

Mobile Computing and
Networking Laboratory

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

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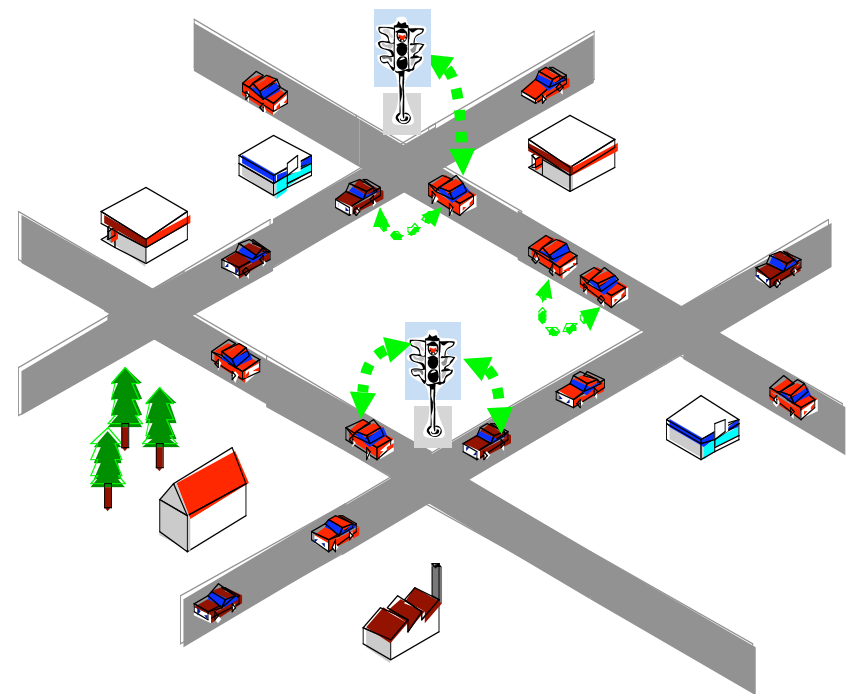
The Big Picture

■ Vehicular ad hoc networks - VANET

- Moving vehicles
- Stationary sites
 - Local broadcasting infostations
 - Sensors
 - Hotspots

■ Task

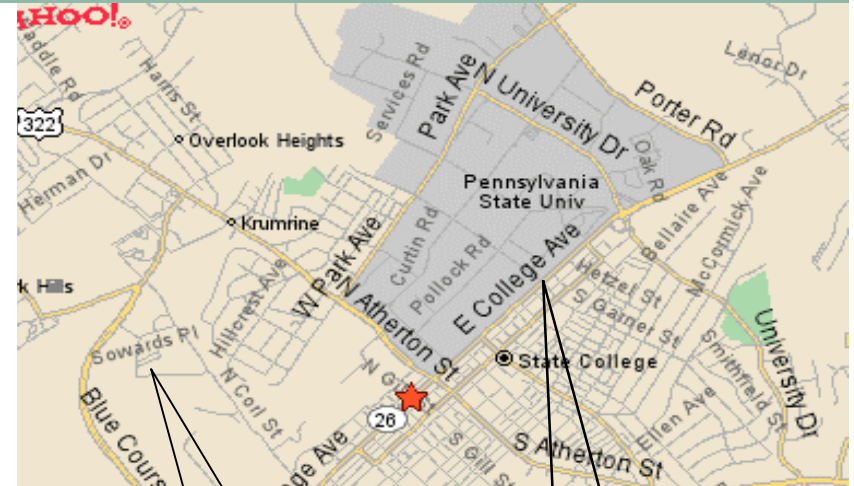
- Delivery a message from mobile vehicle to the fixed site besides street miles away.
 - For delay tolerant applications (DTN)
 - Multi-hop forwarding through VANET



Challenges

■ Partitions

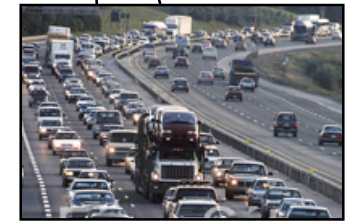
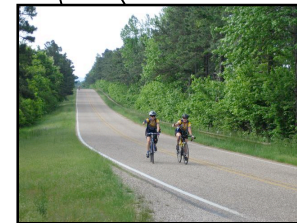
- Large scale sparse networks
- Uneven vehicle distribution
- High mobility



■ End-to-end connection through multi-hop hard to set up

- Most current Ad hoc routing protocols implicitly rely on the existence of end-to-end connectivity; otherwise, drop packets.

- DSR
- AODV
- DSDV



Store, Carry and Forward

- Mobility creates opportunities
 - Buffer and carry the packet when no routes
 - Forward the packet to the nodes moves into the vicinity which can help packet delivery
 - Possible to deliver the packet without an end-to-end connection

- Current “Store, Carry and Forward” protocols
 - No control on mobility - Epidemic packet exchange
 - A. Vahdat and D. Becker, “Epidemic Routing for Partially Connected Ad Hoc Networks”.
 - J. Davis, A. Fagg and B. Levine, “Wearable Computers As Packet Transport Mechanisms In Highly-partitioned Ad-hoc Networks”
 - Controlled mobility
 - W. Zhao, M. Ammar and E. Zegura, "A Message Ferrying Approach for Data Delivery in Sparse Mobile Ad Hoc Networks", ACM MobiHoc 04'.

Vehicle-Assisted Data Delivery (VADD)

■ Approach

- Adopt the idea of “carry and forward”
- Use predictable traffic pattern and vehicle mobility to assist efficient data delivery

■ Objective

- Delivery ratio
- Delay
- Network traffic

■ Assumptions

- A vehicle knows its own location via GPS, knows its neighbors' location by beacon message.
- Vehicles are equipped with pre-loaded digital maps
 - Road information and traffic statistics available

VADD

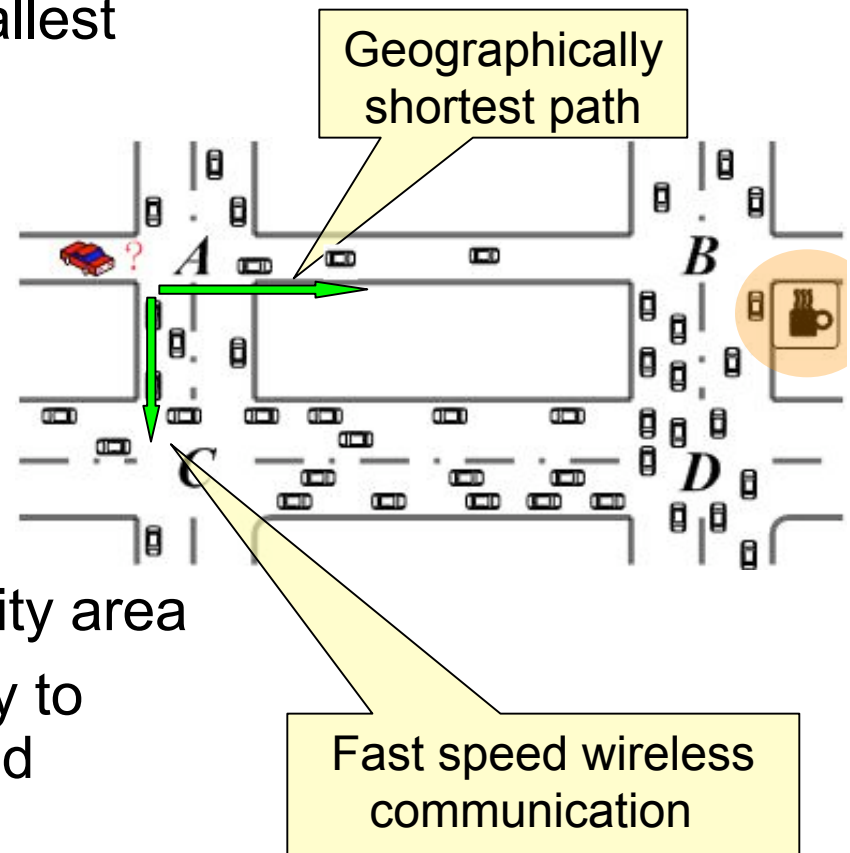
■ Key issue

- Select a forwarding path with smallest packet delivery delay

■ Why not GPSR?

■ Guidelines

- Make the best use of the wireless transmission
- Forward the packet via high density area
- Use intersection as an opportunity to switch the forwarding direction and optimize the forwarding path



VADD: Three Modes

■ Intersection Mode

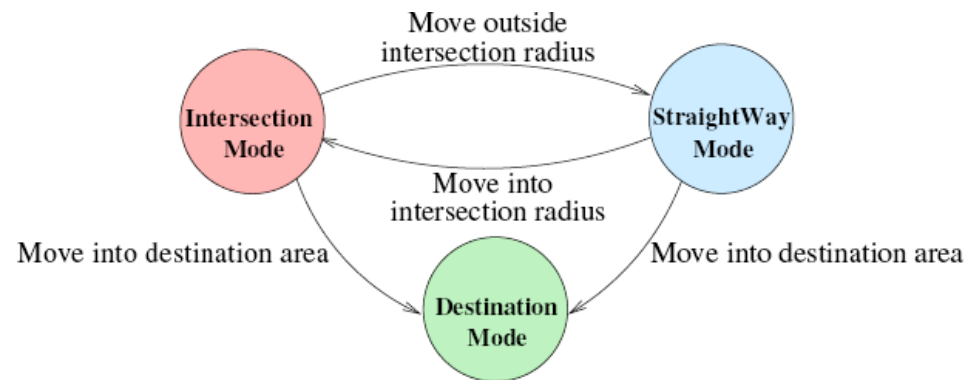
- Optimize the packet forwarding direction

■ StraightWay Mode

- Geographically greedy forwarding towards next target intersection

■ Destination Mode

- broadcast packet to destination



VADD: Intersection Mode

■ Problem

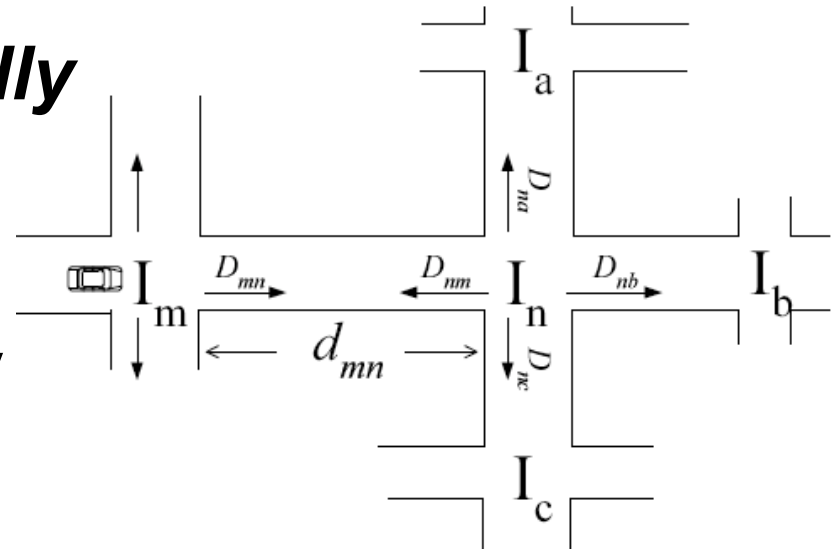
- Which direction to go?
 - VADD Model
- Which carrier to take?
 - VADD Protocols

Carrier:

The node who can forward the packet as the next hop

VADD Model

- Find out the next forwarding direction with ***probabilistically*** the shortest delay
- Probabilistic Method
 - Estimate the expected delivery delay from current intersection to the destination for each possible forwarding directions



$$D_{mn} = d_{mn} + \sum_{j \in N(n)} (P_{nj} \times D_{nj}) \quad \dots \quad (1)$$

$$\begin{array}{l} D_{mk_1} = d_{mk_1} + \dots \\ D_{mk_2} = d_{mk_2} + \dots \\ \vdots \\ D_{mk_n} = d_{mk_n} + \dots \end{array}$$

Compute The Optimal Forwarding Direction

■ Computation Steps

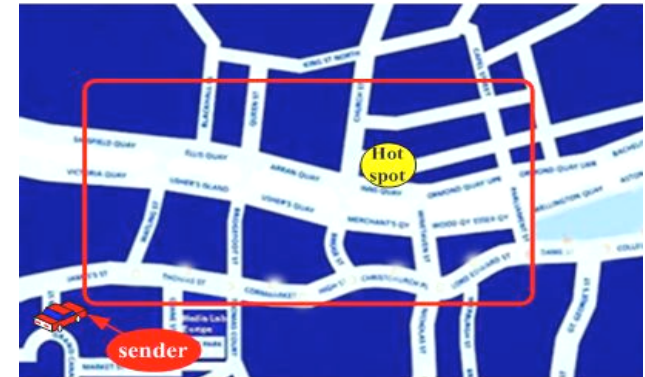
1. Place a boundary including source and destination
2. Derive a linear equation for each intersection within the boundary using Equation (1).
3. Generate a Linear equation system

■ Can be $P \cdot X = -D$ unique si \dots (2)

4. Solve the equation systems by Gaussian Elimination

■ Complexity is

$$\Theta(n^3)$$



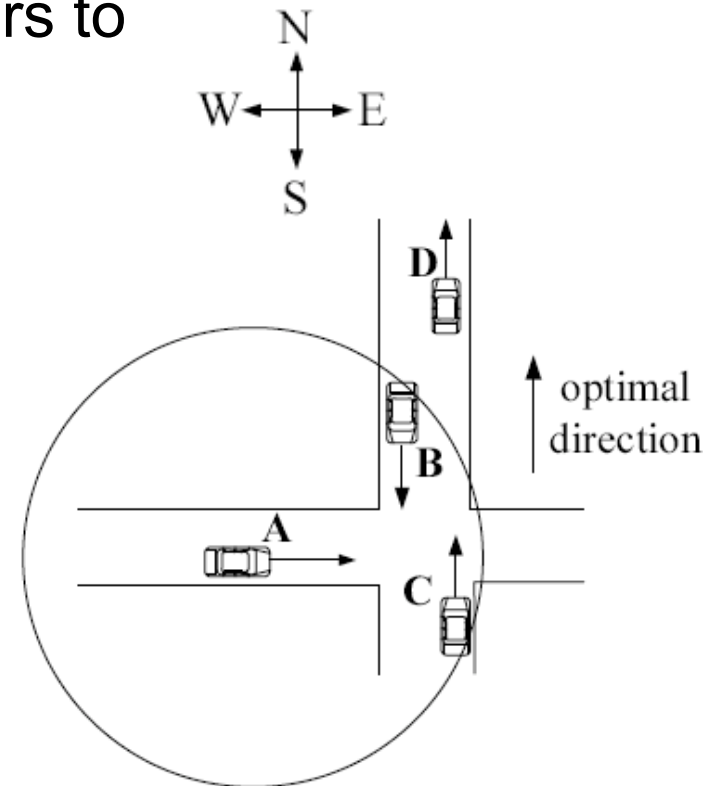
$$P = \begin{bmatrix} P_{11} - 1 & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} - 1 & \cdots & P_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} - 1 \end{bmatrix}$$

$$X = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \quad \text{and} \quad D = \begin{bmatrix} d_1 \\ d_2 \\ \vdots \\ d_n \end{bmatrix}$$

Output: Priority list of the outgoing directions for the packet forwarding

Intersection Forwarding Protocol

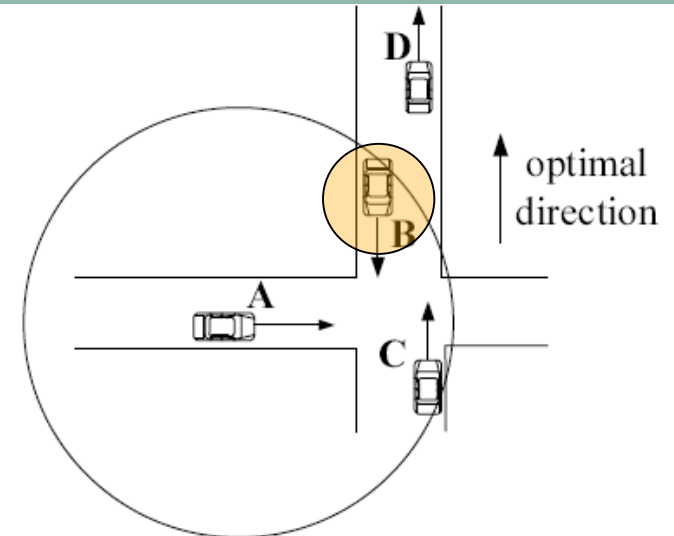
- Known the priority list of outgoing directions, check the available carriers to ensure packet is forwarded to the preferred directions
 - Not trivial, need to consider
 - Location
 - Mobility
- VADD Intersection Protocols
 - Location First VADD (L-VADD)
 - Direction First VADD (D-VADD)
 - Multi-Path D-VADD (M-VADD)
 - Hybrid VADD (H-VADD)



Location First VADD (L-VADD)

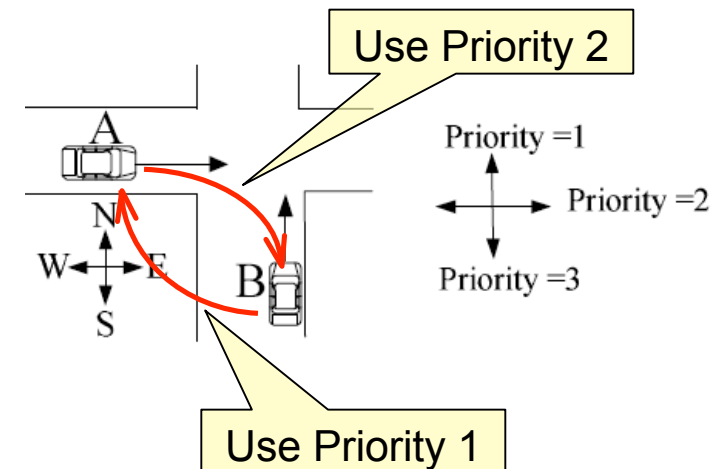
■ Simple L-VADD

- The closest carrier towards the preferred direction in term of location as the next hop, whatever the moving direction of the chosen carrier.
 - e.g. A→B
- Vulnerable to *Forwarding Loop*



■ Loop-free L-VADD

- Detection: Check previous hop
- Recovery: Mark suspect node
- Drawback
 - Due to mobility, a lot of loops can be self-released with node still marked. Thus many valid carrier cannot be used



■ Drawback

- Negative on delivery ratio

Direction First VADD (D-VADD)

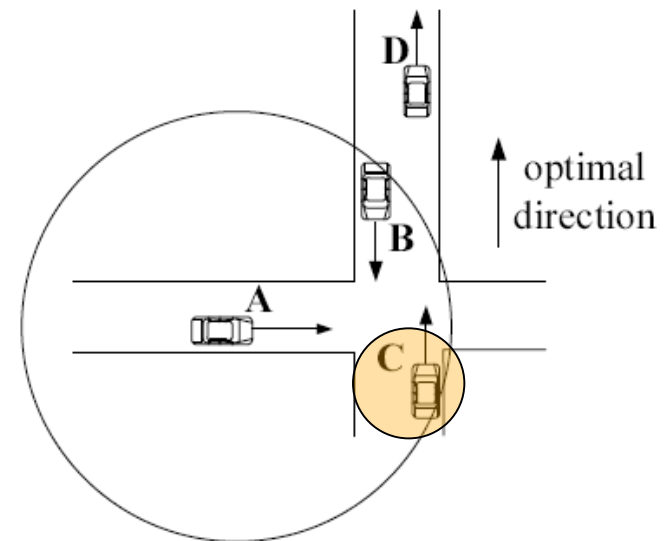
■ Basic Idea

- Only probe the carrier moving towards the preferred direction.
- Pick the one closest towards the preferred direction as the next hop.
- e.g. $A \rightarrow C$

■ Can be proved no *Forwarding Loop*

■ Drawback

- Delay may be higher



Multi-path D-VADD (MD-VADD)

Basic idea

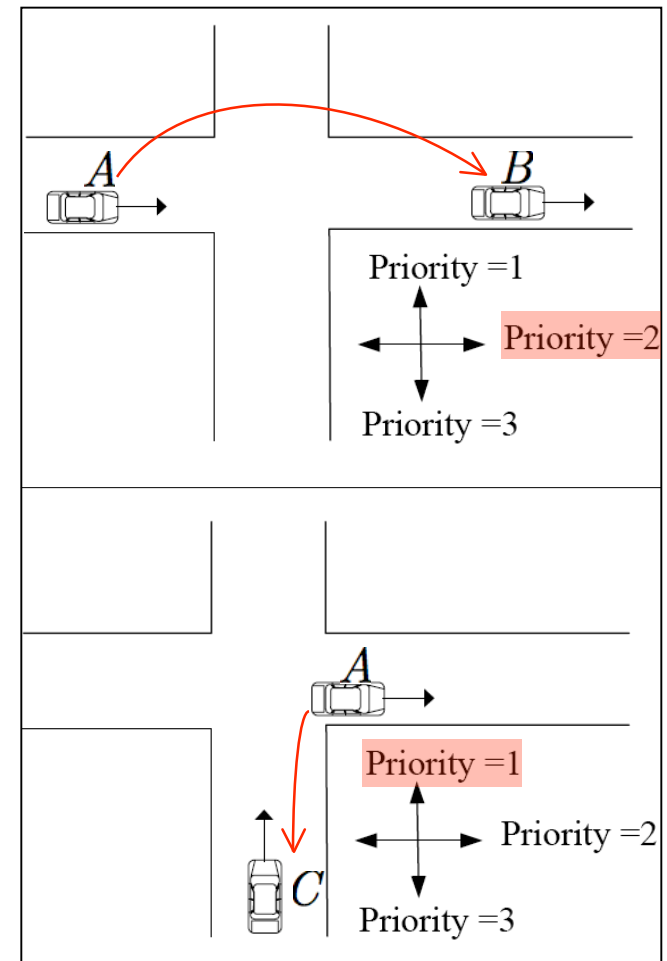
- Continue holds the packet after the packet is forwarded to sub-optimal direction
- Extends the staying time of a packet at the intersection to increase the opportunity of meeting contact towards better direction.

Pros:

- Higher delivery ratio
- Lower delay

Cons:

- Duplicated packet
- More overhead



Hybrid VADD (H-VADD)

■ Basic Idea

- Hybrid of L-VADD and D-VADD/MD-VADD

- “Try and Error”

 - Try L-VADD first, switch to D-VADD/MD-VADD when L-VADD fails.

■ Pros:

- Capture the advantages of both L-VADD and D-VADD.

Performance Evaluation

■ Packet level simulation by ns2

■ Metrics

- Delivery ratio
- Delay
- Network traffic

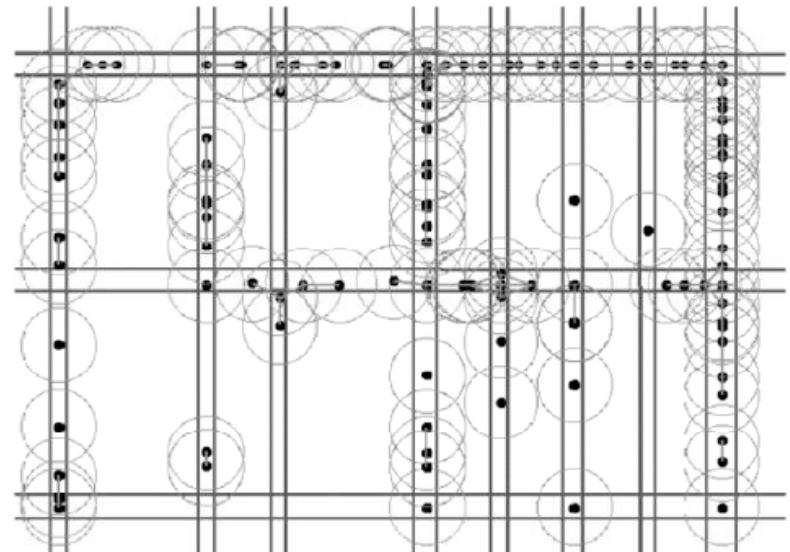
■ Compare the performance with:

- Epidemic Routing
- GPSR (with buffer)

■ Mobility Scenario

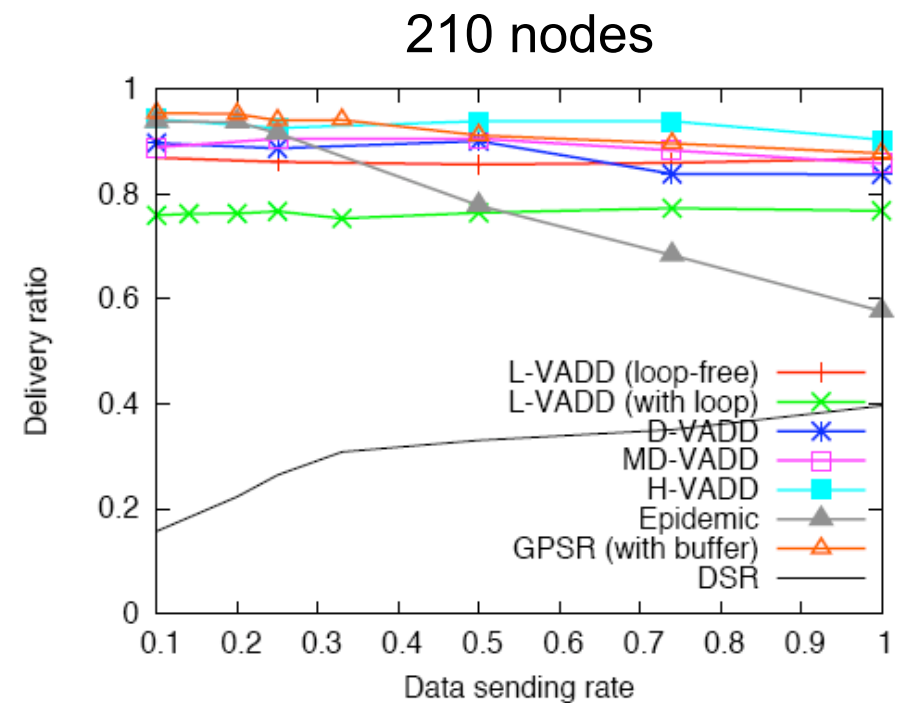
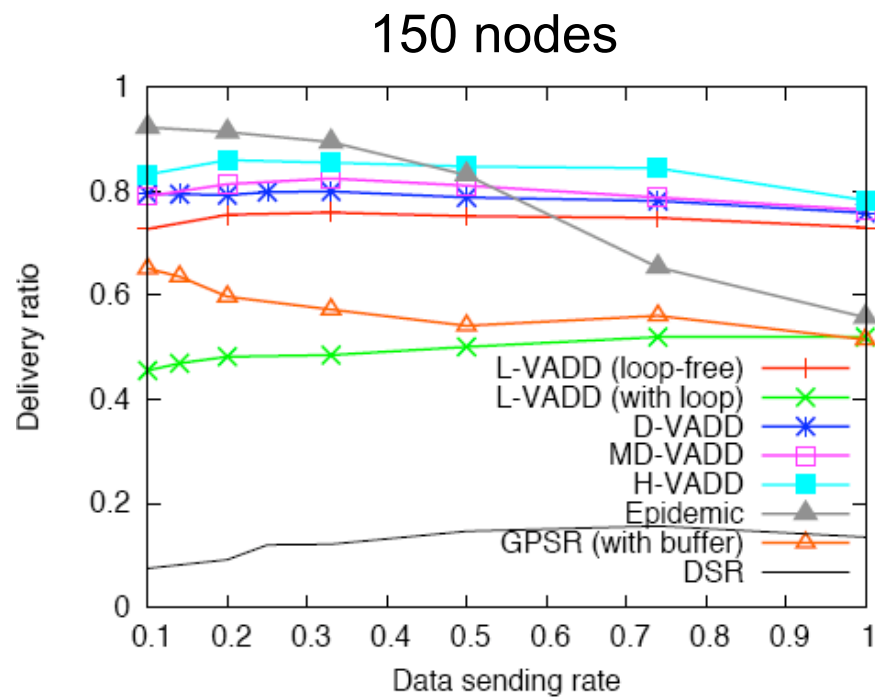
- Traffic model derived from from TIGER database
- Map data are transformed into ns-2 readable data

Parameter	Value
Simulation area	4000m × 3200m
# of intersections	24
Number of vehicles	150, 210
# of packet senders	15
Communication range	200m
Vehicle velocity	15 - 80 miles per hour
Buffer size (in packet)	10, 20, 50, 100, 200, 500, unlimited
CBR rate	0.1 - 1 packet per second
Data packet size	10 B - 4 KB
Vehicle beacon interval	0.5 sec



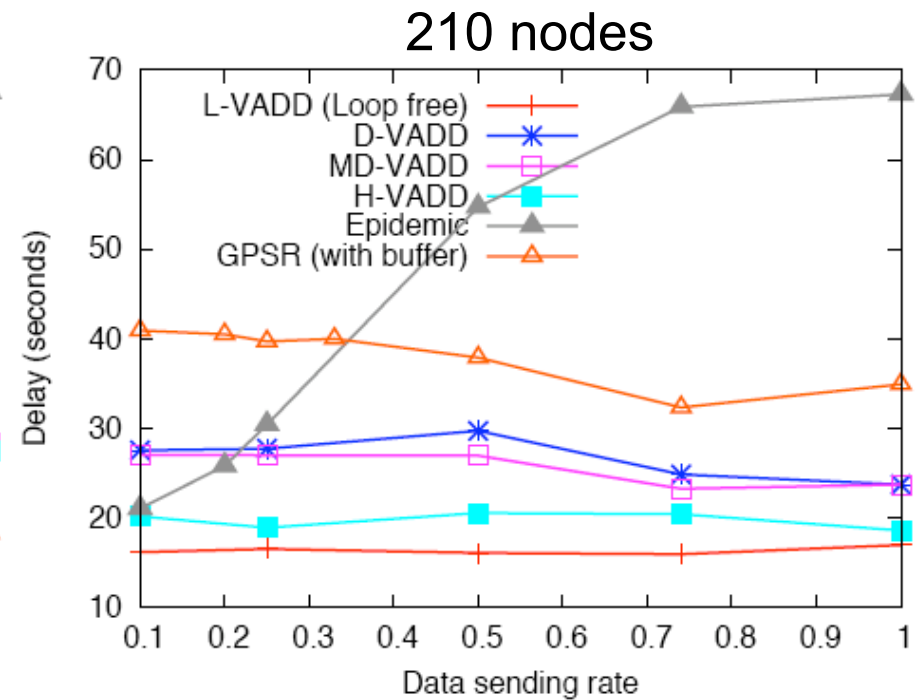
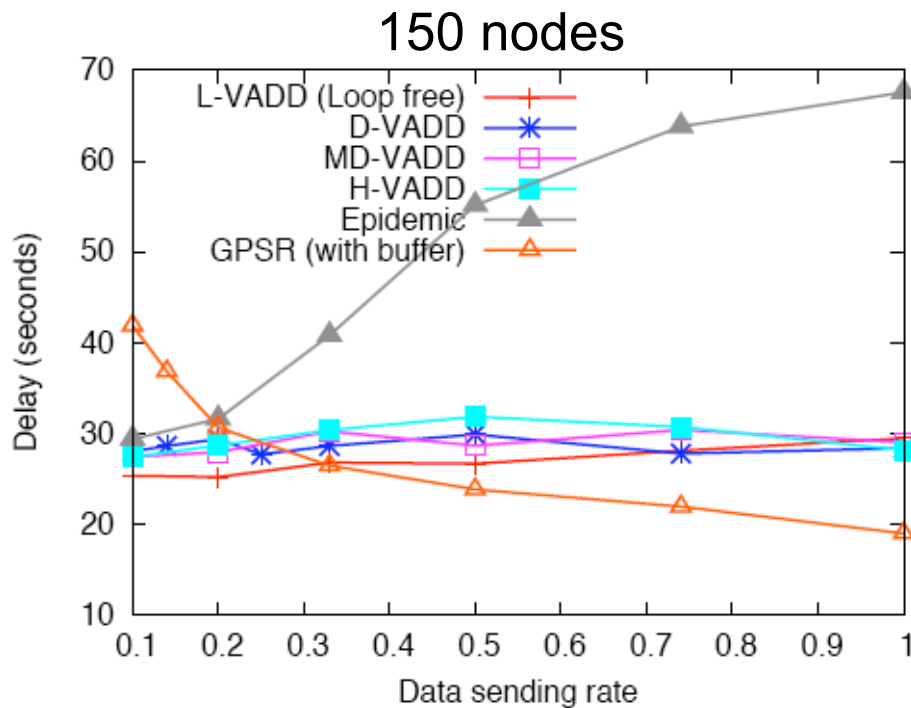
Delivery ratio

■ Low node density VS High node density



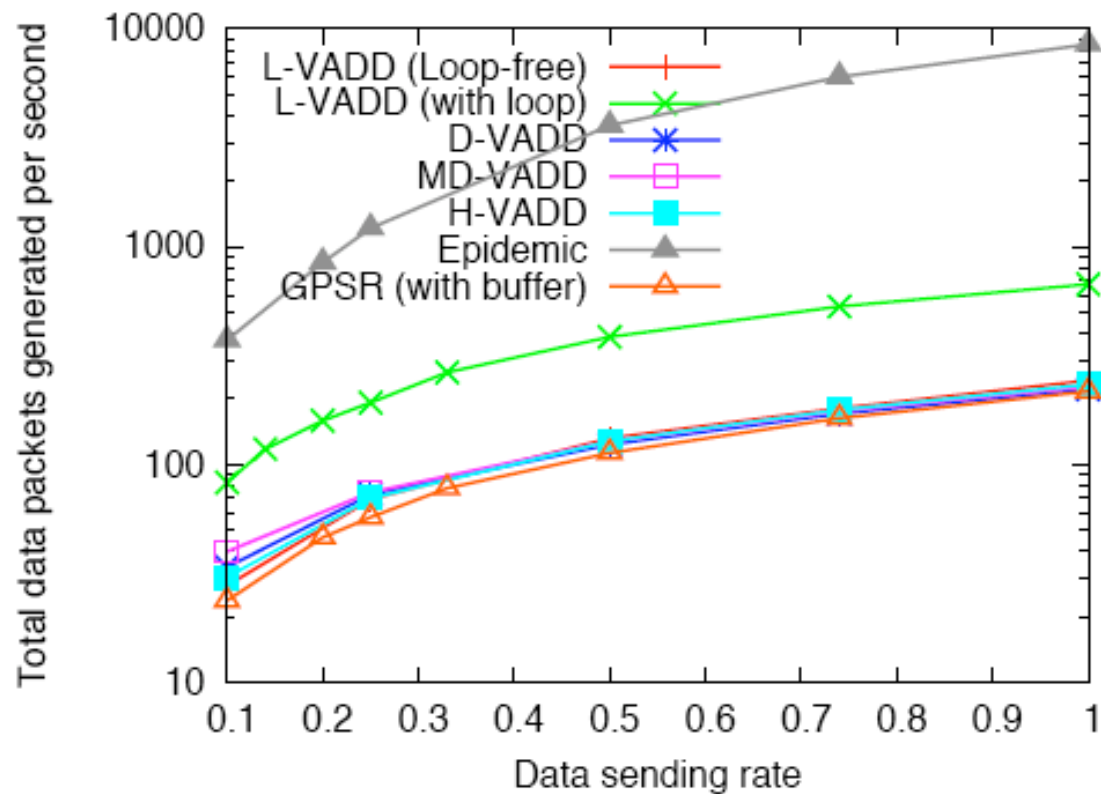
Delay

■ Low node density VS High node density



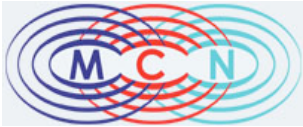
Network Traffic

■ Comparison between different protocols



Conclusion

- Existing routing protocols are not suitable for DTN applications in VANET.
- VADD adopts the idea of “carry and forward”, and also explores the predictable vehicle mobility.
- VADD use a linear equation model combining with probabilistic method to compute the optimal forwarding direction.
- Four VADD protocols to forward the packet towards the optimal direction/path at the intersection.
- Simulation results shows that the VADD protocols are better suitable for the multi-hop data delivery in VANET.



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Thank You

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