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Formative Impact of Gauss Markov Mobility Model on Data Availability in MANET

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Abstract: Recent advancements in wireless communication and the miniaturization of computers support communications among mobile nodes connected to each other by one-hop or multihop links. In Mobile Ad hoc Network (MANET), mobile nodes need to share and access data held by other mobile nodes in applications such as collaborative rescue operations at a disaster site, military operations and sensor networks. Since, disconnections often occur, data in two separated networks become inaccessible to each other. Preventing the deterioration of data availability at the point of network partitioning is a very significant issue. Data replication and data diffusion (dissemination) address the issue of data unavailability. The results of these conventional researches have revealed that mobility heavily affects data availability. The influence of mobility on data availability is determined from various perspectives without using specific applications or specific data replication/diffusion protocols. But several general metrics like the average size of the partitions, distribution of partition sizes, the size of partitions to which the node belongs, the change in size of partition to which the node belongs, the total number of connected nodes to a node, the no of nodes to which a node can disseminate its data and the distribution of the connected nodes are analyzed to determine the impact of mobility on the data availability. The values of proposed metrics are computed and compared for both Gauss Markov and RPGM mobility models. From the simulation results, it is known that the Gauss Markov Mobility Model works well in terms of the data storage capacity and partition stability. For designing the data replication protocol it is effective to share the data among the nodes in the same partition and for designing the data dissemination protocol, aggressive data dissemination is effective in terms of distribution rapidness.

Key words: Mobile Ad hoc Networks (MANETs), Ad hoc on-demand Distance Vector (AODV), Dynamic Source Routing (DSR), Quality of Service (QOS), Authenticated Routing for Ad hoc Networks (ARAN), Secure Efficient Ad hoc Distance vector (SEAD)

INTRODUCTION

Manet: Mobile Ad hoc Network (MANET) is a network comprising wireless Mobile Nodes (MNs) that communicate with each other without centralized control or established infrastructure. MNs that are within each other's radio range can communicate directly while distant MNs rely on their neighboring MNs to forward packets. Each MN acts as either a host or a router. In MANET (Hara, 2010) environment, MNs are free to join or leave the network at any point of time, resulting in a highly dynamic network environment compared to wired network. The considerations about developing routing protocols for MANET are computation-restricted, bandwidth constrained and energy-constrained. For a new protocol development, performance evaluation is important and essential because the result can be used in many applications. Its performance can be evaluated by two typical techniques: simulation and analysis. Simulation is used in many research works. Especially in the MANET (Hara, 2010) the Mobility Model is an important factor that creates realistic moving behavior of MNs. Each device in a MANET is free to move independently in any direction and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use and therefore be a router.

Mobility Models: The Mobility Model is designed to describe the movement pattern of mobile users and how their location, velocity and acceleration change over time. Since, mobility patterns may play a significant role in determining the protocol performance, it is desirable for mobility models to emulate the movement pattern of targeted real life applications in a reasonable way.

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Otherwise, the observations made and the conclusions drawn from the simulation studies may be misleading. Thus, when evaluating MANET protocols (Bai and Helmy, 2005; Hahner *et al*., 2007) it is necessary to choose the proper underlying Mobility Model. Thus, use of real life measurements is currently almost impossible and most certainly expensive. Hence, the commonly used alternative is to simulate the movement patterns. In the performance evaluation of a protocol for an ad hoc network, the protocol should be tested under realistic conditions including but not limited to a sensible transmission range, limited buffer space for the storage of messages, representative data traffic models and realistic movements of the mobile users (Mobility Model).

Gauss-Markov Mobility Model: The Gauss-Markov Mobility Model was first introduced by Liang and Haas and has been widely utilized. In this model, the velocity of the mobile node is assumed to be correlated over time and modeled as a (Jardosh *et al*., 2003) Gauss-Markov stochastic process. Initially, the nodes are placed at random locations in the network. The movement of a node is independent of the other nodes in the network. Each node is assigned a mean speed and mean direction of movement. For every constant time period, a node calculates the speed and direction of movement based on the speed and direction during the previous time period, (Hara and Madria, 2006) along with a certain degree of randomness incorporated in the calculation. The node is assumed to move with the calculated speed and in the calculated direction during the time period.

LITERATURE SURVEY

A mobility measure for mobile Ad hoc networks: The mobility measure for mobile ad hoc networks is proposed that is flexible because one can customize the definition of mobility using a remoteness function. The proposed measure is consistent because it has a linear relationship to the rate at which links are established or broken for a wide range of mobility scenarios where a scenario consists of the choice of Mobility Model (Bai and Helmy, 2005) the physical dimensions of the network, the number of nodes. The canonical mobility measure for mobile ad hoc networks which is flexible and consistent for a wide range of scenarios. The consistency of the mobility measure was demonstrated by the simulation results which showed the ability of the mobility measure to reliably predict the link changes for various simulation scenarios. The proposed mobility measure provides a unified means of measuring the degree of mobility in a MANET.

Impact of Mobility on Mobility Assisted Information Diffusion (MAID) Protocols: A class of protocols that utilize mobility for information diffusion in wireless networks, that his call MAID. Such protocols can be used for resource discovery, routing or node location and hold great promise for future wireless networks. MAID (Bai and Helmy, 2005; Hahner *et al*., 2007) uses encounter history information to create time (or age) gradients towards the target. An analytical model is developed to analyze MAID's performance during the warm-up and the steady state phases. For further conduct extensive simulations to evaluate the proposed models and further understand the effect of mobility on MAID. The first study on sensitivity of this class of protocols to a rich set of Mobility Models (Manhattan, Group and Random Walk and Random Waypoint Models) is provided. Here, encountered nodes are defined for each node as nodes with which it experienced a direct connection by a one-hop wireless link (Jardosh *et al*., 2003), i.e. that are located within its communication range. However, this metric does not truly represent the rapidness of data dissemination because data can be transmitted not only to nodes within the communication range of each other but also to nodes connected by multihop links.

Quantifying network partitioning in MANET: The performance of distributed algorithms in mobile ad hoc networks is strongly influenced by connectivity of the network. In cases where the connectivity is low, network partitioning occurs. The mobility and the density of network nodes as well as the communication technology are fundamental properties that have a large impact on partitioning. There are five proposed metrics and three of them are network wide metrics: number of partitions, size of partitions and partition change ratio. The rest are node-centric metrics: node partition change rate and node separation time. However, these metrics are not enough to fully examine the influences of mobility on data availability. In terms of data availability, the first two metrics represent the capacity of data storage (memory space) of each partition e.g., the larger the partition is and the more data can be stored in it. The other three metrics just represent how frequently members of each partition change or how long before each pair of two nodes disconnects.

Realistic Mobility Models for mobile Ad hoc networks: The most important methods for evaluating the characteristics of ad hoc networking protocols is through the use of simulation. Simulation provides researchers with a number of significant benefits including repeatable scenarios, isolation of parameters and exploration of a variety of metrics. The topology and movement of the nodes in the simulation are key factors in the performance of the network protocol under study. Once the nodes have been initially distributed, the Mobility Model (Tangmunarunkit *et al*., 2002) dictates the movement of the nodes within the network. Because the mobility of the nodes directly impacts the performance of the protocols, simulation results obtained with unrealistic movement models may not correctly reflect the true performance of the protocols. The majority of existing mobility models for ad hoc networks does not provide realistic movement scenarios; they are limited to random walk models without any obstacles. In this study, to create more realistic movement models through the incorporation of obstacles.

Motivation and contribution: The results of these conventional researches have revealed that mobility heavily affects data availability; high mobility sometimes increases data availability, e.g., a mobile node relays data between two separated (partitioned) networks and it sometimes decreases, e.g., a mobile node that holds hot (popular) data disconnects from the network. But propose several general metrics to quantify data availability. Since, there are typically two approaches for improving data availability in MANET applications (Kwak *et al*., 2003) in which data are shared among mobile users or devices: data replication and data diffusion, the proposed metrics are defined to examine the impact of mobility on the performance of these two approaches.

PROPOSED SYSTEM

In proposed system new metrics to quantify the influences of mobility on data availability. In the assumed System Model, M nodes exist in the entire network. The set of all mobile nodes in the system is denoted by $M = \{M_1, M_2,...,M_m\}$ where M_k (k = 1, 2,...,m) is a node identifier. The communication range of each mobile node is expressed by a circle with radius C (Bai and Helmy, 2005; Hahner *et al*., 2007) i.e., the communication ranges of all the nodes are of the same size thus every wireless link is bidirectional.

This assumption is for simplicity but it is deal with more realistic situations in which nodes may have different or noncircular communication ranges by ignoring unidirectional links as many network and application protocols do. The network can be partitioned only due to the limitation of a node's communication range. In this research, a partition denotes a set of mobile nodes that have (one-hop/multihop) communication paths between two arbitrary nodes and no path exists between any pair of nodes in different partitions.

Metrics on capacity and stability

Average size of partitions: The metric is defined as the average number of mobile nodes in each partition which was also used in (Jardosh *et al*., 2003).

Distribution of partition sizes: It is believed that the average size of partitions is not a very significant metric since it treats the two cases equally.

Sizes of partition belongs to: The metric is from the viewpoint of each mobile node and is defined as the histogram that represents the distribution of the sizes of the partitions to which the node belonged. The metric becomes almost equal to the distribution of partition sizes explained above (Yoneki and Bacon, 2005) if every mobile node randomly moves around in the whole area.

Change in size of partitions belong to: The metric is also from the viewpoint of each mobile node and is defined as the histogram that represents how much the sizes of the partitions to which the node has belonged change where the value ranges from 1-m (negative value) to m-1. It aims at making a further consideration of the distribution of sizes of the partitions belonged to and helps to quantify their stability.

Distribution of connected nodes: The metric is also from the viewpoint of each mobile node and is defined as the histogram representing the ratio of the duration during which the node is connected to each node to the entire observation time.

Metrics on data distribution: Next, define two metrics that represent how rapidly data are distributed to mobile nodes in the network.

Total no connected nodes: The metric is from the viewpoint of each node and is defined as the total number of mobile nodes to which the node experienced a connection during a specific duration $l'.t$ ($1 \le l' \le l$).

Total no data reachable nodes: The metric is also from the viewpoint of each node and is defined as the total number of mobile nodes to which data sent by the node are reachable during a specific duration $l^1.t$.

IMPLEMENTATION AND RESULTS

Mobile nodes exist in an area 1500×1500 m. The number of mobile nodes in the entire network is 300 ($M = M_1, M_2,...,M_{300}$). The duration of simulation is 2000 sec, t is taken as 100 sec and thus the value of l is 20, i.e., l×t = 20×100 = 2000 sec. The 1st 100 sec is neglected to remove the impact of the initial state and observe the proposed metrics during 100 sec, from time 0-100 sec. For further conduct extensive simulations to evaluate the proposed models and further understand the effect of mobility on MAID. The first study on sensitivity of this class of protocols to a rich set of mobility models (Manhattan, Group and Random Walk and Random Waypoint Models) is provided.

BonnMotion mobility generator: BonnMotion is a Java based oftware which creates and analyses mobility scenarios. It is developed within the Communication Systems group at the Institute of Computer Science at the University of Bonn, Germany. The scenarios generated can be exported to ns-2 and the Mobility Models that are supported include Random Walk, Manhattan Grid, Gauss Markov and Reference Point Group Mobility Models. For implementation of the proposed (Haas *et al*., 2002; Broch *et al*., 1998) metrics the BonnMotion is slightly modified to output the partition information at each time interval. The information produced by it contains details such as no. of partitions at that time, node id with the partition index and the size of each partition with its partition identifier. The perl language has been chosen for the implementation to compute the proposed metrics due to its high computing capabilities.

Analysis of Gauss Markov Mobility Models: The proposed metrics are computed for both the RPGM and Gauss Markov Mobility Models. The graph is generated using xgraph utility available with the NS-2 package. For generalization of the results, 5 nodes are chosen randomly to compare the results of the RPGM and Gauss Markov Mobility Models is shown in Table 1.

The value of average size of partition for Reference Point Group Mobility Model is 3.6278 and for Gauss Markov Mobility Model is 1.6879. In terms of storage capacity of partitions, the distribution of partition sizes (numbers of nodes in partitions) is more significant than their average and is heavily affected by the adopted Mobility Model. In the RPGM Model, each group has a center which is either a logical center or a group leader node. For the sake of simplicity, the group leader is assumed as the center. Thus, each group is composed of one leader and a number of members. The movement of the group leader determines the mobility behavior of the entire group. The movement of the group leader at time t can be represented by motion vector V^t group (Broch *et al*., 1998; Johnson and Maltz, 1996). Not only does it define the motion of the group leader itself but also it provides the general motion trend of the whole group.

Table 1: Distribution of partition sizes

	Ratio of partition size (Mobility Model)	
Partition size	Gauss Markov	Reference point group
1	0.613	0.115
2	0.218	0.150
3	0.083	0.188
4	0.043	0.173
5	0.017	0.132
6	0.013	0.070
7	0.003	0.048
8	0.003	0.030
9	0.001	0.029
10	0.001	0.016
11	0.001	0.008
12	0.001	0.011
13	0.000	0.005
14	0.000	0.003
15	0.000	0.003

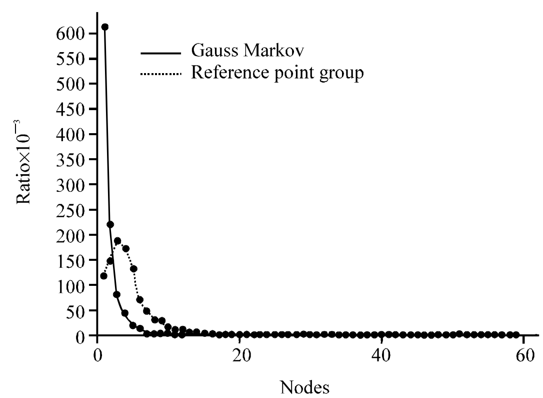

Fig. 1: Distributions of partition sizes

Each member of this group deviates from this general motion vector V^t group by some degree. The motion vector V^t group can be randomly chosen or carefully designed based on certain predefined paths.

In the Fig. 1, it can be noticed that the distribution of partition size is low in Gauss Markov Mobility Model relative to the (Haas *et al*., 2002) Reference point group Mobility Model. The Gauss Markov Mobility Model always forms low size partitions hence, the value of size of partition belonged to is lower than RPGM Model is shown in Table 2.

The Fig. 2, mainframe a change in size of partition determines the stability of the node. The Gauss Markov Mobility Model is more stable than the Reference Point Group Mobility Model thus the change in size of partitions belonged to is less for Gauss Markov Mobility Model is shown in Table 3. The change in size of partiotns belonged to for node 150 and the distribution of connected node is shown in Fig. 3 and 4.

The metric represents to how many nodes each node can disseminate its own data when all data distributions must be directly done by the data owner is shown in

Table 2: Size of partition belonged to

Size of partition	Node 0 GM	Node 0 RPGM	Node 50 GM	Node 50 RPGM	Node 100 GM	Node 100 RPGM	Node 150 GM	Node 150 RPGM	Node 200 GM	Node 200 RPGM
	Ratio of size of partitions									
1	0.25	0.00	0.25	0.00	0.30	0.00	0.40	0.00	0.30	0.00
2	0.25	0.00	0.20	0.00	0.05	0.00	0.20	0.00	0.20	0.00
3	0.10	0.65	0.25	0.00	0.05	0.00	0.10	0.00	0.15	0.00
4	0.20	0.00	0.10	0.00	0.10	0.00	0.15	0.00	0.30	0.00
5	0.10	0.00	0.10	0.75	0.10	0.00	0.05	0.00	0.00	0.00
6	0.05	0.10	0.05	0.00	0.00	0.00	0.00	0.45	0.00	0.75
7	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.05	0.00	0.05
8	0.05	0.10	0.00	0.05	0.20	0.00	0.05	0.05	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.05	0.00	0.10
10	0.00	0.05	0.05	0.10	0.00	0.00	0.00	0.10	0.05	0.05
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
12	0.00	0.00	0.00	0.00	0.05	0.10	0.05	0.10	0.00	0.05
13	0.00	0.05	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.10	0.00	0.00
16	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00

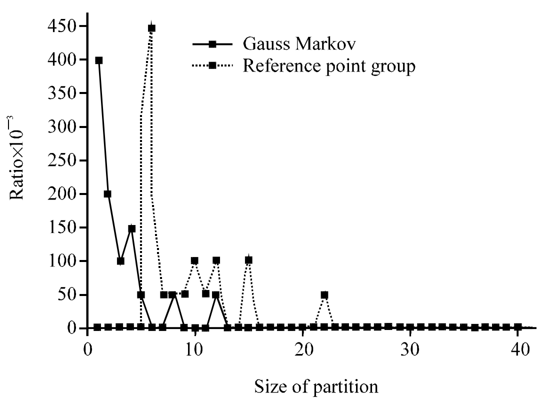

Fig. 2: Distributions of partition belonged to for node 150

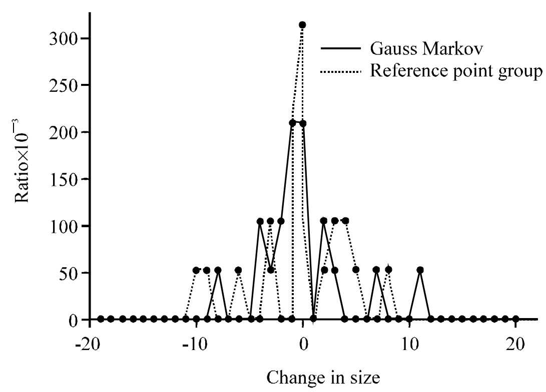

Fig. 3: Change in size of partitions belonged to for node 150

Table 4. The time variations and the total no of connected nodes in Gauss Markov Mobility Model is modest when compared to RPGM but it shows a steady state increase as time passes. Similarly the total no of data reachable nodes is also modest. For the sake of simplicity, the group leader is assumed as the center. Thus, each group is composed of one leader and a number of members. The movement of the group leader determines the mobility behavior of the entire group. The movement of the group leader at time t can be represented by motion vector V^t group (Broch *et al*., 1998; Johnson and Maltz, 1996). Not only does it define the motion of the group leader itself but also it provides the general motion trend of the whole group.

If the metric has a large value, the node can disseminate its data in a wide range (a large number of nodes) even when the sizes of the partitions are very

Table 3: Change in size of partition belonged to

Change in size of partition	Ratio of size of partitions									
	Node 0		Node 50		Node 100		Node 150		Node 200	
	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM
-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
-8	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
-7	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-6	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.05	0.05
-5	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00	0.00
-4	0.00	0.00	0.05	0.00	0.10	0.05	0.10	0.00	0.00	0.05
-3	0.00	0.15	0.00	0.05	0.10	0.10	0.05	0.10	0.05	0.10
-2	0.00	0.00	0.15	0.00	0.00	0.00	0.10	0.00	0.15	0.00
-1	0.26	0.00	0.15	0.00	0.10	0.00	0.21	0.00	0.26	0.05
0	0.26	0.52	0.21	0.52	0.21	0.63	0.21	0.31	0.15	0.47
1	0.05	0.00	0.15	0.00	0.05	0.00	0.00	0.00	0.10	0.05
2	0.21	0.00	0.05	0.00	0.05	0.00	0.10	0.05	0.05	0.00
3	0.00	0.05	0.00	0.05	0.05	0.10	0.05	0.10	0.10	0.10
4	0.05	0.00	0.10	0.00	0.15	0.05	0.00	0.10	0.00	0.05
5	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.05	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
7	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.00	0.05	0.00
8	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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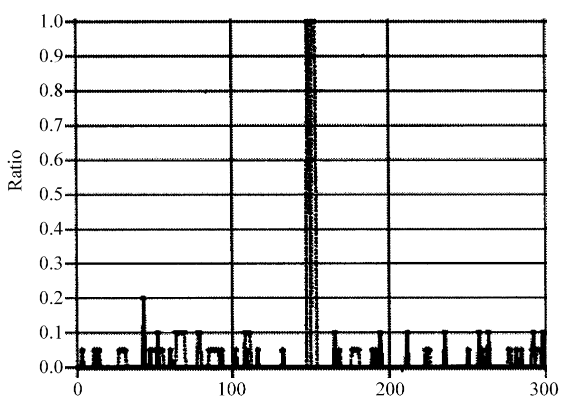

Fig. 4: Distribution of connected nodes

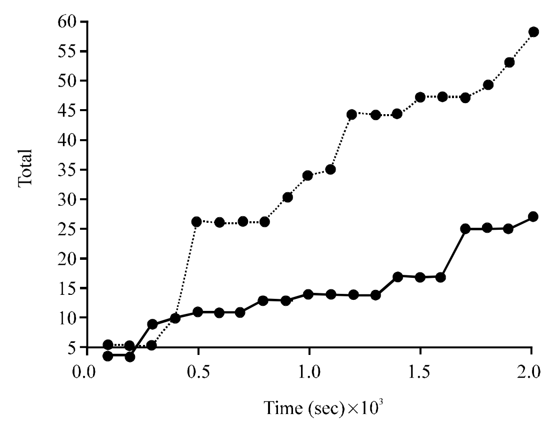

Fig. 5: Total number of connected nodes for node 150

small, i.e., the connectivity among nodes is very low shown in Table 5. The total number of connected nodes is high in RPGM. It shows that all data dissemination method is good for RPGM as shown in Fig. 5.

The Table 6 and Fig. 6 show total number of data reachable nodes. The total number of data reachable nodes for node 50, 100, 150 and 200 for time t is shown in Table 6.

Analysis of Guass Markov graph: From the analysis of the above graphs, the following behaviors are identified:

- Total number of data reachable nodes is high in Reference Point Group Mobility Model
- Distribution of connected nodes is high in Gauss Markov Mobility Model

Table 4: Distribution of connected nodes

	Ratio of size of partitions									
	Node 0		Node 50		Node 100		Node 150		Node 200	
Change in size of partition	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
40	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.05	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00
120	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
140	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
150	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
170	0.05	0.00	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.00
180	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
190	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
210	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
220	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
230	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
240	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
250	0.00	0.05	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
260	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
270	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
280	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
290	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
299	0.00	0.05	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5: Total number of connected nodes

	Ratio of size of partitions									
	Node 0		Node 50		Node 100		Node 150		Node 200	
Time	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM
100	5	5	0	14	7	14	4	5	3	5
200	6	5	4	14	8	14	4	5	4	5
300	6	10	4	14	8	14	9	5	4	5
400	6	19	5	17	8	17	10	10	7	5
500	6	24	5	17	11	17	11	26	8	8
600	8	34	5	17	14	17	11	26	8	8
700	9	41	6	17	14	17	11	26	9	14
800	12	41	11	20	14	20	13	26	10	14
900	12	41	11	20	14	20	13	30	10	14
1000	13	44	12	20	14	20	14	34	10	15
1100	14	44	12	20	14	20	14	35	10	15
1200	14	44	12	20	15	20	14	44	12	15
1300	16	44	12	20	19	20	14	44	12	15
1400	16	44	12	20	25	20	17	44	13	19
1500	17	44	14	24	27	24	17	47	13	19
1600	17	44	14	24	29	24	17	47	14	19
1700	20	44	14	24	30	24	25	47	21	22
1800	20	44	14	24	20	24	25	49	21	22
1900	20	44	14	24	32	24	25	53	21	22
2000	20	44	15	24	32	24	27	58	21	22

- The size of partitions to which the node belongs is low in Gauss Markov
- The change in size of partitions to which the node belongs is low in Gauss Markov Mobility Model

- Total number of connected nodes is high in Reference Point Group Mobility Model
- The average size of partitions is high in Reference Point Group Mobility Model

Table 6: Total number of data reachable nodes

	Ratio of size of partitions									
	Node 0		Node 50		Node 100		Node 150		Node 200	
Time	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM	GM	RPGM
100	5	5	0	4	7	14	4	5	3	5
200	9	5	4	9	12	17	8	5	5	5
300	13	10	11	9	15	17	10	5	8	5
400	18	23	15	9	19	34	14	10	13	5
500	27	48	19	17	28	53	16	29	19	8
600	33	52	21	27	31	59	18	29	25	8
700	48	71	24	47	42	81	19	47	30	18
800	56	81	26	54	51	108	26	52	38	26
900	62	106	30	91	65	155	30	63	45	36
1000	69	139	38	127	80	175	36	88	52	47
1100	75	168	41	147	87	194	41	116	61	77
1200	83	200	45	181	97	224	42	152	67	102
1300	86	213	51	207	104	241	43	172	78	123
1400	88	232	59	224	108	262	48	195	80	156
1500	97	239	68	226	121	271	62	208	83	178
1600	104	249	74	232	128	275	74	218	88	186
1700	110	271	82	248	133	287	76	238	105	210
1800	130	277	94	254	140	289	80	249	113	225
1900	139	280	97	258	143	294	94	254	124	240
2000	151	284	106	265	147	294	97	266	128	250

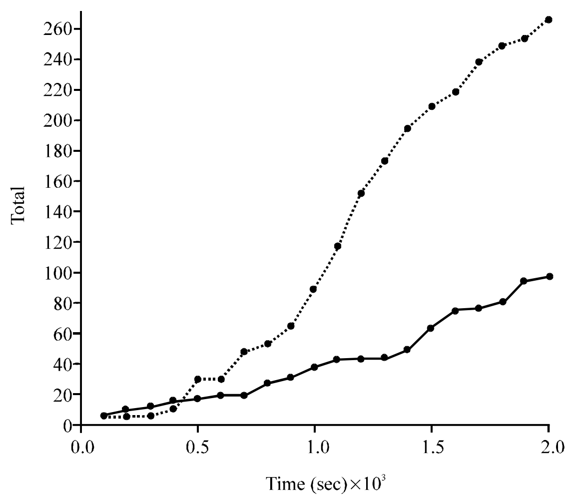

Fig. 6: Total number of reachable nodes for node 150

CONCLUSION

From the results of the metric comparison it is identified that the Gauss Markov Mobility Model often forms partitions with smaller size but rarely forms large ones when the node density is very high. This Mobility Model causes several isolated nodes resulting in the poor average of the partition size. Moreover, the ratio of not changing the partition size is relatively high and the maximum change in size is small. Totally this model works well in terms of data storage capacity and partition stability while the maximum capacity is small. For designing the data replication protocol, it is effective to share the data among the nodes within the same partition. Since, the change in size of partitions is low it improves the data availability when the data is shared among the nodes belonging to the same group.

The total no of connected nodes in Gauss Markov Mobility Model is modest when compared to RPGM but it shows a steady state increase as time passes. Similarly the total no of data reachable nodes is also modest. Therefore, it is advised to use aggressive data dissemination when designing the data diffusion protocol for the Gauss Markov Mobility Model.

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