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PERFORMANCE EVALUATION OF SINGLE-PATH AND MULTIPATH MANETS ROUTING PROTOCOLS FOR DENSE AND SPARSE TOPOLOGY

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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 from source node to destination node, while a multipath routing protocol uses multiple routes from the source to the 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 with varying node densities (Dense and Sparse). Network Simulator (NS2) was used to evaluate the performance of these routing protocols. Our experimental simulation results show that: AOMDV protocol is better than AODV and CBRP in terms of Delay for both Dense and Sparse topologies with variant traffic sources, whereas AODV is better than CBRP and AOMDV in terms of Packet Delivery Ratio (PDR) with all traffic sources in Sparse topology.

Keywords: MANET, Routing Protocols, Node Density, Single path and Multipath.

INTRODUCTION

A Mobile Ad hoc Network (MANET) is a group of wireless mobile nodes that connect with another without using any existing network infrastructure. MANETs can be used in classrooms, battlefields and disaster recovery (Murthy, 2004).

Routing protocols play the most important role in the communication and connection within a network. A primary goal of routing protocols is to create and maintain a route between a pair of mobile nodes so that data packets are delivered in a reliable and suitable time (Mahdi & Wan; Royer & Toh, 1999).

Based on the scheme of routes discovering and maintaining, MANET protocols can be categorized into three classifications: proactive, reactive and hybrid (A. R. Sangi, Liu, & Liu., May 2010). The protocols in MANETs can also be distinguished as single or multipath, unicast or multicast, and distance vector or link state (A. R. Sangi, J. Liu, and Z. Liu., 2010)

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 impact of link failures possibility between the mobile nodes, multipath routing protocols for MANETs are superior over conventional single-path routing protocols (Nasipuri, 2001).

This paper evaluates the efficiency of single-path routing protocols (CBRP and AODV) along with multipath protocol (AOMDV) in MANET topology with difference node densities (Dense and Sparse). Based on the simulation results, we can identify the best protocol type (single path or multipath).

OVERVIEW OF MANET ROUTING PROTOCOLS

Based on the schemes of discovering and maintaining paths, MANETs protocols are classified into three categories: reactive, proactive and hybrid (Abolhasan et al., 2004). Each 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.

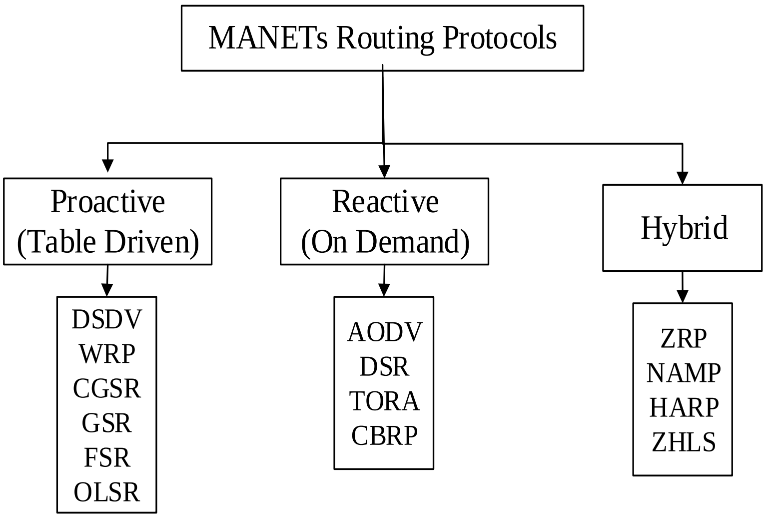

Figure 1. MANETs Routing protocols Taxonomy

MANET Single Path Routing Protocols

MANET single-path routing protocols are primarily used to discover a single route from the source to the 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.

1. Ad hoc On-demand Distance Vector (AODV)

AODV (Perkins., Belding-Royer, & Das, 2003) is an on-demand routing protocol that allows dynamic and multi-hop routing among mobile nodes that are needed to form 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 sequence numbers and cyclic beacons to discover and maintain the paths. Also, AODV uses sequence numbers to avoid long-term loops when the topology of network changes.

Although AODV lets MANET mobile nodes to get the paths rapidly for new destinations, it does not need mobile nodes in order to maintain the paths to the destinations which the communication among these nodes not active.

2. Cluster-Based Routing Protocol (CBRP)

CBRP (Jiang, Li, & Tay, 1999, Yu et al., 2012.) 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. Every cluster has a cluster head (CH) that manages data packet broadcast within the same cluster and with another clusters. An example of grouping nodes in three clusters can be seen in Figure 2.

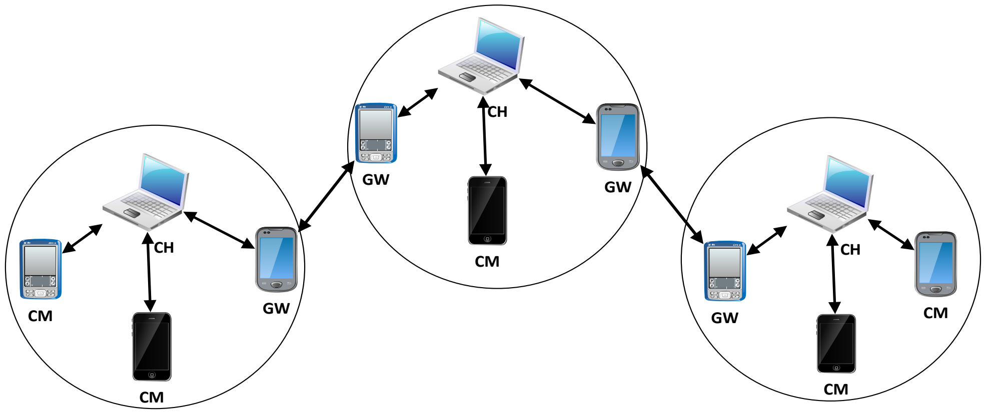

Figure 2. Cluster Based Routing protocol (CBRP)

In CBRP only CHs interchange routing data, thus the total of control routing overheads is less than the traditional flooding approaches. Nevertheless, as in any another hierarchical routing protocols, there are routing overheads that are in connection with cluster creation and maintenance. It is because some mobile nodes can carry varying topologies data due to the long broadcast (Abolhasan et al., 2004). The CBRP intends to discover a shortening path for performance optimization because the CBRP uses an on demand routing scheme. All data about the path can be obtained by a node when receiving a data packet. Nodes employ path shortening to select the most neighboring node in a path as the next hop to diminish the number of hop and to adjust changing of network topology. Another optimization scheme that is used in CBRP is the local route repair, where broken paths are repaired locally without needed to rediscover the routes.

MANET Multi Path Routing Protocols

Multipath routing protocols in MANETs are intended to discover and use multiple routes between source nodes and destination nodes. Multipath routing addresses recurrent of changing topology and instable link since the use of multiple routes can reduce the influence of broken links potential between nodes (Sihai, Z., & Layuan, 2011). Thus, multipath MANETs protocols are superior to conventional single-path protocols (Nasipuri, 2001) because the multipath protocols can distribute traffic among multiple paths to reduce the average delay, provide load balancing among multiple routes, increase transmission reliability and improve the security and overall QoS (Mohammed. et al., 2009).

Some of MANET multipath protocols have been intended for MANETs. Based on the source routing protocol DSR, multipath source routing (MSR) (L. Wang et al., 2000) is found. Furthermore, multipath routing protocols based on the Ad hoc On-demand routing scheme are found as (AOMDV) (Marina & Das, 2002, 2006b).

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

AOMDV (Marina & Das, 2002, 2006b) extends the AODV protocol to compute numerous routes from the source nodes to the destination nodes over route discovery. AOMDV uses several routes by generating numerous link-disjoint paths and loop-free. Some of the features of AOMDV are: it provides disjoint paths through distributed calculation without needed the source routing, it generates multiple paths in single route discovery procedure, and it calculates replacement routes with minimal additional routing overhead through AODV. AOMDV protocol calculates multiple loop-free paths, where every mobile node maintains an advertised hop count for every destination node to accomplish loop freedom, where it represents the maximum hop counts for all multiple paths.

NODE DENSITY

The node density of MANET was studied in (Royer, 2001.) who discussed the settlements between node connectivity and network density in the face of node speed increasing. In addition, a search for the best of node density value is proposed for the connectivity in a fixed network. The connection of the node density in MANET should allow the extent of the nodes transmission range covering the network area. Furthermore, the transmission range coverage of the nodes will provide a better estimation for node density and it aids identify how well the network is connected.

In this paper, the network density is known as Dense when considerable number of mobile nodes are adjacent and connected to each other inside a specific area and conversely for Sparse. Nevertheless, when defining density for a certain network, what should be considered is the network connectivity in terms of transmission range that covers the specific area. The connectivity of network that is based on the density of the numbers of adjacent mobile nodes, was studied and discussed in (Bettstetter,

$$\mu = \rho \pi r^2 \quad (1)$$

$$P(k\text{-}con) \approx (1 - e^{-\mu})^n \quad (2)$$

2002). In this paper the network density is determined as Dense or Sparse based on the following three equations:

where P is the probability of the connectivity, the connectivity among mobile nodes is

$$\rho = {}^{n}/_{A} \qquad (3)$$

con, and n is the number of mobile nodes found in the area A. In addition, μ is denoted by *Eq. 2*, where the network density is ρ , π is the perimeter, and r is the transmission range. The k variable is set to 1 in this paper. This indicates that in any specific network aforementioned as Dense specified the connection probability of $P(k\text{-}con) \geq 0.95$ where $k = 1$, there is 1 reciprocally autonomous route connecting of the mobile nodes in the specific network area (Natsheh , 2010, 2015). Thus, the network is considered as 1-connected when $P(1\text{-} con) >= 0.95$ is based on the definition given in (Bettstetter, 2002; Ong L. , 2006).

- **Dense and Sparse definition**

The calculation on the degree of mobile node density of the network regions in this paper is based on the formula *P (1-con).* Two types of node density are identified based on *P (1-con)*, Dense and Sparse. These two types of node density are defined below.

The node density is considered to be Dense based on the following cases:

- It has at least one route to other mobile nodes in the same region which is autonomous of one another.
- $P (1\text{-}con) \geq 0.95$.

The node density is considered to be Sparse based on the following cases:

- Nodes neighborhood cannot surety at least a single connection in the network.
- $P (1\text{-}con) < 0.95$

SIMULATION EXPERIMENTS

The simulation setting is established uses the NS-2 (NS2) version 2.35. The IEEE 802.11, Distributed Coordinated Function (DCF) uses as the source for the tests with a 2Mb/sec as channel capacity. A 250 m sets as transmission range to each node using the Two-Ray Ground Propagation model.

1. Node Density Topology Configuration

The node density for simulation setting is configured based on the node density as defined in *Equation 1*. Two types of topologies are studied in this paper, Dense and Sparse topologies. Based on the number of nodes which are 50 nodes and transmission range which is 250m and topology (1000x1000), the connection probability of *P (1-con)* will be greater than 0.95, which means that the topology in this setting is Dense. Also, based on the same transmission range and the number of nodes and topology (1500x1500), the *P (1-con)* will be less than 0.95, which means that the topology in this setting is Sparse.

2. Mobility and Traffic Model

Random Waypoint mobility model is used for all experiments. The mobile nodes are moving with 0 pause time and difference node mobility (1, 2, 4, 6, 8, 10, 12 and 15) m/s in the both topologies: Dense and Sparse. These node speeds are used to see the behavior of the routing protocols with low and high mobility speed. 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. One hundred and twenty-eight 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 described in Table 1 below.

Table 1. Simulation Configuration

Parameters	**Value**
Simulation duration	500s
Topology	• Dense: 1000x1000 m • Sparse: 1500x1500 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

3. 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:

- ***Packet Delivery Ratio (PDR):*** The proportion of the total number of data packets that are received at the destination node to the number of data packets that are sent from the source node, as shown below:

$$PDR\,\% = \frac{R}{S}\ x\ 100 \qquad (4)$$

where *R* refers to the number of data packet received and *S* refers to the number of data packet sent.

- ***Average Delay (Delay):*** The average time from the starting of a packet sending at a source node until the packet is delivered to a destination node, as shown below:

$$Average\ Delay\ = \frac{TR - TS}{R} \qquad (5)$$

where *TR* refers to time of data packet received, *TS* refers to time of data packet sent, and *R* refers to the number of data packet received.

- ***Normalized Routing Load (NRL):*** The proportion of the number of control routing packets that are sent from the source node to the number of data packets that are received at the destination node, as shown in:

$$Normalized\ Routing\ Load\ (NRL)\ = \frac{C}{R} \qquad (6)$$

where *C* refers to the number of control routing packets sent and *R* refers to number of data packet received.

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 Dense and Sparse topologies along with the performance metrics and different traffic source numbers.

1. Dense Topology

Figures from 3 to 5 represent the performance metrics (NRL, PDR and Average Delay) for (CBRP, AODV and AOMDV) routing protocols for 50 nodes Dense topology (1000x1000) with 10 and 40 traffic sources.

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.

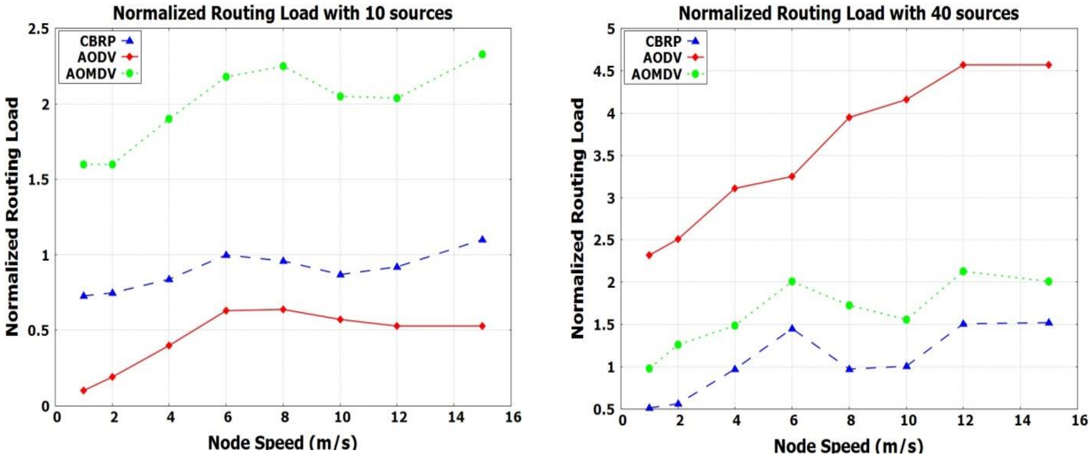

Figure 3. Normalized Routing Load for 50 nodes with 10 and 40 sources for Dense Topology

Figure 4 reveals that PDR in AOMDV protocol is higher than the other two protocols (AODV and CBRP) with 40 sources and lower PDR with 10 sources. Figure 5 shows that AOMDV is better than the other protocols in terms of Delay, where AOMDV has the lowest Delay for all traffic sources (10 and 40).

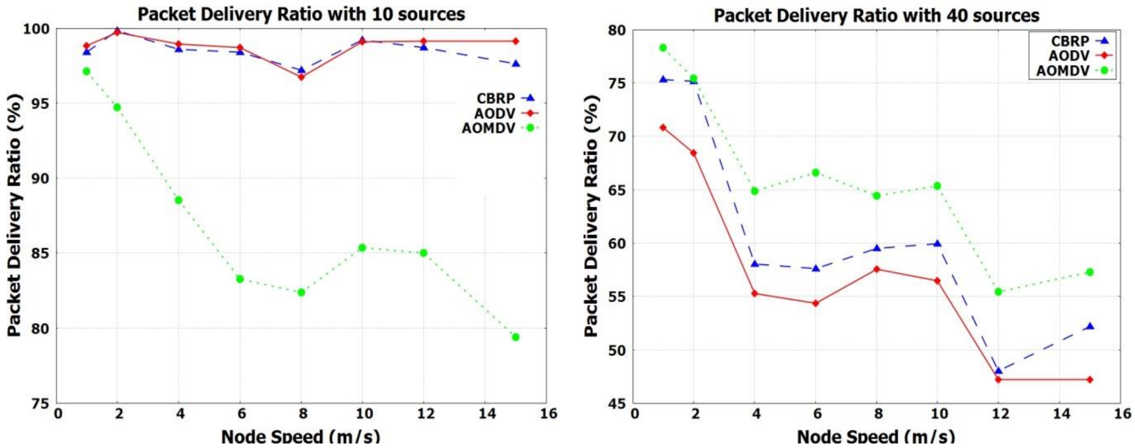

Figure 4. Packet Delivery Ratio for 50 nodes with 10 and 40 sources for Dense Topology

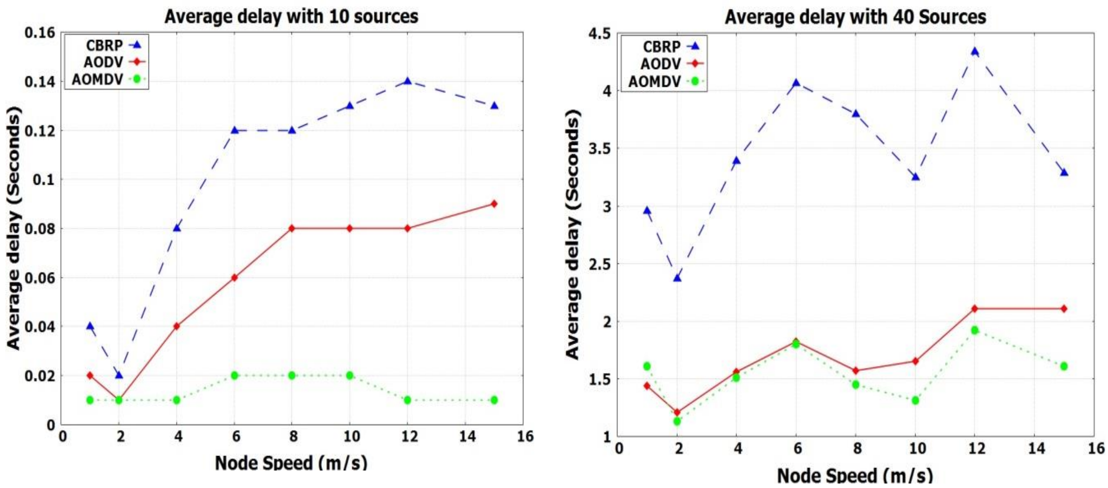

Figure 5. Average Delay for 50 nodes with 10 and 40 sources for Dense Topology

2. Sparse Topology

Figures 6 to 8 show the performance metrics (NRL, PDR and Delay) for CBRP, AODV and AOMDV protocols for 50 nodes-Sparse topology (1500x1500) and traffic sources (10 and 40). Figure 6 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.

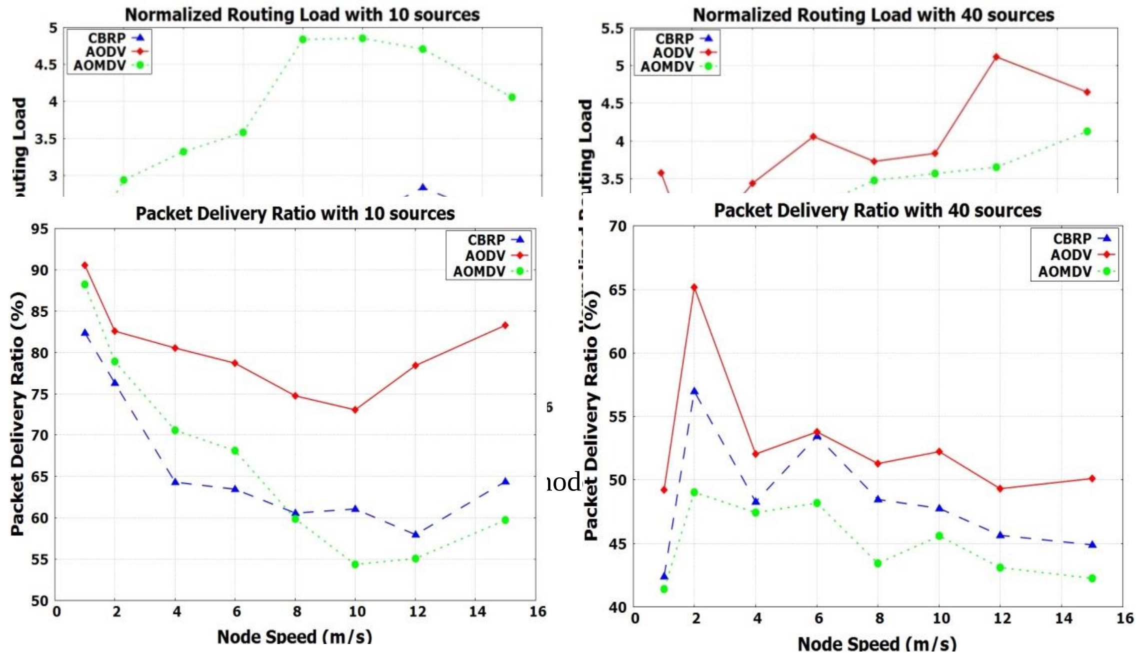

Figure 7. Packet Delivery Ratio for 50 nodes with 10 and 40 sources for Sparse Topology

Figure 7 shows that PDR in AODV protocol is higher than the other two protocols (CBRP and AOMDV) with 10 sources whereas AOMDV has the highest PDR with 40 sources. Figure 8 shows that AOMDV performs well in terms of Delay where AOMDV has lower delay with 10 sources and slightly lower delay with 40 sources, whereas CBRP has the highest Delay for both (10 and 40) sources.

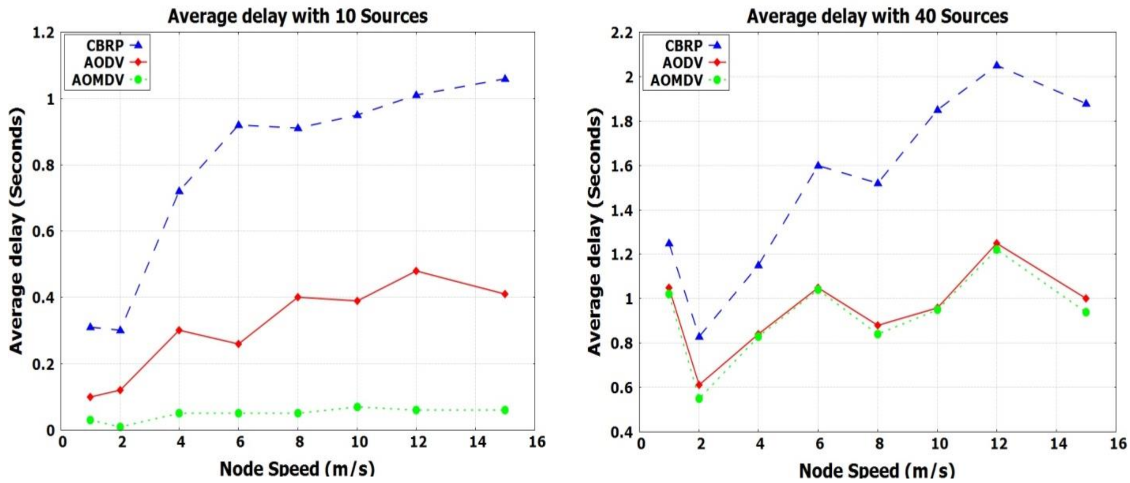

Figure 8. Average Delay for 50 nodes with 10 and 40 sources for Sparse Topology

CONCLUSION

This paper evaluated the performance of single-path (CBRP and AODV) and multipath (AOMDV) MANETs routing protocols in both Dense and Sparse network topologies. The experiment simulation results show that in Dense topology AOMDV protocol is better than both AODV and CBRP in terms of Delay at different traffic sources, and that AOMDV has better PDR with 40 sources. The results also reveal that AODV has the lowest NRL with 10 sources and has the highest NRL with 40 sources.

In Sparse topology, AOMDV is better than both CBRP and AODV in terms of Delay, where AOMDV has lower delay with 10 sources and slightly lower delay with 40 sources; whereas AODV is better than both AOMDV and CBRP in terms of PDR with all traffic sources. Also, AODV has the lowest NRL with 10 sources and has the highest NRL with 40 sources. Thus, it can be concluded that the node density in MANET has effects on the performance of AODV, AOMDV and CBRP protocols, where the performance of these protocols in Dense network is better than the performance of these protocols in Sparse network. It can also be concluded that AODMV protocol is the best in the Delay in both Dense and Sparse topologies. For additional study, we will plan to study the efficient performance for CBRP, AODV and AOMDV protocols in MANETs with non-uniform node density using NS3 simulator.

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