Performance Evaluation of Gauss-Markov Mobility Model in Mobile Ad-hoc Networks

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Abstract— *The mobility and node density is the fundamental characteristic which differentiates MANETs from other wireless or wired network. A Mobile Ad Hoc Network (MANET) is a continuously self-configuring network without infrastructure, where every node functions as a transmitter, router, and data sink. The main aim to design MANET routing protocols to adaptively cater for dynamic changes in topology while maximizing packet delivery ratio and, throughput and minimizing delay, packet overhead, and minimum packet drop rate. NS2 network simulator is used to implement MANET by using Destination-Sequenced Distance Vector (DSDV), Ad Hoc Demand Vector (AODV), and Dynamic Source Routing (DSR) by using mobility generator tool, Bonnmotion-3.0.1 in this paper. The effect of mobility and mobility models of nodes changing in MANET is investigated and compared some reactive and proactive routing protocols including AODV, DSR, and DSDV. The simulated study on Gauss-Markov mobility model aim to analyze the performance of current MANET routing protocols. This paper compares mobility model on AODV, DSDV, and DSR routing protocols with QoS performance metrics throughput, packet delivery ratio, end to end delay, packet overhead and packet dropping rate.*

Keywords— MANET, AODV, DSDV, DSR, Gauss-Markov

I. INTRODUCTION

A Mobile Ad hoc Network (MANET) is a collection of wireless mobile nodes forming a self-configuring network without using any existing infrastructure. Rather than all the parameters, mobility and mobility models play a very substantial role in actuating the performance of routing protocols in MANET. Mobility models characterize the movement pattern of MANET nodes, and each routing protocols exhibits specific characteristics of these models. The performance of MANET routing protocols needs to be analyzed at node density, node speeds, traffic nodes, as well as network size to find the most adaptive and efficient routing protocol for dynamic MANET topologies. If the mobile node moves out of range during receiving and forwarding of packets, the mobility influences ongoing transmissions. Challenging issues in MANET includes limited bandwidth, energy constraints, high cost, and security. The desired challenges in MANET includes unreliability of wireless links between nodes, dynamic topologies, threats from malicious nodes inside the network, lacking firm boundaries, requiring centralized management facility, restricted power supply, and scalability [i.e Kour et al., 2015]. Security issues are also there like attacks, session hijacking, eavesdropping, jamming, Denial of Service, etc. [i.e. Murthy et al., 2004]. In section 2, research methodology of paper is discussed along with brief overview of MANET routing protocols and mobility models, Section 3 covers the result from performance metrics, and finally, in section 4, results are concluded.

II. RESEARCH METHODOLOGY

A key component to the design of any Wireless network system is a thorough knowledge and understanding of the factors that influence the specific network for which the routing protocol is intended. The literature study also includes an investigation into available mobile ad hoc network mobility models, in order to identify common problems faced by these models as well as taking into consideration the specific requirements of mobile ad hoc networks and the common flaws of available models. The existing models will be simulated to verify its functionality and compared, in simulation, to verify its improvement in network lifetime over existing models. There will be an Extensive Literature Survey, study and analysis of advance issues and concepts of Mobility efficiency, localization and Routing in Mobile ad hoc network by going through the IEEE transactions, journals, conference papers, Ph.D. Dissertations and books etc. Mathematical modeling will connect various parameters like mobility speed, locationization, routing aspects with respect to standard mathematical notation. At last, performance Evaluation of mobility models over routing protocols will be done and compilation of results and to draw conclusions.

MANET routing protocols are Internet Protocol (IP) based and may use unicast, multicast or hybrid approaches and may act as regular wired IP services rather than being regarded as an entirely separate entity. Figure 1 shows the classification of different routing protocols of MANET based on proactive, reactive and hybrid approaches

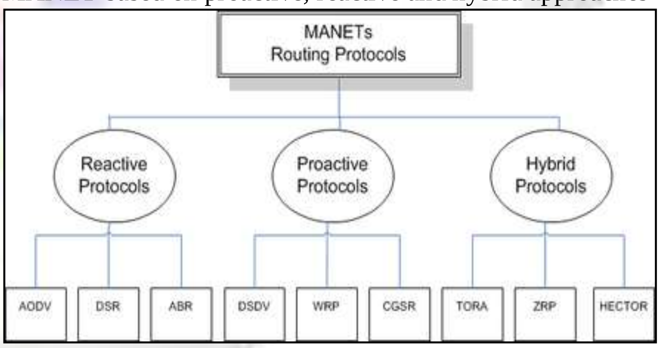

Fig. 1: Proactive, Hybrid, and Reactive Routing Protocols in MANET

Ad-hoc on Demand Distance Vector (AODV) is a category of reactive protocol that requests for a route only when it needs and does not require that the mobile nodes maintain routes to destinations that are not communicating. AODV guarantees loop-free paths by using sequence numbers that indicate how new, or fresh, a route is. Each node has a routing table containing one route entry for each destination. Each route entry keeps track of some areas such as Destination IP Address, Destination sequence number, Next Hop, and Hop Count. Three control messages are broadcast by AODV on the network to establish a path from source to destination: Route Request (RREQ), Route Reply (RREP), and Route Error (RERR). By the use of sequence numbers, the nodes of origin are always able to find new valid paths [i.e. Roopa Devi et al., 2014]. A Destination-Sequenced Distance-Vector Routing (DSDV) follows a table-driven approach based on the Bellman-Ford algorithm [i.e. Bettstetter et al., 2004]. It resolves the problem of looping. A sequence number is embedded in each packet. The sequence numbers are even if a link is present; else, an odd number is used. The destination generates the number, and the emitter needs to send out the next update with this. The routing information is distributed among nodes infrequently and smaller incremental updates more frequently [i.e. Goyal et al., 2011]. Dynamic Source Routing (DSR) DSR establishes a path to the destination when a source node requests one. DSR uses the path of origin strategy. The originator must know the complete hop sequence to the destination before starting transmission. Each node maintains a route cache, where all routes it knows are stored. The route discovery process is initiated if the desired path cannot be found in the route cache. A node broadcasts the route request message only if its address is not present in the route record of the message to limit the number of route requests propagated. The sequence of hops is included in each packet's header. However, one significant advantage is that intermediate nodes can learn routes from the source routes in the packets they receive. The factors: time, bandwidth and energy are strong arguments for finding a way, is such a costly operation for using source routing. The routing of origin avoids the need for up-to-date routing information in the intermediate. Finally, it prevents routing loops quickly because the entire route is determined by a single node instead of making the decision hop-by-hop [i.e. Barati et al., 2012].

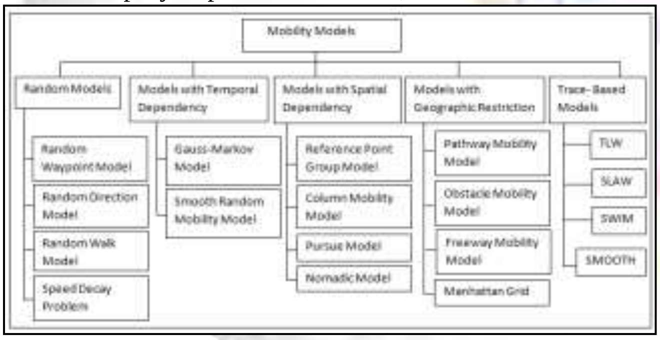

Fig. 2: Classification of Mobility Models

We provide a classification of various mobility models into several classes based on their specific movement characteristics in figure 2. For some movement patterns, the flow of the mobile node is likely to be affected by its change history, known as mobility with temporal dependence. The mobile nodes with spatial dependency are travel in a correlated manner. If the movements of nodes are bounded by streets, freeways or obstacles, this class deals with mobility models with geographic restrictions [i.e. Ishrat, 2011]. Mobility models that are based on real datasets are called trace-based mobility models. Movement traces collected from several indoor or outdoor sites. Traces are also available on CRAWDAD which is the largest repository for real datasets collected from diverse scenarios [Personal communication, 17 August 2016]. To implement the simulation, we are choosing Gauss-Markov mobility model because of its extensive and live use.

Liang and Hass [i.e. Liang et al., 1999] first introduced the Gauss-Markov Mobility Model. The velocity of a mobile node is assumed to be correlated over time and modeled as a Gauss-Markov stochastic process [i.e. Bai et al.]. The direction of a node is flipped to 180 degrees when the node is going to travel beyond the boundaries of the simulation area. The temporal dependency shows the mobility behavior of Gauss-Markov model [i.e. Jinthana et al., 2006]. It adapts the different levels of randomness via tuning parameters. Initially, each mobile node is assigned a current speed and direction [i.e. Johansson et al., 1999]. In a two-dimensional simulation field, the Gauss-Markov stochastic process can be represented by the following equations:

$$\bar{V_t} = \bar{\alpha}\overline{V_{t-1}} + (1-\bar{\alpha})\bar{v} + \bar{\sigma}\sqrt{1-\overline{\alpha^2}}\,\overline{W_{t-1}} \qquad (1)$$

where $\bar{V_t} = \left[v_t^x, v_t^y\right]^T$ and $\overline{V_{t-1}} = \left[v_{t-1}^x, v_{t-1}^y\right]^T$ are the velocity vector at time *t* and time *t-1*, respectively. $\overline{W_{t-1}} = \left[w_{t-1}^x, w_{t-1}^y\right]^T$ is the uncorrelated random Gaussian process with mean 0 and variance σ^2, $\bar{\alpha} = [\alpha^x, \alpha^y]$, $\bar{v} = [v^x, v^y]^T$ and $\bar{\sigma} = [\sigma^x, \sigma^y]^T$ are the vectors that represent the memory level, asymptotic mean and asymptotic standard deviation, respectively. In general for, the above-said equations can be written as:

$$\begin{cases} v_t^x = \alpha v_{t-1}^x + (1-\alpha)v^x + \sigma^x\sqrt{1-\alpha^2}\,w_{t-1}^x \\ v_t^y = \alpha v_{t-1}^y + (1-\alpha)v^y + \sigma^y\sqrt{1-\alpha^2}\,w_{t-1}^y \end{cases} \qquad (2)$$

The velocity $\bar{V_t} = \left[v_t^x, v_t^y\right]^T$ of mobile node at time slot *t* is dependent on the velocity $\overline{V_{t-1}} = \left[v_{t-1}^x, v_{t-1}^y\right]^T$ at time slot *t-1*. So, the Gauss-Markov model is temporarily dependent mobility model whereas the degree of dependency is determined by the memory level parameter α. To reflect the randomness of Gauss-Markov process α is a used parameter. The value of α can vary for different kind of mobility behaviors in various scenarios:

If the Gauss-Markov model is memoryless, i.e., $\alpha = 0$, then the equation 12 will be written as

$$\begin{cases} v_t^x = v^x + \sigma^x w_{t-1}^x \\ v_t^y = v^y + \sigma^y w_{t-1}^y \end{cases} \qquad (3)$$

Where the velocity of the mobile node at time slot *t* is only determined by the fixed drift velocity $\bar{v} = [v^x, v^y]^T$ and the Gaussian random variable $\overline{W_{t-1}} = \left[w_{t-1}^x, w_{t-1}^y\right]^T$. So, it becomes the random walk model.

If the Gauss-Markov model has strong memory, i.e.,$\alpha = 1$, then the equation 12 is

$$\begin{cases} v_t^x = v_{t-1}^x \\ v_t^y = v_{t-1}^y \end{cases} \qquad (4)$$

Where the velocity of the mobile node at time slot *t* is exactly same as its previous velocity. In this case, the model is called as fluid flow model.

If the Gauss-Markov model has some memory, i.e.,$0 < \alpha < 1$. The velocity at current time slot is dependent on both its velocity $\bar{V} = [v^x, v^y]^T$ at time *t-1* and a new Gaussian random variable $\overline{W_{t-1}} = \left[w_{t-1}^x, w_{t-1}^y\right]^T$. The degree of randomness is adjusted by the memory level parameter α. As the value of α increases, the current velocity is more influenced by its previous speed. Otherwise, it will be mainly affected by the Gaussian Random Variable.

Figure 3 shows the flow pattern of Gauss-Markov mobility model.

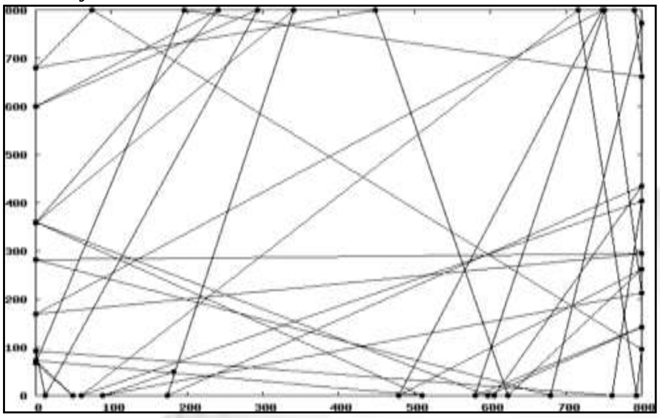

Fig. 3: Movement patter of nodes in Gauss-Markov mobility model

III. RESULTS & DISCUSSION

Simulations have been performed in network simulator, NS2, to determine the performance of routing protocols. We evaluate three MANET routing protocols (AODV, DSDV, and DSR) against Gauss-Markov Mobility Model. Simulation parameters list is defined in Table 1.

Parameters List		
Experiment Parameter	Analysis Value	Description
Simulator	NS2	Network Simulator
Mobility Generator	Bonnmotion-3.0.1	Mobility Generator Tool
Simulation Time	100 S	Simulation Duration
Terrain Dimension	X-2285, Y-1224	X, Y Dimension of motion
No. of mobile nodes	300	No. of nodes in a network
Mobility Speed	0-5 meter per second	Mobility of nodes
No. of Connection	92	Connections
Mobility Model	Gauss-Markov	Mobility direction
Routing Protocols	AODV, DSR, DSDV	Path-finding
MAC Protocol	802.11	Wireless Protocol

Table 1: Simulation Parameters List

The comparison is performed by measuring the following QoS performance metrics:

– Packet Delivery Ratio (PDR) is defined as the ratio of data packets delivered successfully to destination nodes and the total number of data packets generated for those destinations. PDR characterizes the packet loss rate, which limits the throughput of t he network [i.e. Razouqi et al., 2013]. The higher the delivery ratio better is the performance of the routing protocol. PDR is determined as:

$$PDR= (P_r / P_s) \times 100$$

Where P_r and P_s are the value of packets received, and packets sent respectively. Figure 4 shows the fraction of the originated application data packets each protocol was able to deliver, as a function of nodes.

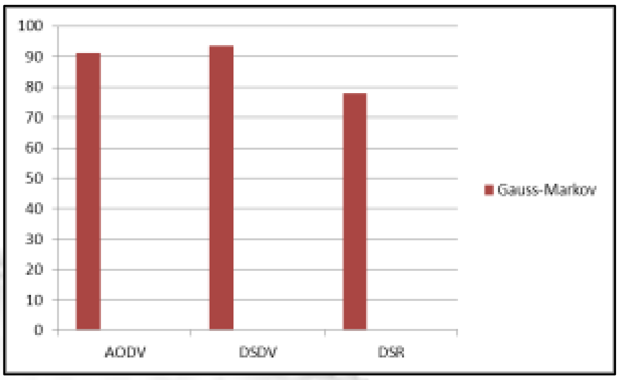

Fig. 4: Packet Delivery Ratio

Average End to End Delay (D_{avg}) indicates that the time taken for a packet to travel from the source node application layer of the destination node [i.e. Kaur et al., 2015]. It also includes the route discovery wait time that may be experienced by a node when a map is initially not available. The average end to end delay is computed as:

$$D_{avg} = \Sigma (t_r - t_s) / P_r$$

Where t_s is the packet send time, t_r is the packet receive time for the same packet at the destination, and P_r is the total packets received. The average delay increases for all routing protocols as shown in figure 5.

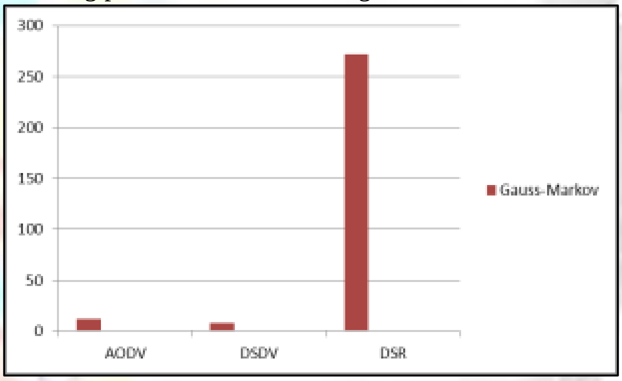

Fig. 5: Average End-to-End Delay

– Throughput: The average rate of successful message delivery over a communication channel [i.e. Maurya et al., 2014] is called throughput. The average end to end throughput is shown in figure 6 which reflects the usage degree of the network resources for the conventional routing protocols.

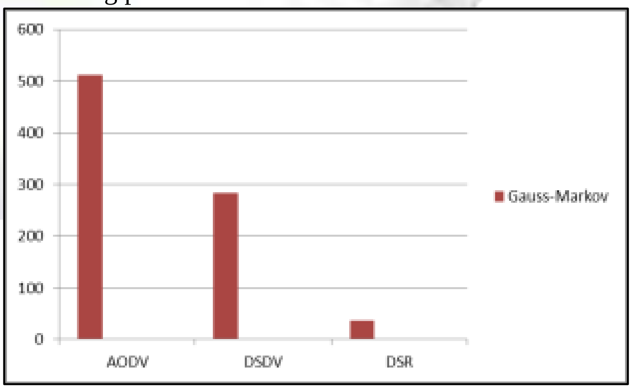

Fig. 6: Throughput

– Packet Overhead: It is the number of all nodes transmission packets including data and encoded packet. Figure 7 shows the packet overhead rate Gauss-Markov model.

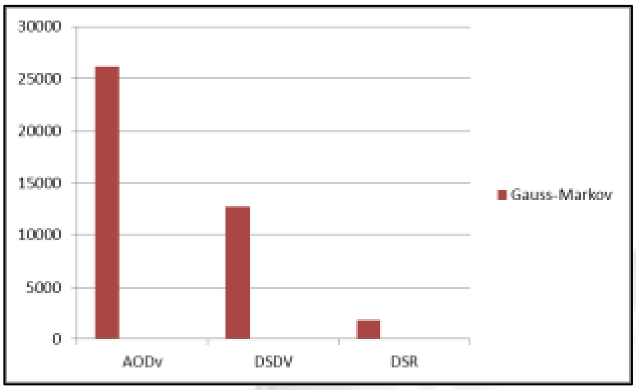

Fig. 7: Packet Overhead

– Average Packet Loss: The number of packets lost due to incorrect or unavailable routes and MAC layer collisions [i.e. Pandya et al., 2013] is known as average packet loss. Figure 8 shows the relationship between the network size and the average packet dropped off the standardized protocols which indicate the degree of each protocol.

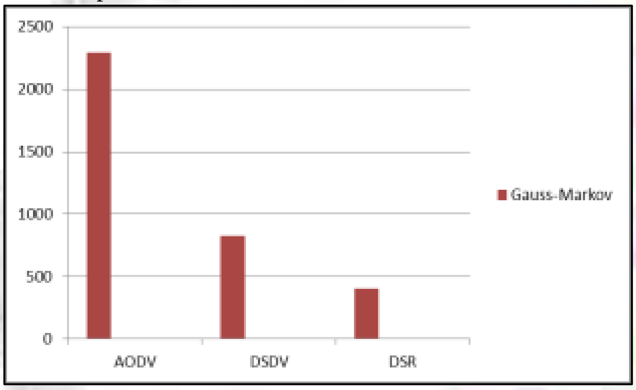

Fig. 8: Average Packet Loss

The same parameters are used during simulation for each routing protocol to ensure the simulation produced accurate results. From the results, the objective of this project which is to evaluate the QoS performances for AODV, DSR, and DSDV MANET protocols over mobility model is fulfilled. The analysis has been done through simulation using commercial and highly reliable NS2 simulator over Bonnmotion-3.0.1 mobility tool. As a result shown in Figure 3, packet delivery ratio is increased for DSDV with Gauss-Markov. In performance metric Average End to End Delay, DSDV has lesser delay than AODV, and DSR. AODV provides more throughput and packet overhead. DSR is acting well in case of packet loss with the Gauss-Markov mobility model.

IV. Conclusion

We analyzed the behavior of MANET routing protocols under temporal dependency based mobility model. The results of our extensive NS2 simulations clearly indicate the significant impact that node movement pattern has on routing performance. We observe that a change in mobility pattern has a different impact on all routing protocols. The RWP plays as a base mobility model to analyze the performance of routing protocols when there is no group movement but it has sharp movement when reaches to boundary line. The aim of this research to develop an understanding of the effect of temporal dependency based over the routing performance. In future, we intend to study mobility models to determine the MANET protocol best suited to military mobile ad-hoc networks.

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