VANETs:
Vehicular ad hoc networks

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What are VANETs?

Vehicular ad hoc networks

- Essentially mobile ad hoc networks that are specific to the domain of vehicles.
- Purpose is to relay information between cars
- Can consist of both vehicle and roadside nodes

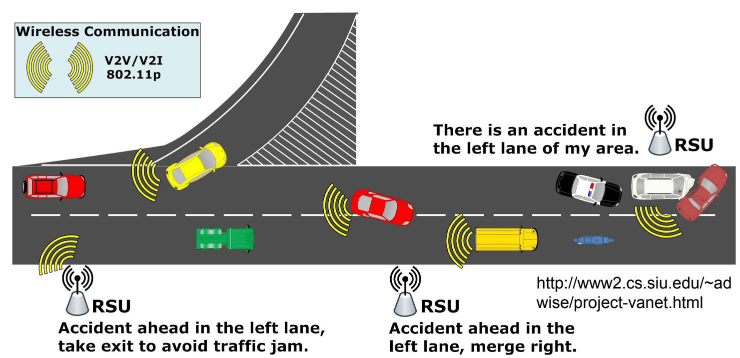
Applications of VANETs:

Forming trains of cars which accelerate, brake, and steer cooperatively, allowing them to drive inches from each other

Quickly distribute information about emergencies or relevant navigation information such and traffic and obstacles

Provide connectivity to internet services including information and personal entertainment

Example VANET application:



Challenges for VANETs:

The bad news:

- Routing is complicated by moving vehicles
- Topology changes quickly
- Links between vehicles are not robust
- High variability in the node density
- Extremely large number of nodes

The good news

- Vehicles tend to move in an organized fashion
- Vehicles are constrained to moving along a paved road

Technologies and Standards:

United States

- IEEE 1609 WAVE protocol, built on 802.11p WLAN in 5.9 GHz band

Europe

- ETSI ITS G5, built on variant of 802.11 in 5.9 GHz band

Japan

- ARIB STD-T109, built on one frequency in 700 MHZ band

Background - GSR and GPSR

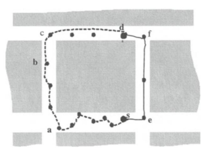


Fig. 1. Challenges of Position-Based Routing in IVCS

GSR - Geographic Source Routing

- Each node must know its own geographic location
- Use geographic location of self and destination to decide where to forward

GPSR - Greedy Perimeter Stateless Routing

- Forward as close to the destination as possible
- *Local maximum* - current node is closer to destination than any other node within range
  - Enters perimeter mode - uses right hand rule to traverse through nodes

A-STAR

Anchor-based Street and Traffic Aware Routing

- “Street awareness” for anchor path computation
- Traffic awareness to form statistically rated map
- Out-of-service marking for routes

Features of A-STAR

Utilize street maps to determine more optimal routes

- Weight streets based on number of bus lines served
- Use Dijkstra's least weight path algorithm to for statistically-rated map
- Mark routes as "out of service" when a local maximum occurs so other to prevent other packets from travelling through void area
- A better weight-assignment technique is possible by monitoring traffic and making a dynamically-rated map

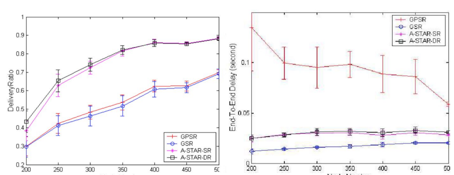
How it works:

A-STAR is different than GSR and GPSR in two major ways:

- Traffic awareness using statistically rated and dynamically rated maps
    - Contribute to making the IVCS (inter-vehicular communication systems) more aware than GSR system
- Employing a new local recovery strategy
    - Street at which the local maximum is detected is temporarily put out of service
    - Nodes will receive the maps including the void areas to make their forwarding decisions
    - "Out of commission" nodes will regain operationality after a pre ascertained amount of time
    - GPSR's perimeter mode local recovery algorithm and GSR switching back to greedy approach is quite inefficient in a city

Results

- Significantly higher packet delivery ratio than GSR and GPSR
- Longer route lengths than GSR and GPSR
- Delivers significantly more packets than GSR and GPSR, especially as number of hops increases
- Slightly longer end-to-end delay than GSR but significantly shorter than GPSR



(a) Packet Delivery Ratio (b) End-to-End Delay

DR - dynamic routing

Our take:

The good:

- Packets are routed through places w/ higher node density
- Higher deliver ratio and smaller delay than GSR/GPSR

The bad:

- Packets are constricted to travelling along roads, which can lead to inefficiencies
- More hops for each delivery
- Results are entirely simulated, no real-world data

TrafRoute

- Utilizes maps to identify intersections and improve scalability
- Paths are defined by landmarks instead of by vehicles

Features:

Routes to destination are described as a sequence of landmarks

- Instead of a more typical sequence of specific nodes

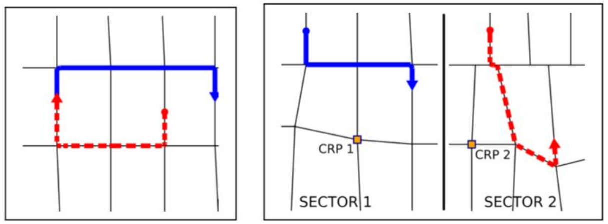
Geography is defined by sectors

- Each sector has a Central Relay Point (CRP) that is a roadside unit
- Intra vs. inter-sector transmissions happen in different ways

Forwarder self-election based on the distance from nearest Forwarding Point (FP)

- Forwarding choice is determined on a per-packet basis

How it works:



(a) Intra-sector Paths (b) Inter-sector Paths

Results:

This routing scheme evaluated on four metrics

- How vehicular density affects the forwarding scheme
  - In every simulated scenario, the elected set of forwarders within every FP is sufficient to interconnect the entire network
- Route Discovery
  - The main advantage of the TrafRoute discovery procedure is that the resulting path is not bound to specific nodes
- Route Usage
  - Source routing is seen as a better candidate as there are often time uneven distributions of vehicular nodes
- Data Transfer
  - Average delay of around 100ms

	Intra Sector	Inter Sector
TrafRoute Delivery Ratio	0.74	0.83
CBR Delivery Ratio	0.61	0.69
Packet Drop on Route Ratio	0.058	0.065
Packet Drop on Last Hop Ratio	0.044	0.001
RCHECK initiated	12.9	12.3
Successful RCHECK	4.2	5.3
End-to-End Delay [ms]	Min: 9 Max: 2241 Avg: 85	Min: 17 Max: 5532 Avg: 102
Number of Hops	Min: 2.7 Max: 5.1 Avg: 3.9	Min: 5.0 Max: 6.1 Avg: 5.5

TABLE I
TRAFROUTE PERFORMANCE METRICS

Our take:

The good:

- Central Relay Points ensure entire network is connected
- Path is not bound to specific nodes, but instead is bound to more robust landmarks

The bad:

- Not all intersections are LOS as is assumed for this protocol
- Intersections can be spread out long distances from each other
- Sometimes very long end-to-end delays
- Requires a decent amount of infrastructure

DAZL

Density-Aware Zone-based Limited forwarding

- Packets are forwarded to a geographic zone
- Priority is given to forwarders nearer to destination
- Forwarding is dependent on vehicle density

Features:

Forwarding protocol utilizing geographic zones instead of nodes

- It is difficult to find a good balance between hop-length and signal integrity, and “vehicle diversity” addresses this problem
- Vehicles in geographic zone can become potential forwarders
- Give preference to forwarders nearer to the destination
- More receivers means more potential forwarders and less packet loss
- Vehicular diversity becomes a hindrance in high density scenario, so there is a tradeoff that must be made
- Density aware - limit contention and replication by limiting number of forwarding vehicles delaying forwarding packets

How it works:

Fig. 1: Existing proposals suffer with link instability and variable node densities.

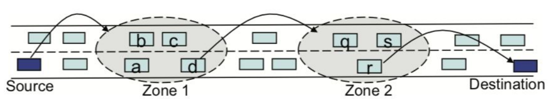


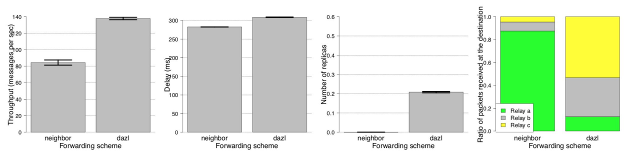
Fig. 2: The proposed zone-based forwarding scheme.

Results:

90% throughput of ideal protocol which uses all information available in network

Near-zero latency in transmission

Substantially less replication than neighbor-based approach



(a) Throughput (b) End-to-end latency (c) Number of replicas (d) Relay diversity

Fig. 6: Experimental performance results.

Our take:

The good:

- No additional infrastructure that is needed to implement
- Greatly improves throughput and decreases latency
- Most of the time only use one forwarder, but have other options in case the first doesn't work

The bad:

- Results are based off a VERY controlled and highly unlikely scenario
- Overhead of duplicated messages may cause issues in high density situations
- Doesn't address issue of fragmented network

LASP

Look-Ahead Spatial Protocol

- Generalization of DAZL
- Performs DFS for forwarding attempts
- Implements density-aware forwarder coordination

Features:

More or less a generalization of DAZL

- Utilizes real-time conditions to make forwarding decisions within a local neighborhood (same as DAZL)
- Utilizes global historical spatial look-ahead graph to make routing decisions across the entire network
- Built on the premise that historic Packet Delivery Ratios (PDRs) can be used in determining future forwarding paths

How it works:

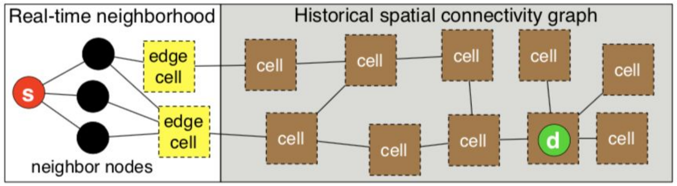


Fig. 4. LASP mixes real-time and historical spatial connectivity information.

How it works:

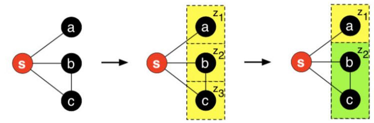


Fig. 5. Candidate forwarding zone formation.

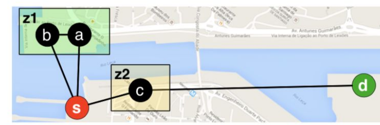


Fig. 6. LASP example operation.

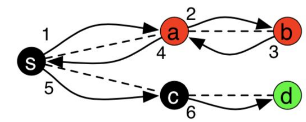


Fig. 7. LASP backtracking example.

Results:

LASP is evaluated on four metrics:

- Packet Delivery ratio
  - GPSR - 70%, LASP-SF - 83%, LASP - 94%
- Path length
- Transmission Count
  - transmission count for 75% of the packets:
    - GPSR - within 200% of the optimum
    - LASP - within 160% of the optimum
- Hop Count
  - GPSR performed better in 2 and 3 hop cases
  - LASP had 50% more than the optimal for 30% of the packets

Our take:

The good:

- No additional infrastructure that is needed to implement
- Overcomes a lack of information about global topology

The bad:

- Very complicated protocol without much improvement over GPSR
- Not close enough to the theoretical optimal protocol to justify this complexity

Thank you!
Questions?