TOPOLOGY CONTROL THROUGH DYNAMIC CLUSTERING PROCESS TO IMPROVE THE QUALITY OF SERVICE IN MOBILE ADHOC NETWORK

[1]D. Sundaranarayana, [2]Dr.K.Venkatachalapathy
[1]Ph.D. Research scholar, [2]Professor
[1]Department of Computer Science and Engineering
[1]Annamalai University, Tamilnadu, India

Abstract: Mobile adhoc networks are dynamic in nature in such a way that the nodes which are wirelessly connected for communicating with each other are uncertain with its mobility. They have limitations with respect to processing capability, power and so on. These limitations hinder the efficient usage of these nodes in power intensive applications. In this scenario, the necessity to improve the quality of service of the accumulated mobile nodes emerges. Clustering is a process which is used to group a number of mobile nodes and make them manageable under a single node which is termed to be as cluster head (CH). Clustering improves the network scalability, as a result, improves the throughput, packet delivery ratio and so on. The process of clustering and cluster head election differs, based on the parameters considered. The advantage of improving the network efficiency through clustering entirely depends upon the process of clustering and electing heads for those clusters. In this paper we focus on electing efficient cluster heads for cluster of nodes by Dynamic clustering process (DCP). We use a Dynamic range clustering which clusters the network and uses a variable weight function for the purpose of selecting head node for the cluster. This is based on the node density and bandwidth utilization. In addition to that a 'Hello' message is transmitted by each mobile nodes and we define a term Cluster head Prowess (CHP) which represents the dexterity of a mobile node to take the role of a head in its cluster. The performance of the proposed methodology shows promising results in reducing the delay, packet loss probability and re-clustering instances.

Index Terms **– Clustering, Node density, Bandwidth utilization, Variable weight function.**

I. INTRODUCTION

Mobile adhoc network is a collection of self-disciplined nodes where it does not require any central node to manage and give instructions to them. They are managed individually without relying on other nodes. The primary objective of using these mobile nodes and forming them into a network is "Communication". This dynamic characteristic of these nodes are needed in several time critical applications where the network of nodes for communication can be formed instantly without any predefined infrastructure requirements.

This is one of the greatest advantages in mobile adhoc nodes perspective [11]. On the other hand this characteristics also serves to be a detriment in the perspective of the processing capacity, endurance, uncertainty in connectivity overall performance hindrance and so on. Many improvement procedures are being undertaken to improve various fields in MANET such as security, stability, performance, quality of service and energy enhancement. The applications which are focusing on MANET include real time applications such as commercial, residential and military specific applications. The coverage area of the mobile adhoc networks extends to a large region through connecting gateway nodes and relaying process which facilitates the users to exploit more on this network. Communications in mobile adhoc network have different protocols and routing methodologies. The communication i.e. data transmission takes place with one hop and multi hop neighbors [9].

The self-disciplined nodes as mentioned earlier, due to the lack of the central controller and its autonomous nature, rely on its neighbors and its characteristics for packet transmissions. Another problem here is the network scalability. Scaling the nodes in the network is monotonous due to the mobility which in turn causes the breakage in the link and results in loss of data [8]. The Network Scalability can be improved by the process of clustering. The mobile nodes are grouped into one or more clusters based on their positions in the network. The Clusters are usually managed by a single node which is termed to be as "Cluster head" [10]. The cluster head is responsible for the data and information exchange for the nodes within its cluster. The information about the nodes and their capability are updated periodically to the cluster heads.

Potential risk exists in this clustering process, where the cluster head acts as the communication head representing a number of nodes under its coverage. When a cluster head node fails or when it has been attacked, it serves as a bottleneck to the entire network. So relying entirely on a single node as a cluster head has the bottleneck which is mentioned above and it also have a disadvantage of exhausting its energy and as a result it exits from the network communication. This initiates the process of re-clustering. Re-clustering instance must be reduced accordingly in order to improve the performance of the network, because congestion occurs as a result of retransmission of packets which occurs due to re-clustering.

The procedure for election of the head of a cluster is important in order to maintain the balance in the network by reducing the delay, packet loss and communication overhead. So, the Quality of service in the mobile ad-hoc network will be significantly improved. The cluster network model is shown in the below Fig.1.

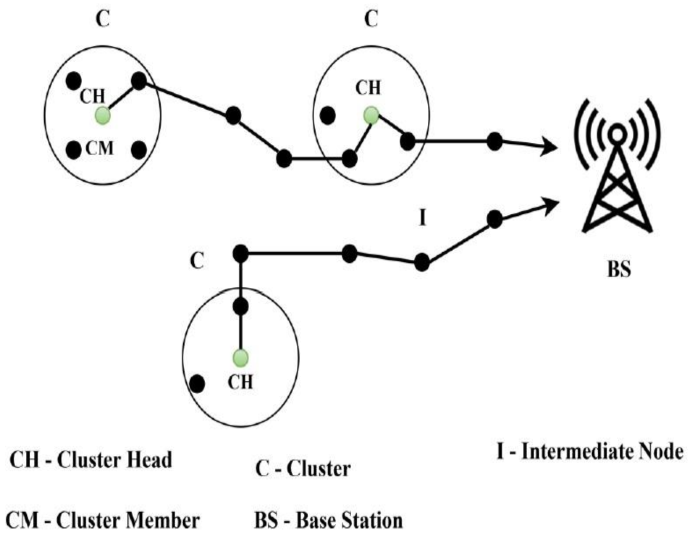

Fig.1 Cluster Network Model

II. RELATED WORKS

Clustering process has been further classified into two types by Y.Yi et al. Active clustering and passive clustering is the term proposed by them. The mobile nodes cooperate in the cluster head election process and they undergo the information exchange process periodically irrespective of data transmission in the network. This is the process involved in active clustering. To the contrast, Passive clustering process, this involves with the process of electing cluster heads only during the data transmission process in the network. It suspends the clustering process when the nodes do not involve with any communication activities [7].

Distributed clustering algorithms were proposed by Y.Yi et al which is known as Lowest ID algorithm and highest degree algorithm. This process comes under the active clustering methodology. In LID a 'Hello' control message has been broadcasted by the nodes to other nodes within its range. As a result, the node with lowest ID in the neighbor is elected as the head of its cluster. In Highest degree method, the node with highest degree ID in the neighbor is elected as the head. These processes are based on the location information of the mobile nodes [6].

Vote based clustering has been proposed by F.Li et al. which considers the location information as a secondary factor, where, the primary factor is the energy level of the mobile nodes. This works similar to that of the highest degree method which considers the node with highest neighbor as cluster head, in addition to that, the energy of the selected higher degree node is taken as the primary consideration. This showed significant improvement in the performance of the network when compared with the previous active clustering approaches [1].

A bio- inspired clustering methodology has been proposed by khatoon and amirtanjali to solve the mobility and the energy expenditure issue in the network. The remaining energy of the nodes and the mobility becomes the primary factor in deciding the head for a cluster. The neighbor density is the additional factor considered in this process. The frequent changes of the head node are minimized by this process and the delay has been reduced. This as a result improves the network lifetime as a whole [2].

In group based networks, the network stability is improved and the cluster life time is increased by the methodology proposed by Massin et al. which is a generic clustering algorithm. The node density again becomes the primary factor in this process [3].The cluster head selection involves with the process of a honey bee algorithm which was proposed by M.Ahmad et al. They consider that the process of clustering results in the dynamic optimization. The explicit characteristics of the node such as the vector, magnitude and density are considered mainly for choosing the head for the cluster of nodes. This results in lesser delay and increased packet forwarding rates but has an issue with re-transmission which has to be controlled efficiently [5].

The transmission range based clustering (TRBC) is proposed by muthuramalingam and rajaram. Coverage area and the mean transmission power have been taken into consideration. In the process of cluster creation, the cluster heads are selected by the following metrics. They are node density, coverage area, condition index and the degree of the nodes [4].

III. DYNAMIC CLUSTERING PROCESS

In the distributed network of X*Y, the $\{n_1, n_2 \ldots n_n\} \in N$ represents the nodes. The linkages between the nodes for the process of data transfer are the wireless links (V). The network is represented as graph G, Where G= (N, V) denotes the nodes in the network and the link between the nodes. A node i in the network will have a link with another node j within the network if the following condition is satisfied: if dist. (i, j) < R (i) || R (j), where R is the radio range of the node i or j. In this scenario, the nodes are grouped into clusters where the cluster head has to be elected based on the below methodologies. The cluster head acts as the representative and it guides the cluster which ensures data delivery to the destination and improving the network scalability.

The Proposed Dynamic clustering process (DCP) involves with two phases. i) The Dynamic range clustering and ii) Cluster head Prowess procedure. The dynamic range clustering deals with the formation of clusters and the cluster range modification, based on the number of nodes required for a data transfer.

It is a learning process which observes the network characteristics for a period of time and acts accordingly. The learning process includes two explicit constraints and one implicit constraint. The neighbor density and the bandwidth utilization are the explicit constraints. The implicit constraint is the number of packets. The cluster range is decided by this constraint. The variable weight function (∇w) acts as a deciding factor for selecting the head of a cluster. This variable weight function is the output of a neural computation. The variable weight function requires the metrics such as bandwidth utilization and the neighbor density which are explicit. This does not take the number of packets into consideration as it is not known at the initial stage

The bandwidth utilization "$\mathbf{b_u}$" for 'm' transmissions can be computed using the following equation:

$$b_u = v_c * \left(1 - \frac{t_r - t_t}{t_t}\right), \forall\, m \qquad (1)$$

Where $\mathbf{v_c}$ is the link capacity, $\mathbf{t_t}$ is the transmit time and $\mathbf{t_r}$ is the receipt time of a node n. The node density is another metric which is taken into consideration for the variable weight function. The number of neighbors associated with a node decides the node's density (ρ) which is estimated by the following equation.

$$\rho = |\{V_{ij} \in N_n : dist(i,j) \leq R\}| \qquad (2)$$

From the above equations the bandwidth utilization and the density of the nodes can be calculated. In this context, the bandwidth utilization of a node must be lower, in order to manage the incoming network traffic. To the contrast, the density of the node must be higher to perform switch over between the nodes. Thus there exists a contradictory scenario in selecting a node to become the head of its cluster. Therefore a variant weight function (∇w) comes into existence to resolve the inequality problem discussed above. Based on the bandwidth utilization and the density, the below equation is used for weight computation.

$$\nabla w = \sum_{j=1}^{n} V_{ij} * \sigma(n_j) + b_u \qquad (3)$$

$$\text{Where } \sigma(n) = \frac{e^{\rho(n)} - e^{-\rho(n)}}{e^{\rho(n)} + e^{-\rho(n)}} \text{ and } V_{ij} \in \{0, 1\}$$

The node with the higher ∇w value has been considered for electing as the cluster head. With this context, the second phase which involves with Cluster head prowess procedure takes place. The mobile nodes in the cluster of the network have been assigned a unique identity number which is a positive integer. The identity is termed as MN_ID. When assigned a cluster head (CH) to the cluster, the CH also possess an identifier CH_ID. This process involves with the transfer of control "Hello" message to the neighbor nodes. The mobile nodes acquire information of its neighbors through this control message.

In this context the proposed cluster head prowess (CHP) comes into function which analyses the capability of a mobile node to undertake the role of the head in a cluster. The "Hello" message includes the identification of the sender ID (MN_ID) and the CHP. The CHP represents the weighted sum of the sender's degree i.e. number of neighbors [acquired through Eq. (2)] and its energy level. The CHP values are calculated through the below equation.

$$CHP = \{c_1 \times d + c_2 \times b\} \qquad (4)$$

Where, c_1 and c_2 are the coefficients of the mobile node degree and battery availability. Here $c_1 >= 0$ and $c_2 <= 1$ and $c_1 + c_2 = 1$. *'d'* is the degree of the mobile node i.e. number of neighbors. '*b*' is the remaining lifetime of the node (percentage of present energy level in comparison with its initial energy). The process proceeds as follows in a step by step methodology.

- The 'hello cycle' is the time period where the hello message will be communicated between the nodes in a random fashion.
- The degree (d) is also calculated based on this hello message, where, the mobile nodes count the hello messages it has received during the 'hello cycle' period.
- During the next 'hello cycle' the mobile nodes broadcast the 'hello' message in accordance with the CHP field values which are calculated according to eq. (4).

This process involves with two hello cycles where recording the hello messages by the mobile nodes in this period takes place. The sender with highest CHP value is noted in this context. Therefore considering the two metrics with seamless integration in this scenario the node with higher variable weight function (∇w) and higher cluster head prowess (CHP) value is elected ultimately as the head for its cluster. This cluster head ensures prolonged lifetime avoiding re-clustering, re-transmission and control messages flooding. As the energy levels of the nodes are also considered primarily for the cluster head election, it becomes reliable and has a longer lifetime without exiting from the cluster/network.

The network scalability is a primary difficulty in the mobile adhoc networks. The mobility nature of the nodes makes this process more monotonous which may result in loss of connectivity in the network and link between the nodes. This ultimately distresses the network performance and its quality of service. Therefore, Clustering is one solution for solving this scalability issue in the network. The nodes are grouped into clusters and these clusters are managed by their respective cluster heads. The node details in the cluster are updated periodically to the head. On the other hand the each and every node in the cluster need not maintain the routing and topology information, if they maintain, it will result in exhaustion of the nodes frequently every time resulting in linkage failure.

So, the head of the cluster maintains this information. The efficient election of the head for the cluster is the primary key in this context, which when done perfectly, then the clustering will address the performance overhead of the network in an efficient manner.

IV. PERFORMANCE ANALYSIS

The simulation is done through the Network simulator- 2. The simulation result shows significant improvement when compared to the Mobility aware energy efficient clustering with particle swarm optimization (ME-PSO) technique in terms of delay, packet loss probability and re-clustering instance. The parameters considered for the simulations are listed below in the table I

Table 1 Simulation Parameters and Values

Parameter	Value
Network Region	500m x 500m
Number of Mobile Nodes	100
MAC Protocol	802.11
Range	250m
Application Type	Constant Bit Rate
Packet Size	512Kb
E_{init}	16J
Pause Time	2 ms
Simulation Time	100s

4.1. Delay Investigation

The Dynamic clustering process (DCP) seamlessly integrates the variable weight function along with the cluster head prowess function to elect the cluster head. This process provides a stable cluster head which avoids unnecessary delay through retransmission, congestion and so on. The below Fig.2 graph depicts the delay comparison between the ME-PSO and the proposed DCP in which the DCP results with significantly 16.31 % lower delay when compared to the ME-PSO.

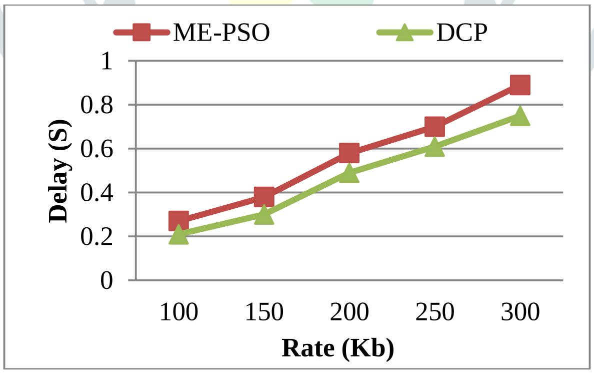

Fig. 2 Delay comparison

4.2. Packet loss probability

The packet loss in the communication has been curtailed significantly by the efficient bandwidth utilization and the node density factor. The considerable reduction in the probability for packet loss ensures improvement in the data transfer process. The delay will also be significantly reduced as it also depends on the loss probability. The packet loss will have a major impact over the delay. The packet loss probability in the Proposed DCP procedure is 29.38 % lower when compared with that of ME-PSO approach. The probability varies according to the size of the data transmission. Our Proposed Dynamic Clustering Process stabilizes at a particular point of data transmission instead of continual inclination as that of the previous approach. This has been depicted in the below Fig.3 graph.

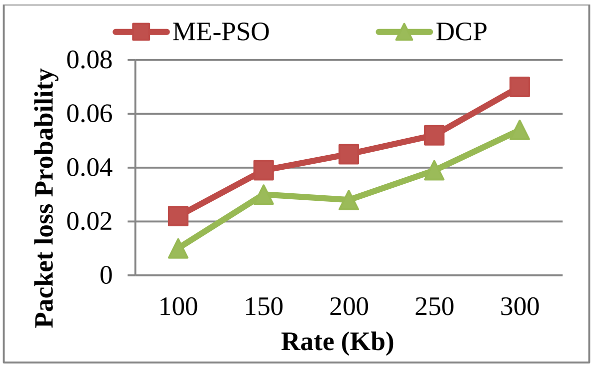

Fig. 3 Packet loss probability comparison

4.3. Re-Clustering Instance

Frequent re-clustering involves with Packet re-transmissions which results in congestion. The cluster overload with number of mobile nodes is avoided in this process which results in avoiding the failure of the head node due to its overloaded communication. The stability of the cluster is retained through the dynamic clustering procedure. The precise neighbor density factor and the bandwidth utilization factor determine a reliable cluster head that sustains prolonged communications. The below Fig. 4 graph depicts the average re-clustering instances, where the DCP has lower re-clustering instance which is 26.20% lesser when compared to the ME-PSO approach.

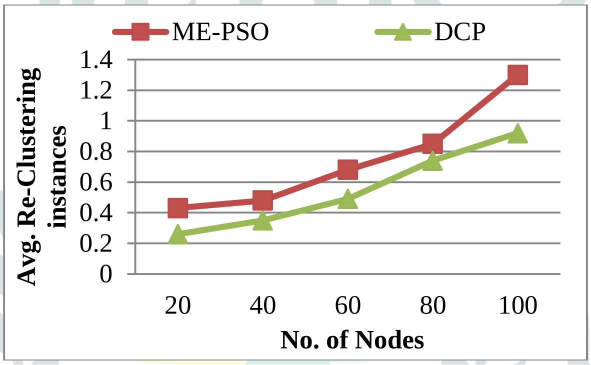

Fig. 4 Average re-clustering instances comparison

The Performance comparison of the ME-PSO and the Proposed DCP approach has been illustrated in the below Table2, with respect to delay, packet loss probability and average re-clustering instances. DCP has significantly improved performance when compared to that of the ME-PSO approach.

Table 2 Performance Comparison Measures

Performance Measures	Clustering Techniques	
	ME-PSO	DCP
Delay (s)	0.564	0.472
Packet loss probability	0.0456	0.0322
Average Re-clustering Instances	0.748	0.552

V. CONCLUSION

The Dynamic clustering process solves the problem of network scalability through clustering. This process involves with dynamic range clustering which considers two explicit constraints to determine the variable weight function. On the other hand the control message packet which has cluster head prowess helps in scrutinizing the cluster head election from the mobile nodes. The proposed Dynamic clustering process outperforms the similar clustering mechanism in several aspects such as delay, packet loss and re-clustering instances. As a result, the network quality of service is improved significantly. In future, a learning based routing approach will be integrated with this clustering method along with a range variance clustering in order to improve the energy efficiency of the nodes in the mobile adhoc network.

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Authors Biography

D.Sundaranarayana has received his Bachelor's degree in Computer Science & Engineering from Rajiv Gandhi College of Engineering & Technology, Pondicherry University, Puducherry in 2013 and his Master's degree in Computer Science & Engineering from Christ College of Engineering & Technology, Pondicherry University, Puducherry in 2015. He is currently pursuing his Ph.D. research in the Department of Computer Science & Engineering, Faculty of Engineering & Technology, Annamalai University, Chidambaram. He has published 5 research papers in International Journals and Conferences. His field of interest includes Computer networks, Cloud and Mobile Computing. He is a life member in IAENG (International Association of Engineers).

Dr.K.Venkatachalapathy received his B.Sc degree in Physics from Madras University, Tamilnadu in 1987 and he received his Master's degree in Computer Applications from Pondicherry University in 1990. He completed his Ph.D. in Computer Science & Engineering from Annamalai University, Tamilnadu, India in 2008. He is currently working as a Professor and Head of the department in the Department of Computer and Information Science, Faculty of Science, Annamalai University. He is having 25 years of experience in teaching. He has published more than 50 research papers in International Conferences and Journals. His field of interest includes Image processing and Computer networks. He is currently guiding 8 research scholars towards Ph.D. He is a life member in various professional bodies like ISTE, CSI.