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# A Novel Load Balancing Scheme for Multipath Routing Protocol in MANET

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The recent advancements in information and communication technology create a great demand for multipath routing protocols. In MANET, nodes can be arbitrarily located and can move freely at any given time. The topology of MANET can change rapidly and unpredictably. Because wireless link capacities are usually limited, congestion is possible in MANETs. Hence, balancing the load in a MANET is important since nodes with high load will deplete their batteries quickly, thereby increasing the probability of disconnecting or partitioning the network. To overcome these, the multipath protocol should be aware of load at route discovery phase. The main objective of the proposed article is to balance the load on a node and to extend the lifetime of the node due to the congestion, energy depletion and link failures. This article describes a novel load and congestion aware scheme called Path Efficient Ad-hoc On-demand Multipath Distance Vector (PE-AOMDV) protocol to increase the performance of routing process in MANET in terms of congestion, end-to-end delay and load balancing. A new threshold value and a counter variable are introduced to limit the number of communication paths passing over a node in route discovery phase. For every new request the counter variable is incremented by one and the threshold value is compared to see whether the maximum number of connections has been reached or not. The proposed method is network simulator ns-2 and it is found that there is a significant improvement in the proposed scheme. It reduces the energy consumption, average end-to-end delay and normalized routing overhead. Also the proposed scheme increases packet delivery ratio, throughput and minimizes routing overheads.

*ACM CCS (2012) Classification:* Networks → Network protocols → Network layer protocols → Routing protocols

*Keywords*: MANET, on-demand routing, multipath routing, AOMDV, load balancing

## 1. Introduction

The greatest development in mobile computing and penetration of handheld devices created many opportunities for Mobile Ad-hoc Network (MANET). MANET [1], [2] is composed of wireless mobile nodes and wireless links to communicate over wireless medium. The mobile nodes communicate with each other using multi-hop fashion. MANET is dynamically deployable, temporary, infrastructure-less and spontaneous network. Now MANET is increasingly appearing and used in home-area wireless networking, on-the-fly conferencing applications, multimedia and video sharing applications, data acquisition operations, emergency search, rescue operations, communication between mobile robots and many more.

The nodes in MANET have limited bandwidth, processing power, memory space and battery power. In MANET, nodes are used to discover themselves and maintain routes through the network. Since the transmission range of network interfaces is very limited, intermediate nodes are needed. Thus each node will have two roles at the same time: namely terminal role and router to forward packets of other mobile nodes. In fact, restrictions on the bandwidth, memory and energy make MANET a network with complicated topology. Consequently, MANETs must adapt dynamically to be able to maintain ongoing communications in spite of the changes.

Among the many issues to be addressed in MANET, routing plays a very important role in communicating between nodes. But it is a challenging issue due to its dynamic nature of network topology and limitations of resource constraints. The routing depends on many factors that include topology of a network, selection of routes and selection of routing algorithms and techniques. There is a huge need to design an efficient routing protocol that should be fully distributed, adaptive to dynamic topology and mobility, fast and easy route computation and maintenance process. The single-path routing protocols use shortest-path routing approach, so centre of the network gets more congestion comparing to the perimeter of the network. Also, it causes more overheads and consumes more bandwidth. Route discovery frequency is also high due to dynamic node's mobility and link failures.

To overcome the limitations of the single path routing protocol and achieve high performance, multipath routing protocols are introduced. The objectives of multipath routing are to ensure load-balancing, reliable communication, efficient Quality of service (QoS), maximize node and network life time, improve throughput etc. Numerous on-demand multipath routing protocols have been proposed for MANET [3], [4]. These multipath routing protocols attempt to discover multipath between source and destination pairs in the network and it discovers multipath in a single route discovery process. The selected multipath should be loop-free paths, disjointness of paths, less route discovery frequency, lower routing overheads and consume optimal bandwidth. Multipath routing protocols relatively have a greater ability to reduce route discovery frequency than single-path routing protocols. Multipath routing protocols discover new routes when all paths become fails at the same time and also the possibility of such failure is very small.

In MANET, balancing the load can evenly distribute the traffic over the network and prevent early expiration of overloaded nodes due to excessive power consumption in forwarding packets. Due to the special characteristics of MANET, such as dynamic nature, energy constrains, lack of centralized infrastructure and link capacity, make load balancing over these networks challenging objectives. Also, the presence of mobility implies that link breaks happen often in an in-deterministic fashion. So this leads to congestion and delay for overall network. To overcome this, the optimal solution is to select a load balanced path for extending lifetime and aggregate QoS.

Over the years, several load balanced ad hoc routing protocols have been proposed. Most of the approaches are on-demand-based protocols; that is, they combine load balancing strategies with route discovery. A route with the least load among multiple possible routes from source to destination is usually chosen. The routing protocols are generally categorized into three types (based on their load balancing techniques):

- Delay-based: Where load balancing is achieved by attempting to avoid nodes with high link delay.
- Traffic-based: Where load balancing is achieved by evenly distributing traffic load among network nodes.
- Hybrid-based: Where load balancing is achieved by combining the features of traffic-based and delay-based techniques.

In addition to classifying protocols based on their load balancing techniques, one should also consider the load metrics used by these protocols. The term load metric reflects how busily a node is engaged in receiving and forwarding packets over the wireless media. It also refers to processing, memory, bandwidth, and power load on the node. Different load balanced ad hoc routing protocols use different load metrics as follows:

- Active path: This refers to the number of active routing paths supported by a node. Generally, the higher the number of active routing paths, the busier the node since it is responsible for forwarding data packets from an upstream node to a downstream node.
- Traffic size: This refers to the traffic load present at a node and its associated neighbours (measured in bytes).
- Packets in interface queue: This refers to the total number of packets buffered at both the incoming and outgoing wireless interfaces.

- Channel access probability: This refers to the likelihood of successful access to the wireless media. It is also related to the degree of channel contention with neighbouring nodes.
- Node delay: This refers to the delays incurred in packet queuing, processing, and successful transmission.

Existing load balanced ad hoc routing protocols use the above-mentioned load metrics to model load. In a broader context, the term load can be interpreted as:

- Channel load: Represents the load on the channel where multiple nodes contend to access the shared media.
- Nodal load: Relates to a node's activity. Specifically, it refers to how busy a node is in processing, computation, and so on.
- Neighbouring load: Represents the load generated by communication activities among neighbouring nodes.

The design of routing protocols in MANETs is influenced by the above factors. These factors must be got over before efficient communication can be achieved in MANETs.

The remaining of the paper is organised as follows. After the Introduction, Section 2 briefs the related work done in this field and Section 3 illustrates the proposed scheme. The results obtained from the proposed scheme are discussed in Section 4 and, at last, in Section 5 Conclusion follows.

## 2. Related Work

The load balancing is an important principal factor for achieving good throughput in MANET [5]. The objectives of load balancing are to distribute workload across multipath, achieve optimal resource utilization, maximize throughput, minimize response time, increase network life time, avoid overload and more overheads. Some of the issues related to load balancing in on-demand multipath protocols are uncertainty of RTT values, inhomogeneous load distribution, priority based path selection, unability to switch the route dynamically and improper bandwidth usage.

Li et al. [6] proposed an Energy-aware Multipath Routing Protocol (EMPR) for MANET and it efficiently utilizes network resources by sharing information among physical layer, MAC sub-layer and network layer. Node energy and bandwidth of link are taken into account for this process. This protocol calculates the weight ($w$) of each node along the path to make a decision to select a path, where $w$ is sum of energy and queue length of each node. Finally, EMPR sorts all available routes in an ascending order of $w$ and selects the top $N$ set of routes as primary paths to transmit data and select next $N$ sets of routes as backup paths. Simultaneously, transmitting packets along these routes achieves better energy efficiency, lower end-to-end delay and higher volume of packets delivered.

Yang et al. [7] introduced a Bandwidth Aware Multipath Routing Protocol (BMR) to select multipath based on the node's available bandwidth. In BMR, available bandwidth of a node is obtained based on cross-layer mechanism, which can provide a metric for route discovery. Node's available bandwidth is obtained by calculating node's local available bandwidth and neighbourhood available bandwidth. BMR gives better result with respect to end-to-end throughput and packet delivery ratio.

Wang et al. [8] proposed Multipath Source Routing (MSR) based on DSR and presented a delay model for multipath routing protocol. They show that delay performance of a network can be improved by load balancing. In order to monitor real-time delay information along each path, a special type of packet called probing packet is sent periodically to estimate RTT. This delay information is considered in order to distribute traffic so that paths with greater delays eventually produce less delay, hence alleviating congestion. This protocol distributes traffic over different paths to achieve a minimum mean delay in a whole network.

Shin et al. [9] proposed an Adaptive Adhoc On-demand Multipath Distance Vector ($A^2$OMDV), which resolves the problem of dynamic route switching when link failure occurs. Based on the delay of multipath, a source node selects its route dynamically and checks quality of the alternative routes according to the changes on the network. Path selection is made based on priority mechanism. In $A^2$OMDV each source node prioritizes its routes based on RTT value and transmits data through the route with highest priority as primary route and other routes as alternative routes. This method avoids contention and bottleneck.

Pham and Perreau [10] introduced a Multipath Routing Protocol with Load Balance policy (MRP-LB). The main objective of MRP-LB is to distribute the traffic equally into multipath, that is, the total number of congested packets on each route is equal. They introduced analytical model and achieved guaranteed throughput based on congestion and contention. The results reveal that multipath routing provides better performance than reactive single-path route in terms of congestion and connection throughput, provided that the average route length is smaller than certain upper bounds which are derived and depend on the analytical model.

In SMR [11], the main objective is to reduce the frequency of route discovery process and thereby reduce the control overheads in the network. This protocol uses a per packet allocation scheme to distribute a load into multipath. This load balancing mechanism is achieved by selecting efficient primary and alternate paths. Primary path is the shortest one. The secondary path is link disjoint paths. Because of this path selection, Split Multipath Routing (SMR) has a less frequent route discovery mechanism to reduce the control overhead in the time of route failures.

Alternate path routing (APR) [12] can provide load balancing and route failure protection by distributing traffic among a set of diverse paths. These benefits make APR appear to be ideal for the bandwidth limited and mobile ad hoc networks. The coupling problem is much more serious in single channel networks but APR is able to provide 20% reduction in end-to-end delay for busty data streams in multiple channel environments.

AODVM-PSP [13] comes under the category of minimum overhead multipath routing. AODVM-PSP considers delay along a path while making a routing decision. When a node sends a packet to a destination, each packet includes the information as to what time it was transmitted. An intermediate node or a destination node can estimate the delay based on the information included in the packet. A source node determines the goodness of a route based on the transmission delay time along a path, which is defined as $P_i(s, d) \propto 1/T_i(s, d)$, where $T_i(s, d)$ is the transmission delay time between a source and destination nodes along the $i^{th}$ path, so that congestion is reduced by decreasing transmission delay.

Yahya et al. [14] introduced Fibonacci Multipath Load Balancing (FMLB) protocol that distributes transmitted packets over multipath through these mobile nodes using Fibonacci sequence. This distribution will increase the delivery ratio and it reduces the congestion. The responsibility of Fibonacci Multipath Load Balancing (FMLB) protocol is balancing the packet transmission over the selected paths and ordering them according to their hop counts. This approach finds multiple routes between the source and destination. These routes are selected according to their path length. Paths with small number of hops are strongly nominated. A Fibonacci weight is given for each of these paths. The source node transmits its packet over these selected routes based on their Fibonacci weight. So it alleviates congestion in an optimal way.

Kumar and Banu [15] introduced AOMDV-LB that selects a path with a lower hop count and discards routes with higher hop counts. This adaptive load balancing approach is carried out in Route Request procedure. When Route Request (RREQ) messages are flooded to acquire routes, only the qualified nodes are allowed to establish a path that will not be congested and the traffic will be distributed evenly. The threshold value is used to judge the intermediate node and it is based on queue occupancy of a node. Based on this value, the overloaded nodes are not allowed to carry the data packets. The nodes on the paths are not overloaded and cannot be congested.

Ali et al. [16] introduced Load Balancing Parallel Routing Protocol (LBPRP) model that increases MANET life time by balancing load. This new scheme works based on parallelisms in sending data using multiple disjoint paths. Based on the Maximum Available Bandwidth (MAB) value the protocol selects and distributes the loads. In LBPRP, the primary path is the shortest path with the minimum hop count and the remaining paths are arranged in descending order according to the path speed based on the MAB value. So the load can be equally shared among the multipath.

## 3. Proposed Routing Protocol: PE-AOMDV

In the shortest path routing, nodes on the shortest path will get more heavily loaded than others since they are frequently chosen as the routing path. Having a heavy load can exhaust a node's resources such as bandwidth, processing power, battery energy, and memory storage. Furthermore, if one of the heavily loaded nodes is congested, this can lead to packet loss and buffer overflow, resulting in longer end-to-end delay, degradation in throughput, and loss of transport connections. Hence, it is important that some form of load balancing is present in the network.

In general, the number of links passing over a node is not restricted. In the meantime, when the number of links increases, this leads to congestion and contention problem. It causes a high delay, more control overheads and performance degradation due to its node mobility, large queue size and deficiency of bandwidth. To overcome this problem, we introduce a threshold value that limits the number of links passing over a node. This new congestion-avoidance routing scheme is called Path Efficient Ad-hoc On-demand Multipath Distance Vector (PE-AOMDV) routing protocol.

### 3.1. Network Model

Consider a MANET with $N$ nodes whose topology can be described as the interconnection of links between $N$ nodes, as well as a connected graph G(V, E), where $V = \{n_i, i = 1,\ldots,N\}$ is the set of nodes and $E \subset V \times V$ is the set of edges of the graph. Let $Rt(n_i)$ and $Rc(n_i)$ denote the transmission range and carrier sensing range of node $n_i$, respectively. For $n_i \in V$ and $1 \le i \le N$ if $n_i$ is inside the transmission range of $n_j$ as well as $n_j$ is also inside the transmission range of $n_i$, then the edge $e_{ij} \in E$.

**Definition 1.** Path $L_{ij}$ denotes a sequence of edges from a source node $n_i$ to a destination node $n_j$, and $L_{ij}$ includes all successive links from $n_i$ to $n_j$. All nodes but the source and the destination over a path are called intermediate nodes. If there are $M$ paths from node $n_i$ to $n_j$, then the multipath can be represented as $L_{ij} = \{Lm_{ij}, 1 \le m \le M\}$.

### 3.2. Multipath Evaluation Based on Link Load

Based on the network model mentioned previously, the traffic load at node $n_i$ can be defined by

$$T(n_i) = \sum_{k=m}^{M} S_k$$

where $M$ is the number of paths and $S_k$ is the average number of links passed through at node $n_i$ over path $Lm_{ij}$ which should not exceed the Active Path (AP) threshold value, depending on the application in consideration (network size, network load etc.). Let $Q(L_{ij})$ denote the traffic load on the link between nodes $n_i$ and $n_j$. Then the link load can be defined by

$$Q(L_{ij}) = \sum_{p=n_i}^{n_j} T(p)$$

From the above evaluation model load-balancing approach that computes the *path vacant ratio* is proposed for multipath. The *path vacant ratio* can be used to evaluate the load over multipath, which is derived from taking account of load balancing, path load, important paths, and importance of nodes over multipath. To implement the proposed idea, we introduce a new variable called *Active Path* (*AP*) *threshold* which defines the maximum number of paths passing over a node and *AP counter* is used to keep current active number of paths on a node. The AP counter variable is incremented by one for every new communication path establishment. These two variables, *AP counter* and *AP threshold,* are introduced in the existing structure of PE-AOMDV routing protocol's routing table and Route Request (RREQ) packet as shown in Table 1.

*Table 1.* Structure of Routing Table Entry and Route Request of PE-AOMDV protocol.

a) Routing Table of PE-AOMDV

| |
|---|
| Destination IP Address |
| Destination Sequence Number |
| Advertised hop count |
| Route List (next_hop,last_hop,hop-count) |
| Expiration Time Out |
| **AP (Active path) counter** |

b) Route Request Packet of PE-AOMDV

| **Type** | **Reserved** | **Last hop** | **Hop count** | **AP threshold** |
|---|---|---|---|---|
| Request ID | | | | |
| Destination IP Address | | | | |
| Destination Sequence Number | | | | |
| Originator IP address | | | | |
| Originator Sequence Number | | | | |

Algorithm 1 shown below describes the route update process of the PE-AOMDV. Normally the source node first searches its route cache to find any known routes to the destination and if the route is not available, the source node will initiate route discovery process by flooding or broadcasting RREQ packet over the network. When an intermediate node receives RREQ packet then it checks whether it is destination or not and then it sends a RREP to the source if they have a valid path to the destination. Otherwise they will re-broadcast the RREQ packet to other nodes in the network. Before broadcasting the RREQ again, the forwarding node itself makes a decision whether it is qualified for congestion-aware path or not.

If its *AP counter* value is below the RREQ packets' *AP threshold* value, then the node is qualified and able to broadcast RREQ packet. Now *AP counter* is incremented by one and update its value in routing table of that intermediate node. So that the selected node will re-broadcast RREQ packets throughout the network, only if the number of hops is less than or equal to the last-hop-count recorded in routing table. By doing so, the overloaded nodes are excluded from the paths and an on-demand routing protocol using this scheme will distribute the traffic load

*Algorithm 1.* Route Update Rules of PE-AOMDV Protocol.

**if** $\left(\text{seqnum}_i^d < \text{seqnum}_j^d\right)$ **then**
    $\text{seqnum}_i^d := \text{seqnum}_j^d$
    **if** $(i \neq d)$ **then**
        **if** $(\text{activepath}_{\text{threshold } i} > \text{active\_path\_counter}_i)$ **then**
            $\text{active\_path\_counter}_i^j := \text{active\_path\_counter}_i^j + 1$
            $\text{advertised\_hopcount}_i^d := \infty$
            $\text{route\_list}_i^d := \text{null}$
        **insert** $(j, \text{advertised\_hopcount}_i^d := \text{null} + 1, \text{activepath}_{\text{threshold } i})$ **into** $\text{route\_list}_i^d$
        **end if**
    **end if**
**else if** $\left(\text{seqnum}_i^d = \text{seqnum}_j^d\right)$ **and**
            $((\text{advertised\_hopcount}_i^d, i) > (\text{advertised\_hopcount}_i^d, j))$ **then**
        $\text{active\_path\_counter}_i^j := \text{active\_path\_counter}_i^j + 1$
        **insert** $(j, \text{advertised\_hopcount}_i^d + 1, \text{activepath}_{\text{threshold } i})$ **into** $\text{route\_list}_i^d$
**end if**

evenly on multiple nodes in the network. When the communication is ended or path breakage occurs, the AP counter is decremented by one. It is done based on ACK packet (if communication ends) and Route Error (RERR) packet (if path or link breakage). The above discussed process is illustrated with flowchart and pseudo code is shown in Figure 1.

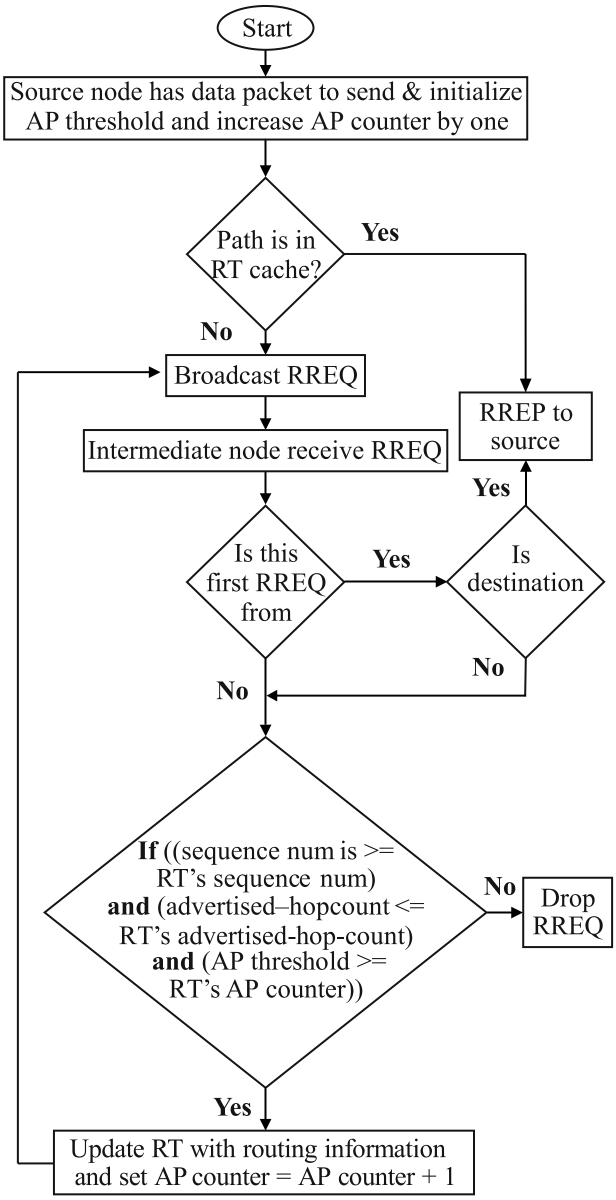


*Figure 1*. Flow diagram of PE-AOMDV Algorithm.

## 3.3. Illustration of the Proposed Scheme

To illustrate the proposed scheme, we consider a network model as shown in Figure 2 with 19 wireless nodes. Let us consider that the nodes

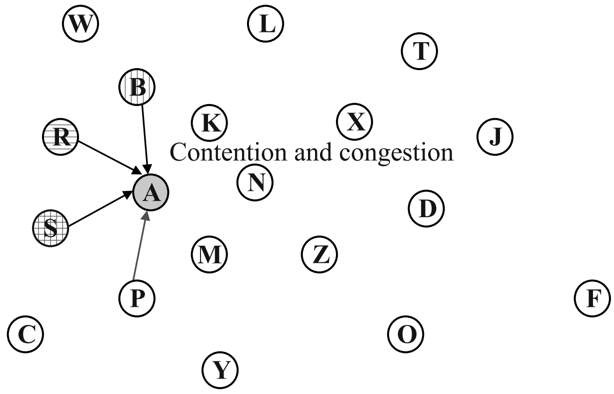


*Figure 2*. Contention and congestion Problem of node A.

S, R and B are source nodes and D, Z and Y are their corresponding destinations and they use multipath routing scheme. The possible paths for each pair are:

(i) (S-D) → {(S-A-N-D),(S-P-M-N-D), (S-A-K-X-D),(S-P-Y-Z-D),(S-A-K-L-X-D)}

(ii) (R-Z) → {(R-A-M-Z), (R-A-M-Y-Z), (R-A-K-N-Z),(R-A-P-Y-Z),(R-S-P-Y-Z)}

(iii) (B-Y) → {(B-A-P-Y), (B-A-M-Y), (B-A-S-P-Y),(B-R-S-P-Y)}

From the possible paths of the above routing information, it is found that there are 10 paths already passing over the node A. Here the maximum number of paths is limited to 10 (AP threshold value). Now a node P wishes to communicate with its destination node L and looks for a path via the node A. If this new path is also allowed via the node A, it may lead to contention and congestion problem. Since there are already 10 communication paths passing over the node A and this new RREQ will not be al-

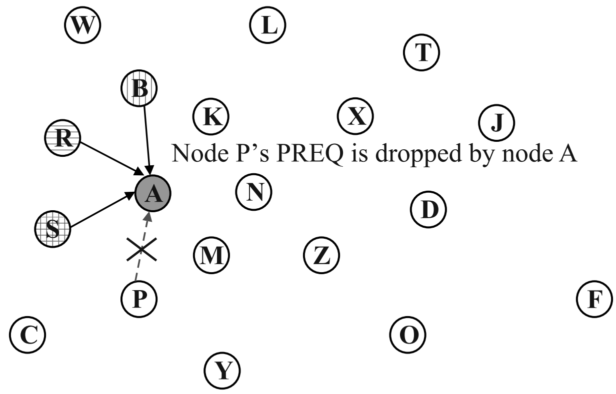


*Figure 3*. Proposed scheme to alleviate contention and congestion Problem of node A.

lowed because the AP threshold value is 10 and the AP counter has also reached 10. So the node A will not allow new route request and will drop the route request packet as shown in Figure 3. By applying this condition to all nodes in the path, congestion and contention problem is avoided before forwarding data packets. This proposed idea provides equal chance to all the paths and forwarding data packets.

The delay incurred while waiting for multiple route request or reply messages is an important factor to be considered in this design of PE-AOMDV mobile ad hoc routing protocols. In addition, finding an appropriate waiting time is a challenge. If a large waiting time is chosen, network performance will be reduced. Meanwhile, choosing a small waiting time can result in the failure of fully exploiting the presence of multipath. So the proposed scheme PE-AOMDV provides network load or network size based AP threshold value to optimally choose the waiting time of a node for data communication. Here the AP threshold value is 10 depending on the network size. In PE-AOMDV distribution of traffic over different wireless links and paths helps prevent congestion in the network.

## 4. Experimental Results and Discussion

The proposed method is tested using the standard simulator ns-2 [17] and the results are compared with the standard routing protocol AOMDV. The performance metrics such as packet loss, normalized routing overhead, packet delivery fraction, throughput and routing overhead are taken into account. The considered simulation parameters are given in Table 2.

### 4.1. Packet Loss Ratio

The reasons for packet drops can be incorrect routing information, mobility, collisions and contention. AOMDV cannot maintain precise routes and drops when nodes move often. The usage of stale routes from its caches is the major reason for AOMDV packet drops. The result obtained from the simulation is given in Table 3 and Figure 4 respectively. PE-AOMDV has fewer packet drops compared to AOMDV when nodes move very often because it selects the paths based on AP Threshold value. So it doesn't invoke frequent Route Discovery.

*Table 2*. Simulation parameters.

| Parameter | Value |
|---|---|
| Simulator | NS-2.34 |
| Simulation Time | 100 seconds |
| Simulation Area | $1520 \times 1520$ m$^2$ |
| Transmission Range | 250 m |
| Packet Size | 512 bytes |
| Traffic & Mobility Model | CBR/TCP |
| Traffic Rate | 10 packets/second |
| Simulation Model | Random Way Point |
| Pass Time | 5 seconds |
| Number of Nodes | 100 |
| MAC Type | 802.11 DCF |
| Channel Type | Wireless Channel |
| Routing Protocols | AOMDV,PE-AOMDV |
| Antenna Model | Omni |
| Network Load<br>Radio Propagation Model<br>Interface Queue Length | 4 packets/sec.<br>TwoWayGround<br>50 |
| Interface Queue Type | DropTail/PriQueue |
| Speed | 5 m/sec. |
| Frequency | 2.4 GHz |
| Data Rate | 11.4 Mbps |
| Carrier Sensing Range | 500 m |
| Carrier Receiving Range | 250 m |

*Table 3*. Packet Loss Ratio (packets).

| No of nodes | AOMDV | PE-AOMDV |
|---|---|---|
| 25 | 97 | 103 |
| 50 | 77 | 59 |
| 75 | 197 | 181 |
| 100 | 181 | 161 |

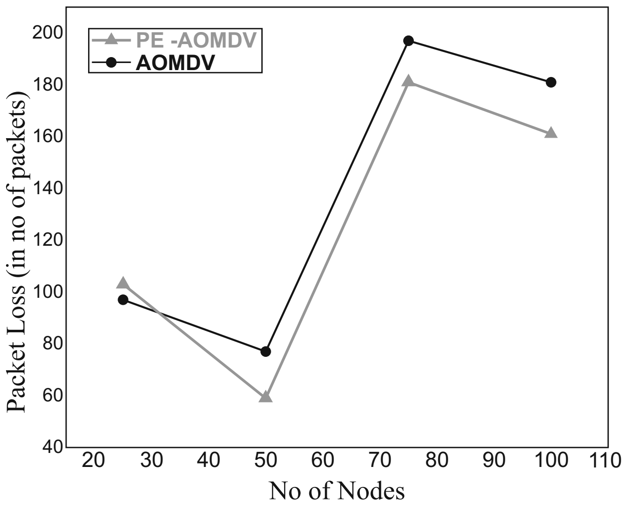


*Figure 4*. Packet Loss Ratio of PE-AOMDV with AOMDV (in packets).

## 4.2. Packet Delivery Fraction

The packet delivery ratio can be represented as the ratio of an amount of successively received packets of a destination from an amount of transmitted packets by a source node during the simulation time. Table 4 and Figure 5 show packet delivery fractions of PE-AOMDV and AOMDV. PE-AOMDV packet delivery ratio is high, because limited defined numbers of active paths are transmitting packets to its destination.

*Table 4*. Packet Delivery Ratio (%).

| No of nodes | AOMDV | PE-AOMDV |
|---|---|---|
| 25 | 98.7267 | 98.6230 |
| 50 | 98.4283 | 98.8086 |
| 75 | 94.5232 | 95.9013 |
| 100 | 94.8841 | 95.9158 |

## 4.3. Normalized Routing Load

Normalized routing load is the number of routing packets transmitted per data packet sent to the destination. Also each forwarded packet is counted as one transmission. This metric is also highly correlated with the number of route changes occurred in the simulation. Normally, routing control messages such as RREQ, RREP, RRER, HELLO, etc., measured in kbit/s. Table 5 and Figure 6 present control overheads in normalized routing load. When there is less mobility and less congestion AOMDV has less overhead; if mobility is increased, it leads to high overhead. But when high mobility takes place, PE-AOMDV yields less overhead due to its optimized path selection criteria.

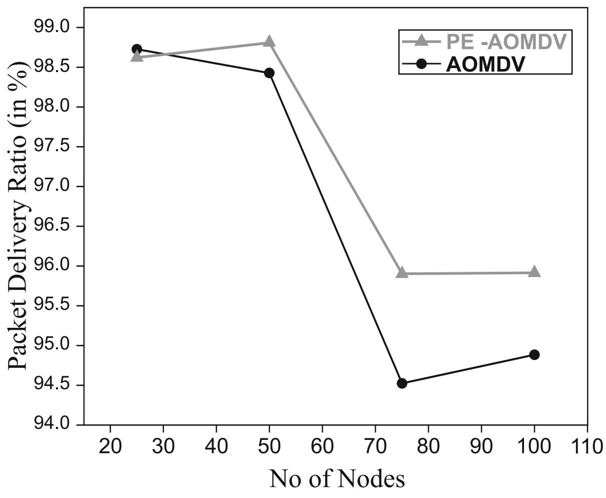


*Figure 5*. Packet Delivery Ratio of PE-AOMDV with AOMDV.

*Table 5*. Normalized Routing Overheads (seconds).

| No of nodes | AOMDV | PE-AOMDV |
|---|---|---|
| 25 | 0.00624917 | 0.00650671 |
| 50 | 0.00871008 | 0.00878806 |
| 75 | 0.05323530 | 0.04014170 |
| 100 | 0.04706580 | 0.03544040 |

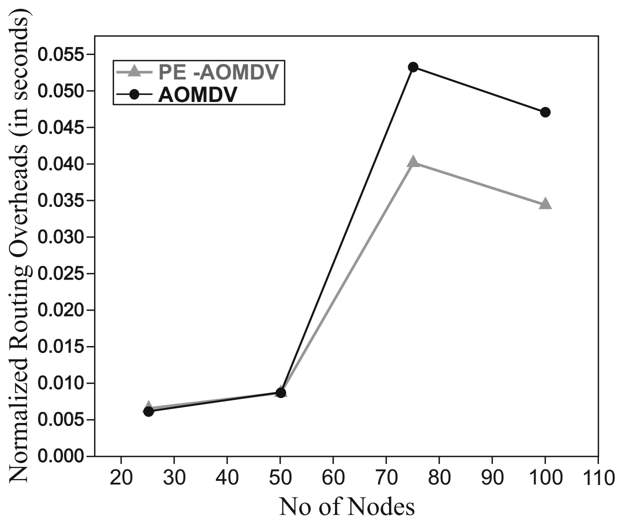


*Figure 6*. Normalized Routing overhead of PE-AOMDV with AOMDV (in seconds).

## 4.4. Routing Overhead

Routing overhead is the total number of control or routing packets generated by routing protocol during simulation. In AOMDV routing overheads are increased, due to the earliest exhaustion of node and path life time. AOMDV path selection doesn't care about active number of paths and their count. This causes large queue size, less processing power and link breaks. Table 6 and Figure 7 compare the routing overheads of PE-AOMDV and AOMDV. PE-AOMDV reduces routing overhead in the way of selecting congestion aware paths at the time of route discovery.

*Table 6*. Routing Overheads (packets).

| No of nodes | AOMDV | PE-AOMDV |
|---|---|---|
| 25 | 47 | 48 |
| 50 | 42 | 43 |
| 75 | 181 | 170 |
| 100 | 158 | 134 |

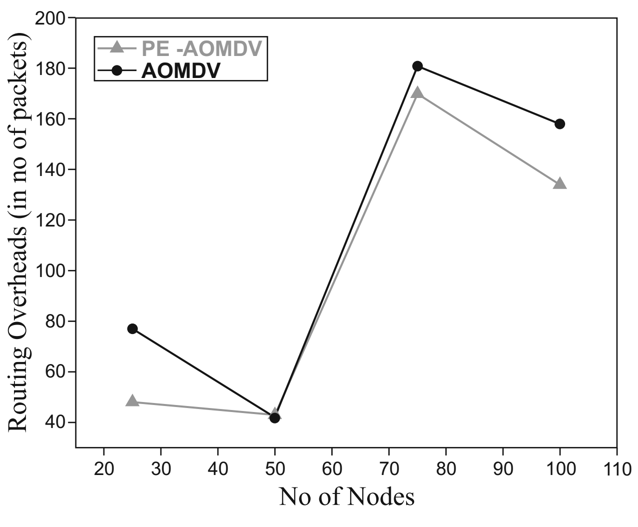


*Figure 7*. Routing overheads of PE-AOMDV with AOMDV (in packets).

## 4.5. Throughput

Throughput is obtained by calculating how many packets are received at the destination from the source during a specified time interval (kbps). Table 7 and Figure 8 show throughputs of each protocol in packet delivery fraction. PE-AOMDV protocols throughput becomes high when nodes scalability is increased. But AOMDV protocols throughput becomes less when nodes scalability is increased. Due to the mobility AOMDV causes high packet delays and more overheads to maintain data loads on the communication path.

*Table 7*. Throughput (kbps).

| No of nodes | AOMDV | PE-AOMDV |
|---|---|---|
| 25 | 307.95 | 302.05 |
| 50 | 197.41 | 200.30 |
| 75 | 138.80 | 173.02 |
| 100 | 136.67 | 154.34 |

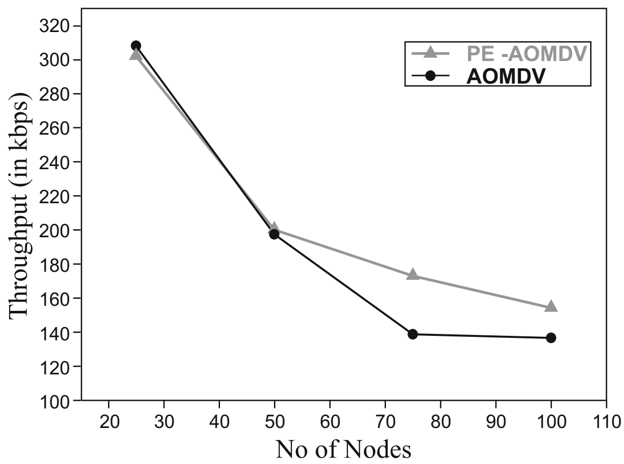


*Figure 8*. Throughput of PE-AOMDV with AOMDV (in kbps).

## 5. Conclusion

The proposed novel scheme called *Path Efficient Ad-hoc On-demand Multipath Distance Vector (PE-AOMDV)* routing protocol balances the load on the paths efficiently. In AOMDV the existing routes can be broken due to link changes and lead to congestion and contention issue. To overcome this issue, the new threshold variable and counter variable are introduced to limit the number of communication paths passing over a node. By doing so, both congestion and contention are reduced. In PE-AOMDV, distribution of traffic over different wireless links and paths helps prevent congestion in the network. The simulated results show that there are significant improvements in the proposed scheme compared to the standard routing protocol called AOMDV with respect to packet loss, normalized routing overhead, packet delivery fraction, throughput and routing overhead.

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