Related Work

Over the past one decade a number of routing protocols have been proposed to reduce the communication overhead in VANETs. High mobility of the vehicles, frequent change in the network topology, road layout, different traffic scenarios such as city and highway, and limited lifetime are the characteristics of VANET that make routing decisions more challenging in this network [25]. The traditional routing protocols require knowledge of the entire network topology that changes frequently due to high mobility of the vehicles. However, unlike topology based routing, position-based routing protocols that use position information of nodes for making routing decision. Therefore, these protocols may be more useful for VANET and can also reduce communication and route maintenance overheads. The study of these protocols form the basis of the work presented in this thesis. In this chapter, we have reviewed the position-based routing protocols used in VANET.

2.1 Review of Position-Based Routing Protocols in VANET

Since the advent of GPS technology a number of position-based routing protocols have been designed and developed in last few years. The high dynamic nature of the nodes in VANET, causing fast and frequent change in location of the nodes demands for routing protocols that can deal with such vehicular environment. These demands attracted the researchers to use position-based routing protocols for VANET.

The research work on position-based routing [26] started in the late 1980s. In position-based routing, decision to forward a packet from source to destination depends on the
position of destination and the position of the direct neighbors of the source node (shown in figure 2.1). Position-based routing assumes that each node in the network have knowledge about its physical location by GPS or by some other position determining services.

![Figure 2.1: Position-based routing method](image)

Position-based routing protocols consist of following components [27, 28]:

- **Beaconing**
- **Location Service**
- **Forwarding and Recovery Method**

**Beaconing:** Nodes in the networks periodically broadcast short messages with its current physical position and the unique ID (IP Address). These short messages are called beacon. On the reception of a beacon, a node updates its information and stores it in its location table. Therefore, beaconing is used to collect information of direct neighbor nodes. In this thesis, the terms beacon and Hello message are used interchangeably.

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Location service: When a node does not contain information about the current position of required node in its location table, location service is used to find the current position of the desired node [27]. To find the current physical position of the desired node, the requesting node sends location message query with unique ID of the desired node to the location server. However, this service is used when the requesting node and the desired node are multiple hops away from each other. In this service, intermediate node updates their location tables with the current position information of both the requesting and desired node. The position information of a desired node can be obtained directly if the desired node is one-hop neighbor of the requesting node.

Forwarding and Recovery Strategy: Forwarding and recovery strategy are used to forward data from source to destination node. Generally position-based routing protocols used three types of forwarding methods for VANET to deliver data packets from source to destination [27,29].

- Geographical forwarding
- Hierarchical forwarding
- Greedy forwarding

In Geographical forwarding, neighbor nodes only present in a specific geographical region further forward message to the next level. This geographical region is known as "forwarding zone". The beacon is not exchanged between nodes since this method does not require position information of neighboring nodes. A source node creates forwarding zone between itself and the destination node, and broadcasts the packet that further transmitted by nodes present in the forwarding zone towards destination. In geographical forwarding, to increase the packet delivery ratio, forwarding zone should be large, but it causes increase in flooding overhead. This issue can be handled by using some efficient
flooding methods like “Distance-aware-timer-based Suppression method”, “directed flooding method”, etc. [30].

In hierarchical forwarding, protocols hierarchy is used as different steps to forward packets from source to destination. The hierarchical forwarding performs routing for neighboring nodes within the transmission range and also for nodes at greater distance. Forwarding strategy for hierarchical routing used is “geodesic packet forwarding” (GPF) and anchor based GPF [29].

Greedy forwarding is another efficient forwarding strategy in position-based routing in which a sender node selects the neighbor node which is closest to destination as the next-hop node based on position information of next-hop nodes (shown in figure 2.2). In greedy forwarding method, sending node finds a route to destination with minimum number of hops. Greedy forwarding is well suitable for VANET with high mobility of vehicles. In a failure situation, when there is no node closest to the destination, greedy forwarding use recovery strategy to overcome the problem.

Figure 2.2: Greedy forwarding method

Unlike topology based routing, position-based routing does not require any route maintenance. A route is determined only when there is a need for forwarding packets.

Related Work
Another advantage of position-based routing is that it contains information of source, destination and their neighboring nodes [28]. The above mentioned characteristics make position-based routing more suitable for VANET. Several position-based routing protocols have been proposed by different authors in the literature. The protocols use position information of nodes for making routing decisions. Although these position-based routing protocols are most suitable for VANET but these protocols still have some challenges. We discuss some of recently suggested position-based routing protocols in the literature including GPSR, A-STAR, MFR, and DIR with their issues in the next section. We have also examined the recent improvements that have been carried out in these protocols to address the issues.

2.2 Greedy Perimeter Stateless Routing Protocol (GPSR)

GPSR is one of the most popular position-based routing protocols [20]. In GPSR a node finds the location of its neighbors by exchanging Hello messages, and position of destination with the help of location service. GPSR requires that each node in the network is able to find its current position by using GPS receiver which provides current location, speed, current time and direction of the vehicles. With all these information, a node selects a neighboring node closest to the destination located in the geographical region as next-hop node that forwards incoming packets further. This operating mode is known as Greedy Forwarding.
GPSR basically forwards the packet in greedy mode. In some cases, when Hello messages get lost due to temporary transmission errors, some vehicles become unaware of existence of its neighbors. However, in some regions of the network, a local maximum may occur when a forwarding node has no neighbor that is closer to the destination. In this situation, GPSR uses a most advance recovery strategy called perimeter routing, which uses a planer graph traversal algorithm to find a way out of the local maximum region (shown in figure 2.3). Considering only position information may forward packets in the wrong direction. Since the topology of a vehicular network in urban or city environment it is likely to meet local maximum. We have turned recovery strategy of perimeter routing on during our experiments.

GPSR combines both greedy forwarding and perimeter forwarding to provide better routing decision on both full and planarized network graph by maintaining neighbor's information in its location table. The forwarding decisions in GPSR include the following distinct characteristics [20].
• GPSR packet header has the flag identity that is used to identify whether packet is in greedy forwarding or in perimeter forwarding.

• GPSR packet header also contains location of packet in the perimeter mode and the location of the new face to take a decision whether to hold the packet in the perimeter mode or to return it to the greedy mode.

• GPSR discards packets that are repeatedly forwarded to the destination that is not in range of sender. The packets in perimeter mode are never sent twice through the same link, if destination is in the range.

• It provides maximum robustness in highly dynamic wireless ad-hoc networks such as VANET.

The forwarding decisions in GPSR may include the following issues in VANETs.

• In GPSR, sometime greedy forwarding method is not suitable for the vehicular networks where the nodes are highly mobile. In this situation, node may not be able to maintain its next-hop neighbor's information as the other node may go out of range due to high mobility. This may lead to data packets loss.

• During beacon exchange process, beacons may be lost due to bad signal. This problem can lead to removal of neighbor information from the location table [31].

• GPSR uses planarized graphs as its repair strategy where greedy forwarding fails. But these graphs perform well in the highway scenario due to their distributed algorithms [32]. GPSR do not perform well in such environment of vehicular communication where a lot of radio obstacles are involved such as in city scenario.

• Distributed nature of planarized graph may lead to partitioning of network and packet delivery failure especially, in the dense networks.
2.3 Anchor-based Street and Traffic Aware Routing (A-STAR)

A-STAR is specially designed for city environment. In a city area, almost all the roads and streets are covered by tall buildings, flyovers and trees. There are close ends in the streets, frequent stop signal, turns, and speed breakers that make routing more challenging. A-STAR is anchor-based routing protocol [22]. Anchor is similar to junctions or intersections in urban or city environment. A-STAR assures to determine an end-to-end link even in a VANET with low traffic density. A-STAR uses street map to compute the sequence of junctions (anchors) through which a packet must pass to reach its destination. It uses Dijkstra algorithm with a high probability of having plenty of vehicles to allow transmission of the packet. Since the anchor path is city street vehicle traffic aware, packets are forwarded by intermediate nodes between two successive anchors by using greedy forwarding methods. This protocol also includes a new recovery strategy when a packet reaches a local maximum by computing a new anchor path from local maximum through which the packet is then routed. When a packet faces problem to pass from a junction, that junction is marked as “out of service” so that other packets are restricted to traverse that junction until the junction changed to “Operational” state [33]. When any junction is out of order, each node in the network is informed about that junction so that it updates routing information and city maps by marking that junction out of order. Therefore, no node uses that junction as an anchor to be traversed to reach the destination.

The forwarding decisions in A-STAR may include the following issues in VANETs.

- A-STAR adopts only higher connectivity anchor based paths to find the route towards destination in large city environments.
- In A-STAR, a routing path may not be optimal because it is along the anchor path
that has severe bandwidth congestion resulting in large delay.

- It is only suitable for urban or city scenario.

2.4 Most Forward Progress within Radius (MFR)

MFR is a well-known method for finding routes in a network by utilizing position information of nodes [19]. The neighbor with the greatest progress towards the destination is chosen as next-hop node for forwarding packets further. Therefore MFR forwards the packet to the node that is closest to the destination in an attempt to minimize the number of hops. In figure 2.4, \( S \) and \( D \) denote the source and destination nodes and the circle with radius \( R \) indicates maximum transmission range of source node \( S \). The source node \( S \) has five neighbors within its transmission range. It selects node \( A \) as next-hop node for forwarding packet to the destination since the projection \( A' \) of \( A \) on the line \( SD \) is closest to destination \( D \).

![Diagram of MFR selection](image)

Figure 2.4: Selection of neighbor nodes \( F \) and \( A \) as the next-hop node in DIR and MFR method [19]

2.5 DIrectional Routing (DIR)

DIR (referred as the Compass Routing) is based on the greedy forwarding method in
which a source node uses position information of the destination node to calculate its
direction [19]. A message is forwarded to the nearest neighbor having direction closest
to the straight line joining source and destination. Therefore, a message is forwarded to
the neighboring node that form minimum angle in the direction of the destination. In
figure 2.4, node $F$ has the closest direction (node $F$ has minimum angle among all the
neighbors within the transmission range) to the line $SD$, therefore, it is selected as next-
hop node for forwarding the packets.

In DIR, next-hop neighbor node is decided through unicast forwarding by using the
position information of the sender node, its next-hop neighbor nodes, and the destination
node. To obtain the position information of each other within one-hop neighborhood,
each node sends a beacon or a Hello packet containing its identity (ID), the current
position and other relevant information.