Different Routing Techniques in VANET

Introduction:

VANET is an emerging technology to achieve intelligent inter-vehicle communications, seamless internet connectivity resulting in improved road safety, essential alerts and accessing comforts and entertainments. The technology integrates WLAN/cellular and Ad Hoc networks to achieve the continuous connectivity.

The feature of VANET mostly resembles the operation technology of MANET in the sense that the process of self-organization, self-management, low bandwidth and shared radio transmission criteria remain same. But the key hindrance in operation of VANET comes from the high speed and uncertain mobility [in contrast to MANET] of the mobile nodes (vehicles) along the paths. This suggested that the design of efficient routing protocol demands upgradation of MANET architecture to accommodate the fast mobility of the VANET nodes in an efficient manner. This warranted various research challenges to design appropriate routing protocol. It is therefore important at this stage to reiterate the key characteristics of VANET that may be accounted for the design of various routing protocols.

Specific Characteristics of VANET:

High Dynamic topology: The speed and choice of path defines the dynamic topology of VANET. If we assume two vehicles moving away from each other with a speed of 60 mph (25m/sec) and if the transmission range is about 250m, then the link between these two vehicles will last for only 5 seconds (250m/50ms⁻¹). This defines its highly dynamic topology.

Frequent disconnected Network: The above feature necessitates that in about every 5 seconds or so, the nodes needed another link with nearby vehicle to maintain seamless connectivity. But in case of such failure, particularly in case of low vehicle density zone, frequent disruption of network connectivity will occur. Such problems are at times addressed by road-side deployment of relay nodes.

Mobility Modeling and Prediction: The above features for connectivity therefore needed the knowledge of node positions and their movements which as such is very difficult to predict keeping in view the nature and pattern of movement of each vehicles. Nonetheless, a mobility model and node prediction based on study of predefined roadways model and vehicle speed is of paramount importance for effective network design.

Communication Environment: The mobility model highly varies from highways to that of city environment. The node prediction design and routing algorithm also therefore need to adapt for these changes. Highway mobility model, which is essentially a one-dimensional model, is rather simple and easy to predict. But for city mobility model, street structure, variable node density, presence of buildings and trees that behave as obstacles to even small distance communication make the model application that very complex and difficult.
**Hard Delay Constraints:** The safety aspect (such as accidents, brake event) of VANET application warrants on time delivery of message to relevant nodes. It simply cannot compromise with any hard data delay in this regard. Therefore high data rates are not as important an issue for VANET as overcoming the issues of hard delay constraints.

**Interaction with onboard sensors:** This sensors helps in providing node location and their movement nature that are used for effective communication link and routing purposes.

**ROUTING PROTOCOLS:**

**Ad Hoc Routing:** As mentioned earlier, the operational principles of VANET and MANET matches in most aspects except the high speed mobility and high nature of unpredictability of their movement. This suggests the applicability of most MANET routing protocols in VANET.

Some of the well known ad hoc routing protocols such as AODV (Ad Hoc on demand distance vector) and DSR (Dynamic source routing) are therefore can be applied to VANET as well. However, the simulation of these algorithms in VANET brought out frequent communication break which is mainly attributed to high dynamic nature of its nodes. To meet the VANET challenges, these existing algorithms are suitably modified.

Namboodiri et al. [3] considered the following application in their model:

- A highly partitioned highway scenario is used where most path segments are relatively small.
- The initial simulation with AODV algorithm resulted in frequent link break as expected, owing to dynamic nature of node’s mobility.
- Two predictions are added to AODV to upgrade the algorithm.
- In one, node position and their speed information are fed in AODV to predict link life time. This is referred as PR-AODV and it constructs a new alternate link before the end of estimated link lifetime. (In AODV, the link created only after the failure of connectivity occurs).
- In second modified algorithm (PRAOVD-M), it computed the maximum predicted life time among various route options (in contrast to selecting shortest path as in PRAODV or AODV).
- The simulation on both showed improved packet driving ratio.
- However, the success of this algorithm largely depends on the authenticity of node position and mobility.

In another model, AODV is modified to forward the route request within a zone (rectangular or circular) of relevance (ZOR) from the point of event occurrence to make the algorithm more effective.

**Position based Routing:** The technique employs the awareness of vehicle about the position of other vehicle to develop routing strategy. One among the best known position based routing is
GPSR (Greedy Perimeter Stateless Routing) which works in the principle of combining greed forwarding and face routing. This algorithm has following advantages and constraints.

- It works best in open space scenario (Highways) with evenly distributed nodes. The absence of fewer obstacles in highway scenario is attributed to its good performance.
- The comparison of simulation result of GPSR from that of DSR in highway scenario is generally considered to be better.
- In city condition, GPSR suffers from many problems:
  - Greedy forwarding are restricted owing to obstacles
  - Routing performance degrades because of longer path resulting higher delays
  - Node mobility can induce routing loops for face routing
  - Packet can at times be forwarded in wrong direction resulting higher delays

Considering above constraints in city model, certain proposals are made to improve the algorithm.

In one, Lochert et al proposed feeding digital map in navigation system to define preferred route for source and destination. The simulation results in better average delivery rate, smaller total bandwidth consumption and similar latency as with DSR or AODV.

In another, Lochert et al proposed the model with GPCR (Greedy Perimeter Coordinator Routing) instead of using digital map and source routing. Here, a restrictive greedy algorithm is simply followed when nodes are in street and an actual routing decision is taken when at the junction of streets. Here the packet is forwarded to a node in the junction rather sending it across the junction. The simulation of this algorithm using NS-2 simulator in a real city scenario the authors proved that GPCR has higher delivery rate than that of GPSR with large average number of hops and slight increase in latency.

However, these models fail to work efficiently in city scenario with high rise building, uneven concentration of vehicles on roads. Here another position based routing technique A-STAR (Anchor based street and traffic aware Routing) is put forth that uses street map as well to take routing decisions at junctions (anchors). It uses statistically or dynamically rated maps to assess traffic condition and identify anchor path with high connectivity for packet delivery. A-STAR also employs a new local recovery strategy for packets to a local minimum that is more suitable in such city condition. On simulation, A-STAR provided better performance as compared to GSR and GPCR.

A brief demonstration of methods used in Greedy forwarding and face routing (Geographic or Position-based Routing) techniques is explained in figures below.

**Greedy Forwarding Technique:** [Source: http://en.wikipedia.org/wiki/Geographic_routing]

In attempt to send the packet close to Destination (D), the source (S) forwarded it under various algorithm shown in figure-1 below. This each node starting from source forwarded the message
to the neighboring node. The most suitable neighbor (location E in figure-1) may be one that has minimum distance (known as Greedy) from the destination and lies within the range (circle) of forwarding data from ‘S’. Apart from this method, the scheme can also consider MFR, NFP, ‘Compass Routing’ as explained below.

**Figure-1: Greedy forwarding variants:** The source node (S) has different choices to find a relay node for further forwarding a message to the destination (D). A = Nearest with Forwarding Progress (NFP), B = Most Forwarding progress within Radius (MFR), C = Compass Routing, E = Greedy

**Face Routing Technique:** [Source: http://en.wikipedia.org/wiki/Geographic_routing]

Greedy forwarding at times lead to a dead end. In such cases, it cannot find any nearby neighbor to forward the packet. Face routing technique (figure-2) recover it from that situation and find a path to another node, where greedy forwarding can be resumed.

**Figure-2: Face routing:** A message is routed along the interior of the faces of the communication graph, with face changes at the edges crossing the S-D-line (red). The final routing path is shown in blue. [Source: http://en.wikipedia.org/wiki/Geographic_routing]

**Cluster-based routing:**

In cluster based routing, several clusters of nodes are formed. Each cluster is represented by a cluster head. Inter-communication among different clusters is carried through cluster heads whereas intra-communication within each cluster is made through direct link. This cluster algorithm, in general, is more appropriate for MANET. But for VANET, owing to its high speed,
and unpredictable variation of mobility, the continuity of link in the cluster often breaks. Certain modification in the algorithm (COIN - Clustering for Open IVC Network put forth by Blum et al., LORA-CBF – Location based Routing Algorithm using Cluster based Flooding suggested by Santos et al.) such as incorporation of a dynamic movement scheme, expected decisions of driver under certain scenario, enhancing the tolerance limit of inter-vehicle distances are included that on are observed to provide more stable structure at the cost of little additional overhead.

**Broadcast-based Routing:**
This is most frequently used routing protocol in VANET especially to communicate the safety related messages. Simplest of broadcast method is carried by flooding in which each node rebroadcast the message to other nodes. This ascertains the arrival of message to all targeted destinations but has a higher overhead cost. Moreover, it works well with lesser number of nodes in the network. With a larger density of nodes, this causes exponential increase in message transmission leading to collisions, higher bandwidth consumption and drop in overall performance. Several selective forwarding schemes such as BROADCOMM (by Durresi et al.), UMB (Urban Multihop Broadcast Protocol), Vector-based Tracking Detection (V-TRADE), History Enhanced V-TRADE (HV-TRADE) etc are proposed to counter this network congestion.

**BROADCOMM Scheme:** In this, the highway is segmented to define virtual cells which moves along with the vehicles. Only the selected few nodes in each virtual cell (cell reflectors) are responsible for handling messages within its cell nodes and forwarding/receiving the messages to/from neighboring cell reflectors. The protocol works well with smaller number of nodes with simple highway structure.

**UMB:** In UMB protocol, each node while broadcasting the message, assign only the farthest node to forward the message (rebroadcast). At the street intersections, repeaters are installed to forward the package to all road segments. This scheme has a higher success ration and also can overcome interference, packet collisions etc. to a great extent.

**V-TRADE / HV-TRADE:** This scheme is a GPS based protocol. Based on position and movement information, each node classify its neighboring nodes into different groups and while forwarding message to neighboring nodes, it assigns only few border nodes of each group to forward the packets. Because of lesser number of nodes assigned for multi-hopping, it indicated significant in bandwidth utilization.

**Geocast based Routing:**
It is a location based multicast routing protocol. As name implies, each node deliver the message/packet to other nodes that lie within a specified geographic region predefined based on ZOR (zone of relevance). The philosophy is that the sender node need not deliver the packet to nodes beyond the ZOR, as the information (related to accident, important alerts for example) would have least importance to distant nodes. The scheme followed a directed flooding strategy within a defined ZOR so that it can limit the message overhead.
Mobility Model:
The formulation of algorithm suitable to VANET, as suggested from different routing protocols, largely depends on a authentic mobility model and decision parameters of nodes to forward the packets to other nodes. Again to set a realistic mobility model, the parameters such as street map structure, vehicle density and speed, urban or geographic conditions including obstacles such as buildings and trees need to be properly accounted. Basic methodologies applied in the mobility model is explained below.

**RWP (Random Way Point):**
This is one among the simplest and oldest model used. In this a random destination point and a uniform speed is attributed to each node. Once destination point reached, another random destination point is provided. RWP is widely used in ad hoc network simulation (example: NS-2) but the model as such is far from a realistic one.
To modify this existing model of RWP (by Nadeem et. al.), parameters such as road length, average speed, no of lanes are included to improve its reliability.
Towards further upgradation of model, Saha and Johnson included real road map based on TIGER (Topologically Integrated Geographic Encoding and Referencing) US road map by US Census Bureau. Beside they use a speed 5 mph above and below the prescribed speed limits and define the movement based on shortest path algorithm.

**STRAW (STreet RAndom Waypoint):**
In an attempt to make the above model more realistic, it uses a car-following model with US road information to simulate the realistic traffic situation that includes, traffic controls, traffic congestions, car interactions etc in an urban environment. When authors compared their simulation result using both AODV and DSR under varying traffic conditions (in Chicago, and Boston), it gave significantly different results when compared with the performances of STRAW and RWP.
In the latest technique of more realistic mobility model building, vehicles are monitored by recording their one dimensional position and lane on the highways on every discrete time steps of 0.5 sec. Combining the valid traces from these, a realistic mobility scenario is developed.
Jetcheva et al. developed such a movement scenario by recording the movement traces of buses from Public Transportation system in Seattle, Washington. However, this model has limitations as buses only contribute a small fraction of all vehicles on the road.
Naumov et a. in their mobility model incorporated trace date obtained from MMTS (Multi-agent Microscopic Traffic Simulator) which is capable of simulating public and private traffic over a real road map in Switzerland with a high degree of realism.

**Summary and Conclusions:**
Advanced research work has enabled VANET to enter into several newer applications which can be broadly categorized as (a) Intelligent transportation application and (b) Comfort services.
The services offered in intelligent transport applications are onboard navigation, cooperative traffic monitoring, traffic flow control, traffic congestion analysis based on traffic mobility information. These services helps in getting instant accident information, alert at dead crossing, location of nearby motel and gas stations etc. Besides the analysis of traffic congestion and mobility data could help develop optimum traffic signal system for efficient traffic flow. These applications mostly use broadcast or geocast based routing schemes.

The comfort applications mainly include internet connectivity, multi-media access, inter-vehicle communications etc. Such applications primarily use unicast routing protocols.

For an effective VANET application, a realistic mobility model and appropriate routing protocol is desired. Mostly position based routing and geocasting are used in VANET owing to geographic constraints. However, the choice of routing type may vary depending on the specific VANET application needed. The chart below provides the characteristics of different routing protocols.

**TABLE 1 Comparisons of routing protocols in VANETs:**

<table>
<thead>
<tr>
<th>Routing Protocols</th>
<th>Routing Type</th>
<th>Position Information? (How to Use)</th>
<th>Hierarchical Structure?</th>
<th>Network Simulator</th>
<th>Simulation Scenario</th>
</tr>
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<tbody>
<tr>
<td>AODV</td>
<td>Unicast</td>
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<td>No</td>
<td>—</td>
<td>—</td>
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<td>DSR</td>
<td>Unicast</td>
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<td>No</td>
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<td>—</td>
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<tr>
<td>GPSR</td>
<td>Unicast</td>
<td>Packet Forwarding</td>
<td>No</td>
<td>NS2</td>
<td>Simple Highway Model (20 Km segment only)</td>
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<tr>
<td>PRAODV / PRAODV-M</td>
<td>Unicast</td>
<td>Route Selection (Life time Prediction)</td>
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<td>NS2</td>
<td>Real city model (from map)</td>
</tr>
<tr>
<td>AODV-bis</td>
<td>Unicast</td>
<td>Route-Req Forwarding</td>
<td>No</td>
<td>NS2</td>
<td>Real city model (from map)</td>
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<td>GSR</td>
<td>Unicast</td>
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<td>NS2</td>
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<td>GPCR</td>
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<td>A-STAR</td>
<td>Unicast</td>
<td>Packet Forwarding</td>
<td>No</td>
<td>NS2</td>
<td>Grid city model</td>
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<tr>
<td>COIN</td>
<td>Unicast</td>
<td>Cluster Formation</td>
<td>Yes</td>
<td>Own</td>
<td>Real highway model</td>
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<td>LORA-CBF</td>
<td>Unicast</td>
<td>Packet Forwarding</td>
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<td>Broadcast</td>
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<td>No</td>
<td>—</td>
<td>—</td>
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<td>UMB</td>
<td>Broadcast</td>
<td>Packet Forwarding</td>
<td>No</td>
<td>Own</td>
<td>Simple intersection road</td>
</tr>
<tr>
<td>V-TRADE / HV-TRADE</td>
<td>Broadcast</td>
<td>Classify forwarding group</td>
<td>No</td>
<td>Own</td>
<td>Simple intersection</td>
</tr>
<tr>
<td>BROADCOMM</td>
<td>Broadcast</td>
<td>Formation of cells</td>
<td>No</td>
<td>Own</td>
<td>Simple highway model (15 modes only)</td>
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<tr>
<td>Msg Dis Protocol</td>
<td>Geocast</td>
<td>Packet Forwarding</td>
<td>No</td>
<td>Own</td>
<td>Simple Highway model (10 Km long)</td>
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<tr>
<td>IVG</td>
<td></td>
<td>Packet Forwarding</td>
<td>No</td>
<td>Glomosin</td>
<td>Simple Highway model (10 Km long, 100/200 nodes)</td>
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<td>Cached Geocast</td>
<td>Geocast</td>
<td>Packet Forwarding</td>
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<td>Abiding Geocast</td>
<td>Geocast</td>
<td>Packet Forwarding</td>
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REFERENCES:


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