BANDWIDTH AWARE ON DEMAND MULTIPATH ROUTING IN MANETS

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ABSTRACT

Mobile Ad-hoc Networks (MANETs) are self configuring, decentralized and dynamic nature wireless networks which have no infrastructure. These offer a number of advantages, however the demand of high traffic flows in MANETs increases rapidly. For these demands, limited bandwidth of wireless network is the important parameter that restrains the development of real time multimedia applications. In this work, we propose a solution to utilize available bandwidth of the channel for on demand multiple disjoint paths. The approximate bandwidth of a node is used to find the available bandwidth of the path. The source chooses the primary route for data forwarding on the basis of path bandwidth. The simulation results show that the proposed solution reduces the frequency of broadcast and performs well in improving the end to end throughput, packet delivery ratio, and the end to end delay.

KEYWORDS

MANET, node-disjoint, multipath, bandwidth.

1. INTRODUCTION

Many characteristics of ad hoc networks make QoS (Quality of Service) provisioning and QoS routing, a difficult problem. QoS routing means not only to find a route from source to destination, but to find a quality route that satisfies the end-to-end QoS requirement, often given in terms of bandwidth, delay or loss probability. The single path routing protocols like DSDV and DSR, normally fail to fulfill the above requirements. The dynamic topology of MANETs provides the existence of multiple routes between two nodes, which can be utilized to transmit the packet for better support to real time communications. In case of route break, an alternate route can be used to send the packets to reduce the delay and jitter. Research shows that the use of multipath routing in ad hoc networks which are denser performs better throughput. In this paper, we are proposing a multipath routing protocol, which is the potential improvement of the existing Ad hoc On-demand Multipath Distance Vector (AOMDV) protocol [1], and that could be achieved when utilizing the bandwidth of the channel and bandwidth of the respective paths.

The remaining part of the paper is organized as follows: the next part is the review of the protocols and methodologies in the required fields of MANET. Then, we present the problems and motivations. Since, we have modified the existing AOMDV routing protocol, it is also discussed briefly, with its problems. And then we propose the improvements in AOMDV followed by the simulation results of the comparison of new protocol with the existing one. In the last section, we provide the conclusion and future scope of the proposed work.

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2. RELATED WORK

In [3-13], various approaches to QoS provisioning and QoS routing for single path in MANETs have been studied and derived with the aim to reduce the connection set up latency, delay and bandwidth and to ensure guaranteed performance level to the QoS sensitive applications. Multipath routing is more promising in ad hoc networks since it provides additional features like load balancing, fault-tolerance, higher throughput etc., to ensure QoS assurance in ad hoc networks.

Zhi Zhang, et al., [14] performs bandwidth estimation method with the on-demand node-disjoint multi-path routing protocol. This approach creates the multiple node-disjoint paths during the route discovery process and maintained those paths actively. The detector packets measure the available bandwidth of each hop along the paths. AOMDV uses the basic idea of the popular ad hoc on-demand distance vector (AODV) which is proposed in [2]. AOMDV extends the AODV protocol to find the multiple paths in the route discovery process without discarding those paths. These all multiple paths are guaranteed to be loop-free and disjoint. AOMDV has three important issues compared to other on-demand multipath routing schemes. Firstly, like some other protocols (e.g., TORA, ROAM [15-16]), have high coordination overhead among nodes, but its inter-nodal coordination overheads is less. Second, the disjointness of alternate routes is guaranteed via distributed computation without the use of source routing. Finally, this protocol computes alternate paths over AODV with very less additional overhead; it does this by utilizing the information which is already available with alternate paths as much as possible. There are a number of extensions of AOMDV in various fields including dynamic route switching, stability, load-balancing and randomization.

As the AOMDV is based on static route selection, it could not handle the change of the network such as congestion and contention. D. Shin et al., [17], proposed A2OMDV (Adaptive AOMDV), in this approach author resolve the problem of AOMDV, through dynamic route switching method. A source node finds its route dynamically based on the delay of the multiple paths and observes the quality of the alternative routes according to the change of the ad hoc network. One idea is to accept partially disjoint paths that are more stable than other maximally disjoint paths that could increase paths lifetime. Stability-based Partially Disjoint AOMDV (SPDA) protocol is proposed in [18], which is a modification of the AOMDV protocol, finds partially disjoint paths based on links stability. These Partially Disjoint paths improves MANET performance in terms of delay, routing packets overhead, and the network throughput. M. Tekaya, et al., [19], also, introduced a multipath routing protocol with load balancing mechanism, to develop a new protocol called QLB-AOMDV (QoS and Load Balancing- Ad Hoc On demand Multipath Distance Vector), with this solution we can achieve better load balancing with respect to the end-to-end QoS requirement. A multipath routing algorithm is proposed by Pinesh A Darji, et al. in [20], that could randomize delivery paths for data transmission also it uses secured traffic load based on some cryptography approach, in which, randomized paths can protect data from the intrusion of malicious nodes. In [21], author proposed an adaptive retransmission limits algorithm for IEEE 802.11 MAC to reduce the false link failures and predict the node mobility. Since the probability that neighbour node is still in transmission range and may be not responding due to some problems other then mobility is maximum. In this approach the signal strength of each node in network is monitored and, while performing transmissions to a neighbour node, if it's received signal strength is raised and is received recently then Adaptive MAC persists in its retransmission attempts.

2.1 Overview of AOMDV

Ad-hoc On-demand Multi path Distance Vector Routing (AOMDV) protocol is an extension to the AODV protocol for computing multiple loop-free and link disjoint paths. The routing entries for each destination contain a list of the next-hops along with the corresponding hop counts. Multiple paths maintained at each node for each destination have the same destination sequence number which helps in keeping track of the route. For each destination, a node maintains the advertised hop count, which is defined as the maximum hop count for all the paths, which is used for sending route advertisements of the destination. The duplicate route advertisement received by a node defines an alternate path to the same destination. Loop freedom is assured for a node by accepting alternate paths to destination if it has a less hop count than the advertised hop count for that destination. Because the maximum hop count is used, the advertised hop count therefore does not change for the same sequence number. When a route advertisement is received for a destination with a greater sequence number, the next-hop list and the advertised hop count are reinitialized.

AOMDV can be used to find node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject duplicate RREQs. Each RREQs arriving via a different neighbor of the source defines a node-disjoint path. Since the nodes cannot broadcast duplicate RREQs, so any two RREQs arriving at an intermediate node through a different neighbor of the source could not have traversed the same node. In an attempt to get multiple link-disjoint routes, the destination replies to duplicate RREQs, the destination only replies to RREQs arriving via unique neighbors. After the first hop, the RREPs follow the reverse paths, which are node disjoint and thus link-disjoint. The trajectories of each RREP may intersect at an intermediate node, but each takes a different reverse path to the source to ensure link disjointness. Using AOMDV protocol is advantageous since it allows intermediate nodes to reply to RREQs, while still selecting disjoint paths. One of the drawbacks of AOMDV is, it has more message overheads during route discovery due to increased flooding and since it is a multipath routing protocol, the destination replies to the multiple RREQs that results are in larger overhead.

2.2 Problems And Motivations

It is concluded from above discussion, that a reactive routing protocol generates a large number of overhead control messages in the network during route discovery process. So, routing with QoS is difficult in MANET due to several reasons like high overhead, dynamic nature of MANETs, and guarantee of reserved resources.

The existing AOMDV protocol has given the improved results compared to AODV. As it does not have large inter-nodal coordination overheads, it provides disjoint alternate routes, and these are with minimal additional overhead over AODV. Still, there are some problems in AOMDV which are considered in various modifications of it. Those modifications have been discussed in section 2. The modified protocols have resolved the problems of AOMDV up to some extent, but none of them has considered the resource utilization of the MANET. There are various problems in AOMDV extensions, these are:

- None of the protocol has given the strategy to prioritize the alternate routes for resource utilization.
- The selection of the alternate routes performed without comparison of performances.
- The existing protocols are not effective to compute more disjoint paths between source and destination pairs while considering the effect of other resources on performance of the network.

3. THE PROPOSED PROTOCOL

In this section, we propose an extension to AOMDV protocol, in which the channel bandwidth is utilizes in order to improve the network performance. AOMDV allows finding many routes between source and destination during the same route discovery procedure that guarantees loop freedom and disjointness of alternate paths, and only one path is used to transmit data. The routing table entry structure of AOMDV is modified for the proposed method in which only one field is added which gives the information about the path bandwidth of the multiple paths stored in route list entries and is given in Figure 1.

Destination	sequence number	advertised hop count	route list				
			Next_hop1 Next_hop2	Last_hop1 Last_hop2	Hop_count1 Hop_count2	Timeout1 Timeout2	Pathbandwidth1 Pathbandwidth2 .. ..

Figure 1. Routing table entry structure of proposed protocol

3.1 Route discovery

The route discovery procedure of the proposed method constructs multiple bandwidth aware paths between a source and destination. Route request and Route reply packets now contain the existing information and the available bandwidth of the node forwarding it. The source is able to learn the bandwidth of the multiple paths during the route discovery by using the Maximum-Minimum approach to measure the quality of the path. In this approach, the available bandwidth of the entire path is just the available bandwidth of the weakest link. Once the source receives the RREPs, it stores its next hop information and chooses the path with the greatest available bandwidth as its primary path for data transmission. The bandwidth of the route is determined periodically in order to find the optimal route in the change of the network topology with the help of *detector* packet as explained in section 3.4. The source node will switch from its current primary path to an alternate path if the difference in their available bandwidth is higher than the predefined threshold in contrast to wait for its primary path to break. In Figure 2, the AOMDV route decision procedure is summarized, which is modified for the proposed solution, and is given in Figure 3.

```
If (no route to destination)
{
Initiate route discovery as in AODV;
}
If (single known route)
{
Forward data packet to specified route;
}
Else //if N routes are known from source to destination.
{
Forward data packet to best route;
// on the basis of minimum hop count.
}
```

Figure 2. AOMDV route decision

```
If (no route to destination)
{
Initiate route discovery as in AOMDV;
}
If (single known route)
{
Forward data packet to specified route;
}
Else
// if N routes are known from source to destination
{
Forward data packet to route with max. available bandwidth ;
}
```

Figure 3. Modified AOMDV route decision

We also propose to modify the route request as well as route reply packet, which are given below:

RREQ(proposed) = RREQ(AOMDV) + ABW (node)
where,
ABW (node) = MIN [ABW (RREQ recieved) , B_{avail} *(node)]*

In the proposed RREQ packet, the B_{avail} of node is the available bandwidth of the node sending the packet. The estimation of B_{avail} is discussed in section 3.3. Upon receiving the packet, each node will compare its own available bandwidth with the bandwidth received in the packet, and then update the packet with the minimum bandwidth. Once the destination receives the RREQ, it generates route reply packet ie, RREP which is also modified in the similar manner.

3.2 Hello message

The Hello packet used in AOMDV only keeps the address of the node which has generates this packet. We modify the Hello packet for the new solution by adding the bandwidth information of the node sending the hello packet and the neighbors of the node with their bandwidth information. Each node broadcast this hello packet periodically, and updates all its neighbors about its bandwidth. The format of hello packet is given in Figure 4. Where $B_{consumed}$ is the bandwidth consumed by each node for sending packets in the network.

<SenderID, $B_{consumed}$, timestamp>	<neighborsID, $B_{consumed}$, timestamp>

Figure 4. Format of Hello message

3.3 Bandwidth Estimation

For the forwarding of data packets where multiple routes are known from source to destination, the maximum available bandwidth of the routes is estimated. Each node estimates its consumed bandwidth by tracking the packets it transmits into the network. This value is recorded in the bandwidth consumption register at the node and updated periodically. Once a node knows the bandwidth consumption of its one-hop neighbors and its two-hop neighbors, the residual bandwidth can be estimated as (1), the raw channel bandwidth (B_{raw}) minus the overall consumed bandwidth ($B_{all\_consumed}$), multiplied by a weight factor. We need to multiply the residual bandwidth by a weight factor α due to overhead of IEEE 802.11 MAC, overhead of routing protocol and overhead for the situation where a node is in sender's interference range but it isn't in any of sender's neighbors' transmission range [14]. In this situation, the sender will never know this node bandwidth usage. However, these instances do not happen frequently since it has to meet strict requirements. So weight factor is used to overcome this situation. From the equation in (1), the more interference traffic in the channel the more conservative the estimation will be.

$$\mathbf{B}_{\mathbf{avail}} = \alpha\,(\mathbf{B}_{\mathbf{raw}} - \mathbf{B}_{\mathbf{all\_consumed}}) \quad (1)$$

where, $0 < \alpha < 0.8865$

3.4 Alternate Route Maintenance

The alternate routes constructed between a pair of source and destination is to be maintained for a time period. The algorithm for alternate route maintenance is given below. The *detector* packet is unicast from source to destination along the alternate paths. This packet contains one field apart from source and destination addresses that is to collect the minimum bandwidth along each path.

Algorithm :

1. Source node periodically sends detector packet to the destination along each of its alternate paths after route discovery.
2. Each node updates the bandwidth field when the detector propagates through the alternate paths.
3. The destination records the bandwidth in the detector and sends a new detector back to the source along the same path.
4. The bandwidth of the entire path is just the bandwidth of the weakest link.
5. The source node chooses the path with the maximum bandwidth for routing.
6. The source node will switch from its current primary path to an alternate path if the difference in their ABW is higher than the predefined threshold in contrast to waits for its primary path to break.

4. SIMULATION RESULTS

We study the new AOMDV performance using ns-2 [22, 23] simulations. The main objective of our simulation is to evaluate the effectiveness of new AOMDV relative to AOMDV in the presence of mobility-related route failures. Other objective includes evaluating the number of alternate node disjoint paths that can be found using new AOMDV.

4.1 Simulation Environment

The simulation experiment is carried out in LINUX (ubuntu 10.4). The detailed simulation model based on network simulator-2 (ver-2.35), is used in the evaluation. Table 1 shows the simulation parameters. In this simulation, each packet starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0–20 m/s). Simulations are run for 50s, 100s, 150s, 200s, 250s and 300s simulated for 100 nodes under CBR traffic pattern. The weight factor α is defined as 0.65.

Table 1. Simulation Parameters

Parameter	**Values**
Dimensions	1000m×1000m
Traffic type	CBR
Number of nodes	100
Simulation Time	300s

Pause Time	50, 100, 150, 200, 250, 300s
Total Sources and	49 and 71
Maximum Speed of Nodes	20m/s
Packet rate	4pkts/s
Packet size	512 byte
Mobility model	Random Waypoint Model
Channel bandwidth	2Mbps

4.2 Performance Metrics

The performance of routing protocol is evaluated using three different metrics to compare the performance of the new protocol with the existing AOMDV routing protocol. They are:

1. **Packet delivery fraction (PDF)** — The packet delivery fraction is the ratio of the data packets delivered to the destinations to those generated by the sources.

2. **End-to-end delay (E2E Delay)** — The end-to-end delay of data packets refers to the time taken for a packet to be transmitted across a network from source to destination.

3. **Normalized routing load (NRL)** — The Normalized routing loads is computed by the ratio of total number of routing packets sent by the number of data packets delivered successfully.

4. **Throughput (THPT)** — The throughput is the amount of data packets received at the destination per unit time.

The performance results of AOMDV and B-AOMDV for 100 nodes and the comparison of new protocol with the existing AOMDV protocol are given below in Table 2 and 3.

Table 2. Performance Results of AOMDV and B-AOMDV for 100 nodes

Simulation time (s)	B-AOMDV				AOMDV			
	PDF (%)	E2E Delay (s)	NRL	THPT	PDF (%)	E2E Delay (s)	NRL	THPT
50	90.95	0.01301	2.636	653.11	93.33	0.022	2.908	587
100	92.43	0.09289	1.502	958.33	95.206	0.0208	1.587	1027
150	79.52	1.82	1.261	1300	75.25	1.35	1.95	1295
200	64.27	3.67	1.21	1516.35	59	3.35	3.403	1490
250	56.063	5.26	1.258	1633.09	50	4.86	4.49	1629.3
300	51.101	5.99	1.402	1706.63	42	5.96	4.96	1711.6

Table 3. Comparison Table

Metrics	B-AOMDV	AOMDV
PDF	High	Low
E2E	Low	High
NRL	Low	High
THPT	High	Low

Packet Delivery Fraction: Figure 5 compares the packet delivery fraction of AOMDV and proposed modification in varying pause time and random node speed. The graph demonstrates that proposed modification performs better than the AOMDV at nearly all pauses of time. The AOMDV perform well at less pause time but degrade at high pause time, while the proposed protocol does not degrade too much. Higher packet delivery fraction of new protocol is because of the availability of the bandwidth utilization among alternate paths to forward the packets when the source switched from its primary path.

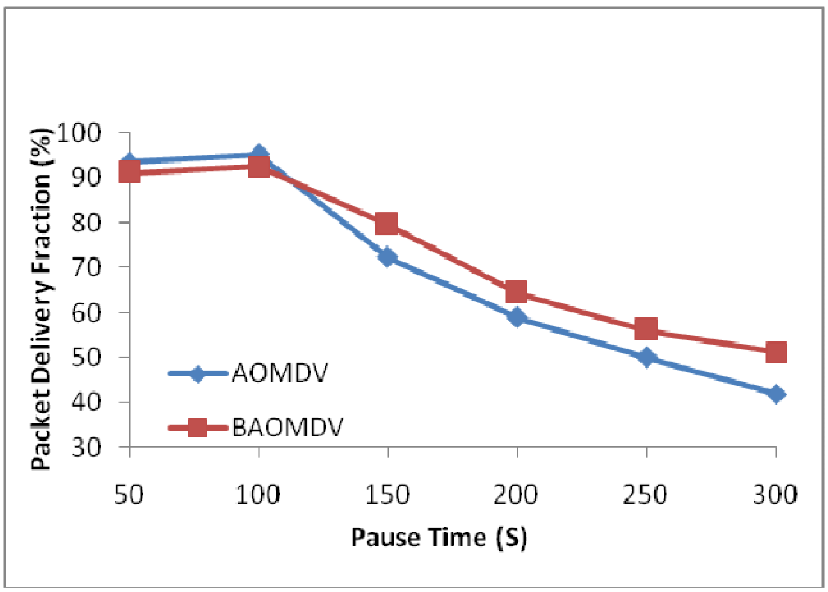

Figure 5. Packet delivery fraction

End to end delay: Figure 6 compares the End to end delay of AOMDV and proposed modification in varying pause time and random node speed. The graph demonstrates that proposed modification results in less delay than the AOMDV at nearly all pause time. The AOMDV perform well at less pause time but delay increase at high pause time, while the proposed protocol does not increase the delay at almost all pause time.

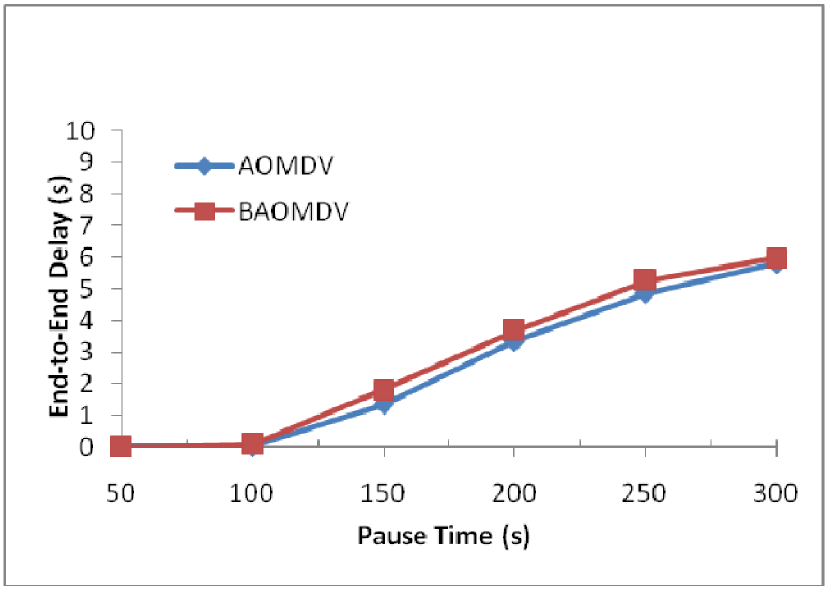

Figure 6. End-to-End Delay

Normalized Routing Load: Figure 7 compares the Normalized Routing Load of AOMDV and proposed modification in varying pause time and random node speed. The graph demonstrates that proposed modification results in less normalized routing load than the AOMDV. The AOMDV perform well at less pause time but load increase at high pause time, while the proposed protocol results high normalized load at less pause time but normalized routing load is decreased as the pause tme is increased.

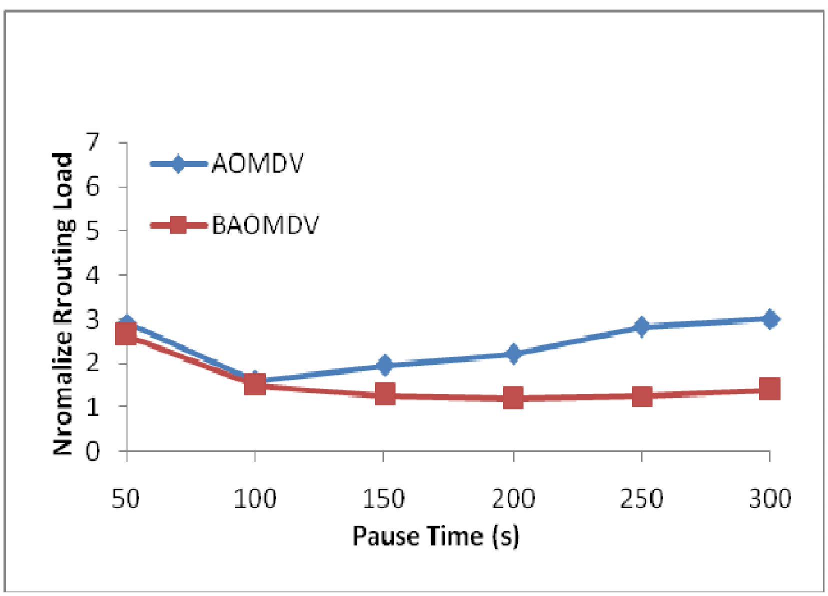

Figure 7. Normalized Routing Load

Throughput : Figure 8 compares the throughput of AOMDV and proposed modification in varying pause time and random node speed. The graph demonstrates that proposed modification results in high throughput than the AOMDV. The AOMDV performs well at less pause time but at high pause time, the new protocol results high throughput as compared to AOMDV protocol.

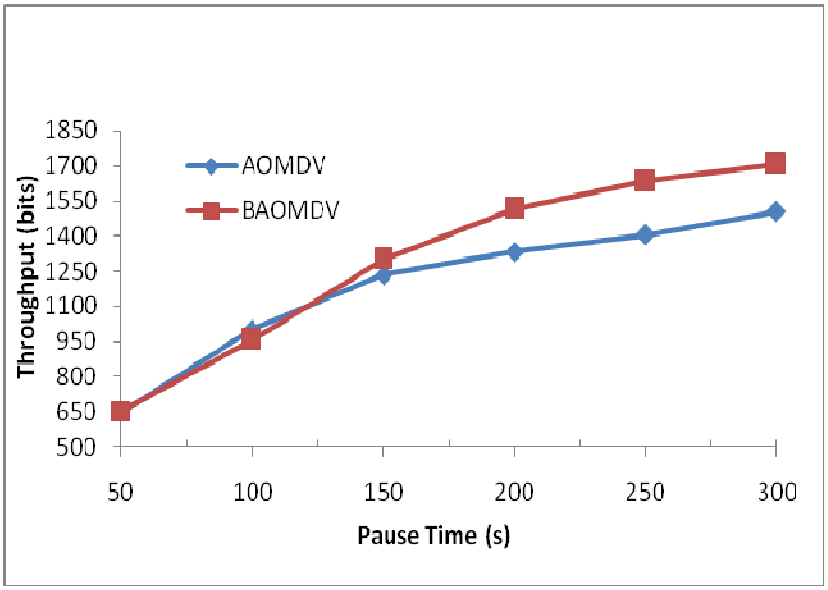

Figure 8. Throughput

5 CONCLUSION AND FUTURE SCOPE:

In this paper, we proposed an approach for multi-path routing in mobile ad hoc networks and used bandwidth estimation by disseminating bandwidth information through *detector* packets. The primary property of this approach is that it can adapt the change in network topology by proactively estimating the available bandwidth of each path to the destination and always using the best path. Simulation results show that the performance of the protocol is superior to the AOMDV in all most all scenarios. Future research will focus on optimally distributing traffic over multiple paths to upgrade the performance of the protocol.

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