A STUDY ON ROUTING PROTOCOLS IN VANET

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ABSTRACT

Vehicles serve as nodes in Vehicular Ad Hoc Networks (VANETs), a subtype of Mobile Ad Hoc Networks (MANETs), which communicate with roadside infrastructure and one another. Effective routing is severely hampered by the special features of VANETs, such as their high mobility and frequent topology changes. The routing protocols in VANETs are thoroughly examined in this research, which divides them into cluster-based, position-based, topology-based, and hybrid protocols. We examine their capabilities, advantages, disadvantages, and most recent developments, such as their incorporation of 5G and artificial intelligence. The purpose of this study is to direct future investigations and the creation of efficient routing plans for VANETs.

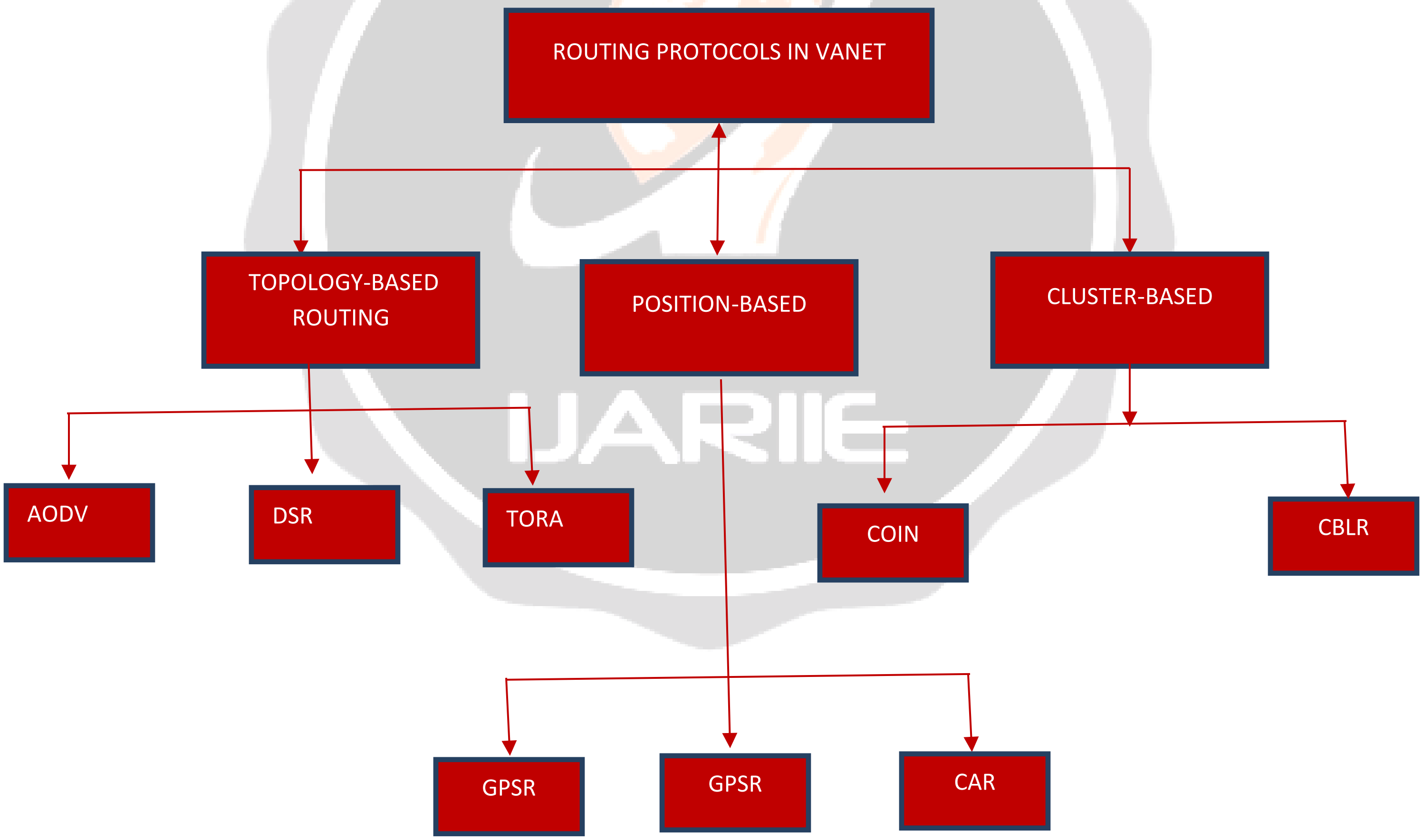
Keyword : - *VANET, ROUTING PROTOCOLS, AODV, DSR, GPSR, TORA, QOS, VEHICULAR COMMUNICATION*

1. INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) are essential components of intelligent transportation systems (ITS) because they provide communication between vehicles and infrastructure. Reliable data transmission is severely hampered by the dynamic character of automotive environments, which include high-speed mobility and continuously shifting network structure. Routing protocols are crucial in VANETs, as they determine how data is forwarded between nodes. The several VANET routing protocols, their classifications, and their performance in various vehicle scenarios are all thoroughly reviewed in this study.

2. CLASSIFICATION OF VANET ROUTING PROTOCOLS

Routing protocols in VANETs are generally categorized into the following types:
1. Topology-based: Includes AODV, DSR, and TORA, which use link information to perform packet forwarding.
2. Position-based: Includes GPSR, GPCR, and CAR, which utilize GPS and geographical information.
3. Cluster-based: Examples are COIN and CBLR, where the network is divided into clusters for better management.
4. Hybrid and Geocast protocols: Combine multiple strategies to optimize routing decisions.



2.1 TOPOLOGY-BASED ROUTING PROTOCOLS

Topology-based routing protocols in VANETs utilize the existing link and connectivity information of the network to forward data packets. These protocols typically rely on how nodes (vehicles) are interconnected and how routes can be computed through the topology of the network. Due to frequent changes in vehicular topology caused by mobility, topology-based protocols face challenges in maintaining reliable and updated routing paths. Despite these challenges, they are foundational in many VANET environments, especially when integrated with adaptive strategies.

Types of Topology-Based Routing Protocols

Topology-based routing protocols are generally categorized into two main types:

2.1.1 Proactive Routing Protocols (Table-Driven)

Proactive protocols maintain **up-to-date routing tables** containing the paths to all nodes in the network. Routing information is exchanged periodically to ensure the accuracy of the routing table.

Key Features:

- Routes are always available.
- Low latency for data transmission.
- Higher bandwidth usage due to constant updates.

Advantages:

- Immediate availability of routing paths.
- Reduced delay for time-critical applications.

Disadvantages:

- High control overhead due to regular table updates.
- Not efficient in rapidly changing topologies.

2.1.2 Reactive Routing Protocols (On-Demand)

Reactive protocols create routes **only when needed**. When a node needs to send data, it initiates a route discovery process, thus reducing overhead.

Key Features:

- No periodic updates.
- Lower control overhead in idle states.
- Increased initial delay due to route discovery.

Advantages:

- Efficient bandwidth usage.
- Better performance in networks with frequent changes.

Disadvantages:

- Delay during route discovery.
- Can suffer from route maintenance issues in high mobility scenarios.

2.2 POSITION-BASED ROUTING PROTOCOLS IN VANET

Position-based routing protocols—also known as **geographic routing protocols**—use the **geographical position of nodes** (typically obtained via GPS) to make routing decisions. These protocols eliminate the need for full-path route discovery or maintenance by relying on the destination's coordinates and the positions of neighboring vehicles. Given the high mobility and dynamic topology of VANETs, position-based routing is particularly effective as it adapts well to rapid changes in network structure and scale.

Key Features of Position-Based Routing

- **No need for global route discovery**.
- **Utilizes GPS or location services** for node positioning.
- **Forwarding decisions are localized**, based on neighbors' positions.
- **Scalability**: Well-suited for large and dense networks.
- Can suffer in **GPS-denied environments** (e.g., tunnels, urban canyons).

Types of Position-Based Routing Protocols

2.2.1 Greedy Forwarding Protocols

Packets are forwarded to the **neighbor geographically closest to the destination**.

- If no closer neighbor exists (local maximum), switches to **perimeter mode** using planar graphs.
- Stateless routing: Only neighbor positions are required.

Advantages:

- Simple and efficient.
- Low overhead.

Disadvantages:

- Fails in local maximum scenarios.
- Assumes accurate location data.

2.2.2 Topology-Enhanced Geographic Protocols

Designed specifically for **urban environments**. Uses **road junctions** to guide packet forwarding. No need for external digital maps.

Advantages:

- More reliable in city traffic with road intersections.
- Handles city map constraints better than GPSR.

Disadvantages:

- Junction detection can be inaccurate in some scenarios.

2.3 Cluster-Based Routing Protocols in VANET

In VANETs, **cluster-based routing protocols** organize vehicles into dynamic groups called **clusters**, each typically led by a **cluster head (CH)**. The CH manages intra-cluster communication and acts as a bridge for inter-cluster data exchange. This hierarchical structure improves **scalability**, **efficiency**, and **routing stability**, especially in **high-density** traffic environments. Clustering is particularly useful in **urban scenarios**, where vehicles form logical groups based on location, speed, direction, or communication range.

Key Features of Cluster-Based Routing

- **Hierarchical structure** for better organization.
- **Cluster Head (CH)** coordinates routing decisions within the cluster.
- **Gateway nodes** connect adjacent clusters.
- Reduces **routing overhead** by localizing communication.
- Enhances **scalability and network stability**.

Types of Cluster-Based Routing Protocols

2.3.1 LORA-CBF (Location Routing Algorithm with Cluster-Based Flooding)

- Combines **location-based** and **clustering** strategies.
- The CH floods messages within the cluster, reducing redundant transmissions.
- Effective in **dense urban areas**.

Advantages:

  - Controlled message flooding.
  - Good scalability.

Disadvantages:

  - Flooding may still consume bandwidth in very large clusters.

2.3.2 COIN (Cluster-based Overlay Information Network)

Forms an **overlay network** over clusters. Uses both **vehicle mobility** and **position information** for clustering. Suitable for **safety message dissemination**.

Advantages:

Efficient for infotainment and non-safety applications.

Disadvantages:

High dependency on stable CH selection.

2.4 Hybrid Routing Protocols in VANET

Hybrid routing protocols combine the strengths of different routing strategies—typically proactive, reactive, position-based, or clustering methods—to achieve improved performance in varying VANET scenarios. These protocols aim to provide **robust, scalable, and adaptive routing** in environments with fluctuating traffic density, high mobility, and frequent topology changes. By leveraging multiple techniques, hybrid protocols can dynamically adjust their routing behavior depending on the network conditions, such as density, mobility, and application type (e.g., safety vs infotainment).

2.4.1 CAR (Connectivity Aware Routing)

Uses location information and traffic density to find the most reliable path. Integrates AODV-like route discovery with geographical forwarding.

Advantages:

Handles disconnected networks well.
Maintains route stability.

Limitations:

Relies on location services and map data.

2.4.2 SADV (Static Node Assisted Adaptive Routing)

Deploys static nodes (e.g., roadside units) to store and forward packets when vehicle density is low. Uses position-based routing when connectivity is strong.

Advantages:

Handles partitioned or sparse networks effectively.

Limitations:

Requires deployment of static infrastructure.

3. Comparative Analysis of Routing Protocols in VANET

Routing protocols in VANETs can be evaluated based on metrics such as Packet Delivery Ratio (PDR), end-to-end delay, throughput, routing overhead, and scalability. The following table summarizes the comparison:

- AODV and DSR provide good PDR but may suffer from high delay in dense networks.
- GPSR and GPCR utilize location information for better scalability but depend on accurate GPS data.
- Cluster-based protocols reduce overhead but require complex cluster management.
- Hybrid protocols balance strengths but can be complex to implement.

COMPARATIVE ANALYSIS IN VANET

Protocol Type	Examples	Advantages	Limitations
Proactive	OLSR	Low latency	High overhead
Reactive	AODV	Low overhead	Route discovery delay
Geographic	GPSR	Scalable, GPS-based	GPS required, urban obstruction
Cluster-based	COIN	Reduced routing load	Cluster maintenance
Broadcast	BROADCOMM	Fast dissemination	Broadcast storms
Geocast	IVG	Area-specific alerts	High overhead in dense areas
DTN	VADD	Works in sparse traffic	High delay

5. CHALLENGES IN VANET ROUTING

- **High Mobility:** Routes break frequently due to fast movement.
- **Dynamic Topology:** Frequent changes in network topology.
- **Network Partitioning:** Common in rural or low-traffic areas.
- **Scalability:** Large networks with thousands of vehicles.
- **Security:** Vulnerability to attacks like spoofing and DoS.

V CONCLUSION

Routing protocols in VANETs are an essential component in enabling safe and efficient transportation systems. Each class of protocols presents unique strengths and weaknesses depending on the vehicular environment, such as city traffic, highways, or sparse rural roads. A hybrid and context-aware routing approach seems to be the most promising direction for the future of VANETs.

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