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Impact of Mobility Models in Clustered Dynamic Mobile Ad Hoc Networks

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Abstract: MANET is self-configuring network formed by wireless mobile nodes without the use of any stable infrastructure. Since nodes are free to move, network topology changes rapidly. In a MANET, providing stability for a long time is a challenging task. The groups of randomly aggregated nodes are called clustering. This property of nodes supports to improve the several network features in MANET. These groups are formed based on the resource level f each nodes and their trust value. Each cluster groups are controlled by a single node is called Cluster Head (CH). This node is being elected by the voting support of all other neighboring nodes within the cluster. The other Cluster Member (CM) nodes within the clusters can communicate through the CH by single hop communication. The mostly MANET research area is based on simulation because not much MANETs have been deployed. In MANET nodes mobility is based on the mobility models and it is one of the most important parameters of the simulation of the MANET. In this study, we have considered four mobility models: random walk, random way point, reference group point mobility, manhattan mobility. These mobility model scenarios are used to evaluate the performance of clustered MANET. Obviously the clustered MANET performance will vary according to each mobility model. Performance comparison illustrates the importance of choosing a stable mobility model for the simulation of MANET protocols.

Key words: MANETs, mobility models, clustering, performance, resource level

INTRODUCTION

In recent years the deployments of MANETs have increasing attention due to their flexibility, mobility, energy resource, dynamic topology. Ad hoc networks are suitable for emergency situations like natural disasters, military conflicts because of its features like quick deployment, less configuration and decentralization. Grouping of nodes into clusters (Kumar and Rajesh, 2009) has been considered as a clustering method to improve the effectiveness of MANETs. In MANETs, the routing and data transmission are through Cluster Heads and Cluster Members locally communicate with their Cluster Heads directly. The routing protocol (Corson and Macker, 1999) AODV is used for routing in clustered MANET. The objective of this work is to provide a comparative analysis of various mobility models for clustered dynamic topology MANET performance.

Mobility models (Devicha *et al*., 2007) should attempt to mimic the movement pattern of mobile nodes. There are two major types of mobility model such as entity mobility model and group mobility model. The independent node movements are represented in the Entity mobility model (Jardosh *et al*., 2003). The group mobility model (Chaba *et al*., 2007) describes that the mobile nodes (Hong *et al*., 1999) whose movements are dependent of each other. In this study, four mobility models considered to check the protocol, performance of the MANET. These four mobility models are random walk, reference point group mobility, manhattan mobility and random way point. The mobility models random way point, manhattan and random walk are entity mobility models and reference point group mobility is a group mobility model. Since, a mobility model plays a vital role in the simulation, it should provide realistic information about the node's mobility, speed and direction.

Cluster head election (Bai *et al*., 2003) process mainly considers nodes mobility, energy level and trustworthiness. The energy level of nodes is kept as private information by the node and not to disclose to any other node. The dynamic change of topology affects the cluster groups and its structure (Ni *et al*., 2011). So, the mobility of nodes is considered as a crucial factor in case of MANET. Due to mobility factor of each nodes, the dependency of the nodes might be change by the outward movements (Basu *et al*., 2001) of nodes from its current cluster and may rejoin to the new cluster in the network. This is referred to as re-association. Due to the

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mobility of cluster heads may fails to maintain relative stable communication to its cluster members. This is also called as rotation of the cluster head.

MANET is formed as a set of 1-hop clusters: (Gowrishankar *et al*., 2007) and each node has aggregated to any one of the cluster in the network and has one cluster head. The selected leader can run the IDS for security of each cluster members since nodes are energy limited. The each cluster members combinely elect a node as leader which has significant energy resource to serve IDS for the entire cluster members and low mobility (Wu and Li, 1999). Since, the resource level of each node is private information and nodes might misbehave or perform maliciously by acting selfishly and lying about their resource level unless sufficient incentives are provided.

The proposed clustering framework provides reputation based incentives to for encouraging the selfish nodes, longer lifetime connectivity to the current cluster, fewer re-association rates and shorter re-association time. The relative speeds of nodes is estimated by Doppler shift effect (Mohammed *et al*., 2011). The solution for the addressed problem has two main stages: cluster formation stage; cluster maintaining stage. Each node estimates it's the average relative speed by to its neighbors in terms swapping of hello packets periodically in cluster formation stage. The cost of analysis function based on energy resource level and reputation value. The low cost and lowest relative mobility are selected as leaders based on the estimated results.

In cluster maintenance stage, the mobility related information's such as speed, direction and velocity are used to solve the problems caused by relative node movements of the nodes and CHs. This approach gives the improvement in network and network stability.

MATERIALS AND METHODS

Mobility models

Random Walk Mobility model (RWM): In Random Walk Mobility model, node movements are from its current location to a new location with random speed and direction (Camp *et al*., 2002). The direction (0, 2 σ) and speed [$speed_{min}$, $speed_{max}$] values are predefined according to this model. If the mobile node reaches a simulation boundary, it "bounces" of the simulation border and continues along the new path with the same velocity and different direction.

Figure 1 random walk model has been shown. The node changes their speed and direction at each time interval 't'. This model was originally proposed to simulate the unpredictable movement of mobile nodes. This is widely used mobility model and it is also called as the "Brounian Motion".

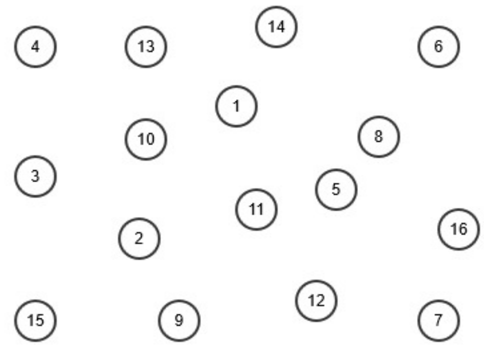

Fig. 1: Random walk mobility model

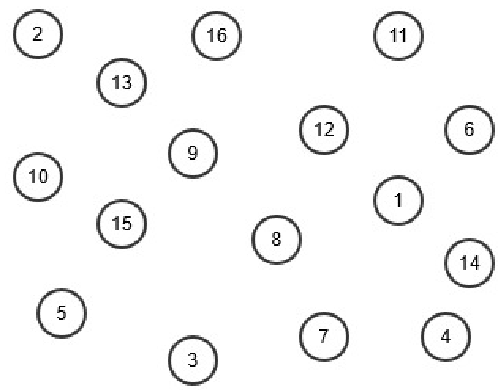

Fig. 2: Random way point mobility model

Random Way Point Mobility model (RWPM): This model is the most widely used mobility models in the research area (Radha and Shanmugavel, 2007). This model is simple and flexible to evaluate the performance of MANET. RWPM is similar to RWM; the only difference is 'pause time'. Once a mobile node chooses its destination, it moves towards with random velocity from a Uniform distribution (0,V_{max}). After reaching the destination, the mobile node stays at that location for a specified 'pause time'. The nature of the model depicts in Fig. 2. If the pause time is elapsed, the mobile node chooses the destination randomly and moves towards the destination with the selected speed from minimum speed to maximum speed. This process will be repeated until the simulation completed.

Reference Point Group Mobility Model (RPGM): The reference point group mobility model is simple, that is easy to analyze and implement, thus it has been the commonly used model for simulations. RPGM describes the random motion of a group of mobile nodes as well as the random motion of an individual MN within the group.

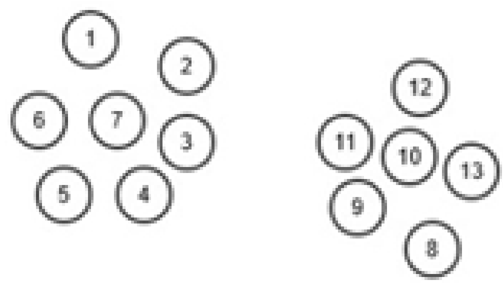

Fig. 3: Reference point group mobility model

Each group has a logical center or a group leader. The group leader calculates the group motion by group motion vector $\overline{GM}$. The group motion is completely based on its corresponding group of mobile nodes. A MN of each group deviates from its motion vector by some degree. This model is illustrated in Fig. 3. The randomly chosen motion vector or designed of the model is based on certain of the predefined paths. The group leaders movements are significantly affect the movement of each individual node belongs to the current group. Each node is assigned to a 'reference point' which follows the group movement. In group mobility, node movement can be described as follows:

$$|\theta_{member}(t)| = |\theta_{leader(t)}| + random() \times ADR \times max\_angel$$
$$|\nu_{member}(t)| = |\theta_{member(t)}| + random() \times SDR \times max\_speed$$

ADR is the angle deviation ratio. And sdr is the speed deviation ratio.

Manhattan Grid Model (MGM): This is one of the City Section Mobility Model. It is used to emulate the mobility patterns of nodes on the streets. Maps are used to describe the node movements. Manhattan Grid Model is shown in Fig. 4. This model comprises of horizontal and vertical streets topography. Nodes can move either in horizontal way or in vertical way. In case, if a mobile node is at an intersection of horizontal and Vertical Street, the mobile node can turn left or right or go straight with certain probabilities for each.

Clustering: Any mobile node can forward or route data packets to other nodes (Bettstetter, 2001). Since, all MANET nodes are energy constrained energy depletion will be higher if all nodes involve routing. Thus clustering involves cluster head selection to save energy level of the MANET. For effective cluster head election, the two main factors such as mobility and energy level of the nodes to be considered.

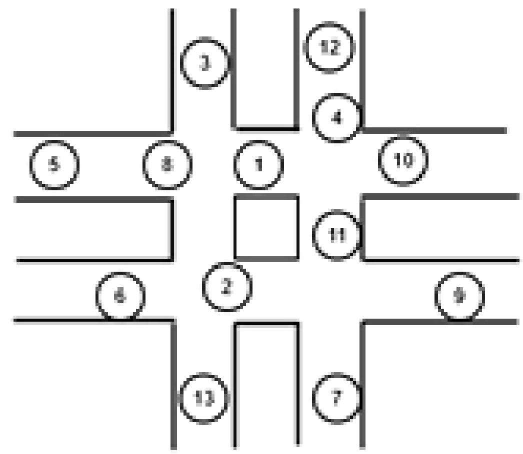

Fig. 4: Manhattan grid model

Cost of analysis: The node energy resource and trust value is used to estimate the cost of analysis. It provides two properties: sprite and privacy. The factor is to permit nodes to extend their life by less resource to function leaders. The latter is to avoid the malicious use of resource level by the selfish node.

The E_i is the energy level of node i. The nT_i is the number of time slots alive within a cluster. The PF_i power factor of node i. The TV_i is the trust value of the node i. The PS is sampling percentage of cluster members.

$$PS_i = \frac{TV_i}{\sum_{i=1}^{N} TV_i} \quad (1)$$

Cost of analysis of node i:

$$c_i = \begin{cases} \infty, \text{if} \left(E_i < E_{ids}\right) \\ \frac{PS_i}{PF_i}, \text{otherwise} \end{cases} \quad (2)$$

Mobility estimation: Let the relative position of the node 'a' is X and for 'b' is Y. The node 'b' moves with constant velocity and relative speed ν_{b-a} towards a. In this model, received signal average power is:

$$P_r = \frac{P_t G}{d^\alpha} = \frac{G'}{d^\alpha}; \; d = \sqrt[\alpha]{G'/P_r}$$

Where:

P_t = Transmission power
d = Distance between the two nodes
G = Constant, depends on the characteristics of radio transceivers, α is a path loss exponent

The relative speed is estimated after the node b receives two Hello packets from a at positions X and Z with time interval t_i, f_{dY} and P_Y are doppler shift and average power of received signal at position Y, f_{dz} and P_z are Doppler shift and average power of received signal at position Z. The difference between the average powers of receiving signals at two positions P is:

$$P_{\Delta} = P_Z - P_Y$$

The v_{b-a} can be solved as:

$$V_{b \to a} = \frac{\sqrt{s f_{dY} \sqrt{\alpha}}}{P_{\Delta} f} \sqrt{2 P_{\Delta} P_Y - \alpha P_Y^2 + \alpha \left(\frac{P_Y^{\alpha + 1}}{P_Z} \right)^{\frac{2}{\alpha}}} \qquad (3)$$

Node lifetime within a cluster:

$$\gamma_{b,a} = \frac{\overline{YW} - \overline{YZ}}{V_{b \to a}} \qquad (4)$$

Effective neighbor set of a node: Let Ni be the total number of neighboring nodes of node i. If Ni>NU the NU nodes that have the lowest relative speed to node i forms the effective neighbor set of the node i which is denoted as Ne, i.. If Ni = NU, the effective neighbor set of the node i includes all its neighboring nodes. Effective Average Relative Speed (EARS) of node 'i' is defined as:

$$\overline{V_i} = \frac{1}{\left| N_{e,i} \right|} \sum_{j \in N_{e,i}} V_{i \to j} \qquad (5)$$

Where, N_{ei} is the number of nodes in $N_{e,i}$.

Effective Leader Election (ELE) algorithm: Each node starts the election process by dissemination of Hello messages to all its neighbors. This message contains its ID and hash rate of the cost.

Algorithm 1: (Executed by every node):

/*all nodes reply with their cost once after receiving Hello message */
If (Hello message received from all neighbors) then
Send Begin_Election (ID_k; $cost_k$; EARS);
Else if (neighbors (k) =Ø) then
Launch IDS to CM
End if

Every node sends the Begin_Election message after receiving all the hash rates from all its neighbors. This message contains the initial values, the node ID and average relative speed.

Algorithm 2 (Executed by each node):

/*Voting process - Each node votes to elect one leader */
if ($\forall$ n $\in$ neighbor (k), $\exists$ i$\in$n : $c_i = c_n$) then
Vote (ID_k; ID_i ; $cost_{j \to i}$);
Leader_ node (k): = i
End

Each node compares the hash values to verify the least cost and lowest speed after receiving the Begin-Election message. Each node sends Vote message to the corresponding node. The vote message consists of ID of the node, ID of the leader node to which it sends the vote.

Algorithm 3 (Executed by leader node):

/*propagating acknowledge message to the neighbor nodes */
Leader (i):= True
Calculate imbursement, P_i
Revise service_table(i);
Revise reputation_table(i)
Ack = P_i + all the votes
Send Ack (i)

The payment is calculated by leader node and sends an Acknowledge message to all the serving nodes. The Acknowledge message contains the payment in terms of resource allocation and count of votes of received by leader node. The then leader node launches its IDS.

Each active nodes in the cluster group verifies the payment and revise its reputation table unswerving with the payment. All the signed messages are supplied to respective nodes for avoiding any type of quite cheating. At the end of the election process, nodes are divided into two types: Leader and cluster member node. The IDS is run by leader nodes for inspecting packets right through an interval T_{ELECT} with relative reputations of the cluster nodes. We have a tendency to enforce reelection every period of T_{ELECT} since it's unfair and unsafe for one node to be a server forever because of degrading nature of available resource due to its active participation in communication. All cluster member nodes start new election process to elect a new leader or retain existing leader Even though the topology remains same after the period of T_{ELECT}.

Routing protocol: AODV is a pure on-demand routing protocol which intimate a route request only when needed. The source node sends a Route Request (RREQ) packet to all its neighbors (Babu *et al*., 2015). The destination sequence numbers are used in DSDV to ensure that the current routing information contains the latest recent route information and free from looping (Shah *et al*., 2008) Each receiving node checks its routing table for a route to the destination. Intermediate nodes can reply only if it has the route with a greater sequence number. The route performance can be optimized by intermediate nodes record that address of the neighbor from which they receive the request. This process creates a new the reverse path. After reaching of RREQ reaches to its destination or an transitional node with a route to the terminal, a node sends the unicast Route-Reply (RREP) message back to its neighbor routing node. As the RREP reverse back on the current path, the nodes on this path resets their forward route entries to point from which the RREP has just been received by a node. The RREP continues traveling back in the same reverse path till it reaches to the source node.

RESULTS AND DISCUSSION

Simulation environment: This study provides the simulation environment set up to evaluate the performance of routing protocols in clustered MANET with the impact of several mobility models (Pazand and McDonald, 2007). The routing protocol is simulated within the Network Simulator (Version 2.35). Simulation parameters are given in Table 1.

The standard 802.11 MAC layer is used and each nodes in the simulation has omni directional antenna. The simulation is for 20-100 nodes and runs for 2000 seconds. Nodes are placed in the flat 1000×1000 m area. Channel capacity is about 2 Mbps for each node. Each source node sends the data at the rate of 5-12 packets sec^{-1}. The size of the data payload is 512 bytes.

Performance evaluation

Performance metrics: In this study, we analyze the simulation results of clustering algorithm with different mobility models. The following metrics were used in computing the protocol performance.

Throughput: Throughput of the network is given by the average rate of successful message delivery rate over a communication channel. This is typically measured in bits per second (bps) or packets per second or data packets per time slot. The data may be passed through a physical or logical link or certain network node.

$$T_P = T_{br}/S_t$$

Where:

T_P = Throughput
T_{br} = Total No. of bits received
S_t = Total No. of bits sent

Packet delivery ratio: It is the Ratio of number of data packets sent from the source to the number of data packets received at the destination node and the performance of the protocol is achieved by high PDR which implies that how efficiently data packets have been delivered.

$$PDR = P_s/P_r$$

Where:

P_s = No. of packet sent
P_r = No. of packet received

End-to-End delay: The end to end delay is the average time delay for data packets from the source node to the destination node. It is the ratio of time difference between every CBR packet sent and received in the total number of CBR packets received. The protocol, performance will be better for less end-to-end delay:

$$D_t = N(d_{tr} + d_{prop} + d_{pro})$$

Where:

d_{tr} = Transmission delay
d_{prop} = Propagation delay
d_{pro} = Processing delay

Simulation results: We have compared the performance of the AODV protocol for different mobility models with dynamic clustering topology control. The aim of this research is to examine the performance of routing protocol exaggerated with different mobility patterns in the network size of 20-100 nodes. In this analysis the simulation is carried with topography area 1000×1000 m and 'CBR' data packet size 512 bytes is allocated.

The most widely used metrics for representing performance of routing protocols are end to end delay, throughput, packet delivery ratio and control overhead. End-to-End delay is a metric to measure external performance of a protocol and PDR, throughput and control over head are the metrics to analyze internal performance of protocol, These above metrics describe the nature and boundary conditions of mobile ad hoc networks.

The throughput has different effects for various mobility models such as random walk, random way point, reference point group mobility models. As the node speed increases throughput decreases for all mobility models with different starting values. Figure 5 we compared the throughput with four mobility models.

Figure 6 end-to-end delay is calculated for the mobility models. It has been observed that the end-to-end delay for lower for the reference point group mobility model than other models like RWM, RWPM and manhattan grid. Considering the RWM and RWPM, the

Table 2: Performance of cluster approach on mobility models

Mobility models	Throughput (%)	End-to-End delay (%)	PDR (%)	Control overhead (%)	Cluster head change (%)
RWM	72.25	11.67	38.50	64.57	42.86
RWPM	81.21	2.74	88.06	4.800	54.29
RPGM	68.94	20.34	35.78	72.70	36.95
MGM	75.74	14.96	63.00	45.28	68.43

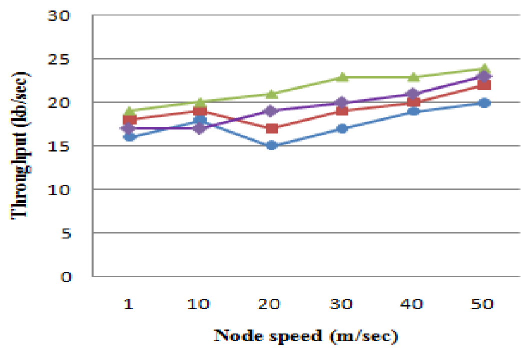

Fig. 5: Node speed vs throughput

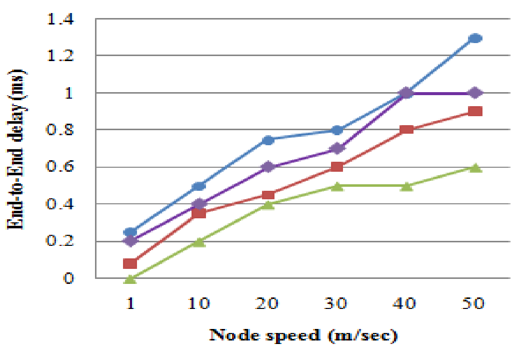

Fig. 6: Node speed vs End-to-End delay

delay has been increased as node speed increases. The PDR of is giving better for RPGM other than RWPM, RWM and Manhattan. RWPM has a lower PDR as node speed increases. Considering the Packet Delivery Ratio in AODV, RPGM has high Packet Delivery Ratio which is shown in Fig. 7. Figure 8 we compared the control overhead against node speed. This is due to the fact that only the stable routes are used by the algorithm for routing the packets. Flooding the Route Request and searching the new route contributes to the increased overhead in routing. The control overhead is less with an increase in packet size in AODV.

The result of a cluster of cluster head change is shown in Fig. 9. Since, the cluster head election is mainly based on two factors like mobility and energy level, node speed causes cluster head change. The Different mobility model has different effects on the cluster head change rate. As the node speed increases Manhattan mobility model has higher rate of change than other models. Table 2 gives the summary of the performance of four mobility models.

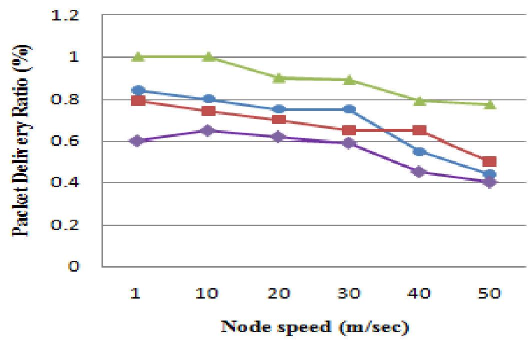

Fig. 7: Node speed vs packet delivery ratio

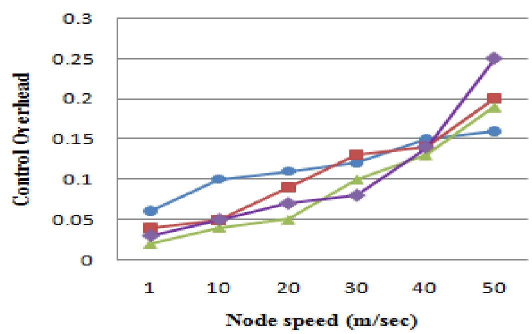

Fig. 8: Node speed vs control overhead

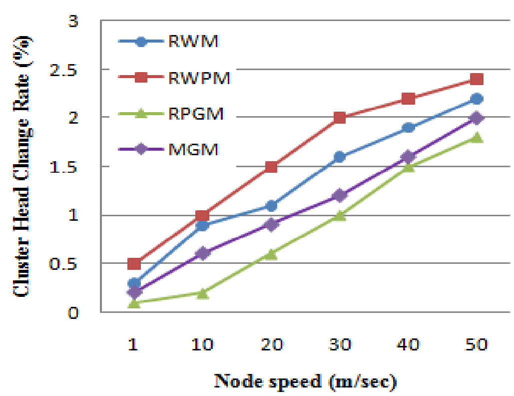

Fig. 9: Node speed vs cluster head change

CONCLUSION

This study deliberate the performance of the most widely used routing protocol AODV with respect to four mobility models such as Random Way Point, Random

Walk, Manhattan Grid Model and Reference Point Group Mobility under clustered topology control. We have considered the clusters to evaluate the performance of the routing protocol. Simulation results show that the performance of the routing protocol AODV has different effects for each mobility model. The reactive protocol AODV experiences the most stable performance with all mobility models under clustered topology controlled scheme. It has been observed that the Reference Point Group Mobility model experiences better performance by the effective cluster head election process. In future work we have planned to evaluate the performance of multicast routing protocol by varying the network size, node speed and with different mobility models.

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