Survey of Cluster Based Routing Protocols in Mobile Ad hoc Networks

M. Anupama and Bachala Sathyanarayana

Abstract—**Clustering in Mobile Ad Hoc Networks (MANETs) has many advantages compared to the traditional networks. But the highly dynamic and unstable nature of MANETs makes it difficult for the cluster based routing protocols to divide a mobile network into clusters and determination of cluster heads for each cluster. In this paper, we analyze and compare some of existing works on clustering in MANETs. We categorize the works as Location based, Neighbor based, Power Based, Artificial Intelligence Based, Mobility based and Weight Based. We also present the advantages and disadvantages of these techniques and suggest a best clustering approach based on the observation.**

Index Terms—**Clustering, mobile AD hoc network (MANET), routing protocols, wireless networks.**

I. Introduction

A collection of wireless nodes that self-configure to form a network without the aid of any established infrastructure is called mobile Ad hoc network (MANET) [1]. They can be also defined as a collection of mobile nodes that intercommunicate on shared wireless channels.

The nodes entering or leaving the network have routing capabilities which allow them to create multi hop paths connecting node which are not within radio range [2]. The characteristics of MANETs like no fixed network infrastructure, dynamic network configuration, mobility of nodes and frequent node failure, low battery power, etc differentiate them from other wireless networks. Hence routing in MANETs became one of the most challenging tasks [3]. Routing in networking is the process of selecting paths in a network to send network traffic. Routing in ad hoc networks is different compared to normal wired networks. A heavy computational burden on mobile computers makes the use of conventional routing protocols inconvenient in a dynamic network. [4]. Therefore, the need to design a novel routing protocol which seamlessly adapt to changing network topology was inevitable [5].The routing protocols can be divided into three categories: proactive (table driven routing protocols), reactive (on-demand routing protocols), and hybrid.

In the proactive routing scheme each node periodically maintains one or more tables to store consistent and up-to-date routing information from one to every other node in the network [6]. In Reactive routing the evaluation of routes are done only when it is necessary.

When a node wants to find a route to another destiny node the appropriate route is found through a discovery process. Paths are maintained only when they are needed [4]. The Hybrid Routing Protocol proactively maintains routes to the destination node within only a local network consisting of several neighboring, nodes, generally referred to as a cluster, while reactively acquiring routes beyond the cluster [5].

A. Clustering

The process of dividing the network into interconnected substructures is called clustering and the interconnected substructures are called clusters. The cluster head (CH) of each cluster act as a coordinator within the substructure. Each CH acts as a temporary base station within its zone or cluster. It also communicates with other CHs [2]. The Cluster based routing provides an answer to address nodes heterogeneity, and to limit the amount of routing information that propagates inside the network. The grouping of network nodes into a number of overlapping clusters is the main idea behind clustering. A hierarchical routing is possible by clustering in which paths are recorded between clusters instead of between nodes. It increases the routes lifetime, thus decreasing the amount of routing control overhead. The cluster head coordinates the cluster activities inside the cluster. The ordinary nodes in cluster have direct access only to cluster head and gateways. The nodes that can hear two or more cluster heads are called gateways [7].

The proposals introduced for the election of cluster heads in mobile ad -hoc networks include the Highest-Degree, the Lowest-Identifier, Distributed Clustering Algorithm, the Weighted Clustering Algorithm (WCA).

1) Highest-Degree (HD) algorithm: It uses location information for cluster formation. It elects the cluster head from the highest degree node in a neighborhood.
2) The Lowest-Identifier algorithm: The node with the minimum identifier (ID) is elected as a cluster head. This causes battery drainage resulting in short lifetime span of the system.
3) The Distributed Clustering Algorithm: It is a modified version of the Lowest-Identifier algorithm. Each cluster selects its cluster head from its neighboring nodes having the lowest ID. In this algorithm every node can determine its cluster and only one cluster, and transmits only one message.
4) Weighted Cluster Algorithm: It employs combined metrics-based clustering. In order to calculate a weight factor Wv for every node v a number of metrics, including node degree, CH serving time and moving speed, are taken into consideration. As a result, WCA

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has increased number of overheads. The cluster set-up procedure is invoked, when a node moves to a region which is not covered by the clusterhead, throughout the whole system [8].

B. Advantages of Clustering

Clustering in Ad Hoc networks has many advantages compared to the traditional networks. They are as follows:

1) It allows the better performance of the protocol for the Medium Access Control (MAC) layer by improving the spatial reuse, throughput, scalability and power consumption.
2) It helps to improve routing at the network layer by reducing the size of the routing tables.
3) It decreases transmission overhead by updating the routing tables after topological changes occur [4].
4) It helps to aggregate topology information as the nodes of a cluster are smaller when compared to the nodes of entire network. Here each node stores only a fraction of the total network routing information.
5) It saves energy and communication bandwidth in ad-hoc networks [3].

C. Issues of Clustering

The highly dynamic and unstable nature of MANET's makes it difficult for the Cluster based routing protocol to divide a mobile network into clusters and determination of cluster heads for each cluster. Clustering reduces communication and control overheads due to pre determined paths of communication through cluster heads. It is vital for scalability of media access protocols, routing protocols and the security infrastructure [3]. Routing protocols which considers only bidirectional links may have link asymmetry due inefficient or abnormal routing. Untapped network capacity is represented by the undiscovered unidirectional links, which reduces the network connectivity [6].

A large number of mobile terminals are managed by a MANET using a cluster topology. The construction and maintenance of a cluster structure requires additional cost compared with a topology control without cluster. Clustering has some side effects and drawbacks.

1) The maintenance cost for a large and dynamic mobile network requires explicit message exchange between mobile node pairs. As the network topology changes quickly and concerns many mobile nodes, the number of information message exchange grows to reach a critical point. This information exchange consumes a lot of network bandwidth and energy in mobile nodes.
2) A ripple effect of re-clustering occurs if any local events take place like the movement or the death of a mobile node, as a result it may lead to the re-election of a new cluster-head. When a new cluster-head is re-elected it may cause re-elections in the whole of the cluster structure. Thus, the performance of upper-layer protocols is affected by the ripple effect of re-clustering.
3) One of the major drawbacks of clustering in MANETs is that some nodes consume more power when compared to others nodes of the same cluster. As special node like a cluster-head or a cluster-gateway manage and forward all messages of the local cluster their power consumption will be high compared to ordinary nodes. It may cause untimely shutdown of nodes [9].

II. Related Work

In this section we present some of existing works on survey of clustering in MANETs

Roberto Carlos Hincapi´e, et al [4] have presented a survey on clustering techniques for MANET. They introduced some preliminary concepts that form the basis for the development of clustering algorithms. They also discussed the related clustering issues with the network topology, routing schemes, graph partitioning and mobility algorithms. They also described some of the most popular clustering techniques like Lowest-ID heuristic, Highest degree heuristic, DMAC (distributed mobility-adaptive clustering), WCA (weighted clustering algorithm).They also reviewed several clustering algorithms to organize mobile ad hoc networks in a hierarchical manner and explained their advantages and disadvantages.

Ratish Agarwal and Dr. Mahesh Motwani [7] have reviewed several clustering algorithms to organize mobile ad hoc networks in a hierarchical manner and presented their main characteristics. The survey examined the important issues related to cluster-based MANET, such as the cluster structure stability, the control overhead of cluster construction and maintenance, the energy consumption of mobile nodes with different cluster-related status, the traffic load distribution in clusters, and the fairness of serving as cluster heads for a mobile node.

III. Survey on Cluster based Routing in Manets

A. Location Based Clustering

In the location-based routing protocol, the location information of mobile nodes are used to confine routing space into a smaller range .It reduces routing overhead and broadcast storm. [11].

In [11] Tzay-Farn Shih and Hsu Chun Yen have proposed a cluster-based routing protocol, named Core Location-Aided Cluster-based Routing protocol (CLACR). The characteristics of CLACR are stated as the entire network is partitioned into square clusters. In each cluster, the selection of cluster head is done by a cluster head election algorithm. The number of nodes responsible for routing and data transfer is decreased considerably by the usage of the cluster mechanism. It also diminished the routing overhead and increased the route lifetime massively. The path is computed using Dijkstra algorithm in a cluster-by-cluster basis by the CLACR.

In [10] Biao Zhou et al proposed cluster-based inter-domain routing (CIDR) protocol. The clusters are formed by the affinity of geography, motion, or task. The cluster head acts as a local DNS for own cluster and its neighbor cluster. The advertising protocol acts as the BG protocol. The proposed work routes the packets to remote nodes through cluster head advertised routes and to the local destinations using the local routing algorithm. The experiment results showed that the proposed inter-domain

routing has achieved the scalability in large network, the robustness to mobility, and the independency of underlying intra-domain routing protocols.

In [13] Hatem Hamad et al proposed a location enhanced routing protocol for clustered MANETs. In LECBRP, local position information is used to assist routing and to improve the performance of the basic protocol. Cluster formation, adjacency cluster discovery and routing are the three main components of the LECBRP.

Cluster formation: A CH is elected by exchanging hello messages between the nodes which wake up in undecided state. When a CH sends a Hello message to a new undecided node, it joins its cluster. In LECBRP, each node estimates its neighbor's locations and stores it in Location Table (LT).It also stores the relative locations of non-neighbor nodes.

Adjacent cluster discovery: Every CH has a Cluster Adjacency Table (CAT) which records information about its entire neighboring CHs. Each node sends a Hello periodically. It contains a neighbor table (NT) and CAT. A CH discovers its adjacent CH using the Hello message alone.

In LECBRP the control overhead is much smaller than CBRP, LEOD, and AODV.

In [14] Mangai .S and Tamilarasi .A proposed an Improved Location aided Cluster based Routing Protocol (ILCRP) for GPS enabled MANETs. The protocol has three phases namely, cluster formation followed by cluster maintenance and route discovery phase.

Cluster formation: The nodes which are m-hops far away from the cluster head forms the clusters between them. All nodes can become cluster head as all nodes are GPS enabled. A HELLO message with node ID and location information is sent by all nodes in the network. The node value is calculated based on the updated neighbor nodes list using parameters such as degree difference, mobility of the node and the remaining battery power of the node. By sending CH_INFO, the node with the highest node value and having NV greater than the threshold value of the max node value declares itself as the Cluster head.

B. Mobility Based Clustering

In [15] S. Muthuramalingam et al proposed a modified algorithm that uses Weighted Clustering Algorithm (WCA) for cluster formation and Mobility Prediction for cluster maintenance. In a MANET node management is done by Clustering.

Cluster formation: At first, a beacon message is send by each node to notify its presence to its neighbors. A beacon message contains the state of the node. A neighbor list is built by each node based on the received beacon messages. The cluster head is elected based on the weight values of the nodes. The node with the lowest weight is chosen as the CH.

Maintenance: It has two distinct types of operations like the battery power threshold property and the node movement to the outside of its cluster boundary.

Mobility prediction: The improvement in the weighted clustering algorithm is due to the use of mobility prediction in the cluster maintenance phase.

In [1] Arash Dana et al presented a new clustering-based routing protocol named Cross-CBRP. In the proposed approach the interaction between Physical, MAC and Routing layers are exploited. Hence it better adapt the clustering algorithm to varying link and network condition due to mobility. The proposed Cross-CBRP algorithm uses signal power information at the physical layer for routing layer so that the stability of the formed clusters can be maximized.

Cluster formation: Each node sends "Hello message" to its neighboring nodes in CRBP to proclaim its presence. When a hello message is received each node updates its neighbor tables. Each node enters the network in an "undecided" state. On receiving a hello message each node compares its own ID with its neighbor's. If the node founds that its ID is the lowest among its neighbors, it declares itself as the cluster head. All nodes having bi-directional link to the cluster head are the members of the cluster.

In [16] Charalampos Konstantopoulos et al presented a novel clustering algorithm, which guarantees longer lifetime of the clustering structure. The proposed algorithm has a scheme which accurately predicts the mobility of each mobile host based on its neighborhood stability.

Cluster formation: The host weights are found using the weight formula. The MH u having the highest weight among its neighbors sends the message CLUSTER HEAD (u) to its neighbors, declaring itself as the CH. If the MH u does not have the highest weight in its neighborhood, it waits for the decision of all the MH with higher weight than its own weight and decides its own role.

C. Neighbor Based Clustering

In [17] Hui -Yao An et al proposed a Cluster-Based Multipath Dynamic Source Routing in MANET (CMDSR). In this scheme, the hierarchy is used to perform Route Discovery and distributes traffic among diverse multiple paths.

Cluster Architecture: The CMDSR is based on the 3-level hierarchical scheme. The 0-node is the first level of the cluster. 1-cell cluster is the second level of cluster. Here each node of the cell is 1-hop away from the Cluster Head. The 2-server cluster gathers a set of cells of which the Server is the leader. The cluster changes due to the nodal mobility dynamically. Hence the cluster will be disassembled or reassembled and also the cluster members update at every turn.

In [6] Yi-Yu Su proposed an efficient cluster-based routing protocol which supports unidirectional network environments. In this approach, the node determines its own status by the exchange of cluster information with its neighbor nodes after updating the cluster information. The cluster head manages the degree of the node and the number of nodes in the proposed clustering algorithm. It also considers the number of pendent node and integrates it into the weight function. Nodes having more pendent nodes within its 2-hop neighbors have higher possibility to become a cluster head. Thus the clusterhead formed by the pendent nodes can be reduced. Hence the efficiency of the cluster structure is improved. The proposed weight function requires only status and degree of nodes.

In [5] Chang Wook Ahn et al proposed a new routing protocol for mobile ad-hoc networks. The proposed routing protocol is a Hybrid Routing Protocol (HRP) that works on

the basis of a virtual cluster, consisting of a collection of only those nodes that are one-hop distance away. There are as many virtual clusters as there are nodes in any network. Hence it can significantly reduce the control overheads.

The simulation results showed that their proposed protocol achieved the overhead performance comparable to that of AODV.

In [18] Curt Cramer et al have developed a reactive clustering protocol named On-Demand Group Mobility-Based Clustering (ODGMBC). The Neighborhood Recognition Protocol (NRP) is employed so that the monitoring nodes know which neighbors are present and suitable for clustering. The neighborhood recognition works in one direction only and the detected neighbors are informed of their detection. It helps detecting undirectional physical links.

In [19] Narendra Singh Yadav et al proposed a novel clustering algorithm called Incremental Maintenance Clustering Scheme (IMS) for Mobile Ad Hoc Networks. The goals of the proposed are yielding low number of cluster head and cluster member changes, maintaining stable clusters, minimizing the number of clustering overhead.

The node with lowest ID in the neighborhood is selected as the cluster head. When two cluster heads are within range of each other, cluster head change is delayed for delay_period which is equal to Hello_interval initially in the proposed scheme. After the delay_period, if both are again within the range of each other then the delay_period is increased by Hello_interval. This continues till delay_period is less than equal to max_limit. Max_limit is obtained by dividing two times transmission range by speed.if both are still within the range the node with smaller ID is elected as the cluster head and the competitor gives up.

The simulation result showed the superiority of IMS over LCC and maintenance scheme of CBRP in terms of the number of cluster head changes, number of cluster-member changes and clustering overhead by varying mobility and speed.

In [20] Stephen S. Yau and Wei Gao presented a scheme to construct multi-hop clusters in MANETs, based on the neighborhood benchmark (NB) scores of mobile nodes. A partial probability-based approach is presented to control the possible deviation of cluster sizes. The simulation results showed the proposed clustering scheme provides stable clustered network structures with balanced cluster sizes in various network scenarios.

Cluster selection: The cluster heads are elected based on the NB scores of the mobile nodes in an autonomous manner. After the network initialization autonomous selection is conducted on all the mobile nodes in parallel. In each mobile node, the cluster head selection process consists of R iterations. R denotes the cluster radius in terms of the maximum number of hops from a node in the cluster to the cluster head. A node Ni puts all the cluster heads of its 1-hop neighbors, and its own cluster head into a selection pool in each iteration. The Ni considers itself as its cluster head when it does not have any cluster head. The node with the highest NB score in the selection pool is selected as the cluster head by the Ni. Each iteration updates the Ni's cluster head and is finalized in the last iteration of the selection process.

D. Power Based Clustering

In [21] Jehn-Ruey Jiang et al proposed a hybrid PS protocol for an IEEE 802.11-based MANET. The concept of dual-channel and dual-transmission-range clustering is used in the proposed protocol. In their proposed work all the hosts are divided into clusters. In each of the host one is selected as head and the other as the members. Individual clusters are operated using the synchronous PS protocol. Cluster heads are operated using QAPS protocols. The proposed protocol operates on the basis of neighborhood information so adapts to changes in network topology as quickly as possible.

In [22] Pi-Rong Sheu and Chia-Wei Wang proposed an efficient clustering algorithm that can establish a stable clustering architecture by keeping a host with weak battery power from being elected as a cluster head. In their proposed new clustering algorithm, a stable clustering architecture is formed by defining a bottleneck node to be a node with battery power lower than a predefined value Ethreshold. Bottleneck cluster head refers to the bottleneck node elected as a cluster head. The proposed clustering algorithm is based on the assumption that if the clustering architecture has fewer bottleneck then the cluster heads have a longer lifetime.

In [23] Y.S. Tan and W.C. Wong proposed reliability improvements to the Cluster Based Routing Protocol (CBRP). It introduced the estimation of link reliability to facilitate alternate route redundancy together with the use of adaptive power control.

Nodes send HELLO packets regularly in CBRP. It contains information about the nodes links to its neighboring nodes. Each node maintains three tables namely, a 1- hop Neighbour Table, a 2-hop Table and a Cluster Adjacency Table. When an item is added to the Neighbour Table, it stores the received signal power of the last HELLO packet received from the corresponding 1-hopneighbour. Their proposed method improves the PDR and reduces the average path delay while reducing the average transmission power.

E. Artificial Intelligence Based Clustering

In [24] Chongdeuk Lee and Taegwon Jeong proposed a Fuzzy Relevance-based Cluster head selection Algorithm (FRCA). The proposed mechanism selects the cluster head using fuzzy relevance for clustering in wireless mobile *ad hoc* sensor networks. In the network, the Fuzzy Relevance-based Cluster head selection Algorithm (FRCA) efficiently clusters and manages sensors using the fuzzy information of node status. The Fuzzy Relevance Degree (FRD) with fuzzy value μ is used to perform and manage clustering in the proposed FRCA. In the proposed algorithm, some nodes acting as coordinators of the clustering are chosen by FRD to perform clustering.

In [25] J.Arunadevi and Dr.V.Rajamani used a greedy forwarding approach with the hybrid evolutionary optimization provided to the spatial clustering algorithm. In the proposed approach clustering in the network is done using PSO (Particle Swarm Optimization) and ACO (Ant colony Optimization). Hybrid evolutionary clustering algorithm incorporates both repositioning and greedy forwarding approach that improves performance in ad hoc network containing dead-ends. The implementation of repositioning by genetic algorithm improves the recovery

process.

In [26] Mustafa Al-Ghazal et al proposed an algorithm for improving routing in clustering algorithm. It is based onboth cluster head gateway switching protocol (CGSR) and the mechanisms of a genetic algorithm (GA).

The clusterhead election is done based on the weight of each node. The combined weight Wv for each node V is calculated using the parameters such as the degree difference, nodes degree, consumed battery power and the average speed of the node. The node with the smallest Wv is chosen as the clusterhead. The results showed that with the usage of genetic algorithm technique each cluster head handles the maximum possible number of mobile nodes in its cluster in order to facilitate the optimal operation of the medium access control (MAC) protocol.

In [27] K. Venkata Subbaiah and Dr. M.M. Naidu proposed a fuzzy logic based cluster head election using energy concept for cluster head routing protocol in MANET'S. A cluster head election scheme is presented using fuzzy logic system (FLS) for mobile ad hoc networks. Distance of a node to the cluster centroid, its remaining battery capacity, and its degree of mobility are the three descriptors used. Cluster head possibility is provided as the output of the FLS. Hence the node with the highest possibility is elected as the cluster head. The performance of fuzzy cluster head selection is compared to LEACH protocol with out fuzzy cluster head election procedures and is evaluated using simulation. The results showed that the proposed work is efficient than the previous one.

In [28] Amritha Sampath et al presented an effective algorithm for selecting cluster heads in mobile ad hoc networks using ant colony optimization. The proposed algorithm combines four main clustering schemes namely the ID based clustering, connectivity based, probability based and the weighted approach.

A cluster head is selected based on the pheromone value associated with each node and visibility. The process continues till all the nodes in the network are covered. If the node is a cluster head or it falls in the range of already selected cluster head then the node is said to be covered. The pheromone value is updated each time when a node is selected as a cluster head.

F. Weighed Based Clustering

In [3] Naveen Chauhan et al proposed and implemented a distributed weighted clustering algorithm for MANETs. The proposed approach is based on combined weight metric in which system parameters like the node degree, transmission range, energy and mobility of the nodes are considered. The cluster head can be determined using some of these parameters in the metric depending on the type of application. When a packet is routed from source to destination more cluster head will lead to extra number of hops. On the other hand minimum number of cluster heads is chosen to maximize the resource utilization. The simulation results showed that the original distributed weighted clustering algorithm (DWCA) was outperformed by the proposed scheme.

In [12] S.Karunakaran and P.Thangaraj have proposed service discovery architecture based on clustering. It performs the cluster head selection by allotting a combined weight value based on the factors Power Level, Connectivity and Stability, intended for wireless mobile ad hoc networks. The proposed method permits switch over of the service discovery messages only among the cluster members. It also considers the capabilities of the nodes for the distribution of workload. Hence minimizes the cost of communication.

In [29] Zouhair El-Bazzal et al propose a Flexible Weight Based Clustering Algorithm (FWCA) in Mobile Ad hoc Networks. It aims at yielding low number of clusters, maintaining stable clusters, minimizing the number of invocations for the algorithm and maximizing lifetime of mobile nodes in the system.

Each node maintains a counter to count the number of nodes inside a cluster. The cluster heads are elected based on the weight values of the nodes. The parameters used by each node to compute its weight value are the degree difference, actual transmission power of the node, average speed of the node and the remaining battery power of the node.

In [30] S.Karunakaran and Dr.P.Thangaraj proposed an adaptive weighted cluster based routing for mobile ad-hoc networks. The cluster head selection in the proposed approach was done by assigning a weight value (W) based on the factors like energy level, connectivity and stability. The node having minimum W is chosen as the cluster head. When a node becomes the cluster head, the node or its members is marked as "considered". Then the election process is carried out with all "unconsidered" nodes. Once all the nodes have been considered the election algorithm gets terminated.

In [31] Yu-Xuan Wang and Forrest Sheng Bao have proposed weighing-based clustering algorithm. Entropy based WCA is proposed by them which prompt the stability of the network.

When a node has minimum weighted sum of four indices namely, the number of potential members; the sum of the distances to other nodes in its radio distance; the node's average moving speed, and time of it being a cluster head, it is selected as a cluster head. When a node moves out of one cluster it checks whether it can be a member of other clusters. If such a cluster is available it detaches from its current cluster and joins the new cluster. This process is known as reaffiliation. The cluster head election routine is recalled in the whole network if the reaffiliation fails. When a nodes becomes the clusterhead, the node or its members are marked as "considered". Then the election process is carried out on all "unconsidered" nodes. When all the nodes are considered the election algorithm gets terminated.

In [32] R. Pandi Selvam and V.Palanisamy presented a flexible weight based clustering algorithm in mobile ad hoc networks. The proposed algorithm is a 2-hop clustering algorithm. The performance of the proposed clustering algorithm showed that it outperformed the existing LID, HD and WCA to make the number of clusters. It also increases the number of nodes, transmission range and maximum displacement.

The weight of each node is calculated by the weight function w(p). The cluster head election is done by comparing the weight of each node with its neighbors in the two hop range. The node with highest weight declares itself as the cluster head.

In [2] M. Rezaee and M. Yaghmaee proposed a cluster based routing protocol for mobile ad hoc network. The proposed algorithm allocates weight to every node. The weights are in three groups in which each group gives the credit measures of node to become head. The nodes send message to the head. The node in the higher group which delivers messages to the neighbor nodes sooner is chosen as the CH. Each node sent LIVE messages periodically to declare itself and to have knowledge of its neighbor nodes. It is used to calculate its W parameter where W specifies weight group. The weight of each node is periodically calculated using the parameters such as the number of neighbors of the node, the remaining battery lifetime, cumulative time and the transmission power.

In [8] Sahar Adabi et al paper proposed a new Distributed Score Based Clustering Algorithm (DSBCA) for Mobile Ad-hoc Networks (MANETs). The Battery Remaining, Number of Neighbors, Number of Members, and Stability are considered by the proposed clustering algorithm to calculate the node's score with a linear algorithm. The neighbors of the node are notified after the completion of independent node score calculation by each node. The clusterhead is selected from the neighboring nodes having the highest score by each node. The simulation result showed that the proposed algorithm provides better end-to-end throughput and overhead, a longer lifespan and a smaller number of clusters when compared to both WCA and DWCA.

IV. Comparison of the Clustering Techniques

Serial No:	Name of protocol	Type	Advantages	Performance metrics	Overhead
1.	Core Location-Aided Cluster-Based Routing Protocol for Mobile Ad Hoc Networks[11]	Location based	i) Route life time increases. ii) Collision probability reduced. iii) Broadcast storm problem diminished.	Route construction success ratio, Route set up time, Route life time, Data delivery rate.	yes
2.	Cluster-based Inter-domain Routing (CIDR) Protocol for MANETs [10]	Location based	i) Scalability ii) Robustness to mobility. iii) Independency of underlying intra-domain routing protocols.	Packet Delivery Ratio	yes
3.	Location Enhanced Cluster Based Routing Protocol[13]	Location based	i) packet delivery ratio increased, ii)the delay decreased iii)the control packets overhead deceased	Control overhead	yes
4.	A new approach to Geographic Routing for Location aided Cluster based MANETs[14]	Location based	i) delivery ratio increases, ii) Reduces the control overhead. iii) makes the route, loop free.	End to End Delay, Packet Delivery Ratio, Control Overhead	yes
5.	A Dynamic Clustering Algorithm for MANETs by modifying Weighted Clustering Algorithm with Mobility Prediction[15]	Mobility based	i) Reduce the Power Consumption. ii) Reduces the bandwidth wastage for signals other than Data. iii) Increase the Stability of the Cluster.	Minimum life span of nodes, Stability of the Cluster, Throughput, Control overhead, Packet delivery ratio, Connectivity.	Yes
6.	A Robust Cross-Layer Design of Clustering-Based Routing Protocol for MANET[1]	Mobility based	i) Optimized performance. ii) Adapts to the varying network conditions.	Packet Delivery Ratio, Throughput, Overhead Packets, End-to-end Delay	yes
7.	Clustering in mobile ad hoc networks through neighborhood stability-based mobility prediction [16]	Mobility based	i) Achieves accurate estimation of future host mobility, ii) highly resistant to the topological changes due to host mobility.	Reaffiliations, control messages overhead, Number of trie nodes, Number of neighborhoods in the trie, Number of instructions, Cluster head Duration, Number of clusters per clusterheads.	Yes
8.	A Cluster-Based Multipath Dynamic Source	Neighbor based	i) improves scalability, ii) Prevents the	average end-to-end delay, Received packets, Success delivery ratio,	Yes

	Routing in MANET[17]		network flooding, iii) overhead is minimized, iv) Higher and more consistent success delivery ratio. v) Lower error ratio.	Error delivery ratio, control overhead,	
9.	An Efficient Cluster-Based Routing Algorithm in Ad Hoc Networks with Unidirectional Links [6].	Neighbor based	i) Higher routing performance. ii) Less number of role changes and cluster switches. iii) Better stability. iv)Less maintenance overhead	Number of clusters, Number of role changes, Number of cluster switches, Delivery ratio, Number of RREQ forwarding nodes, Average hop count	No
10.	Efficient Clustering-based Routing Protocol in Mobile Ad-Hoc Networks[5]	Neighbor based`	i) Insensitive to network topology changes. ii)shorter transfer delay iii) reasonable control overheads iv) Appreciable throughput.	Route failure ratio, Average packet delay, Throughput of wireless resources, Control overheads	Yes
11.	Demand-Driven Clustering in MANETs[18]	Neighbor based	i) Stable clustering ii) will not consume bandwidth when clusters are not used.	Number of Leaders and Cluster Size, Leader Change Frequency, Cluster Change Frequency, Stability and Overhead	Yes
12.	A Low Control Overhead Cluster Maintenance Scheme for Mobile Ad hoc NETworks (MANETs)[19]	Neighbor based	i) Provides stable cluster structure.	Number of cluster member change, Number of cluster head change, clustering overhead,	Yes
13.	Multi-hop Clustering Based on Neighborhood Benchmark in Mobile Ad-hoc Networks[20]	Neighbor based	i) Stable. ii) Flexible.	Average number of clusterhead changes, Communication Overhead, Percentage of clustered nodes, Standard deviation of cluster sizes,	yes
14.	A Hybrid Power-Saving Protocol by Dual-Channel and Dual-Transmission-Rang e Clustering for IEEE 802.11-Based MANETs[21]	Power based	i) Power efficient, ii) Scalable, iii) Adaptive to topology changes.	Ratio of cluster heads , Survival ratio, Throughput Lifetime	No
15	A Stable Clustering Algorithm Based on Battery Power for Mobile Ad Hoc Networks[22]	Power based	i) better performance, ii) higher stability,	Clustering architecture life time, Minimum battery power, Network lifetime.	No
16	Robust Adaptive Cluster Based Routing[23]	Power based	i) reliable network performance, ii) reduces the average path delay, iii) Reduces the average transmission power.	Packet Delivery Ratio, Routing Overhead, Delay, Average Power, Path Optimality	Yes
17	FRCA: A Fuzzy Relevance-Based Cluster Head Selection Algorithm for Wireless Mobile Ad-Hoc Sensor Networks[24]	Artificial intelligence based	i) reduces the overhead ii) Efficient management of node positions and energy. iii) Improvement of routing performance.	Number of clusters, Overhead rate, Cluster head selection rate,	Yes
18.	Optimized routing in	Artificial based	i) Decrease in the	Average percentage of	No

	Mobile Ad Hoc Networks using Evolutionary Location Intelligence[25]		percentage of concave nodes. ii) reduces the need for recovery	Concave nodes, Average route length,	
19	Routing Optimization using Genetic Algorithm in Ad Hoc Networks[26]	Artificial based	i) fewer link breakages ii)adjust to topology changes iii) frequent information exchange among the participating nodes	Reaffiliations per unit time, Average Number of Clusters, Load balance factor, cumulative distribution	No
20	Cluster head Election for CGSR Routing Protocol Using Fuzzy Logic Controller for Mobile Ad Hoc Network[27]	Artificial intelligence based	Increases the network lifetime.	Node Remaining Energy, Node Distance, Node Mobility.	No
21	An ACO Algorithm for Effective Cluster Head Selection[28]	Artificial intelligence based	finds the minimal set of cluster heads	Number of clusters	No
22	A Distributed Weighted Cluster Based Routing Protocol for Manets[3]	Weighted clustering based	i) reduces the cluster head formation ii) control messages overhead iii)better performance iv) reduces energy utilization	Number of cluster heads, Number of control messages, Number of reaffiliations, Remaining energy.	Yes
23	A Cluster-Based Service Discovery Protocol for Mobile Ad-hoc Networks[12]	Weighted clustering based	i) Reduces communication costs. ii) Reduces delay and overhead. iii) good success ratio.	End-to-End Delay, Success Ratio, Overhead	Yes
24.	A Flexible Weight Based Clustering Algorithm in Mobile Ad hoc Networks[29]	Weighted clustering based	i)better performance in terms of number of formed clusters, number of re-affiliations, average number of transition CHs and number of clusterheads changes ii) provides a reliable method of cluster organization.	Average number of clusters, Average transition number on each CH, Average number of CH changes, Re-affiliation count	No
25.	An Adaptive Weighted Cluster Based Routing (AWCBRP) Protocol for Mobile Ad hoc Networks[30]	Weighted clustering based	i) quickly adapt to the topology changes ii) efficiently search for new paths with minimal power consumption. iii) low computational costs. iv)stability of the network	Control overhead, Average end-to-end delay, Average Packet Delivery Ratio	Yes
26.	An Entropy-based Weighted Clustering Algorithm and Its Optimization for Ad Hoc Networks[31]	Weighted clustering based	i) Reduces the reaffiliation caused by high-speed moving nodes. ii) low computational costs. iii)longer battery life iv)lower frequency of network assignment. v)longer stabilization of network structures	Reaffiliation per unit time, Average number of clusters,	No
27.	Stable and Flexible Weight based Clustering	Weighted clustering based	i) stable and flexible against	transmission ranges, number of nodes and	No

	Algorithm in Mobile Ad hoc Networks[32]		topology changes ii) Increase the number of nodes, transmission range and maximum displacement.	Maximum displacement.	
28.	Cluster based Routing Protocol for Mobile Ad Hoc Networks[2]	Weighted clustering based	i)decreases routing control overhead ii) improves the networks scalability. iii) increases the packet delivery ratio iv) decrease the packet delay	Packet delivery ratio, Average end-to-end delay	No
29.	A Novel Distributed Clustering Algorithm for Mobile Ad-hoc Networks[8]	Weighted clustering based	i) better end-to-end throughput. ii)longer lifespan iii)smaller number of clusters	End-to-end throughput, Average number of re-affiliations, The minimum lifespan of nodes, Overhead of packets	yes

A. Disadvantages of Existing Clustering Techniques

In [5], Virtual Cluster-based Routing Protocol with Backup Route (VCBRP) cannot improve the control overhead performance anymore, since it has to use additional control overheads for retaining and mending the backup routes.

In [3] , in the proposed algorithm, the cluster head selection is limited to single hop neighbors only not considering the multi-hop neighbors.

The Flexible Weight Based Clustering Algorithm [29] does not consider the overheads generated and has not evaluated its impact on the network and in inter-cluster communications.

In [13], the control overhead in LECBRP increases when the network is dense.

In ODGMBC current design [18], protocol overhead is a drawback in dense traffic scenarios due to the neighborhood detection scheme. Some ideas to reduce it are outlined but not yet evaluated.

In [20], as MCNB restricts all the beaconing mechanisms to a localized scope and does not enforce proactive cluster head reselection. The overhead increases in higher mobility due to more frequent beaconing.

In the Cluster head gateway switch routing protocol (CGSR), approach has numerous disadvantages: first, cluster heads selection causes complexity and overhead, hence it degrades the performance. Second, there are traffic bottleneck and single point failures at the cluster heads and gateways [26].

B. Weight Based Approach in Clustering Techniques

Most of the existing works on clustering uses the weight based approach for selection of cluster heads. In some of the clustering techniques, the weight based approach has been combined with other techniques such as location based, neighbor based, mobility based and AI based.

For example, the location based clustering in ILCRP [14] is done using a weighted approach. The node value of the node is calculated by the updates from the neighbor node's list. The node value of each node is calculated based on the degree of difference (Δi), mobility of node (M), remaining battery power of the node (Pa).

In [15] a mobility based approach is used for clustering. Here the selection of cluster head is done based on the weight of each node. Here four factors are taken into consideration while making the selection of cluster-head and maintenance of cluster. They are namely node degree (number of neighbors), distance summation to all its neighboring nodes, mobility and remaining battery power.

In [16] the mobility based approach is used .here a new clustering algorithm named MobHiD was proposed, which combines the highest degree technique with the proposed mobility prediction scheme. Here the weight for each MH is based on probability of neighborhood of MH, node degree of MH and average degree of the future neighborhoods of the MH.

In [6], a neighbor based clustering is done using weighted approach. Here the mobility information, battery power, distance between nodes and transmission rate are required for the weight calculation of each node.

The artificial intelligence (AI) based clustering approaches [24], [26] and [28] also combine weighted approach for efficient clustering. The degree, transmission power, mobility and battery power are some of the parameters that are taken in consideration for the efficient weight based clustering.

V. Conclusion

Based on the comparison of various clustering techniques for MANET and the discussion of weight based approach in the previous section, we can conclude that the weight based clustering approach is the mostly used technique for cluster head selection and the common parameters for weight estimation include node degree, transmission power, mobility, distance and residual battery power. In some cases, stability and connectivity are also taken into account. So we need an artificial intelligence technique like Fuzzy logic or PSO to select the appropriate weight parameters for cluster head there by minimizing the overhead and maximizing the throughput.

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