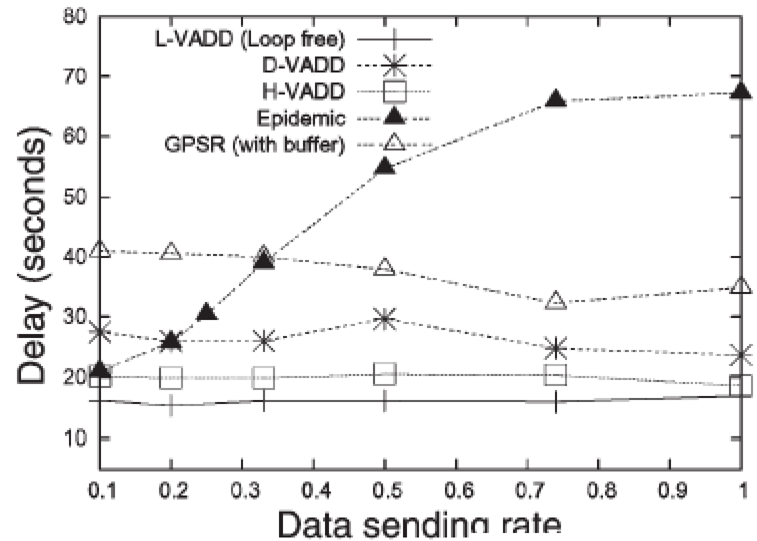


Fig. 10. Percent of data packets dropped due to routing loops or MAC layer packet collisions (150 nodes).

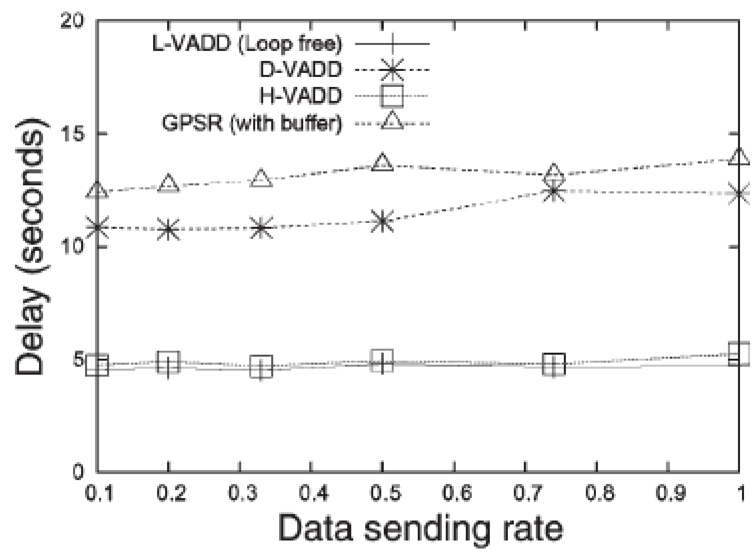
Results



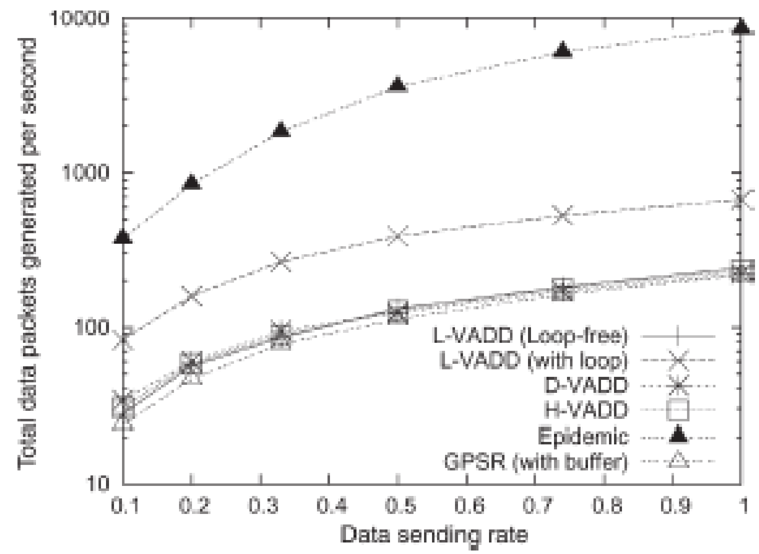
(a) 150 nodes.



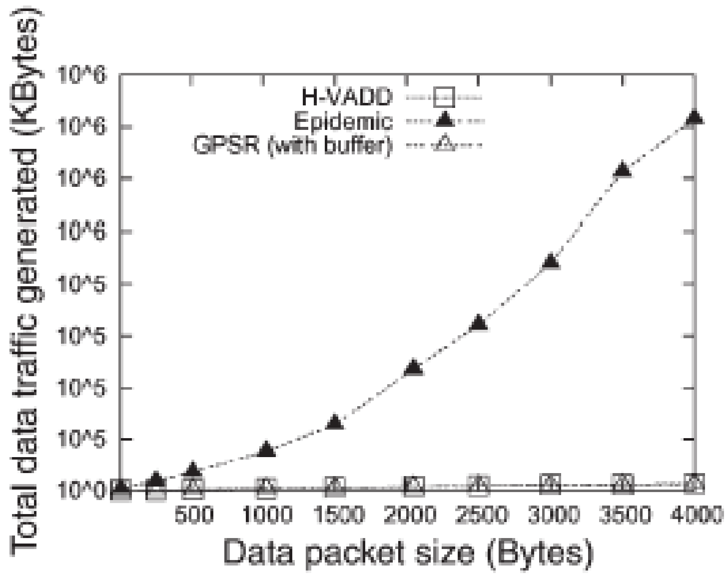
(b) 210 nodes.

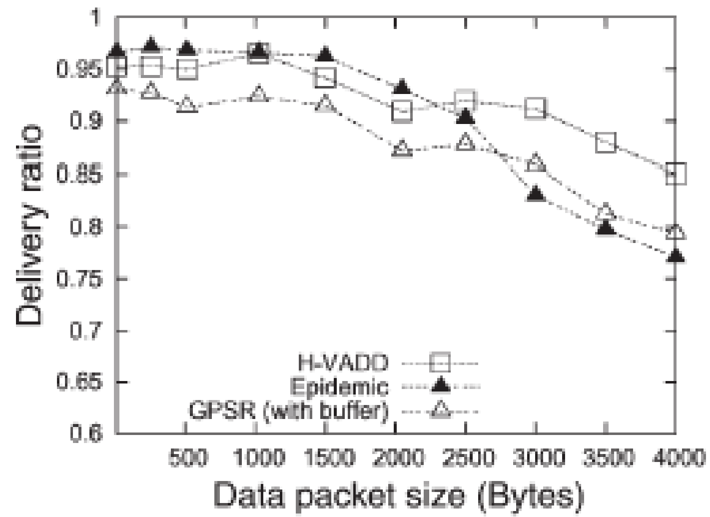


Lowest 75% delivery delay (210 nodes).

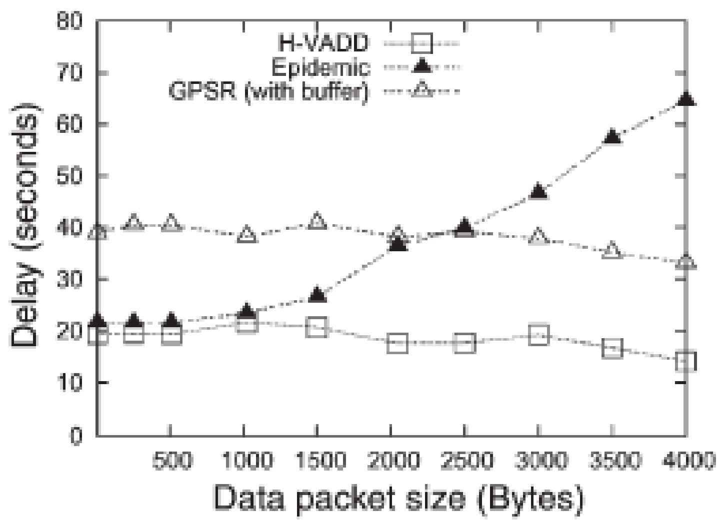


Results





(b)



(c)

Impact of data packet size. (a) Total amount of data traffic generated.

(b) Data-delivery ratio. (c) Data-delivery delay.

Conclusions

- VADD introduces the use of predictable vehicle mobility under the given assumptions
- Experimental results showed that the proposed VADD protocols outperform existing solutions in terms of packet-delivery ratio, data packet delay, and traffic overhead.
- Future work will focus on query data return

Conclusions

- Protocol effective in reducing data traffic and ensuring high delivery rate
- Assumptions don't allow for wide applicability (yet)
- The more practical side of the scenario (response to query) faces complications not yet addressed by the authors

Thank you!