# Performance Evaluation of Single-Path and Multipath MANETs Routing Protocols using Random Mobility Model

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***ABSTRACT:*** Mobile Ad Hoc Network (MANET) is a multi-hop wireless network in which fixed infrastructure is not used. A single-path routing protocol is mainly proposed as a single route between a source and destination node, while a multipath routing protocol uses multiple routes between a source and destination node. This paper evaluates the performance of single-path routing protocols which are Cluster Based Routing Protocol (CBRP) and Ad hoc On-demand Distance Vector (AODV) along with a multipath routing protocol which is Ad hoc On-demand Multipath Distance Vector routing (AOMDV) in MANET environments using Random Mobility Model. For this purpose, the efficiency of each protocol was analyzed to verify their behavior in Random Mobility Model environments to determine the protocol, which is more efficient based on average end-to-end delay, normalized routing load (NRL) and Packet Delivery Ratio (PDR). Network Simulator (NS2) was used to evaluate the performance of these protocols. Our experimental simulation results show that: AOMDV protocol is better than AODV and CBRP in terms of Delay and Packet Delivery Ratio (PDR) with all traffic sources.

***Index Terms***- MANET, Routing Protocols, Node Density, Random Mobility Model, Single path, Multipath, AODV, AOMDV and CBRP.

## I. Introduction

Mobile Ad hoc Network (MANET) is a collection of wireless mobile nodes that connect with each other without using any existing network infrastructure. MANETs can be used in classrooms, battlefields and disaster recovery [1].

Routing protocols play the most important role in the communication and connection within a network. A primary goal of routing protocols is to establish and maintain a route between a pair of nodes so that messages are delivered in a reliable and timely manner [2,3].

According to the scheme of discovering and maintaining routes, MANET routing protocols can be categorized into three categories: proactive, reactive and hybrid [4]. The routing protocols in MANETs can also be distinguished as single or multipath, unicast or multicast, and distance vector or link state [4]

Multipath routing is a technique that is used to solve problems of the link variability and recurrent topological changes. Because using multiple paths could reduce the effect of possible link failures between the mobile nodes, multipath routing protocols for MANETs are superior over conventional single-path routing protocols [5].

This paper evaluates the efficiency of single-path routing protocols (CBRP and AODV) along with multipath protocol (AOMDV) in Random Mobility Model. Based on the simulation results, we can identify the best protocol type (single path or multipath).

## II. Overview Of MANET Routing Protocols

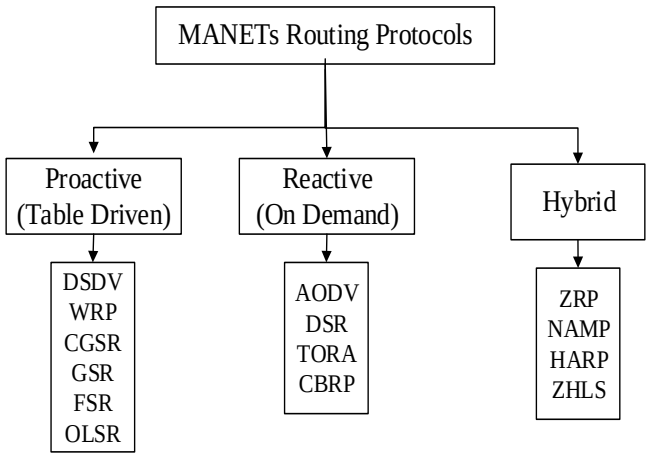



Figure 1. MANETs Routing protocols Taxonomy

Based on the schemes of discovering and maintaining paths, MANETs routing protocols are classified into three classes: proactive, reactive, and hybrid [6]. Each routing protocol reacts differently to node density and mobility. In addition, MANETs routing protocols can be distinguished in terms of reactivity (reactive or proactive approach) and number of paths (single or multi-path). The reactive approach is more efficient than proactive approach because it only discovers and maintains paths between the mobile nodes. This section explains the most

well-known reactive single-path and multipath MANETs routing protocols. Figure 1 shows the taxonomy of MANETs routing protocols.

### A. MANET Single Path Routing Protocols

MANET single-path routing protocols are mainly intended to discover a single route between a source and destination node. The most popular of these routing protocols in MANET are AODV and DSR. In the following subsections we will briefly review two MANETs single-path routing protocols (AODV and CBRP) which are on-demand reactive routing protocols.

#### *Ad hoc On-demand Distance Vector (AODV)*

AODV [7] is an on-demand routing protocol that enables dynamic and multi-hop routing between mobile nodes that are needed to establish and maintain MANETs. AODV is principally a combination between of DSR and DSDV (Destination Sequenced Distance Vector) protocol. Similar to DSR protocol, AODV uses the basic on-demand mechanism of route discovery and route maintenance. Furthermore, similar to DSDV protocol, AODV uses the next hop routing model with sequence numbers and cyclic beacons to find out routes and maintain them. AODV uses sequence numbers to avoid long-term loops when the topology of network changes.

Although AODV allows mobile nodes to obtain paths quickly for new destinations, it does not need nodes to maintain paths to the destinations that are not in active communication.

#### *Cluster-Based Routing Protocol (CBRP)*

CBRP [8,9] is a hierarchical on-demand routing protocol that uses source routing, like to DSR, to avoid creating loops and route packets. CBRP groups the nodes in a network into many clusters. Each cluster has a cluster head which manages data transmission within the cluster and with other clusters. An example of grouping nodes in three clusters can be seen in Figure 2.

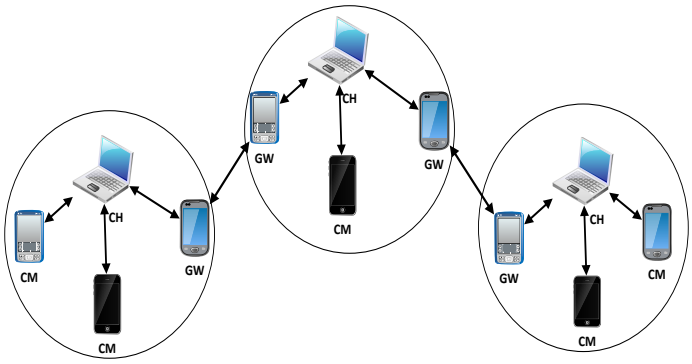



Figure 2. Cluster Based Routing protocol (CBRP)

In CBRP only cluster heads exchange routing data, thus the number of control overheads is less than the traditional flooding approaches. Nevertheless, as in any another hierarchical protocols, there are overheads that are related to cluster formation and maintenance. This is because some nodes may carry varying topologies data due to the long broadcast [6]. The CBRP intends to discover a shortening path for performance optimization because the CBRP uses a source routing scheme. A node when receiving a data packet can obtain all information about the path. Nodes employ path shortening to select the most neighboring node in a route as the next hop to minimize the number of hop and to adapt network topology changes. Another optimization scheme that is used in CBRP is the local route repair, where broken paths could be repaired locally without rediscovery.

### B. MANET Multi Path Routing Protocols

Multipath routing protocols in MANETs are proposed to discover and use multiple routes between source nodes and destination nodes. Multipath routing addresses frequent topological changes and link instability because the use of multiple paths can reduce the effect of possible broken links between nodes [10]. Thus, multipath routing protocols in MANETs are superior to conventional single-path routing protocols because they can distribute traffic among multiple routes to reduce the average delay, increase transmission reliability, provide load balancing among multiple routes, and improve the security and overall Quality of Service [11].

Some multipath routing protocols have been proposed for wireless ad hoc networks. Multipath routing protocols based on the Ad hoc On-demand routing scheme are found as Ad hoc On-demand Multipath Distance Vector routing (AOMDV) [12]

#### *Ad hoc On-demand Multipath Distance Vector routing (AOMDV)*

AOMDV [12] extends the AODV protocol to compute numerous paths between the source nodes and the destination nodes through route discovery. AOMDV uses multiple paths by generating various loop-free and link-disjoint paths. Some of the features of AOMDV are: it provides disjoint paths through distributed calculation without the use of source routing, it generates multiple paths in single route discovery procedure, and it calculates replacement paths with minimal additional routing overhead over AODV. AOMDV protocol calculates multiple loop-free paths, where every node maintains an advertised hop count for each destination node to accomplish loop freedom, where the advertised hop count represents the maximum hop counts for all multiple paths.

## III. Simulation Experiments

The simulation setting is based on the NS-2 network simulator version 2.35 [13]. The IEEE 802.11 DCF (Distributed Coordinated Function) MAC was used as the source for the tests with a channel capacity of 2Mb/sec. The transmission range of each node was set to 250 m using the Two-Ray Ground Propagation model.

### A. Mobility and Traffic Model

Random Waypoint mobility model is used for all experiments. The nodes are moving with 0 pause time and difference node mobility (1, 2, 4, 6, 8, 10, 12 and 15) m/s in. These node speeds are used to see the behavior of the protocols

with low mobility and high mobility. The total simulation time is 500 seconds.

The constant bit rate (CBR) data source running with UDP is used as the traffic pattern in all experiments in this paper [14]. 128 bytes is used as the data packet size because the research focuses on VOIP that needs low packet size. Four packets per second are used as data packet rate, where four packets is the medium value for the bit rate. The numbers of traffic sources are set to 10 and 40 sources. This is done to see the behavior of protocols with both low traffic sources and high traffic sources. The overall configurations setting for the simulation are explained in Table 1 below.

TABLE 1. SIMULATION CONFIGURATION

| Parameters | Value |
|---|---|
| Simulation duration | 500s |
| Topology | 1000x1000 m |
| Number of Nodes | 50 |
| Traffic Model | CBR |
| Numbers Traffic Source | 10 ,40 |
| Mobility speed | 1,2,4,6,8,10,12,15 |
| Routing Protocols | AOMDV,AODV,CBRP |
| Pause Time (Sec) | 0 |
| Bandwidth | 2Mb |
| Transmission range | 250m |
| Packet rate | 4 packets/second. |
| Packet size (Bytes) | 128 |

### A. *Performance Evaluations*

MANETs routing protocol is usually evaluated in terms of performance metrics. These metrics include Packet Delivery Ratio (PDR), Average Delay, and Normalized Routing Load (NRL). Specifically, these metrics are used in this paper to measure the efficiency of the three routing protocols: CBRP, AODV and AOMDV. These metrics can be described in brief as follows:

- ***Normalized Routing Load (NRL):*** The proportion of the number of control packets that are sent from the source node to the number of data packets that are received at the destination node.
- ***Packet Delivery Ratio (PDR):*** The ratio of number of data packets sent from the source to the number of data packets received at the destination.
- ***Average Delay (Delay):*** The average time from the beginning of a packet transmission (including route acquisition delay) at a source node until packet delivery to a destination.

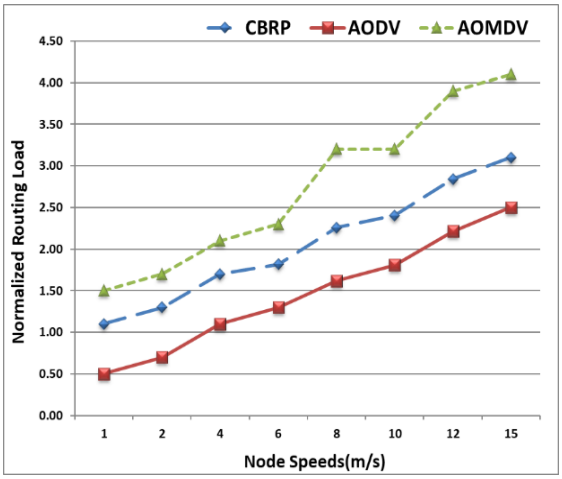
## IV. ANALYSIS RESULTS AND DISCUSSIONS

This section deals with the analysis and discussion of the simulation results. The results are shown in form of graphs. The graphs show the comparison results among the three protocols (CBRP, AODV and AOMDV) in Random Mobility Model along with the performance metrics and different traffic source numbers.

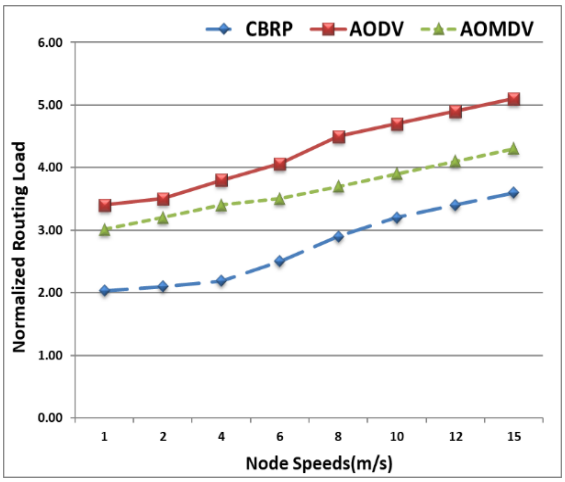
Figures from 3 to 5 represent the performance metrics (NRL, PDR and Average Delay) for (CBRP, AODV and AOMDV) routing protocols for 50 nodes in Random Mobility Model with 10 and 40 traffic sources.

### A. *Normalized Routing Load*

Figure 3 shows that AODV has the lowest NRL with 10 sources and has the highest NRL with 40 sources, whereas CBRP has the lowest NRL with 40 sources. Also, figure 3 shows that AOMDV has the highest NRL between of the other two protocols (AODV and CBRP) with 10 sources.




**10 Sources**

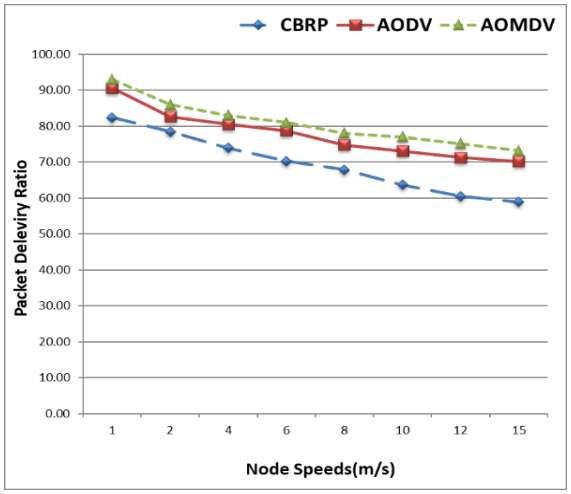



**40 Sources**

Figure 3. Normalized Routing Load for 50 nodes with 10 and 40 sources

### *B. Packet Delivery Ratio (PDR)*

Figure 4 reveals that PDR in AOMDV protocol is higher than the other two protocols (AODV and CBRP) with 10 and 40 sources and CBRP has the lowest PDR between of the other two protocols (AODV and AOMD) with 10 and 40 sources.

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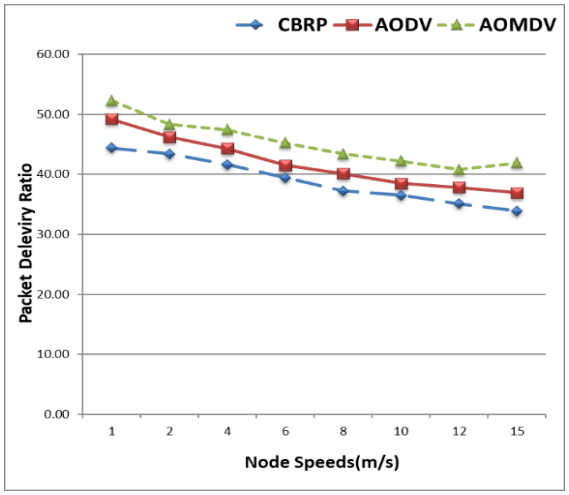
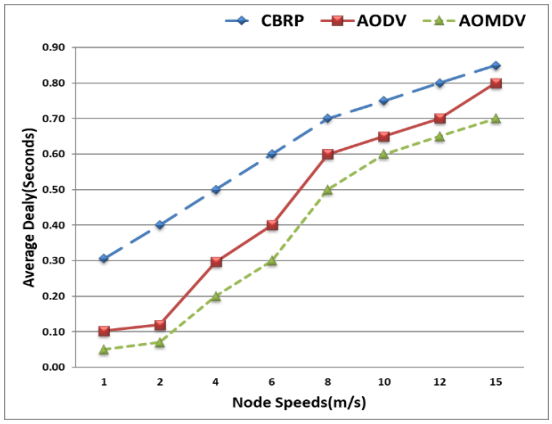



**40 Sources**

Figure 4. Packet Delivery Ratio for 50 nodes with 10 and 40 sources

### *C. Average Delay*

Figure 5 shows that AOMDV is better than the other protocols (AODV and CBRP) in terms of Delay, where AOMDV has the lowest Delay for all traffic sources (10 and 40). Also, figure 5 shows that CBRP has the lowest Delay between of the other two protocols (AODV and AOMD) with 10 and 40 sources.

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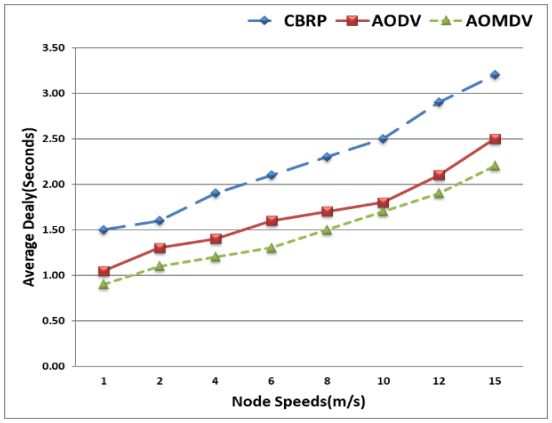


**14 Sources**

Figure 5. Average Delay for 50 nodes with 10 and 40 sources

## V. CONCLUSION

This paper evaluated the performance of single-path (CBRP and AODV) and multipath (AOMDV) MANETs routing protocols in Random Mobility Model. The experiment simulation results show that AOMDV protocol is better than AODV and CBRP in terms of Delay and Packet Delivery Ratio (PDR) with all traffic sources. The results also reveal that CBRP has the lowest NRL with 40 sources. Thus, it can be concluded that the non-uniform density in MANET has effects on the performance of AODV, AOMDV and CBRP protocols. It can also be concluded that AODMV protocol is the best in the Delay and CBRP is the lowest. For further research, we will plan to investigate and study the efficient performance for CBRP, AODV and AOMDV protocols in MANETs using difference mobility models using NS3 simulator.

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