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Simulation Analysis of MANET Routing Protocols under Different Mobility Models

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ABSTRACT

For the last few years Mobile adhoc network is getting publicity due to its versatile applications. There are many factors that impact the performance evaluation of mobile networks. A mobility model is one of the factors affecting network in a very significant way. A mobility model dictates the movement of the nodes within the network. This research aims to study several mobility models that represent mobile nodes whose movements are independent of each other (i.e., entity and group mobility models), and determine their characteristics, weakness, and strengths. Offering more insight into these models will help researcher deciding upon a mobility model to use in the simulation. In order to illustrate how the choice of the mobility models impact the performance results of ad hoc protocols to be simulated, this paper will perform a comparison between these models considering several performance metrics like packet delivery ratio, end-to-end delay and normalized routing load and dropped packets.

Key words :MANETs, Mobility Models, Routing Protocols, AODV, DSR ,OLSR

1. INTRODUCTION

Recent advances in wireless communication technology have generated a great interest in building and using ad hoc mobile networks in many diverse applications. A mobile ad hoc network constitutes multiple wireless stations called nodes which are mobile, capable of moving randomly and communicating with each other in the absence of any centralized administration and fixed infrastructure. MANET has several potential applications including emergency rescue operations during natural calamities, event meetings, conferences, and battlefield communication between moving vehicles and/or soldiers.

The factors like the transmission range, the buffer space for message storage, the battery power, the computing power, the data traffic model and the used mobility model affects the performance of a network. Therefore, simulation results obtained with unrealistic mobility models may not correctly reflect the true performance of a protocol. Group mobility models are frequently used to mimic group motions such as in case of military platoons or emergency relief services operating in battlefield/disaster areas. The work in this paper aims to conduct a parametric study using the simulation technique to evaluate the performance of ad hoc mobile networks using different mobility models.

2. RELATED WORK

There have been several works in the recent past that simulated and evaluated performance comparisons of several routing protocols and algorithms and most of these assessments were based on random mobility models [1-3]. The main disadvantage is that they are not based on real life scenarios. So, MANETs have not been used extensively used despite having significant advantages over traditional communication networks. In [4] authors provide a simulation based performance evaluation and compare various reactive, proactive and hybrid protocols based on Random waypoint mobility models and compare the performance of three routing protocols (AODV,OLSR, ZRP) using Qualnet 4.5. Ashish et al. [5] presented performance evaluation of three different routing protocols, i.e., Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR) and Fisheye State Routing (FSR) in variable pause time using QualNet Simulator based on Average end to end delay, Packet delivery ratio, Throughput and Average Jitter. Sunil et al. [6] analyzed the behavior of five MANETs routing protocols i.e. AODV, DSDV, DSR, OLSR, TORA under the three mobility models (RPGM, CMM, RWP) and then compare the performance of protocols using NS-2 simulator in the area of 700 x 700 m^2 which clearly indicate the significant impact on node mobility pattern has on routing performance. Gupta et al [7] presented simulation results that illustrate the importance of choosing a mobility model in the simulation of an ad hoc network protocol. They compared the performance of the Random Waypoint Mobility Model, the Reference Point Group Mobility (RPGM) model and Freeway Mobility Model tested on AODV and DSDV routing protocols on the basis of throughput.

Given the critical role of the mobility model in supporting realistic and accurate protocol simulations, its correct design and selection is essential. Different mobility models have different characteristics and serve different purposes. Therefore, instead of defaulting to a fixed Mobility Model for every simulation, or implementing a model that fails to model accurate MN behavior, the researchers should conduct a thorough analysis of appropriate mobility models before beginning their simulations.

3. MANET ROUTING PROTOCOLS

Routing ensures selection of a specific path to transmit data from source node to destination node. There are various routing protocols designed for adhoc networks. Some of them that we simulated in this paper are discussed below.

3.1 OLSR (Optimized Link State Routing Protocol)

It is a proactive link state and table driven protocol. OLSR employs three mechanism for routing- Hello message for neighbor sensing message, Control packet using multi-point relay (MPR) and Path selection using shortest path first algorithm [8]. Each nodes using its two-hops by selecting MPR's such that all its two-hop neighbors are accessible .Basically the hello and topology control (TC) messages to discover and then broadcast link state information throughout the mobile ad-hoc network. Individual nodes use this topology information to compute next hop destinations for all nodes in the network using shortest hop forwarding paths [8].

3.2 DSR (Dynamic source routing protocol)

It comes under the category of Reactive protocol for Ad-hoc wireless network [9]. It is not table-driven and based on source routing whereby all the routing information is maintained and updated continuously at mobile nodes. It has two major phases, Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node (route record which is initially contained in Route Request would be inserted into the Route Reply).

3.3 ZRP (Zone Routing Protocol)

It is designed to provide an optimal balance between purely proactive and reactive routing [10]. This applies equally well to routing between nodes at the intra-cluster level and between clusters at the inter-cluster level. ZRP is formed by two sub-protocols, a proactive routing protocol: Intra-zone Routing Protocol (IARP) [11] is used inside routing zones and a reactive routing protocol: Inter-zone Routing Protocol (IERP) is used between routing zones, respectively. The IARP protocol is used by a node to communicate with the other interior nodes of its zone. Existing proactive routing algorithms can be used as the IARP protocol for ZRP. The Inter-zone Routing Protocol (IERP) is used to communicate between nodes of different routing zones. It is a reactive routing protocol and the route discovery process is only initiated when needed or on demand. This makes route finding slower, but the delay can be minimized by use of the Bordercast Resolution Protocol (BRP) [8, 13]. In order to increase efficiency, BRP sends routing requests generated by IERP directly to peripheral nodes.

4. MOBILITY MODELS IN MANET

Mobility models are designed to describe the different type mobility pattern of moving nodes and mobility model consider how their position is changing at a given time, velocity and acceleration changes with time. To finding and analyzing the performance of different protocols mobility models plays a remarkable role. It is expected from mobility models to emulate the movement pattern of nodes targeted life applications and scenario in a very efficient way. Else it could leads to the wrong analysis and the conclusions done from the simulation. When evaluating MANET protocols, it is very important to select the proper mobility model. Figure 1 gives classification of mobility models.

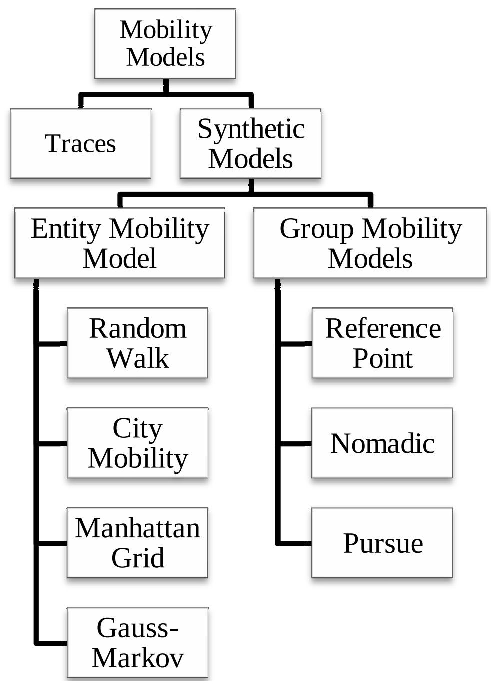

Figure 1. Classification of Mobility Models

Presently, there are two types of mobility models: traces and synthetic models [12]. Traces are those mobility patterns that are observed in real life systems. Traces provide accurate information, especially when they involve a large number of participants and an appropriately long observation period. However, new network environments (e.g. ad hoc networks) are not easily modeled if traces have not yet been created. In this type of situation it is necessary to use synthetic models. Synthetic models attempt to realistically represent the behaviors of MNs without the use of traces.

4.1 Entity Mobility Models

In Entity Mobility Models mobile nodes move independently within the simulation area. They include Random Walk MM, Random Waypoint MM, Random Direction MM, Boundless Simulation Area MM, Gauss-Markov MM, Probabilistic version of Random Waypoint MM, City Area and Street Section MM. In this section, we present various entity mobility models that have been proposed for (or used in) the performance evaluation of an ad hoc network protocol.

- **Random Waypoint:** The Random Waypoint Model is the model which involves pause times before changes in speed and direction of the nodes. A mobile node starts transmission by staying in a particular location for some period of time means a pause time. Once this time period ends, the mobile nodes choose a random location in the defined simulation area and speed from the given range of maximum and minimum speed uniformly [13]. Then mobile nodes then travel toward the newly chosen location in the defined area at the selected speed shown in Figure 2. This process is repeated again and again but before that node takes a pause for short time period.

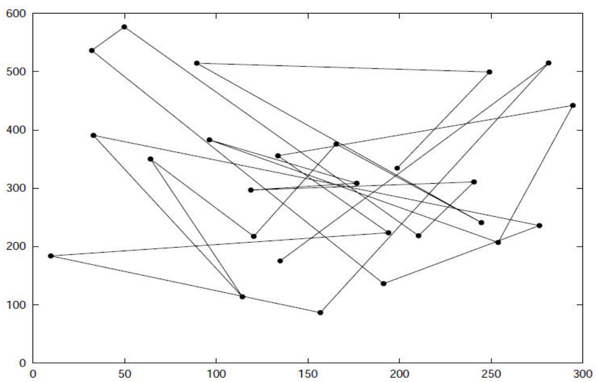

Figure 2. Travelling Pattern of an MN using the Random Waypoint Mobility Model [14]

- **Manhattan Grid:** The Manhattan Grid model [14] is designed to provide a path in matrix form means in row and column points as presented in Figure 3. In this model, nodes move only on pre-specified paths. The –x and -y parameters set the number of blocks and the path between them.
  As an example, "\-v 3 -y 2" places the following paths on the simulation area:

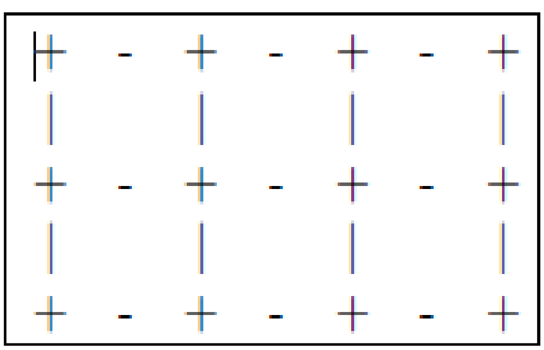

Figure 3. Manhattan Grid Mobile Node Travelling Pattern [14]

There are two more additional parameters that are supported by the Manhattan Grid. First it can decide or change the minimum speed of a mobile node. And second one is we can add the pause probability and the maximum pause time period of the mobile nodes.

- **City Mobility Model:** In this Mobility Model, the simulation area is defined by the street of a city which represents a section of a city where the ad hoc network has to create shown in Figure 4. The streets are based on the type of city being simulated, and the speed is dependent on the type of street. Figure 4 shows the mobility pattern of city section mobility model [15].

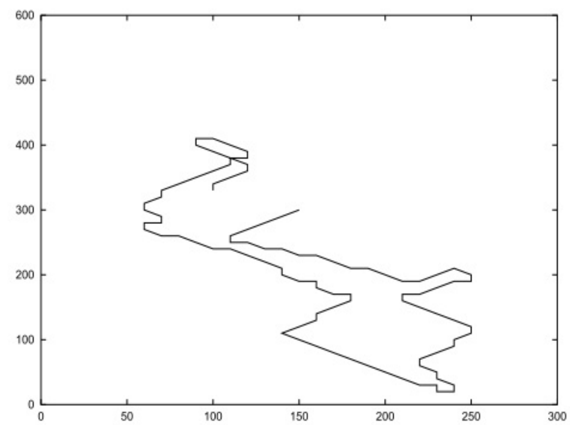

Figure 4. Travelling Pattern of an MN using City Section Model [16]

- **Gauss Markov Model:** The Gauss-Markov Mobility Model was designed to adapt to different levels of randomness via one tuning parameter. It works on timeslot basis where the speed of a MN is correlated over time i.e. the speed and direction of n location is calculated using speed and direction of n-1 location and a random variable as shown below.

$$V_n = \beta V_{n-1} + (1-\beta)\Omega + \sqrt{(1-\beta)^2}\, x_{n-1}$$

where β (0≤β≤1) is tuning parameter for varying randomness;Ω is a constant representing the mean value of speed and direction;As $n \to \infty$, x_{n-1} is a random variable from a Gaussian distribution.

4.2 Group Mobility Models

In Group Mobility Models all the mobile nodes are arranged in a group and the mobility of nodes depends upon the movement pattern of the whole group i.e. all the nodes move together collectively.

- **Reference Point Group Mobility Model (RPGM):** Reference Point Group Mobility shows movement of mobile nodes in group and as an individual. It also represents the random motion of nodes [17]. Motion is dependent on logical centre of the group. This logical center is required for the calculation of group motion vector. Motion for group center specifies group movement, its speed and direction of movement. Apart from logical centre, each node decides its own reference point for random movement. The reference point moves from time t to t+1 and location of this is reported to the group's logical center. When reference points are updated, RP (t+1) is calculated each time and added to the random vector as shown in figure 5.

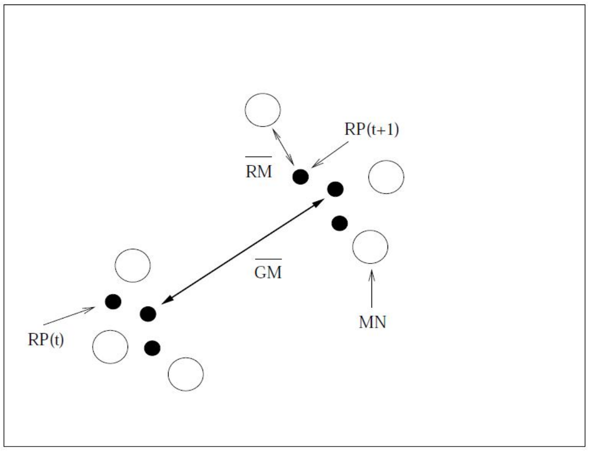

Figure 5. Movements of three MNs using the RPGM Model [16]

- **Nomadic Mobility Model:** As in old times, nomadic societies used to move from one location to another. This concept is used by nomadic mobility model. A group of mobile nodes is formed which moves collectively from one position to another. In this model, each individual node uses entity mobile model which is required for individual node movement across its own point of reference as shown in figure 6. When the point of reference changes, whole group moves to a new area and start wandering in that area [18].

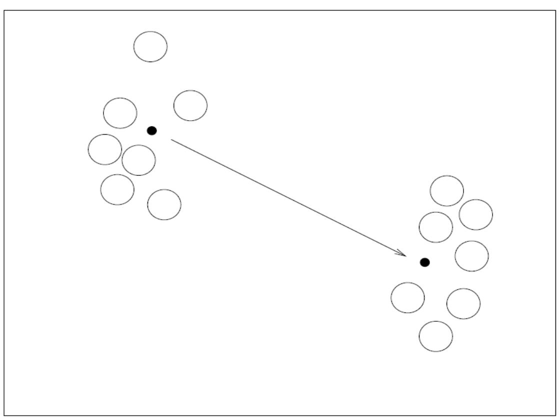

Figure 6. Movements of seven MNs in Nomadic Community Mobility Model [16]

- **Pursue Mobility Model:** In Pursue Mobility Model, the mobile nodes track a particular target. New position is calculated using the following equation for each mobile node:

New position = old position + acceleration [target – old position] + random vector.

Random vector is a offset for each mobile node and acceleration tells the how mobile nodes are pursuing towards target [18]. The degree of randomness of each node is limited to maintain tracking as shown in figure 7.

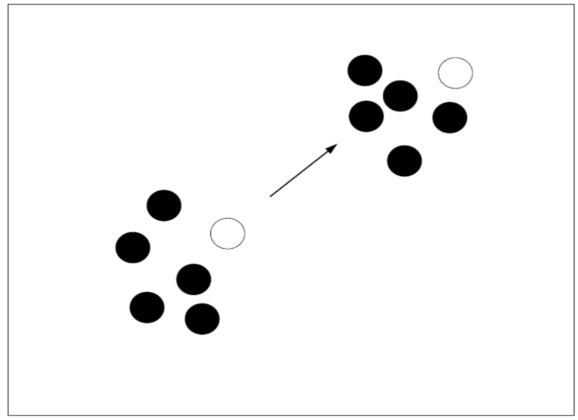

Figure 7. Movements of Six MNs using the Pursue Mobility Model [16]

- **Column Mobility Model:** This model is very useful for searching purposes. This model represents a set of mobile nodes that move around a given column, which moves in a forward direction like a group of children walking in a single-line to their classroom as shown in the figure 8.

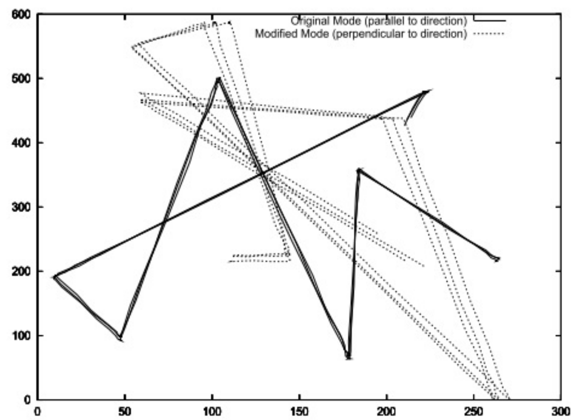

Figure 8. Travelling Pattern of MNs using the Column Mobility Model [16]

5. SIMULATION ENVIRONMENT

The simulation is done using ns2. The simulation time for this experiment is 500 seconds. In table 1, the simulation parameters are presented in detail.

Table 1. Simulation parameters for field trip scenario

Parameter	Value
Simulation time	500 Sec
Simulation area	1200m x 1200m
Antenna	Omni antenna
No. of nodes	21, 41, 61, 81
Speed	2
Mobility Model	Gauss-Markov, RWP, RPGM, Nomadic
Pause Time	2
Packet size	512 Bytes
Max queue length	150
Traffic	CBR (Constant bit rate)
Routing protocol	DSR or OLSR or ZRP
Transport Layer	UDP

5.1 Performance Metrics

- **Packet delivery ratio:** Packet delivery ratio is the ratio of total packets sent by the source node to the successfully received packets by the destination node.
- **Average End-to-End delay:** Average end-to-end delay is the time interval when a data packet generated from source node is completely received to the destination node.
- **Normalize Routing Load (NRL)***:* It is the number of transmitted routing packets per delivery data packets.
- **Dropped Packets:** It is the number of packets sent by the source node that fail to reach to the destination node. The routers might fail to deliver or drop some packets or data if they arrive when their buffer are already full. Some, none, or all the packets or data might be dropped, depending on the state of the network, and it is impossible to determine what will happen in advance.

5.2 Simulation Results of Routing Protocols with varying number of nodes

Increasing number of nodes has impact on all protocols under different mobility models i.e. the degradation varies for different protocols and mobility models.

5.2.1 Simulation Results of OLSR with different mobility models

Figure 9 gives the effect of changing number of nodes on PDF of OLSR. In small networks, OLSR with nomadic mobility model gives better performance in terms of PDF i.e. 86.49% whereas as number of nodes increases from 41 to 81, RPGM overpowers nomadic model with PDF 88.43%.

OLSR with other mobility models (random waypoint and Gauss Markov) PDF is low with average value of 44.99% and 27.75% respectively. In terms of NRL, both nomadic and RPGM shows similar delay which is almost consistent with changing number of nodes. NRL of OLSR under Gauss Markov Model ranges from 0.99 to 8.92.

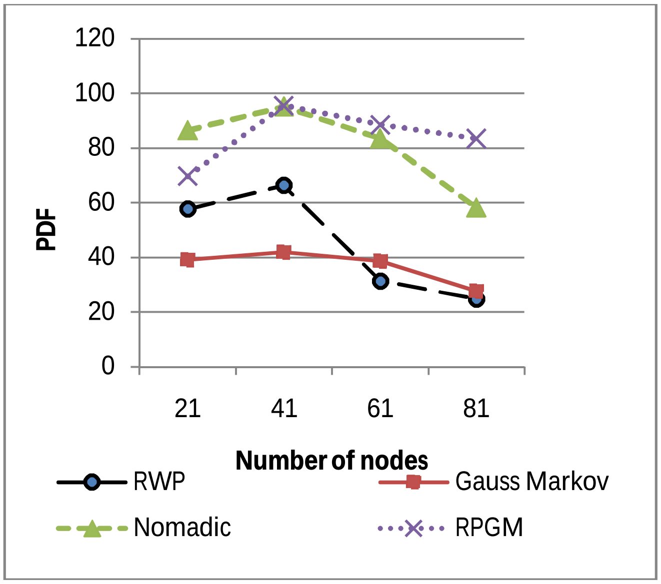

Figure 9. PDF vs Number of nodes

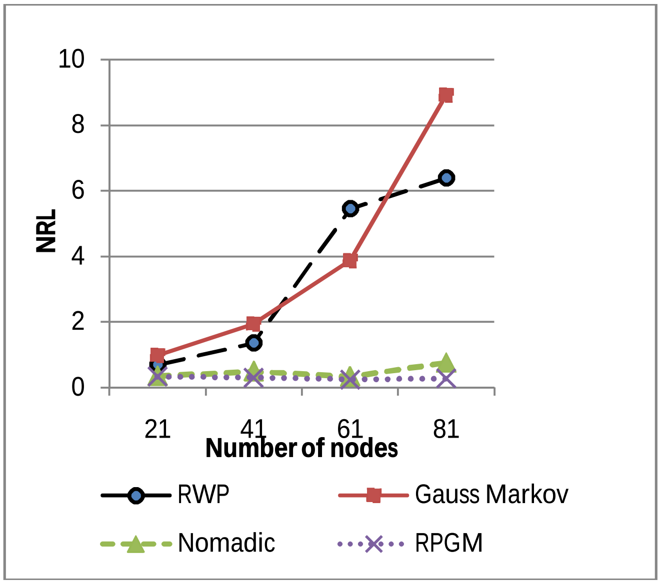

Figure 10. NRL vs Number of nodes

It is observed from Figure 11 that OLSR with RPGM model has lowest E2E delay with an average delay of 7.63 ms but as number of nodes increase from 60, there is an exponential increase in delay.

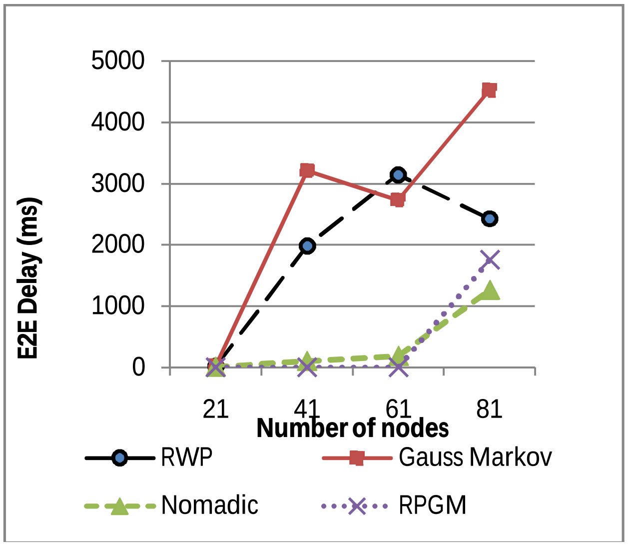

Figure 11.E2E Delay vs Number of nodes

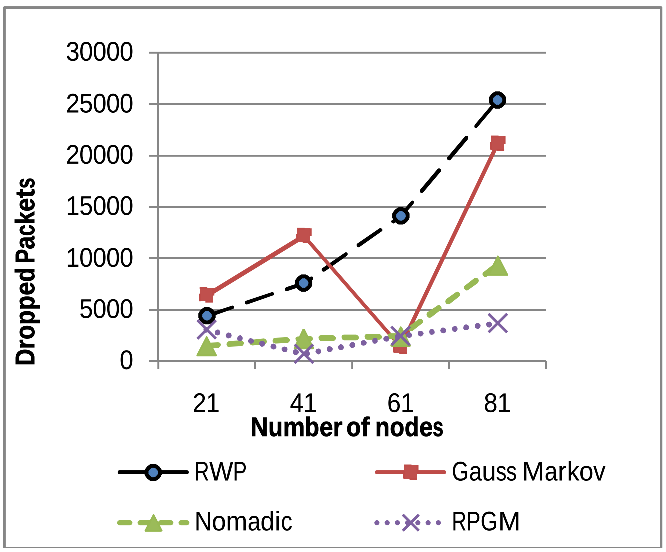

Figure 12. Dropped Packets vs Number of nodes

5.2.2 Simulation Results of DSR with different mobility models

Figure 13-16 shows variation in performance metrics under DSR routing protocol with varying number of nodes. Among entity models, RWP has higher PDF than Gauss Markov Model ranging from 63.15 to 22.57 as number of nodes varies from 21 to 81. Among group models, RPGM has higher PDF than nomadic that varies in between 69.6 and 95.45. With the group model, RPGM, delay performance does not increase much with the increase in network size. Among entity models, RWP demonstrates lower delay in smaller networks and GM in larger networks. As compared with OLSR and ZRP, DSR shows the lowest NRL for all mobility models. This is because DSR uses caching; hence it is more likely to find a route in cache and perform the route discovery less frequently than other routing protocols.

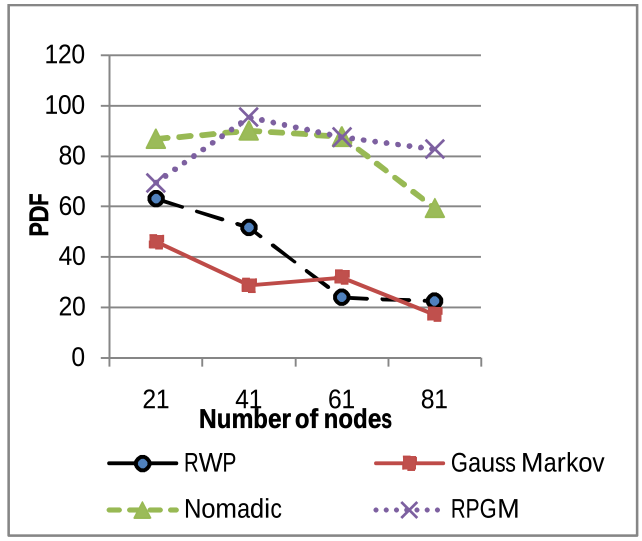

Figure 13. PDF vs Number of nodes

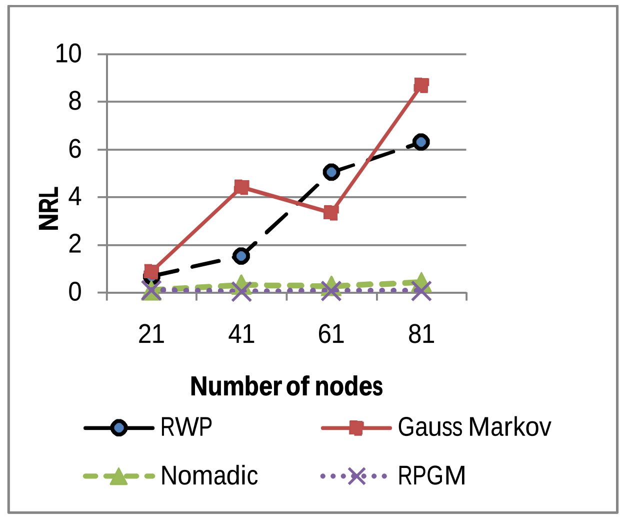

Figure 14. NRL vs Number of nodes

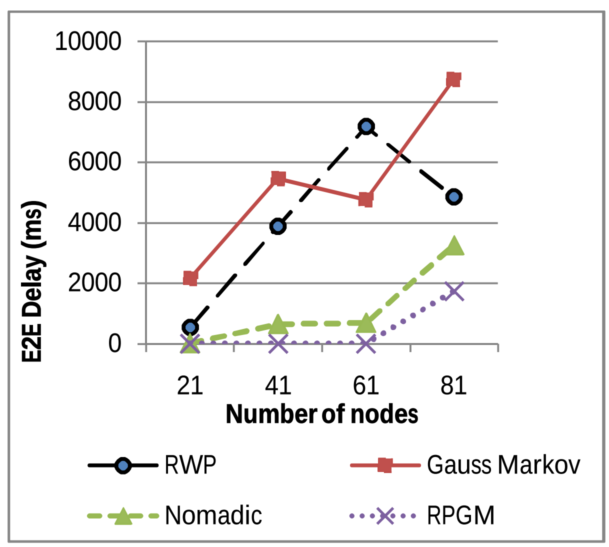

Figure 15. E2E Delay vs Number of nodes

On the other side, OLSR periodically transmits updates to maintain routing tables. There are also event triggered routing table exchanges through incremental dumps.

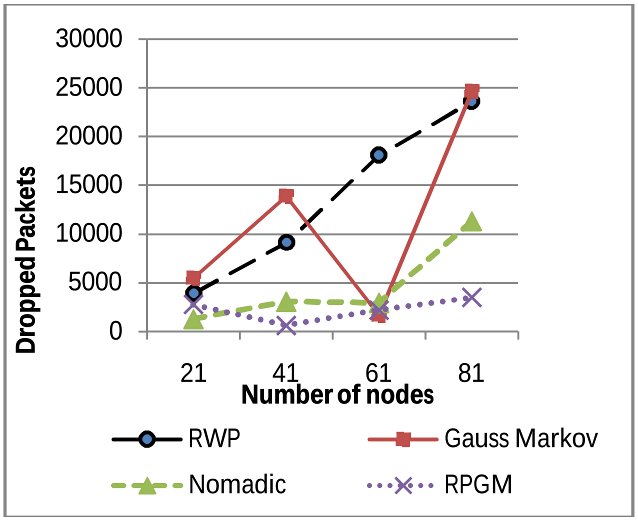

Figure 16. Dropped Packets vs Number of nodes

5.2.3 Simulation Results of ZRP with different mobility models

With the group model, RPGM, PDF of ZRP improves with the increase in network size from 21 to 51 after that it slightly decreases in Figure 17. The network with 21 mobile nodes is much sparser and the entire communication takes place between a few groups. The PDF suffers from transient partitions that exist in a sparse network. When increasing the number of mobile nodes the sparse network effect disappears and RPGM becomes the most recommendable mobility model. Figure 18 shows NRL for ZRP is higher than OLSR and DSR. In nomadic model, NRL is almost consistent with an average value of 4.87ms irrespective of network size.

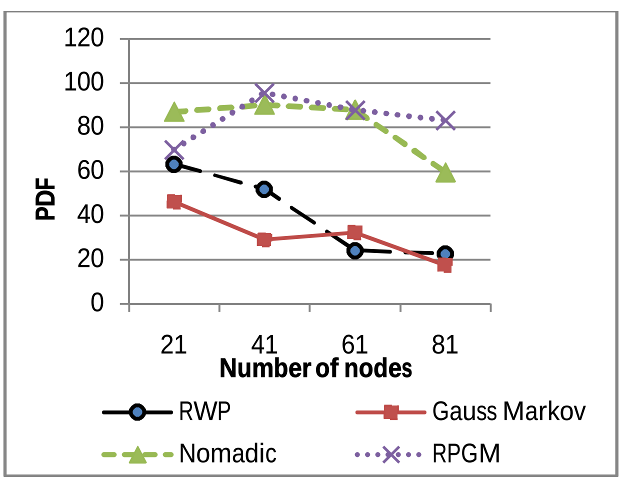

Figure 17. PDF vs Number of nodes

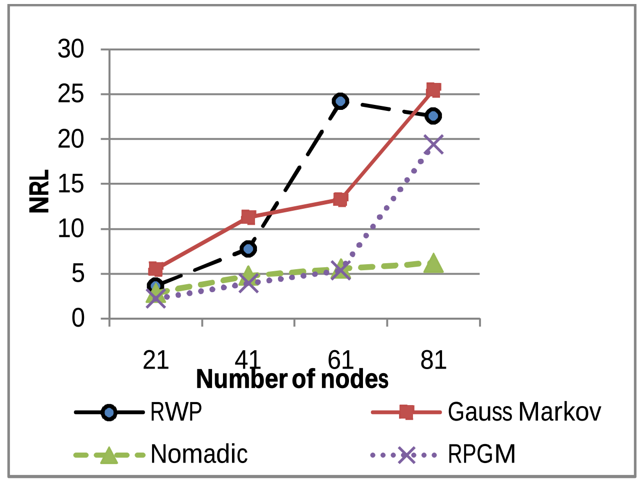

Figure 18. NRL vs Number of nodes

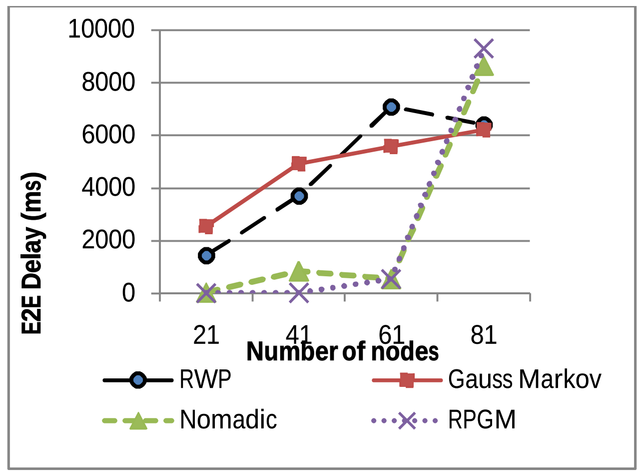

Figure 19. E2E Delay vs Number of nodes

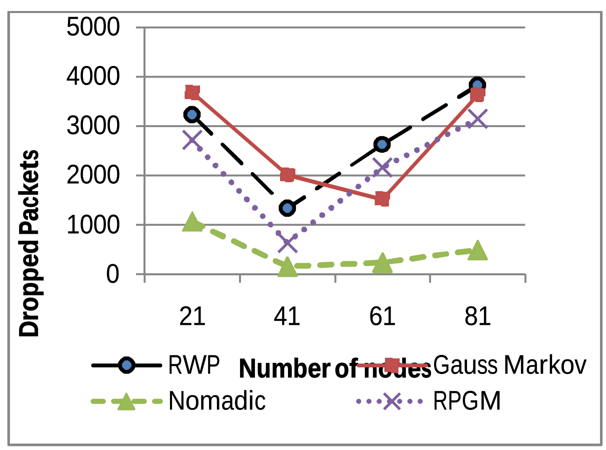

Figure 20. Dropped Packets vs Number of nodes

6. CONCLUSION AND FUTURE SCOPE

It can be concluded that due to the random mobility of node, routing becomes a complex issue. Till now many routing protocols are used in MANET. Each routing protocol has unique features. Simulation results presents that no single protocol can achieve optimal performance for all mobility cases. Based on network environments, we have to choose the suitable routing protocol. Proactive routing protocols are best suited in small networks. In large and dense network, proactive routing protocols can't perform well because maintaining thousands of routing tables properly in large network degrades the efficiency. So for large and dense networks reactive routing approach plays a major role. Our simulation results exhibits that reactive protocols are much better than proactive in terms of packet delivery fraction, average end-to-end delay, normalized routing load and dropped packets. DSR performs better with lesser numbers of nodes and fails when the numbers of nodes increase but DSR shows high end to end delay due to formation of temporary loops within the network.

A possible line of research would extend the simulation analysis to a broader range of mobility models under varying propagation loss models. CBR packets have been used as a traffic source through the course of this study. It would be useful to analyze MANET performance under different traffic patterns such as those generated by Transmission Control Protocol. One of the future directions of research can be extending set of the experiments by taking into consideration energy-consumption reduction, different propagation models and MAC protocols.

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