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Foundational Principles of the AODV Routing Protocol in Mobile Ad-Hoc Networks

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Abstract: Mobile ad hoc networks (MANETs) depend on broadcast mechanisms, such as probabilistic flooding, for route discovery, wherein source nodes disseminate route request (RREQ) packets indiscriminately to all adjacent nodes. This unregulated strategy induces superfluous retransmissions, thereby exacerbating packet collisions, medium access contention, and the broadcast storm problem, which in turn amplifies protocol overhead, routing burden, and energy expenditure. Consequently, sophisticated flooding mitigation algorithms are imperative.

The Ad hoc On-Demand Distance Vector (AODV) protocol, a reactive routing paradigm, counters these inefficiencies by establishing routes solely upon demand. It encompasses two principal phases: route discovery, which utilizes controlled flooding to ascertain shortest paths from source to destination, and route maintenance, involving link failure detection and localized repair via route error (RERR) messages. By eschewing proactive route upkeep, AODV substantially curtails signaling overhead, thereby optimizing performance in highly dynamic MANET topologies.

Keywords: AODV, MANETs, RERR, Broadcast Storm.

INTRODUCTION

The Ad hoc On-Demand Distance Vector (AODV) routing protocol represents a reactive framework optimized for mobile ad hoc networks (MANETs), establishing routes dynamically upon request to eliminate continuous topology broadcasts and minimize signaling overhead. Operating without centralized coordination, AODV exploits multi-hop relaying across mobile nodes with ephemeral topologies. Core operations include route discovery—triggered by the source broadcasting Route Request (RREQ) packets through bounded flooding to neighbors, culminating in the destination's unicast Route Reply (RREP) along the reverse path to forge the shortest hop-count route—and route maintenance, facilitated by Route Error (RERR) messages that disseminate link failure alerts, prompting fresh discoveries. RREQ dissemination inherently provokes the broadcast storm dilemma, characterized by redundant retransmissions, medium contention, and packet collisions that intensify overhead and power consumption; AODV mitigates this partially via sequence numbers to avert loops and suppress duplicates, with various extensions seeking further flooding suppression. This demand-driven approach ideally suits resource-constrained MANETs, balancing rapid path formation with attenuation of storm-related degradations.

REVIEW OF LITERATURE

The Ad-hoc On-Demand Distance Vector (AODV) protocol, formalized in RFC 3561 (2003), constitutes a reactive routing mechanism tailored for Mobile Ad-hoc Networks (MANETs). It facilitates on-demand route acquisition in infrastructure-less environments characterized by nodal mobility and topological flux, thereby curtailing control overhead.

Operational Fundamentals

AODV leverages route request (RREQ) broadcasts to initiate path discovery, followed by unicast route reply (RREP) transmissions to confirm bidirectional routes. Route error (RERR) notifications handle link failures, while destination sequence numbers preclude loops by favoring elevated sequence values alongside minimal hop metrics. Flooding is mitigated through expanding ring techniques employing time-to-live (TTL) thresholds, augmented by periodic Hello messages for neighborhood sensing and localized repair protocols for fault recovery. These features accommodate unidirectional connectivity and subnet routing, enhancing scalability.

Extensions and Empirical Insights

Scholarly analyses affirm AODV's preeminence among reactive protocols, attributable to diminished broadcast frequency and inherent loop prevention. Comprehensive literature surveys reveal that enhancements predominantly target route discovery (57% of investigations), selection (20%), and upkeep, incorporating quality-of-service (QoS) provisions, energy conservation, and overhead mitigation via machine learning/artificial intelligence integrations and signal-strength heuristics. Persistent limitations encompass broadcast storm amplification and power dissipation, prompting innovations such as AODV with improvements (AODVI).

METHODOLOGY

AODV: A Reactive Routing Protocol for MANETs

Ad-hoc On-Demand Distance Vector (AODV) constitutes a reactive routing protocol tailored for dynamic Mobile Ad-hoc Networks (MANETs). Unlike proactive counterparts, AODV initiates route discovery solely upon demand, thereby curtailing control overhead. It integrates distance-vector principles with destination sequence numbers to avert routing loops, guarantee route recency, and mitigate pathologies such as the "counting-to-infinity" problem. Nodes sustain routing tables exclusively for active routes, facilitating rapid adaptation to topology perturbations induced by nodal mobility.

Route Discovery Mechanism

Route establishment commences with the source node broadcasting a Route Request (RREQ) packet, encapsulating its sequence number and hop count. Intermediate nodes propagate the RREQ while caching reverse routes in their tables. Upon receipt by the destination or an intermediate node possessing a valid route, a Route Reply (RREP) is unicast back along the reverse path, thereby instantiating the forward route.

Route Maintenance Procedures

Link failures prompt upstream nodes via Route Error (RERR) messages, initiating route rediscovery. Optional Hello packets enable neighbor discovery. Inactive routes undergo expiration, while sequence numbers embedded in control packets ensure selection of the most current, loop-free paths.

RESULTS AND DISCUSSION

Route Request Mechanism (RREQ)

AODV employs three primary broadcast control messages: Route Request (RREQ), Route Reply (RREP), and Route Error (RERR). These packets are retained with associated status metadata, as they are disseminated via broadcast rather than direct unicast to the destination.

The RREQ packet encapsulates the following fields:

- Source identifier (Ni), broadcast identifier, and destination identifier (Nj).
- Source sequence number ($sq(Ni)$) and destination sequence number ($sq(Nj)$).

- Time-to-live (TTL) value and routing table entry for the destination.

Sequence numbers ensure route freshness through targeted increments:

- Prior to initiating new route discovery: $sq(Ni) \leftarrow sq(Ni)+1$.
- Prior to transmitting RREP: $sq(Ni) \leftarrow \max(sq(Ni), sq(Nj))$ for $i,j=1,\ldots,m$.

The destination node increments $sq(Nj)$ upon receipt from a distinct source $(Ni \neq Nj)$, adopting the updated value, or when no valid route exists.

Routing Table Entries and Neighbour Lists

Routing tables undergo updates under the following conditions:

- Establishment or modification of routes.
- Reception of control packets.

Sequence number revisions adhere to:

- If incoming $sq(Ni)' > sq(Ni)$, then $sq(Ni) \leftarrow sq(Ni)'$.
- If $sq(Ni)' = sq(Ni)$ but hop count is reduced: $\sum j = i + 1\ khop\ C(Ni, Nj) < \sum j = i + 1\ lhop\ (Ni, Nj)$, where $k \leq l \leq m$.
- If sequence number is unknown: $sq(Ni) \leftarrow sq(Ni) + 1$.

Tables maintain active routes alongside precursor lists (intermediate nodes) to facilitate error propagation.

Route Request Propagation and Maintenance

RREQ dissemination occurs via broadcast for invalid or unknown routes. The destination replicates the most recent sequence number and applies an increment: $sq(Nj) \leftarrow sq(Nj) + n_{priority},\ where\ n_{priority}\ denotes\ RREQ\ priority.$

RREQ identifiers increment sequentially: If $(RREQID)i = 1, then\ (RREQID)n + 1 = (RREQID)n + 1\ for\ n = i, \ldots, 1$.

Route maintenance leverages periodic "Hello" packets for neighbor discovery. Link failures trigger RERR dissemination and subsequent rediscovery.

Flooding in AODV and Optimization Strategies

AODV relies on blind flooding for route discovery: the source broadcasts RREQ to one-hop neighbors, which rebroadcast iteratively until the destination responds via RREP (along the reverse path) or RERR (route unavailable). This induces substantial control overhead, elevated energy consumption, and network congestion.

Mitigation techniques encompass:

- EAODV: Mobility-aware RREQ broadcasting.
- Directional flooding: Reduced RREQ propagation volume.
- Density-based forwarding: Alleviated MAC-layer contention and power demands.
- Cluster-based approaches: Adaptive topology management with low-latency path establishment.

CONCLUSION

This Paper substantiates the selection of AODV as the baseline protocol, emphasizing its on-demand route discovery efficiency, while rigorously evaluating the ramifications of blind flooding on control overhead, energy expenditure, MAC-layer contention, and routing performance. Subsequent chapters delineate enhancements via AODV-EXT and AODV-EXT-BP protocols.

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