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 as traffic and obstacles
- Provide connectivity to internet services including information and personal entertainment

Example VANET application:
- http://www2.cs.siu.edu/~adwise/project-vanet.html
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

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

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

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicular Density</td>
<td>5.2</td>
</tr>
<tr>
<td>CRP Throughput</td>
<td>7.8</td>
</tr>
<tr>
<td>Packet Drop in Core Rate</td>
<td>0.005</td>
</tr>
<tr>
<td>Packet Drop at Core Node</td>
<td>0.004</td>
</tr>
<tr>
<td>End-to-End Delay (ms)</td>
<td>17.5</td>
</tr>
</tbody>
</table>

Table 1: 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:
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

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

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.

Results:

LASP is evaluated on four metrics:

- Packet Delivery ratio
  - GPRS - 70%, LASP-SF - 83%, LASP - 94%
- Path length
- Transmission Count
  - Transmission count for 75% of the packets:
    - GPRS - within 200% of the optimum
    - LASP - within 160% of the optimum
- Hop Count
  - GPRS 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 GPRS
- Not close enough to the theoretical optimal protocol to justify this complexity
Thank you!
Questions?