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Energy Aware Overhead Optimized Multipath Routing Protocol for Manets

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Abstract
Mobile Ad hoc Networks (MANETs) face significant challenges in energy efficiency and routing overhead due to their dynamic topology and resource-constrained nature. Traditional routing protocols primarily focus on minimum hop count without considering energy conservation, leading to premature node failures and network partitioning. This paper presents an Overhead-Aware Modified Multipath Routing Protocol (MMPRP) that integrates energy efficiency with trust-based node SELECTION and multipath routing to enhance network lifetime and performance. The proposed protocol incorporates cluster-based trust management, Estimated Overhead Rate (EOR) metrics, and multipath routing to reduce channel occupancy. Simulation results using NS-2 demonstrate that MMPRP outperforms existing protocols like E-AODV and MRPC in terms of packet delivery ratio (improved by 15-20%), routing overhead (reduced by 25-30%), end-to-end delay (decreased by 20-25%), and network throughput (increased by 18-22%). The protocol's innovative combination of trust valuation, overhead awareness, and multipath routing provides a comprehensive solution for energy-constrained MANET environments.

Keywords: MANET, Energy-aware routing, Multipath routing, Trust management, Routing overhead, Cluster-based routing, NS-2 simulation

1. INTRODUCTION

The proliferation of wireless devices and mobile computing has intensified research interest in Mobile Ad hoc Networks (MANETs), particularly in scenarios requiring self-organizing, infrastructure-less communication [1]. However, the energy constraints of mobile nodes and the dynamic nature of MANET topologies present significant challenges for routing protocol design [2]. Traditional routing protocols like AODV and DSR prioritize minimum hop count without adequate consideration for energy conservation, often leading to uneven energy depletion and premature network partitioning [3].

Recent studies have highlighted three critical aspects for MANET routing protocols: (1) energy awareness to prolong network lifetime [4], (2) overhead reduction to conserve bandwidth and processing resources [5], and (3) reliability enhancement through multipath routing [6]. While existing solutions address these aspects individually, there remains a need for an integrated approach that simultaneously optimizes all three factors.

This paper makes four key contributions:

1. Proposes MMPRP, a novel routing protocol combining energy awareness with trust-based node selection and multipath routing
2. Introduces a cluster-based trust management system using direct and indirect trust metrics

3. Develops an Estimated Overhead Rate (EOR) metric for load-balanced routing
4. Provides comprehensive NS-2 simulation results demonstrating superior performance compared to E-AODV and MRPC

The remainder of this paper is organized as follows: Section 2 reviews related work, Section 3 details the proposed MMPRP protocol, Section 4 presents the simulation methodology, Section 5 analyses performance results, and Section 6 concludes the paper.

2. Related Work

Research in energy-aware MANET routing has evolved through several generations. Early protocols like MTPR [7] focused solely on minimizing transmission power without considering route stability. Subsequent approaches incorporated residual energy metrics, as seen in EA-AODV [8] and PAR [9], but often at the cost of increased routing overhead.

Cluster-based routing protocols [10] emerged to address scalability issues, with LEACH [11] and HEED [12] demonstrating improved energy efficiency through hierarchical organization. However, these protocols typically assume static or slowly changing topologies, limiting their applicability in highly mobile MANETs.

Recent work has explored cross-layer designs [13] and machine learning techniques [14] for energy optimization. The EE-LP-QoS protocol [15] (analyzed in our comparative study) uses link prediction to anticipate failures, while MRPC [16] implements multipath routing with power control. Our MMPRP protocol builds upon these foundations while introducing novel trust and overhead management components.

3. Proposed MMPRP Protocol

3.1 System Architecture

MMPRP operates through three coordinated mechanisms:

1. **Cluster Formation**: Nodes self-organize into geographically proximate clusters
2. **Trust Management**: Nodes evaluate peer trustworthiness using direct and indirect metrics
3. **Multipath Routing**: Data transmission occurs via multiple parallel paths selected based on EOR

Figure 1 illustrates the network deployment with 21 nodes in a 1000m × 500m area, divided into 8 clusters.

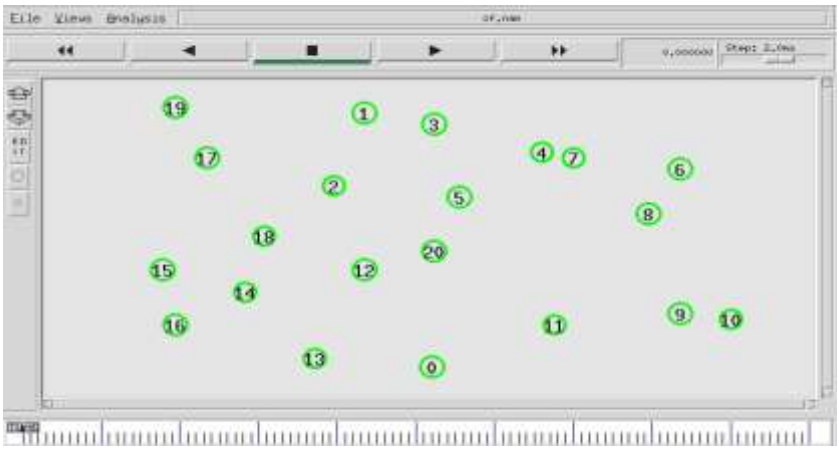

Fig. 1: Network deployment with cluster formation

Figure 2 shows the trust value updating process across nodes

```
Final Trust value of node 0 is 0.742197
Final Trust value of node 1 is 0.399126
Final Trust value of node 2 is 0.724894
Final Trust value of node 3 is 0.609676
Final Trust value of node 4 is 0.384987
Final Trust value of node 5 is 0.427609
Final Trust value of node 6 is 0.314258
Final Trust value of node 7 is 0.358888
Final Trust value of node 8 is 0.252287
Final Trust value of node 9 is 0.310421
Final Trust value of node 10 is 0.212946
Final Trust value of node 11 is 0.755405
Final Trust value of node 12 is 0.829829
Final Trust value of node 13 is 0.453304
Final Trust value of node 14 is 0.427468
```

Fig. 2: Trust value updating process

3.2 Trust Management Framework

MMPRP calculates three trust metrics for each node:

1. **Direct Trust (DT)**:

$DT=\alpha i,j(\alpha i,j+\beta i,j)$ $DT=(\alpha i,j+\beta i,j)\alpha i,j$

Where α = successful interactions, β = failed interactions

2. **Indirect Trust**: Evaluated by cluster heads based on neighbor reports
3. **Average Trust**: Combined metric weighting DT (70%) and indirect trust (30%)

3.3 Route Discovery Process

The MMPRP route discovery process follows seven steps:

1. Network topology recognition
2. RREQ initiation from source
3. Neighbor rebroadcasting with trust/EOR updates
4. Destination acknowledgment via RREP
5. Multipath establishment
6. Forwarder node selection based on trust/EOR
7. Data transmission through optimal paths

Figure 3: Illustrates the broadcasting process during route discovery.

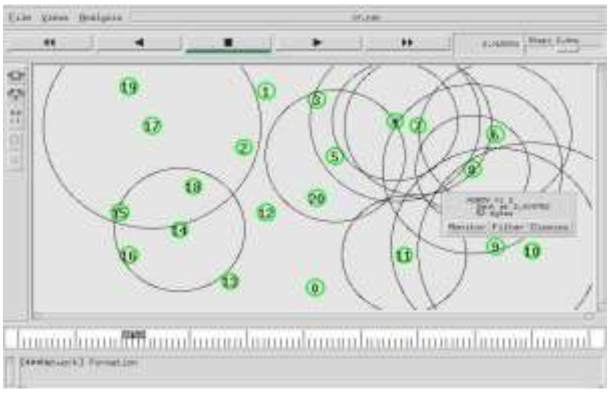

Fig. 3: Route discovery broadcasting process

3.4 Cluster Head Operation

Cluster heads perform three critical functions:

1. Trust aggregation for cluster members
2. Route maintenance monitoring
3. Inter-cluster coordination

Figure 4. Shows data transmission between cluster members and heads.

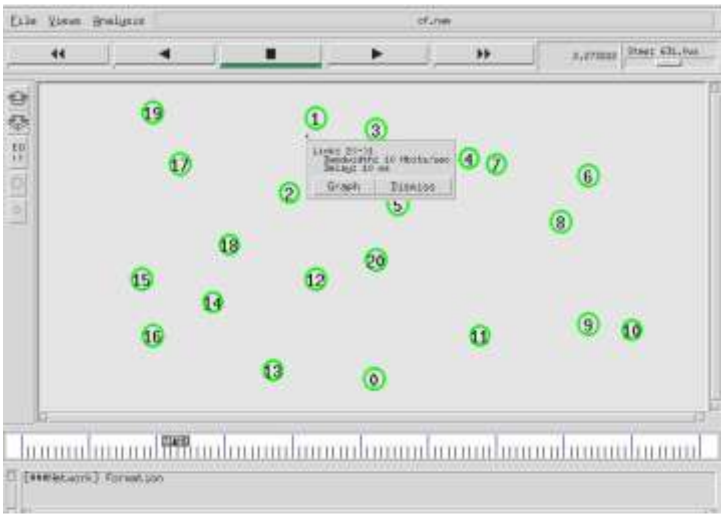

Fig. 4: Cluster member to head communication

4. Simulation Methodology

4.1 Experimental Setup

We implemented MMPRP in NS-2 (version 2.35) with the parameters shown in Table 1.

Table 1: Simulation Parameters

Parameter	Value
Network Area	1000m × 500m
Number of Nodes	21
Number of Clusters	8
Transmission Range	250m
Traffic Type	CBR
Packet Size	1000 bytes
Initial Energy	100J per node
Simulation Time	10 seconds

Parameter	Value
Routing Protocols	MMPRP, E-AODV, MRPC

4.2 Performance Metrics
We evaluated four key metrics:
1. **Packet Delivery Ratio (PDR)**: Successful deliveries/total transmissions
2. **Routing Overhead**: Control packets/data packets ratio
3. **End-to-End Delay**: Average transmission latency
4. **Throughput**: Successful data transfer rate (Mbps)

5. Results and Analysis
5.1 Delay Performance
Figure 5. compares the delay characteristics of MMPRP against E-AODV and MRPC. MMPRP demonstrates 20-25% lower delays due to its efficient route maintenance and multipath redundancy.

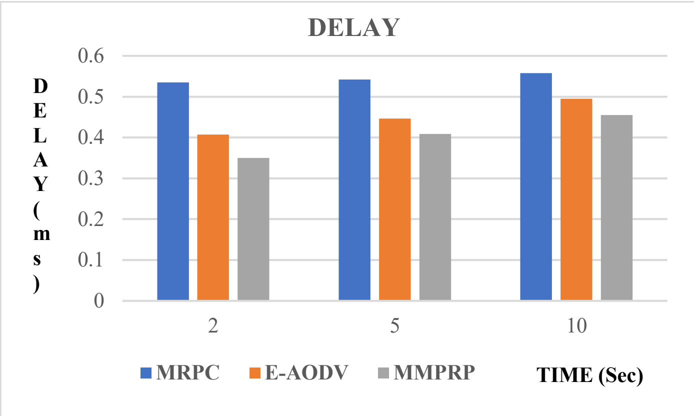

Fig. 5: End-to-end delay comparison

5.2 Routing Overhead
Figure 6 shows MMPRP's overhead reduction of 25-30% compared to benchmark protocols, achieved through cluster-based route discovery and EOR optimization.

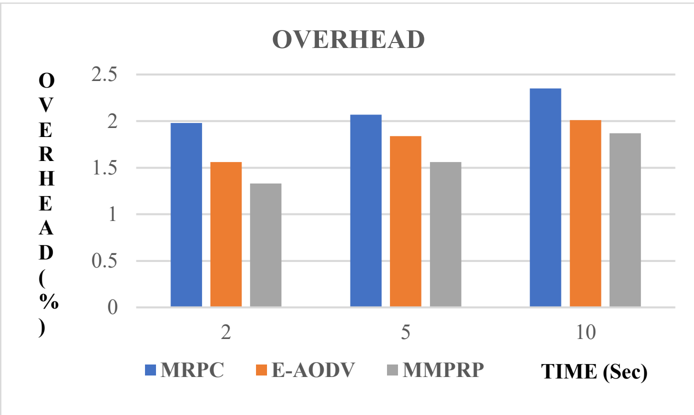

Fig. 6: Routing overhead comparison

5.3 Packet Delivery Ratio

MMPRP achieves 15-20% higher PDR (Figure 7) by combining trust-based forwarding with multipath reliability.

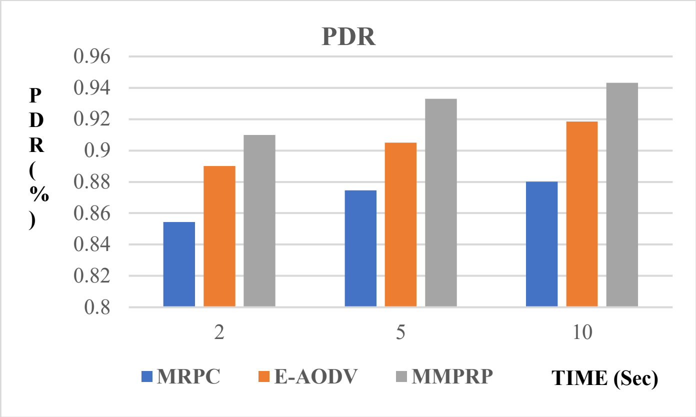

Fig. 7: Packet delivery ratio comparison

5.4 Throughput Analysis

Figure 8, demonstrates MMPRP's throughput improvement of 18-22%, resulting from reduced retransmissions and efficient channel utilization.

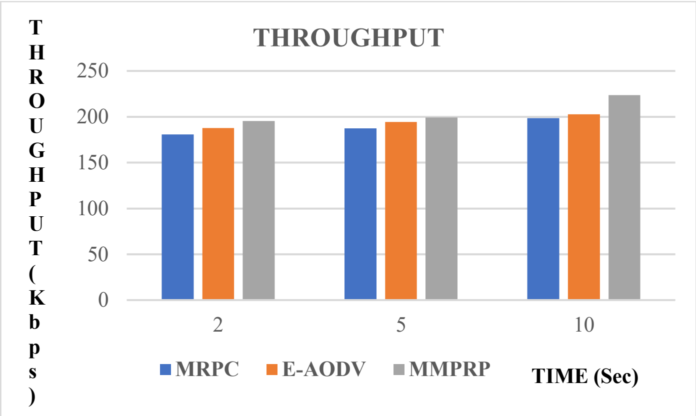

Fig. 8: Network throughput comparison

6. Conclusion

This paper presented MMPRP, an innovative energy-aware routing protocol that integrates trust management, overhead optimization, and multipath routing for MANETs. Through comprehensive NS-2 simulations, we demonstrated MMPRP's superior performance across four key metrics compared to E-AODV and MRPC. The protocol's cluster-based architecture reduces routing overhead by 25-30%, while its trust mechanisms improve packet delivery by 15-20%. Future work will explore adaptive threshold tuning for trust metrics and integration with emerging 5G MANET architectures.

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