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Cluster Enabled Performance Evaluation of MANET Routing Protocols Using Mobility Patterns

[1]Dr. K. Mani, [2]Prasath Sivasubramanian
[1]Associate Professor, [2]Research Scholar
Nehru Memorial College, Puthanampatti, Trichirapalli, India

Abstract: Mobile Adhoc Networks are basically infrastructure less networks that operates in a energy constrained setup. The constant movement of nodes in this type of network environment, enforces implementation constraint, to depute any responsibility on a node, like routing decisions, security enforcement etc. This paper focus on designing a modified clustering scheme to track the node mobility using eccentricity. The objective of bringing clusters is to preserve and monitor nodes mobility pattern using appropriate data structures deputed on the cluster head. Moreover to analyze the effect of this modified clustering scheme, the performance of three routing protocols namely, Adhoc Ondemand Distance Vector Routing(AODV), Clusterhead Gateway Switch Routing(CGSR) and Dynamic Source Routing (DSR) is measured and compared.

Keywords: MANET, Cluster, Node Mobility, Eccentricity.

I. INTRODUCTION

Basically, Adhoc Networks are infrastructure less networks, and is knows as Mobile Ad-hoc Networks (MANET). Since each node acts as router, there will be no fixed router in this architecture. Since the nodes are mobile in nature, their connectivity will be in a dynamic fashion. This dynamic nature enforces the mobile nodes to organize and control their responsibilities by themselves in a distributed manner [1]. The nodes of these networks function as routers [2], which discover and maintain routes to other nodes in the networks. Due to this dynamic nature of the mobile nodes, frequent disconnections in links and change in topological structure are common scenario in MANET and it creates a big hurdle in the functioning of routing protocols that are designed for MANET [3]. To handle this challenge, it is ideal to build a hierarchy among nodes so that the topology changes can easily be tackled. This is possible when nodes are grouped on some parametrical basis to form clusters, C. Clustering is used to partition an adhoc network into some smaller groups [4], and all the partitioned clusters function as a whole. It can also be used for transmission management, backbone formation and routing efficiency. Hence, it is found that clustering and cluster enabled structures enable a better use of network infrastructures in a dynamically larger networks. The clustering enables certain control over the node mobility since the node among themselves are hierarchically arranged. Normally a routing protocol is used for node communication, which facilitates the sharing of information by choosing a better route between any two nodes in a network. The specific route to destination is calculated by routing algorithm. Each router has information of nodes that are directly connected to it. A routing protocol shares this knowledge amongst its first nearest neighbors, and then to the entire network. It is classified as reactive (on- demand), proactive (table-driven) and hybrid protocols [5][6].

In this paper, a modified clustering scheme is proposed to evaluate the performance of routing protocol. For that a simple data structures is incorporated into the cluster heads, CH, through which the position of the mobile nodes can be tracked. This strategy of identifying the position of mobile nodes enables the routing protocol to offer their full functionality since frequent disconnections are due to node mobility.

The rest of this paper is organized as follows. Various work related to clustering and routing is presented in section 2. The mathematical background of clustering is presented in section 3. The proposed methodology is discussed in section 4. Experimental evaluation of results of the performance the routing protocols in a simulated environment are discussed are in section 5, and finally section 6 ends with conclusion.

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II. RELATED WORK

Several heuristics have been proposed to choose CH in an ad hoc network. They are termed as the lowest ID heuristic, highest-degree heuristic and node–weight heuristic. Ratish and Mahesh [7] proposed the Lowest ID algorithm also known as identifier–based clustering algorithm in which CH was selected by assigning unique ID to each node and then selecting the node with the smallest ID. Whenever a node with a lowest ID was detected in the C, the CH must delegate its responsibility to this node and it will be the new CH. Highest-degree algorithm also called connectivity–based algorithm was proposed by Sudipta et al. [8-10]. The number of neighbors of a given node was taken as the degree of the node and the node with highest degree was deputed the role of CH. The drawback of this algorithm was that a CH cannot handle a large number of nodes due to resource limitation even if these nodes were its immediate neighbors and lie well within the transmission range i.e., the degree of node changes very frequently. The weighted mobility patterns for clustering was proposed by Thuy Van et al. [11-14] to obtain 1-hop clusters with one CH . The election of the CH is based on the weight of each node which is computed by combining a set of system parameter like battery and mobility. It can dynamically adapt itself with the ever changing topology of the network based on the mobility of the nodes from time to time.

III. MATHEMATICAL BACKGROUND OF CLUSTERING

A network is modeled as a graph G = (V,E) where V is the set of nodes represented as $V=\{v_1, v_2, \dots, v_n\}$, E is the set of edges represented as $E = \{e_1, e_2, \dots, e_m\}$ and m and n are maximum number of edges and vertices respectively. An edge between any two nodes, say (v_i, v_j) with $i \neq j$ is denoted as e_i and the weight of an edge is a non-negative integer associated with each edge e_i, $w(e_i)$. Two nodes, say (v_i, v_j) are said to be adjacent or neighbors, when there is a direct link e_i between them. The number of links incident on a node v_i is called the degree of the node, $d(v_i)$.

While forming the clusters, it is most essential to identify a CH for each C so as to depute the responsibility of inter cluster and intra cluster communication. Inorder to elect the CH, the following mathematical models are used.

Let h be the total number of C. For each cluster C_i, with n_i nodes, i=1,2,..,h. with $n_i \neq n_2 \neq \dots \neq n_h$. Also $n_i < n$. Moreover,

$$\sum_{i=1}^{h} n_i = n \tag{1}$$

For each node, $v_i \in C_k$, k= { 1, 2, … , h}, find $d(v_i)$. Let Δ_{ij} be the degree difference between two adjacent nodes, say v_i and v_j. Then,

$$\Delta_{ij} = \left| d(v_i) - d(v_j) \right| \text{ with } i \neq j \tag{2}$$

For each v_i, find the distance, $dis(v_i)$ from all its neighbors. Then, the sum of the distance, $S_{dis}(v_i)$ is computed as

$$S_{dis}(v_i) = \sum_{v_k \in adj(v_i)} dis(v_k) \tag{3}$$

As the mobility of node is dynamic, it is necessary to calculate the relative position, $T(v_i)$, of a particular node with respect to particular time and it is computed as:

$T(v_i) = t_e - t_s$ where t_e is the end time and t_s is starting time;

Let at time t_s, the position of a node v_i is (x_{i1},y_{i1}) and at time t_e, the position of a node v_i is (x_{i2},y_{i2}) on a geometrical plane. The distance traversed by a node v_i, $dis(v_i)$ is computed as

$$dis(v_i) = \sqrt{(x_{i2} - xi_1)^2 + (yi_2 - yi_1)^2} \tag{4}$$

and the average traversal time by a node v_i over a period of time T_i is computed as

$$M_{vi} = \frac{dis(v_i)}{T_i} \tag{5}$$

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IV. PROPOSED SYSTEM

A modified clustering scheme for MANET is proposed that enables to track the node movements, by adding suitable data structures which are incorporated in the CH and it is updated as and when the CH receives a broadcasting messages from its neighbors. Once the C is formed, the performance of three well known protocols of MANET are evaluated and compared.

The proposed system carries the following modules and the architecture of the proposed system is given herewith:

- Cluster Formation and Head Selection
- Cluster Maintenance
- Cluster Communication
- Node movement prediction for Cluster stability

A. Cluster formation and head selection

Initially, a cluster structure is formed by grouping the nodes each node is assigned a node ID value. For selecting a CH, each node broadcasts its ID value to its neighbors and builds its neighborhood list, and it computes its degree with the neighbor list.To calculate its own weight the following factors viz., Node Connectivity (NC), Degree Difference (DD), Cumulative Time(CT), Mobility factor (M) and Distance (D). NC is defined as the number of nodes within the transmission range which can communicate with a stipulated node is termed as connectivity of node. DD is the difference between the nodes within its transmission range and ideal degree of a node. CT is the power currently left in each node. Sending and receiving of messages consumes energy and hence the power left in each node is taken. M is the running average of speed of each node till current time T and D is addition of the cumulative distance of all its neighbors is the distance of a node.

Inorder to elect the CH, the node with lowest weight is identified and it is designated as CH. For this each node computes its weight based on the following algorithm:

Algorithm 1: Cluster formation and head selection

Input: Array of node, node ID value, degree dv, list of neighbors
Output: Cluster head node is set.
Parameter used: Degree, neighbor list, distance, mobility, battery power, active mode power.

1: Each node in the network is assigned the unique node ID value.
2: Each node broadcasts its ID value and builds its neighborhood list.
3: Find the degree of each node dv as,

$$dv \leftarrow |N(v)| \leftarrow \sum_{v \in V,\ v \neq v} \{ \text{dist}(v, v1) < \text{tx range} \}$$

where tx range – transmission range of node.
4: Compute the degree difference, using the equation 2.
5: For each node, compute the sum of the distance Dv_i , with all its neighbors using the equation 3.
6: Using equation 4, compute the running average of the speed for every node till current time T, this gives a measure of mobility and it is denoted by Mv, and the mobility of the node Mv_i, is calculated using equation 5.
7: Compute the remaining battery power Pv (cumulative time) for each node.
8: Ideal active mode power of each node (AMP)
9: Calculate the combined weight,

$$Wv \leftarrow w1\Delta_{ij} + w2Dv_i + w3Mv_i + w4Pv_i + AMP$$

where w1,w2, w3, w4 (0.7; 0.2; 0.05; 0.05 respectively) are weighting factor for corresponding system parameters.
10: Choose the node with smallest Wv as cluster head.
11: Repeat step (3 – 10) for the remaining nodes not yet selected as cluster head (CH) or assigned to a cluster.

12: Once the cluster head is elected, its global table is entered with the details of the members of the cluster and the neighboring cluster heads

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(i) Connectivity

Connectivity is the probability that a node is reachable from any other node. Whenever a cluster member is within a shorter transmission range, the CH utilizes low power for communication and when trying to communicate with neighboring CH they use high power. The distance between the CH and the node is calculated using Euclidian distance formula. The connectivity is calculated as

Connectivity = (Cardinality of largest component) / (Cardinality of the graph(N))

B. Cluster maintenance

The second phase is the cluster maintenance, which is done, when a node moves out of the range of its CH, node leaving, if a new node is added or the CH fails. Whenever a new node is added, its weight is calculated, however, even if its weight is more than the CH, it does not immediately become the CH and instead chooses the current CH as its CH to avoid unnecessary overhead in reelection of the CH whenever a new node is added. Whenever the CH fails to offer its service, the nodes that are attached to it, recalculates their weights and a new CH is elected from the cluster nodes with minimum weight. Clustering maintenance phase begins for the changed cluster.

(i) Node Joining

When a new node arrives, it broadcast the node ID to all neighbors in the neighborhood list. The new node calculates its weight values and check with the neighbor if CH already exist then the node join as cluster member to the existing cluster otherwise it form a new cluster and declare it as CH and inform to all the members in the cluster. It is presented in algorithm 2.

Algorithm 2 : Node Joining the cluster

INPUT: new node ID, neighbor's list
OUTPUT: cluster head or Ordinary member node
Parameter used: Neighbors list

1: Send the message to all its neighbor nodes, within the transmission range, process the message received from the neighbor nodes in network then from a connection.
2: Calculate the degree-difference, sum of distance, mobility, Cumulative time, weight factor and active mode power as per the algorithm mentioned for that.
3: If (cluster head (CH) already exist in the neighborhood) Send request to join the cluster
    else
    Form a new cluster and declare it as cluster head (CH)

4: The cluster head informs all cluster members about the newly arriving node.

(ii) Cluster Head Resigned its Role

When a CH resign its role, it will send a leave message to the entire cluster member and its new CH. The cluster reorganization has to perform for the nodes in the cluster. The new CH is elected based on the pre – cluster threshold value which is shown in algorithm 3.

Algorithm 3 : Cluster head resigned its role

INPUT: Threshold value, neighbor's list, cluster head, leave node ID
OUTPUT: New cluster head and cluster member
PARAMETER USED: Neighbors list, threshold value

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1: Determine the pre-cluster head threshold value (Th) [i.e next smallest weight compared to resigning CH weight]
2: Calculate, Th = α + PCW where, α – Load balancing power, PCW – Pre-cluster head weight
3: Cluster head V_i is selected using the threshold stated in step 2. and it should be in min{ weight ($Z_i – V_i$) } where Z_i – weight of leaving cluster head
4: Inform this new election to all cluster members
5: New cluster head copies the global table entries from the old cluster head.

(iii)Moving cluster Member node:

The cluster member node move from one cluster to another cluster it will register itself with the cluster head of the new cluster. The new cluster head will make an entry in its global table regarding the moved- node's identity, that has come into its cluster. When the moved-node's old cluster head wants to send message to this moved-node, it will broadcast a message to all the cluster head stating the moved-node's id. Only the cluster head, where the moved-node register its id, respond to the broadcast message. By this response, the old cluster head can be given an idea where the moved-node is presently located. The old cluster head now reconfig.its global table removing the moved-node's identity. It is shown in algorithm 4.

Algorithm 4 : Moving cluster member node.

INPUT: Cluster head, leave node ID
OUTPUT: New cluster Head
PARAMETER USED: neighbors list, node ID

1: Moved-node register its node id with the cluster head it has move into presently
2: The old cluster head broadcast a message stating the moved-node's id.
3: Cluster head where the moved-node register its id only respond to the broadcast message
4: Old cluster head reconfig.its table by deleting the move- node's details

C. Scenario of Cluster formation

This section depicts the Cluster formation and CH election tasks based on the proposed cluster formation and CH election algorithms. Initially, minimum number of nodes are taken for the cluster formation and the validity of the algorithms are checked. After a successful evaluation, new nodes are added in to the clusters dynamically. Table 1 shows the computation process for 15 nodes and Fig.1 shows the cluster formation process.

Table 1: Cluster computations

Node ID	dv-degree	Δ_{ij}	Dv	Mv	Pv	Wv
1	2	0	3.4	1.2	1	2.79
2	2	0	2.2	1.5	2	3.315
3	2	1	2.2	1.4	1	2.765
4	3	1	2.2	1.6	2	3.32
5	1	1	5.8	1.8	4	4.15
6	2	1	1.4	2.2	2	3.19
7	1	1	2.8	1.5	0	2.635
8	2	0	4.2	2	3	3.12
9	2	0	5.6	2	6	4.92
10	4	2	4.8	2	7	4.11
11	2	0	1.4	1.7	1	3.115
12	3	1	2.8	1.6	2	2.81

13	2	0	2.8	2.1	2	3.26
14	1	1	4.2	1	0	2.89
15	1	1	1.4	1.4	3	3.2

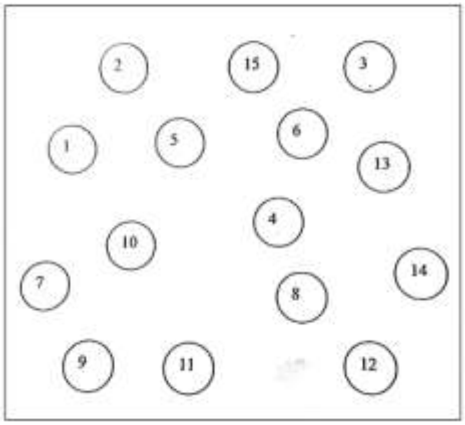

Fig. 1(a) Initial Node Positions

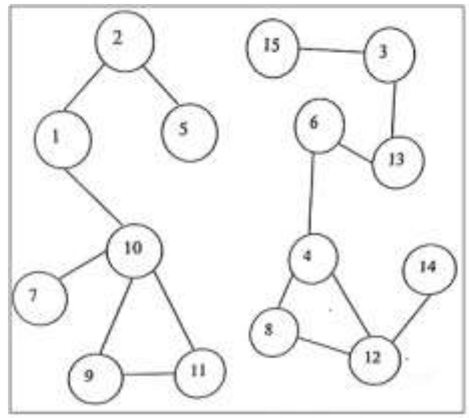

Fig. 1(b) Neighbors Identified

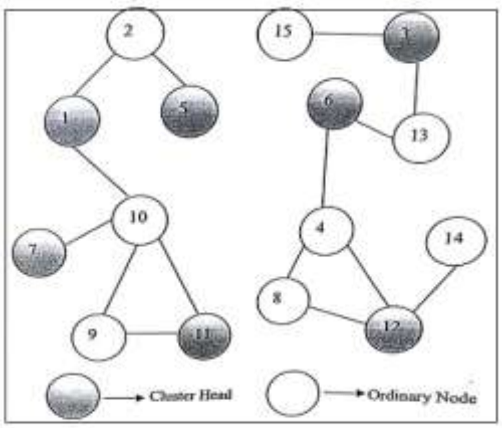

Fig. 1(c) CH Identified

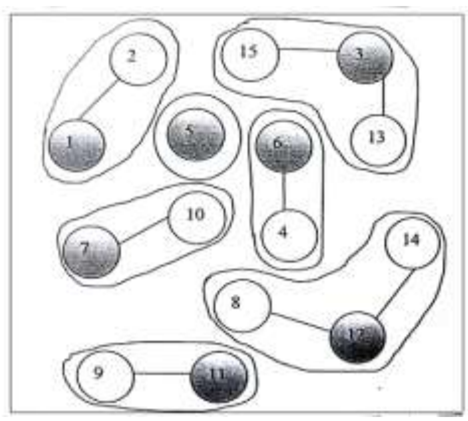

Fig. 1(d) Cluster Formation

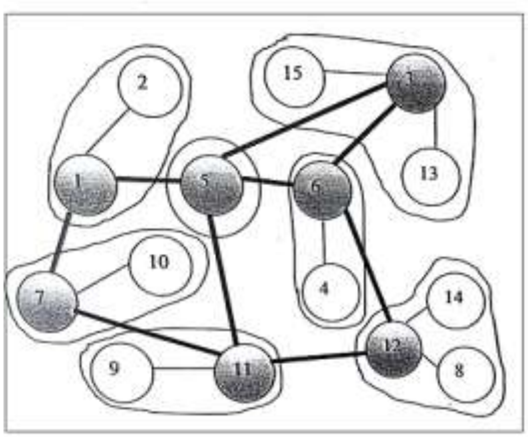

Fig. 1(e) CH Connected

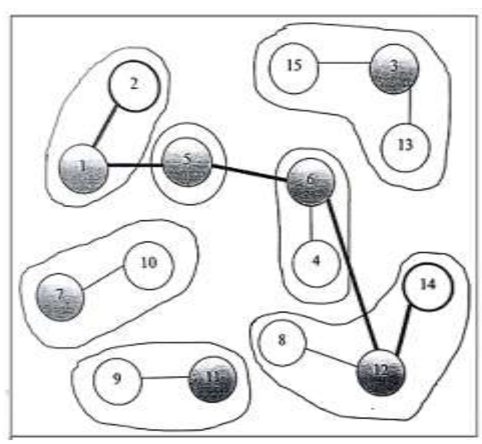

Fig. 1(f) Path Identified

Fig. 1 Cluster formation, Head selection and Path identification

D. Node movement prediction for cluster stability

Predicting the mobility of nodes [15-19] is a constant challenge for researchers to implement a solution in MANETs. In this paper, a topology based mobility prediction methods, i.e., the cluster based mobility on which the prediction process is studied. The positional value of the node location and mobility information may be obtained using appropriate techniques, and it is represented through the data structures deployed. This can be implemented by incorporating tables within the clusters. The tables are termed as Global Service Table (GSR) and also dividing the cluster into a sectorized structure. The process of identifying the mobility patterns are:

(i) The Nil-Cluster Change (Nil-CC) region of each cluster, which contains the nodes of the cluster that are within communication range of each other and they do not satisfy the requirements for membership to any neighboring cluster. Thus, for the nodes in the Nil-CC region, cluster change is not possible. This is calculated by identifying the minimum eccentricity of the CH . Nodes that falls in this range will be place in this region. Since they are very close to the CH comparing to other nodes, they are the candidate nodes that participate in the routing decisions.

(ii) The Min-Cluster Change (Min-CC) region of each cluster, which contains the nodes of the cluster that are reachable by all nodes in the Nil-CC region, either directly, or through other intermediate nodes belonging to the Nil-CC region. Thus, for the nodes in Min-CC region the probability of cluster change is fairly low. Nodes that are present in this region will be considered to take part in the routing process only when there are no nodes present in Nil CC region.

(iii) The Max-Cluster Change (Max-CC) region of each cluster, which contains the nodes of the cluster that are not reachable by any node in the Nil-CC region, either directly, or through other intermediate nodes belonging to the Nil-CC region. The nodes in the Max-CC region are reachable only through the nodes in the Min-CC region and the probability of cluster change for a node in this region is higher than for nodes in the Min-CC region. The nodes present in this region is identified by calculating the eccentricity of the CH which is the largest distance between the cluster head and the other nodes. The nodes present in this region will not be considered for routing process, since they are more prone to cluster change which will drastically affect the performance of the routing process.

Let us consider A as the CH. In order to find the nodes that are positioned on the various regions namely Nil cluster change, Min cluster change and Max cluster change, eccentricity of various member nodes are found. In order to identify the nodes where it is in a particular region viz. Nil-CC, Min-CC and Max-CC, and enabling the CH to decide to which set of nodes it can depute the routing decision, eccentricity is used and compute the values of nodes. The nodes whose values ranging from 1to 3 are placed in Nil-CC; nodes whose values ranging from 4 to 6 are placed in Min-CC; nodes whose values ranging from 7 to maximum are placed in Max-CC.

The eccentricity of a CH, E(CH) is calculated

$$E(CH) = \max_{v_i \in c_i} d(CH, v_i)$$

After calculating E(CH) of each CH, the average eccentricity is calculated as:

$$A_e\,(ch) = \left\lfloor \frac{E(ch)}{3} \right\rfloor \text{ for a 10 nodes cluster.}$$

The nodes that are placed in the three regions are identified using the following equations; for each $v_i \in c_i$

$$\text{if } \begin{cases} E(v_i) \le A_e\,(ch) & \text{, then } v_i \in \text{Nil – CC} \\ A_e\,(ch) < E(v_i) \le 2\,A_e\,(ch) & \text{, then } v_i \in \text{Min– CC} \\ 2\,A_e\,(ch) < E(v_i) \le E(ch) & \text{, then } v_i \in \text{Max– CC} \end{cases}$$

From the fig.2a and 2b, the distance of different member nodes from the CH is calculated using eccentricity radius. For identifying the nodes in the Nil Cluster Change zone, the minimum eccentricity (radius) of the CH is calculated. From fig. 2b. the minimum eccentricity radius is of distance 1 that is for nodes B and K. Hence, these nodes are placed in the Nil cluster change zone. The nodes with distance 2 and distance 3 is placed on Min Cluster change Zone. Hence the nodes C, E, F are placed in the Min Cluster Change Zone. The remaining nodes whose distances are greater than 3 are placed in Max Cluster Change zone.

Fig. 2(a) Sample cluster

Fig. 2(b) Distance Calculation

Fig. 2 Eccentricity Calculation

The routing decisions are deputed only to the nodes which are present in the Nil Cluster Change zone as their eccentricity radius is minimum to the CH and hence their mobility is very minimum. This control measure on the node mobility enables a better results in the performance evaluation of routing protocols of adhoc networks.

V. EXPERIMENTAL EVALUATION

In order to understand the relevance of the proposed methodology, the experimental evaluation of three protocols is carried out using NS2 tool. The simulation is carried out for 100, 150 and 200 nodes separately and the performance is evaluated using XGRAPH tool.

5.1 Parameters taken for evaluation

End to End Delay, Packet delivery ratio and Throughput are taken as parameters for evaluating the performance of the three protocols. Delay, D, is calculated by subtracting time at which first packet was transmitted from source minus the time at which first packet arrived to the destination; Packet Delivery Ratio, PDR, is the total packets received to those transmitted and Throughput, T, which is total number of packets received in a certain unit time interval [20].

5.2 Simulation Environment and Parameters

The simulation of the proposed work in NS2 takes the following steps of fixing a rectangular area where the nodes are randomly placed. Mobility of nodes follows a random waypoint model, where every nodes moves toward a randomly selected location at a speed uniformly distributed between 0 to a maximum speed and then pauses for a configured time, before selecting a random location and repeat the same process. Simulation parameters that are taken for implementation is shown in Table.2.

Table. 2: Simulation Parameters

PARAMETER	VALUES
Number of Nodes	100, 150 & 200
Transmission Range	30m
Mobility model	Random waypoint
Idle Degree	10s
Maximum speed of nodes	2 – 10m/s

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Maximum Displacement	1 – 10m

5.3 Results Analysis

Based on the experimental setup, the performance of the three well known protocols is evaluated using the said parameters in the proposed cluster methodology. The simulation is done varying the number of nodes from 100, 150 and 200. After simulation the results are plotted using Xgraph tool and the performance of them is analyzed.

Fig. 3(a) Packet Delivery Ratio 100 nodes

Fig. 3(b) End to End Delay 100 nodes

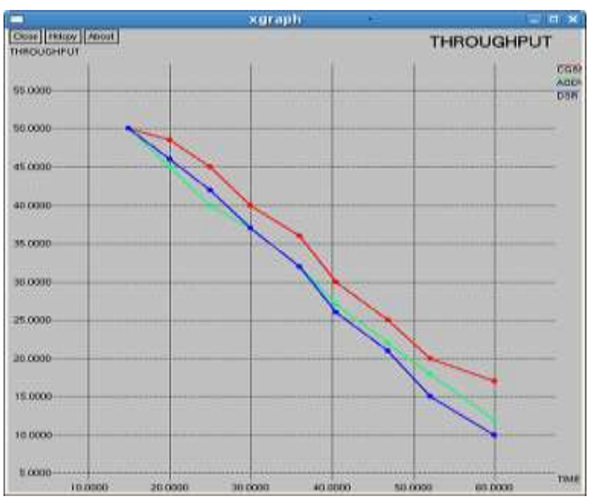

Fig. 3(c) Throughput 100 nodes

Fig. 3(d) Packet Delivery Ratio 150 nodes

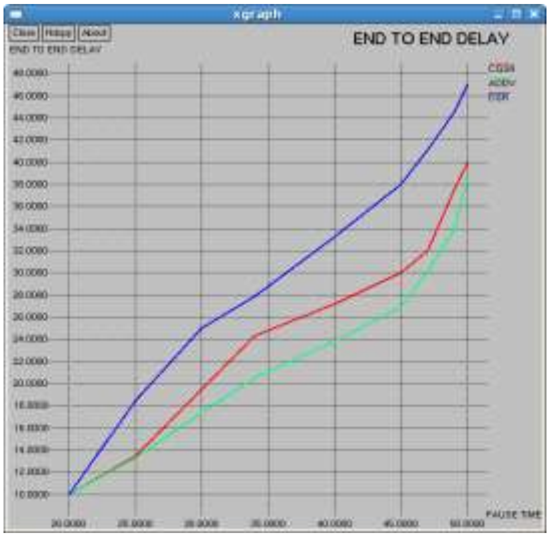

Fig. 3(e) End to End delay 150 nodes

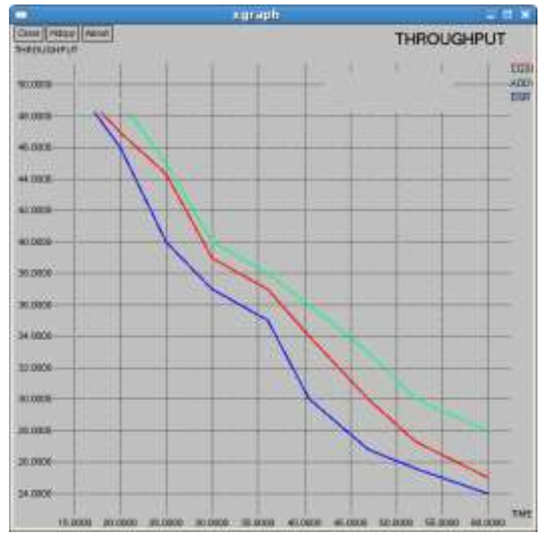

Fig. 3(f) Throughput 150 nodes

Fig. 3(g) Packet Delivery Ratio 200 nodes

Fig. 3(h) End to End delay 200 nodes

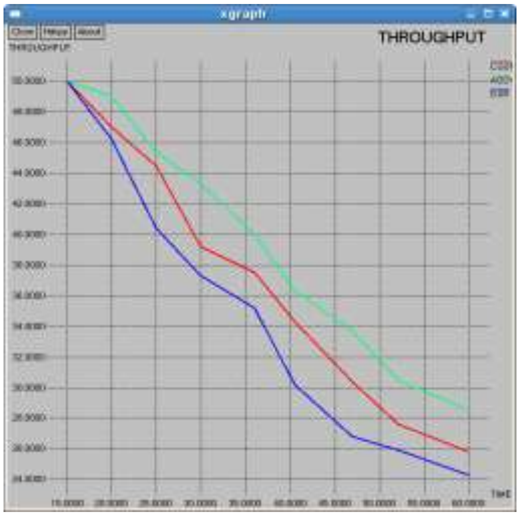

Fig. 3(i)Throughput 200 nodes

Fig. 3. Simulation results of 100, 150 and 200 nodes

Packet delivery ratio

Fig. 3(a), 3(d), 3(g) shows the PDR of CGSR, DSR and AODV for 100, 150 and 200 nodes respectively. It is evident from the graph that the performance of CGSR outperforms the other two protocols when the number of nodes taken for simulation is 100. But when the number of nodes is increased to 150 and 200 the performance of AODV shows a better result. This is because, in a clustered setup, the routing decision is taken in a controlled fashion since each cluster head is given a simple knowledge of the node movement. Moreover when the number of nodes are increased, the possibility of selecting a better node using eccentricity is more. Hence the packet delivery ratio is more. Since AODV minimizes the number of broadcast, and the route creation is done on demand, the proposed clustering methodology supports this process of finding a better route by selecting nodes that are present in Nil Cluster Change region, which results in better performance.

End to end delay

The above Fig 3(b), 3(e) and 3(h) shows the End to End delay in the delivery, for the three protocols. It is evident from the fig.3(b), for 100 nodes simulation, CGSR exhibits a minimum delay followed by AODV and then DSR. For 150 and 200 nodes simulation, the performance of AODV shows minimum delay. Since the cluster will take some time interval to offer a stable operation, initially the protocols shows more delay. The node mobility is addressed by identifying the cluster topology and dividing it into three regions. The intermediate nodes selected for route identification is decided based on the topological position of the node (i.e) the node is selected only if it is present in the Nil Cluster Change area and hence stability is preserved. When the number of nodes is increased above 100, AODV has more advantages exploiting the cluster methodology since the there are more possible nodes that can be selected for routing process thereby minimizing the delay.

Throughput

Fig. 3(c), 3(f) and 3(i) shows the throughput comparison of the three protocols . When analyzing the graph, it is found that for 100 nodes simulation the performance of CGSR shows better throughput. This is due to the fact that that there is a Cluster Head re-affiliation process that takes place is minimized since the number of nodes per cluster is minimum. When the number of nodes is raised above 100, and when the simulation is done for 150 and 200 nodes, the performance of AODV shows a better performance. This is because, in a clustered setup, the node movements are handled in graceful manner, using the data-structure deployed on the nodes. Nodes that are exhibiting frequent movements are avoided when forming a routing path thereby avoiding the packet loss and re-route forming time.

VI. CONCLUSION

In this paper, cluster based routing protocol is proposed to evaluate the performance CGSR, AODV and DSR protocols.. The CH is given a additional information regarding the topological position of the member node using the eccentricity calculation, and it enables the CH to decide which member nodes can participate in the routing decision. Since the routing decision is deployed only on the nodes that are prone to nil movement or less movement, it enables a cluster stability. The said protocols are evaluated on three routing parameters namely PDR, Delay and Throughput. Of the three protocols CGSR shows better performance when the number of nodes taken for simulation is restricted to a maximum of 100. But when the number of nodes are increased to 150 and 200, AODV shows a better performance. This is because when the number of nodes are restricted to a lower number say 100, the cluster stability can be achieved easily and hence CGSR performance is good when compared to other two protocols. But when the nodes are increased to 150 and 200, AODV perform well. It indicates that the cluster enabled operations on MANET environment will shows a better performance, since the cluster stability is preserved by handling the node movements in a graceful way using the concept of eccentricity and hence the routing performance can be enhanced by selecting the nodes with less mobility and the routing decisions can be imparted to those nodes which will have a better performance on routing .

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