PERFORMANCE EVALUATION OF AOMDV PROTOCOL BASED ON VARIOUS SCENARIO AND TRAFFIC PATTERNS

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ABSTRACT

A MANET is an interconnection of mobile devices by wireless links, which forms a dynamic topology. Routing protocols play a vital role in transmission of data across the network. The two major classifications of routing protocols are unipath and multipath. In this paper, we have evaluated the performance of a widely used on-demand multipath routing protocol called AOMDV. This protocol has been selected due to its edge over other protocols in various aspects, such as reducing delay, routing load etc. The evaluation of AOMDV protocol is carried out in terms of four scenario patterns such as RWM, RPGM, MGM, and GMM in two different traffic patterns such as CBR and TCP using NS2 and Bonn Motion.

KEYWORDS

MANET, unipath, multipath, AOMDV, RWM, RPGM, MGM, GMM, CBR, TCP, scenario patterns and traffic patterns.

1. INTRODUCTION

1.1. Mobile Ad Hoc Networks

Mobile Ad hoc NETwork (**MANET**) is an interconnection of mobile devices by wireless links. It does not need much physical infrastructure such as routers, servers, access points or cables. Each mobile device functions as router as well as node. The most important characteristics of MANET are i) Dynamic topologies ii) Bandwidth-constrained links iii) Energy constrained operation and iv) limited physical security [7]. The various applications of MANETs are: *i) military* - communication among soldiers in enemy environments, *ii) personal area network* - printers, PDA, mobile phones, *iii) business indoor application* - meetings, symposium, demos, *iv) civilian outdoor application* - taxis, cars, sport stadiums, *v) emergency application* - emergency rescue operations, police, and earthquakes, and *vi) home intelligence devices*.

DOI : 10.5121/ijcsea.2011.1603

1.2. Routing Protocols

To have communication within the network, a routing protocol is used to discover routes between nodes. The primary goal of such ad-hoc network routing protocol is to establish correct and efficient route between a pair of nodes so that messages may be delivered in a timely manner. Route construction should be done with a minimum of overhead and bandwidth consumption. The two major classifications of MANET routing protocols are unipath and multipath routing protocols.

1.2.1. Unipath Routing Protocols

The unipath routing protocols [1] discover a single route between a pair of source and destination. A new route discovery is required in response to every route break which leads high overhead and latency. The two components of unipath routing protocols are *i) Route Discovery:* finding a route between a source and destination. *ii) Route Maintenance:* repairing a broken route or finding a new route in the presence of a route failure. The most commonly used unipath routing protocols are ***Ad Hoc On-demand Distance Vector*** (AODV) [6], ***Dynamic Source Routing*** (DSR) [6], and ***Destination Sequenced Distance Vector*** (DSDV) [6].

1.2.2. Multipath Routing Protocols

The multipath routing protocols [1] discover multiple routes between a pair of source and destination in order to have load balancing to satisfy Quality of Service (QoS) requirements. The three main components of multipath routing protocols are *i) Route Discovery:* finding multiple nodes disjoint, links disjoint, or non-disjoint routes between a source and destination. *ii) Traffic Allocation:* Once the route discovery is over, the source node has selected a set of paths to the destination and then begins sending data to the destination along the paths. *iii) Path Maintenance:* regenerating paths after initial path discovery in order to avoid link/node failures that happened over time and node mobility.

The benefits of the multipath routing protocols are *i) Fault tolerance:* Being redundant information routed to the destination via alternative paths it reduces the probability of the disruption of communication in case of link failures, *ii) Load Balancing:* selecting diverse traffic through alternative paths in order to avoid congestion in links**,** *iii) Bandwidth aggregation:* Splitting the data into multiple streams and then each of which has routed through a different path to the same destination. Hence the effective bandwidth can be aggregated and *iv) Reduced delay:* In the unipath routing protocols, the path discovery process needs to be initiated to find a new route in order to avoid a route failure and this leads to high route discovery delay. This delay is minimized in multipath routing protocols by backup routes that have been identified in route discovery process. The most recently used multipath algorithms are ***Temporarily-Ordered Routing Algorithm*** (TORA) [3], **Split Multipath Routing** (SMR) [3], ***Multipath Dynamic Source Routing*** (MP-DSR) [1], ***Ad hoc On-demand Distance Vector-Backup Routing*** (AODV-BR)[3] and ***Ad Hoc On-Demand Multipath Distance Vector Routing (***AOMDV) [3].

The ***AOMDV*** protocol is widely used in mobile communication because of its edge over other protocols in various aspects, such as reducing delay, routing load [1,3] etc. It is an on-demand multipath routing protocol – starts a route discovery procedure when needed for **MANET**. We evaluate its performance in terms of different mobility models such as ***Random Way point Mobility*** (RWM), ***Reference Point Group Mobility*** (RPGM), ***Manhattan Grid Mobility*** (MGM) and ***Gauss-Markov Mobility*** (GMM) and also different traffic patterns such as CBR and TCP traffic patterns. To analyze these protocols, traffic patterns and mobility models are essential and are discussed in subsequent sections.

The rest of this paper is organized as follows: In section 2, the characteristics of traffic patterns are discussed; in section 3 the various mobility models are described; in section 4, the functionality of AOMDV protocol is given; in section 5 the simulation model is discussed; in section 6 the performance metrics are described; in section 6 the experimental results are discussed and finally in section 7 the conclusion is given.

2. TRAFFIC PATTERNS

Traffic Patterns describe how the data is transmitted from source to destination. The two types of traffic patterns employed in MANET are CBR and TCP Traffic patterns.

2.1. CBR Traffic Pattern

The qualities of **Constant Bit Rate** (CBR) traffic pattern [2,14] are *i) unreliable:* since it has no connection establishment phase, there is no guarantee that the data is transmitted to the destination, *ii) unidirectional:* there will be no acknowledgment from destination for confirming the data transmission and *iii) predictable:* fixed packet size, fixed interval between packets, and fixed stream duration.

2.2. TCP Traffic pattern

The qualities of **Transmission Control Protocol** (TCP) traffic pattern [2,14] are *i) reliable:* since connection is established prior to transmitting data, there is a guarantee that the data is being transmitted to the destination, *ii) bi-directional:* every packet that has to be transmitted by the source is acknowledged by the destination, and *iii) conformity:* there will be flow control of data to avoid overloading the destination and congestion control exists to shape the traffic such that it conforms to the available network capacity [2]. Today more than 95% of the Internet protocol traffic is carried out through TCP.

3. MOBILITY MODELS

Mobility models describe the movement pattern of the mobile users, their location; velocity and acceleration [4,12]. They play a vital role in determining the performance of a protocol and also differentiated in terms of their spatial and temporal dependencies. i) Spatial dependency is a measure of how two nodes are dependent in their motion. When the two nodes are moving in the same direction, then they have high spatial dependency. ii) Temporal dependency is a measure of how current velocity (magnitude and direction) are related to previous velocity. The two nodes are having the same velocity and direction means that they have high temporal dependency. The commonly used mobility models are **RWM, RPGM, MGM and GMM**.

3.1. Random Way point Mobility (RWM)

RWM [4] model is the commonly used mobility model in which every node randomly chooses a destination and moves towards it from a uniform distribution $(0, V_{max})$ at any moment of time, where V_{max} is the maximum allowable velocity for every node. Each node stops for a duration defined by the ***'pause time'*** parameter when it reaches the destination. After the pause time it again chooses a random destination and repeats the whole process until the end of the simulation.

3.2. Reference Point Group Mobility (RPGM)

The military battlefield communication uses **RPGM** [4] model in which each group has a logical center called **Group Leader** (GL) for determining the group's motion behavior. Each node in this mobility deviates from its velocity (both magnitude and direction) from that of the leader is calculated as follows:

$$|V_M(t)| = |V_L(t)| + random() * SDR * S_{MAX} \rightarrow (1)$$
$$|\theta_M(t)| = |\theta_L(t)| + random() * ADR * A_{MAX} \rightarrow (2),$$

where V_M and V_L are the magnitude of member and leader respectively, θ_M and θ_L are direction of member and leader respectively, S_{MAX} and A_{MAX} are maximum speed and angle respectively, 0 < ADR and SDR < 1, **SDR** is the **Speed Deviation Ratio** and **ADR** is the **Angle Deviation Ratio**. SDR and ADR employed to control the deviation of the velocity of group members from that of the leader.

3.3. Manhattan Grid Mobility (MGM)

MGM [4] models are very useful to emulate the movement pattern of mobile nodes on streets. This is sometimes called **Urban Area (UR)** model. It forms a number of horizontal and vertical streets like a grid called maps. Each mobile node can be allowed to move along the grid of horizontal and vertical streets on the map. It provides a pervasive computing service between portable devices.

3.4. Gauss-Markov Mobility (GMM)

GMM [4] models adopt different levels of randomness through one tuning parameter. In which each mobile node is initialized by a particular speed and direction. The movement updates the speed and direction of each mobile node in a fixed interval of time ***n***. The value of speed and direction of the ***n^th^*** instance is calculated based on the value of speed and direction of the ***(n-1)^th^*** instance as follows:

$$s_n = \alpha s_{n-1} + (1-\alpha) s + \sqrt{(1-\alpha^2)} s \ X_{n-1} \rightarrow (3)$$
$$d_n = \alpha d_{n-1} + (1-\alpha) d + \sqrt{(1-\alpha^2)} d \ X_{n-1} \rightarrow (4),$$

where s_n and d_n are the new speed and direction of the mobile node at interval n, α is the tuning parameter to vary the randomness such that $0 \leq \alpha \leq 1$, s and d are constants of representing speed and direction as $n \rightarrow \alpha$, and $d \ X_{n-1}$ are random variable derived from Gaussian distribution. The random values are obtained by setting $\alpha = 0$ and the linear motion is obtained by setting $\alpha = 1$. The intermediate randomness is obtained by varying α between 0 and 1 and the new position of the mobile node is calculated as follows:

$$x_n = x_{n-1} + s_{n-1} \cos(d_{n-1}) \rightarrow (5)$$
$$y_n = y_{n-1} + s_{n-1} \cos(d_{n-1}) \rightarrow (6),$$

where (x_n, y_n) and (x_{n-1}, y_{n-1}) are the x and y coordinates of the mobile node positions at nth and $(n-1)$ th time intervals respectively.

4. AD HOC ON-DEMAND MULTIPATH DISTANCE VECTOR ROUTING (AOMDV)

The AODV [6] protocol starts a route discovery process through a route request (RREQ) to the destination throughout the network. Once a non-duplicate RREQ is received, the intermediate node records the previous hop and checks for a valid and fresh route entry to the destination. The node sends a route reply (RREP) along with a unique sequence number to the source. On updating the route information, it propagates the route reply and gets additional RREPs if a RREP has either a larger destination sequence number (fresher) or a shorter route found.

To eliminate the occurrence of frequent link failures and route breaks in highly dynamic ad hoc networks, AOMDV has been developed from a unipath path on-demand routing protocol AODV.

The AOMDV [1,3,13] protocol finds multiple paths and this involves two stages which are as follows: i) A route update rule establishes and maintains multiple loop-free paths at each node, and ii) A distributed protocol finds link-disjoint paths.

The AOMDV protocol finds node-disjoint or link-disjoint routes between source and destination. Link failures may occur because of node mobility, node failures, congestion in traffic, packet collisions, and so on. For finding node-disjoint routes, each node does not immediately reject duplicate RREQs. A node-disjoint path is obtained by each RREQ, arriving from different neighbor of the source because nodes cannot broadcast duplicate RREQs. Any two RREQs arriving at an intermediate node through a different neighbor of the source could not have traversed the same node. To get multiple link-disjoint routes, the destination sends RREP to duplicate RREQs regardless of their first hop. For ensuring link-disjointness in the first hop of the RREP, the destination only replies to RREQs arriving through unique neighbors. The RREPs follow the reverse paths, which are node-disjoint and thus link-disjoint after the first hop. Each RREP intersects at an intermediate node and also takes a different reverse path to the source to ensure link-disjointness.

5. SIMULATIONS MODEL

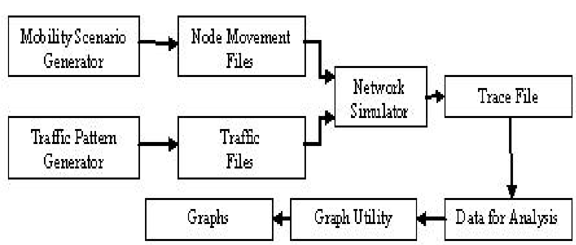

Figure 1. Overview of the simulation model

The performance of **AOMDV** is evaluated in terms of Scenario and Traffic patterns using NS 2 [5,8] and Bonn Motion [11]. The following Figure 1. illustrates the simulation model [18] and the simulation parameters are described in Table 1.

The result of simulation is generated as trace files and the awk & perl scripts are used for report generation.

Table 1. Simulation Parameters

Parameter	Value
Simulator	NS-2.34
MAC Type	802.11
Simulation Time	100 seconds
Channel Type	Wireless Channel
Routing Protocol	AOMDV
Antenna Model	Omni
Simulation Area	1520 m x 1520 m
Traffic Type	CBR(udp), TCP(ftp)
Data Payload	512 bytes/packet
Network Loads	4 packets/sec
Radio Propagation Model	TwoRayGround
Interface Queue Length	50
Interface Queue Type	DropTail/PriQueue
Number of nodes	25,50,75,100
Interval	1000 sec
Mobility Model	Random Way point Mobility, Reference Point Group Mobility, Manhattan Grid Mobility, Gauss-Markov Mobility

6. PERFORMANCE METRICS

Performance Metrics [9,15,16] are quantitative measures that can be used to evaluate any **MANET** routing protocol. We considered the following six metrics in order to evaluate the multi path on-demand routing protocol **AOMDV** in terms of four different scenarios such as **RWM, RPGM, MGM** and **GMM** and also two different traffic patterns such as CBR and TCP traffic patterns.

6.1. Packet Delivery Fraction (PDF)

PDF is the ratio of data packets delivered to the destination to those generated by the sources and is calculated as follows:

$$Packet\ Delivery\ Fraction = \frac{Number\ of\ Packets\ Received}{Number\ of\ Packets\ Sent}\ x\ 100.$$

6.2. Average Throughput

Average Throughput [17] is the number of bytes received successfully and is calculated by

$$Average\ Throughput = \frac{Number\ of\ bytes\ received\ x\ 8}{Simulation\ time\ x\ 1000}\ kbps.$$

6.3. Routing Overhead

Routing overhead is the total number of control packets or routing packets generated by routing protocol during simulation and is obtained by

$$Routing\ Overhead = Number\ of\ RTR\ packets.$$

6.4. Normalized Routing Overhead

Normalized Routing Overhead is the number of routing packets transmitted per data packet towards destination and calculated as follows:

$$Normalized\ Routing\ Overhead = \frac{Number\ of\ Routing\ Packets}{Number\ of\ Packets\ Received}.$$

6.5. Average End-to-End Delay (Average e2e delay)

Average End-to-End [10] delay is the average time of the data packet to be successfully transmitted across a MANET from source to destination. It includes all possible delays such as buffering during the route discovery latency, queuing at the interface queue, retransmission delay at the MAC (Medium Access Control), the propagation and the transfer time. The average e2e delay is computed by,

$$D = \frac{\sum_{i=1}^{n}(R_i - S_i)}{n}\ m\sec,$$

where D is the average end-to-end delay, *n* is the number of data packets successfully transmitted over the MANET, $'i'$ is the unique packet identifier, R_i is the time at which a packet with unique identifier $'i'$ is received and S_i is the time at which a packet with unique identifier $'i'$ is sent. The Average End-to-End Delay should be less for high performance.

6.6. Packet Loss

Packet Loss is the difference between the number of data packets sent and the number of data packets received. It is calculated as follows:

$$Packet\ Loss = Number\ of\ data\ packets\ sent - Number\ of\ data\ packets\ received.$$

7. RESULTS AND DISCUSSION

The performance evaluation of AOMDV protocol is tested in terms of CBR and TCP traffics for different count of nodes namely 25, 50, 75, and 100 under four different scenarios (MANET environments) and the results are as follows:

7.1. Packet Delivery Fraction

Table 2. Packet Delivery Fraction (%)

No.of Nodes	Random Way point Mobility		Reference Point Group Mobility		Manhattan Grid Mobility		Gauss-Markov Mobility	
	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic
25	26.4838	98.672	92.3698	99.1337	17.1023	99.3025	6.42408	92.1907
50	91.926	98.461	56.5843	99.281	81.4465	99.6809	24.4066	99.356
75	87.9534	98.9128	99.9552	99.2748	68.24	98.4355	87.7569	95.9479
100	69.3412	97.5973	83.0721	99.4681	51.7682	99.1142	53.1239	98.209

Figure 2.1 and Figure 2.2 shows the delivery rate of the data packets of this protocol is some what significant in CBR traffic in RWM model. However, it is more significant in TCP traffic in RPGM model (More than 99 percent irrespective of number of nodes).

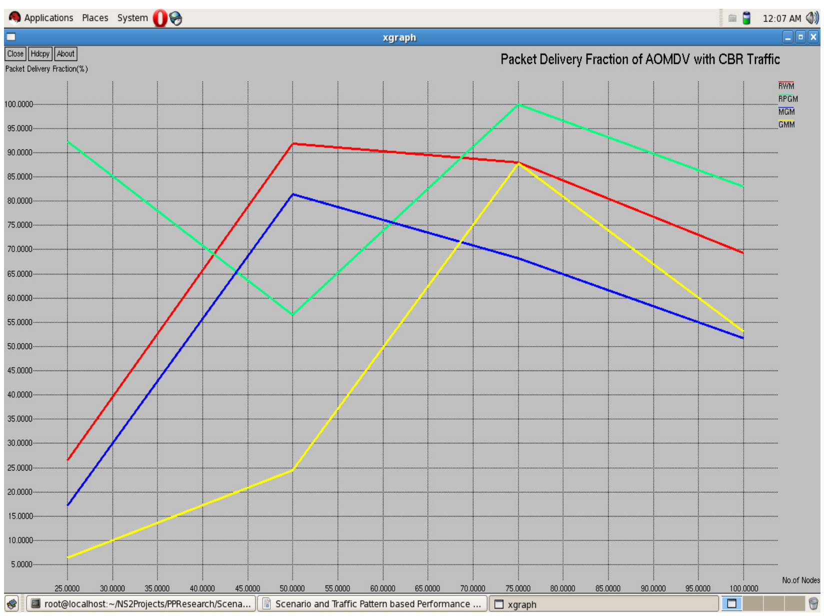

Figure 2.1. Packet Delivery Fraction of AOMDV with CBR Traffic

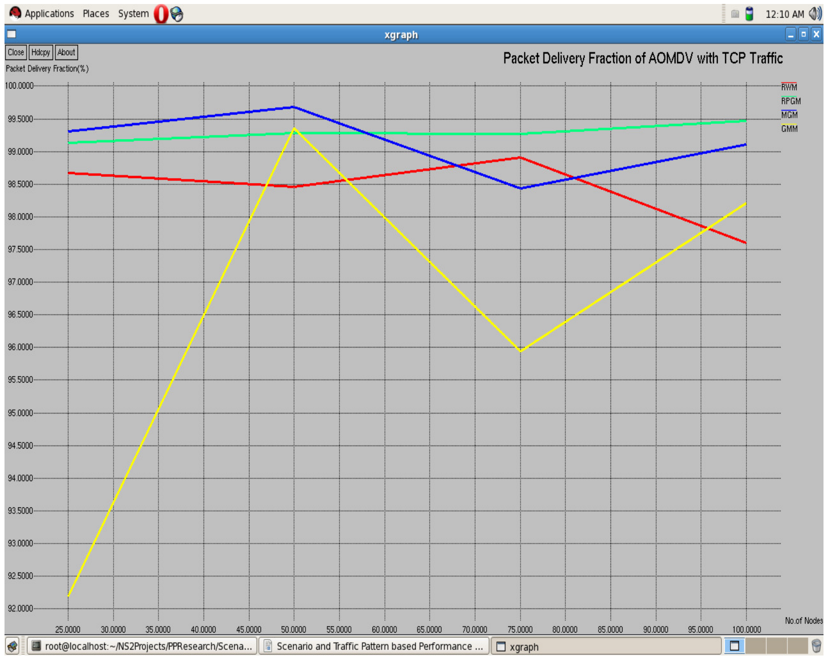

Figure 2.2. Packet Delivery Fraction of AOMDV with TCP Traffic

7.2. Average End to End Delay

No.of Nodes	Random Way point Mobility		Reference Point Group Mobility		Manhattan Grid Mobility		Gauss-Markov Mobility	
	CBR Traffic	**TCP Traffic**	**CBR Traffic**	**TCP Traffic**	**CBR Traffic**	**TCP Traffic**	**CBR Traffic**	**TCP Traffic**
25	0.689685	46.6322	12.9071	150.799	13.453	84.74	1.43374	0
50	35.303	102.126	2.90924	122.038	12.4105	9.14614	0.615091	101.84
75	58.8229	46.8142	45.9368	50.1088	60.1209	1576.36	68.8816	133.305
100	93.9716	72.9806	41.2503	40.4549	565.213	91.4236	630.539	1554.73

Table 3. Average End to End Delay (in ms)

Figure 3.1 and Figure 3.2 shows the end-to-end delay of this protocol is more significant in both CBR and TCP traffics in RPGM model.

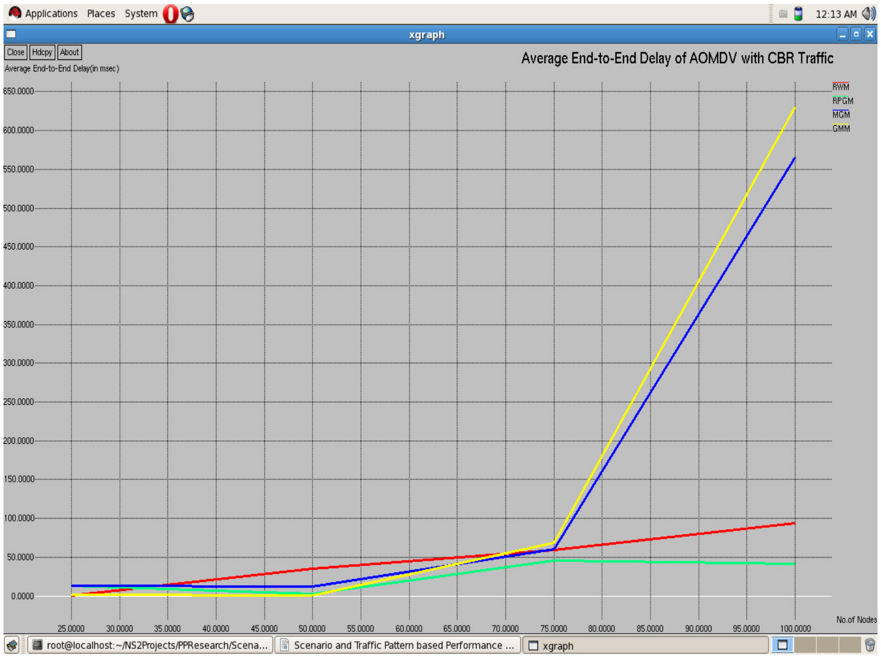

Figure 3.1. Average End-to-End Delay of AOMDV with CBR Traffic

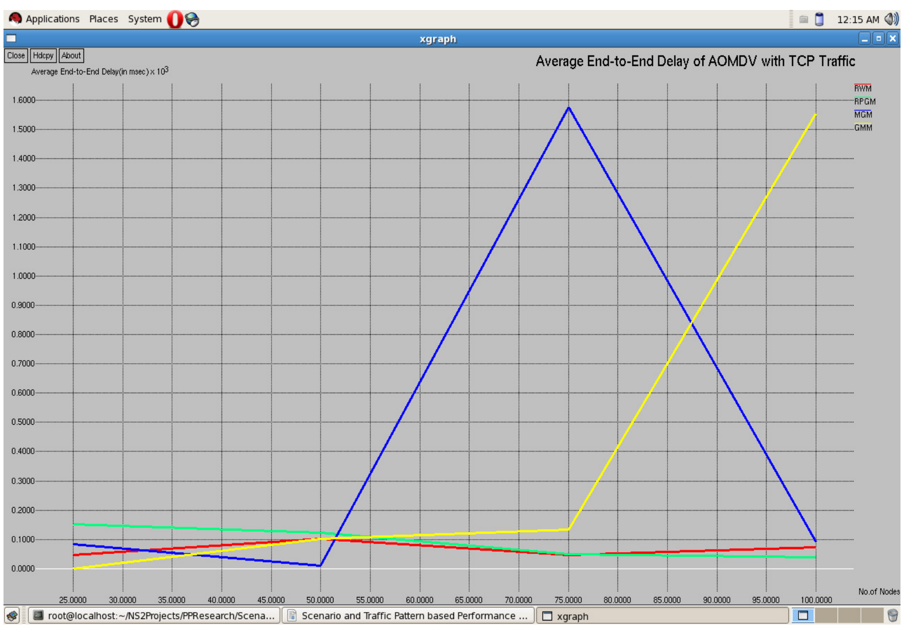

Figure 3.2. Average End-to-End Delay of AOMDV with TCP Traffic

7.3. Average Throughput

Table 4. Throughput (in kbps)

No.of Nodes	Random Way point Mobility		Reference Point Group Mobility		Manhattan Grid Mobility		Gauss-Markov Mobility	
	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic
25	24.13	273.67	84.32	468.39	15.84	355.64	10.4	65.74
50	83.49	348.21	51.57	757.62	74.27	908.06	22.33	499.11
75	80.45	216.96	91.31	745.44	62.22	314.05	80.47	162.45
100	154.37	367.34	184.55	895.97	114.56	494.42	118.43	269.08

Figure 4.1 and Figure 4.2 shows the average throughput of this protocol is more significant in both CBR and TCP traffics in RPGM model. However, it is some what significant in both CBR and TCP traffics in RWM model.

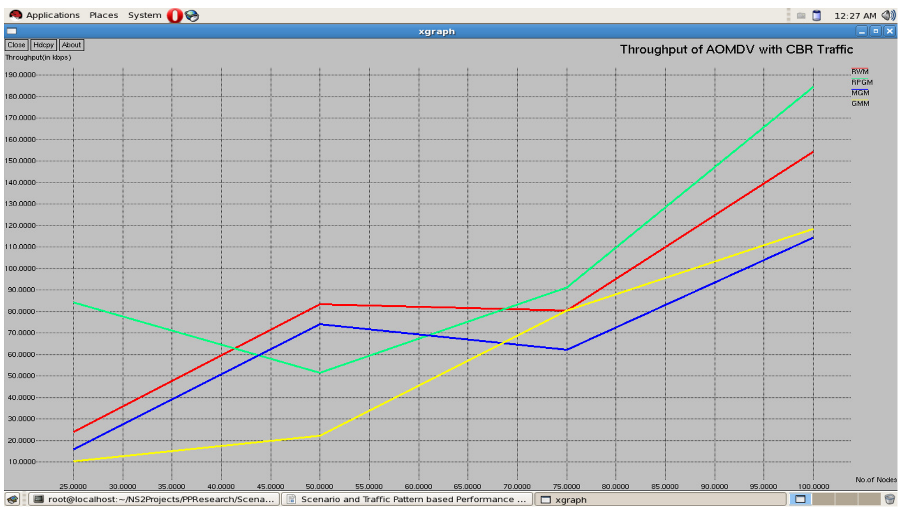

Figure4.1. Throughput of AOMDV with CBR Traffic

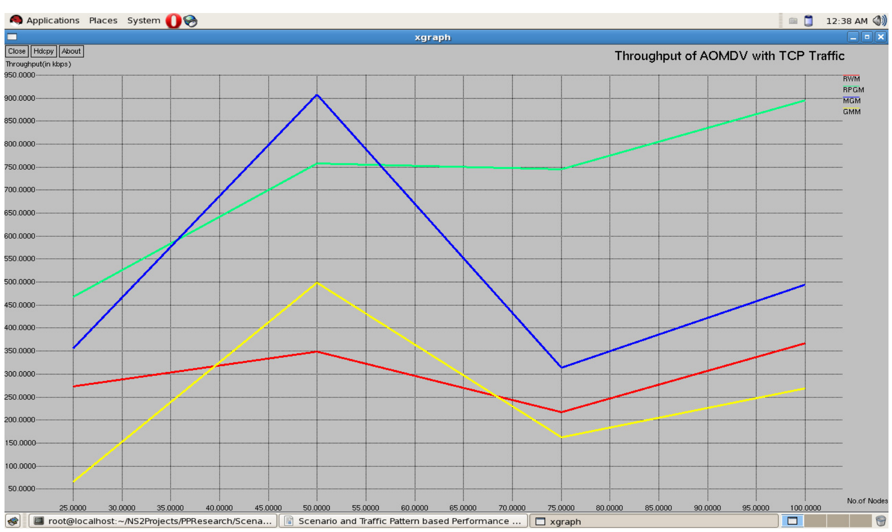

Figure 4.2. Throughput of AOMDV with TCP Traffic

7.4. Packet Loss

Table 5. Packet Loss (in pkts)

No.of Nodes	Random Way point Mobility		Reference Point Group Mobility		Manhattan Grid Mobility		Gauss-Markov Mobility	
	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic
25	1635	90	170	100	1871	61	2083	77
50	179	133	966	134	413	71	1688	79
75	269	58	1	133	707	122	274	168
100	1666	221	918	117	2605	108	2551	120

Figure 5.1 and Figure 5.2 shows the Packet Loss of this protocol is significant in CBR Traffic in RPGM model and in TCP Traffic in MGM model.

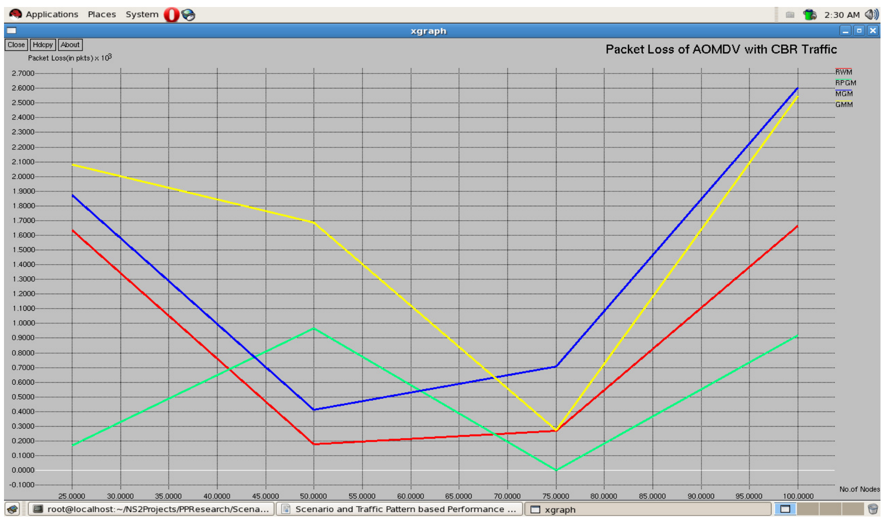

Figure 5.1. Packet Loss of AOMDV with CBR Traffic

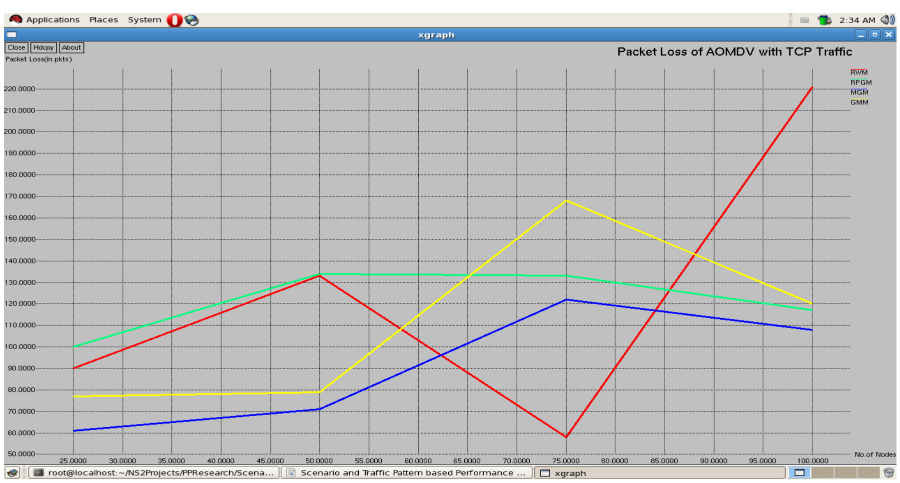

Figure 5.1. Packet Loss of AOMDV with TCP Traffic

7.5. Routing Overhead

Table-6: Routing Overhead (in pkts)

No.of Nodes	Random Way point Mobility		Reference Point Group Mobility		Manhattan Grid Mobility		Gauss-Markov Mobility	
	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic
25	1568	57	152	4	1757	49	1953	73
50	174	36	933	15	410	19	1627	28
75	250	49	0	15	680	92	264	120
100	1112	176	876	8	2084	95	1722	107

Figure 6.1 and Figure 6.2 shows the Routing Overhead of this protocol is low in both CBR and TCP traffics in RPGM model. However, it is some what high in both CBR and TCP traffics in RWM model.

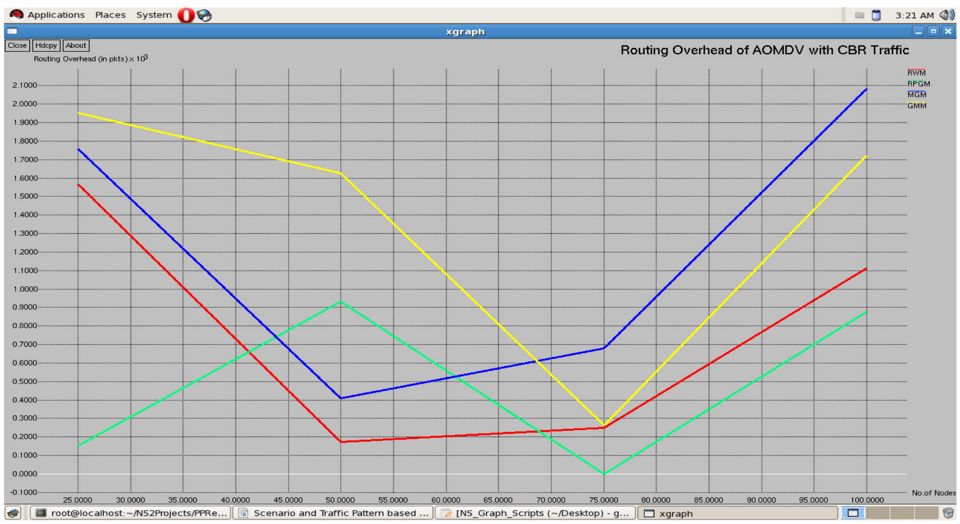

Figure 6.1. Routing Overhead of AOMDV with CBR Traffic

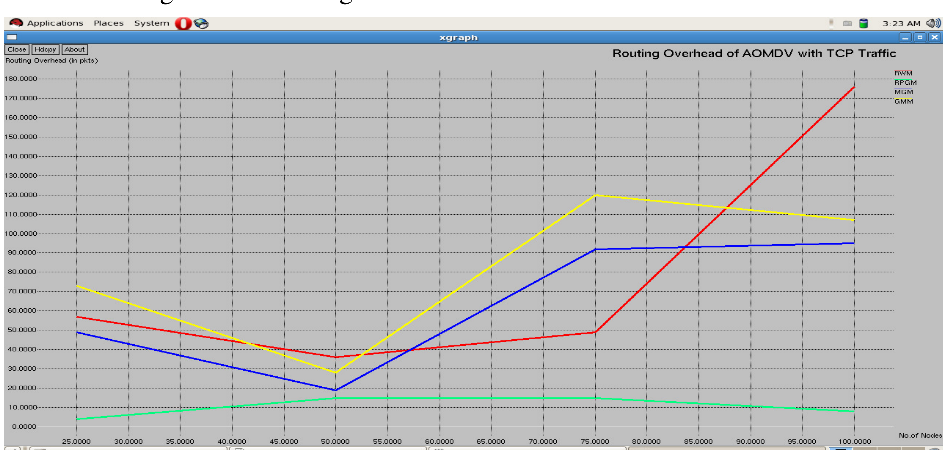

Figure 6.2. Routing Overhead of AOMDV with TCP Traffic

7.6. Normalized Routing Overhead

Table 6. Normalized Routing Overhead

No.of Nodes	Random Way point Mobility		Reference Point Group Mobility		Manhattan Grid Mobility		Gauss-Markov Mobility	
	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic	CBR Traffic	TCP Traffic
25	2.66214	0.008524	0.0738581	0.000349559	4.55181	0.00564256	13.6573	0.080308
50	0.0853778	0.0042308	0.741064	0.000810723	0.226145	0.000856628	2.98532	0.0022973
75	0.127291	0.0092856	0	0.000823859	0.447663	0.0119854	0.13442	0.0301659
100	0.295117	0.0196057	0.194451	0.000365614	0.745351	0.00786164	0.595642	0.0162614

Figure 7.1 and Figure 7.2 shows the Normalized Routing Overhead of this protocol is low in both CBR and TCP traffics in RPGM model. However, it is some what high in both CBR and TCP traffics in RWM model.

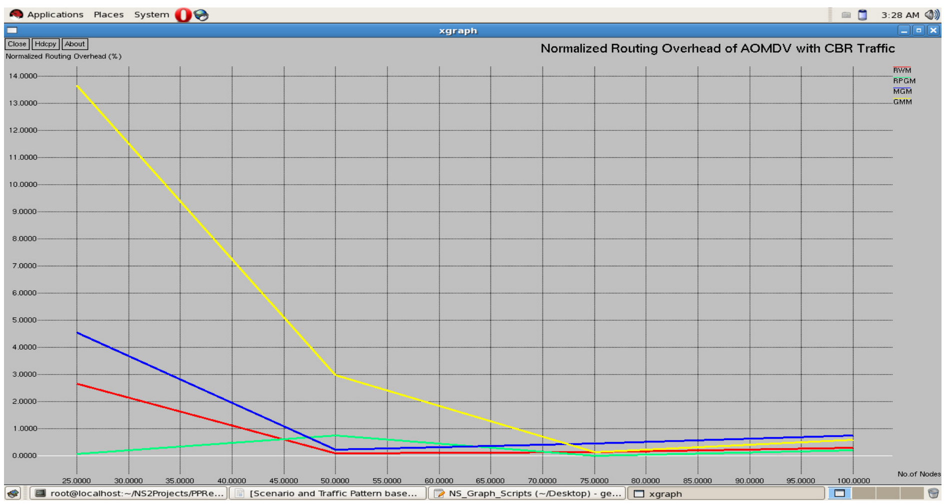

Figure 7.1. Normalized Routing Overhead of AOMDV with CBR Traffic

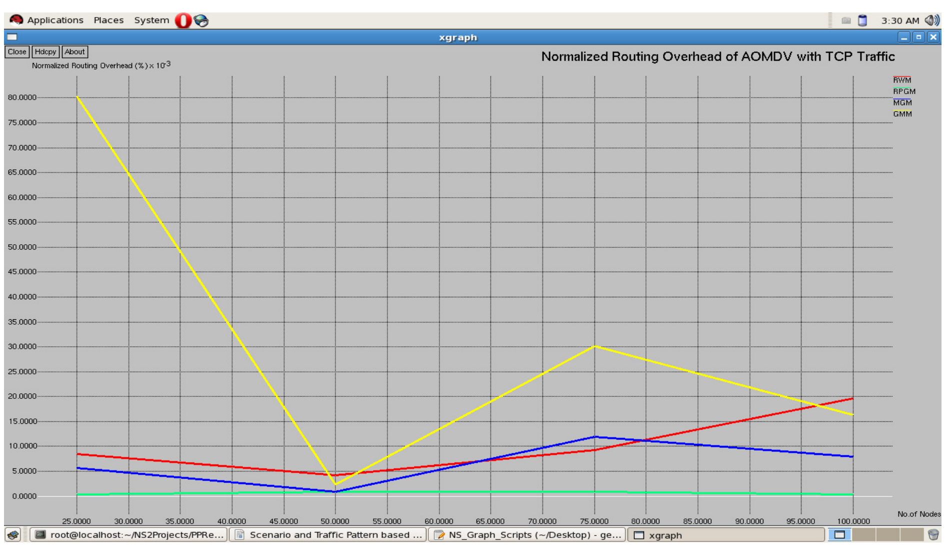

Figure 7.2. Normalized Routing Overhead of AOMDV with TCP Traffic

8. CONCLUSION

In both CBR traffic and TCP traffic, the AOMDV gives significant performance in RPGM model. Due to randomness in mobility among mobile nodes, the RWM model is widely used in MANETs. We have selected AOMDV for evaluation due to its edge over other protocols.

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