A DISSERTATION

ON

OPTIMIZATION OF WEIGHTED CLUSTERING ALGORITHM IN MOBILE ADHOC NETWORKS

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DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

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DECLARATION

I hereby undertake and declare that this submission is my original work and to the best of my knowledge and believe, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree or diploma of any Institute or other University of higher learning, except where due acknowledgement has been made in the text. Project work and published paper associated to the chapters are well discussed and improved under the guide supervision.

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CERTIFICATE

This is to certify that the thesis entitled, "**OPTIMISATION OF WEIGHTED CLUSTERING ALGORITHM IN MOBILE ADHOC NETWORKS**", is a bona fide work done by Mr. Vijayanand Kumar (Roll no: 2K13/SWT/18) in partial fulfilment of requirements for the award of Master of Technology Degree in software technology at Delhi Technological University (New Delhi) is an authentic work carried out by him under my supervision and guidance. The matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma to the best of my knowledge.

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ACKNOWLEDGMENT

I am presenting my work on "**OPTIMISATION OF WEIGHTED CLUSTERING ALGORITHM IN MOBILE ADHOC NETWORKS**" with a lot of pleasure and satisfaction. I take this opportunity to thank my supervisor, Prof. R.K.Yadav, for guiding me and providing me with all the facilities, which paved way to the successful completion of this work. This thesis work was enabled and sustained by his vision and ideas. His scholarly guidance and invaluable suggestions motivated me to complete my thesis work successfully. I would like to express my deep gratitude to my parents. Their continuous love and support gave me strength for pursuing my dream. I am thankful to my friends and colleagues who have been a source of encouragement and inspiration throughout the duration of this thesis. I am also thankful to the SAMSUNG who has provided me opportunity to enrol in the M.Tech Programme and to gain knowledge through this programme. This curriculum provided me knowledge and opportunity to grow in various domains of computer science. Last but not least, I am thankful to all the faculty members who visited the Samsung premises to guide and teach. Their knowledge and efforts helped me to grow and learn in the field of computer science. I feel proud that their contribution helped me to bring out new ideas in my professional life. This project has provided me knowledge in the area of mobile adhoc network domain and helped me in understanding the network topology in wireless domain. I have given ample time and guidance to complete my project under timeline defined by the university. This project has given me opportunity to explore the domain of adhoc wireless network.

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ABSTRACT

Wireless cellular network is restricted with geographical boundary and rely on wired backbone by which all base stations are connected. In utmost emergency situation such networks cannot be set and due to wired configuration cost of scaling increases. Wired (central) backbone cannot be implemented in critical area and situations such as law enforcement operations, battle field communications, disaster recovery situations, and so on. Therefore, mobile multi-hop radio networks, also called adhoc or peer-to-peer networks, play a critical role. Such situations demand a network where all the nodes including the base stations are potentially mobile, and communication must be supported untethered between any two nodes. Wireless systems with multi-cluster, multi hop packet radio network architecture should be dynamically adaptable with changing network configurations. Clusterheads which acts as central nodes are responsible for the cluster formation each consisting of supporting nodes for the cluster head. Cluster head also take responsibility of cluster maintenance.

Dominant set is the set of cluster heads in the network. Responsibility of cluster head is (a) resource allocation to all nodes belonging to the specific cluster (b) serving the mobile nodes of the cluster for routing the data packet and (c) maintaining the cluster. Due to dynamic nature of the mobile nodes, cluster heads changes time to time. Reconfiguration of cluster takes place and associated mobile node gets disassociated with the particular cluster. This is an important issue since frequent clusterhead changes adversely affect the performance of other protocols such as scheduling, routing and resource allocation that rely on it. Election of clusterheads is an NP-hard problem. Probability of electing the optimal cluster heads must of high in any clustering algorithm. Clustering algorithm must be fast and cost of clustering must be as minimal as possible. Network must be stable as long as possible as well as scalable with the clustering process. Best clustering scheme must preserve its structure with dynamics of the mobile node i.e. when node changes its topology or with movement clustering must retain its structure. There is high computation overhead associated with the clustering and cost of clustering affects the network stability. Clustering is nothing but dividing the geographical region into small zones. Any node in the network can be clusterhead, depends on clustering node dynamic such as power, mobility, degree difference and sum of distances. Node associated with particular clusterhead become member of the cluster. Cluster of mobile nodes can be changed as the time progresses in the network.

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1. INTRODUCTION

“Clustering in manet” was introduced to increase the scalability of the network which was not possible for flat topology. To increase scalability and network lifetime hierarchy topology was introduced. Clustering is a type of hierarchy topology which could be one or multi-hop clustering. In the past there were many clustering algorithms such as highest degree, lowest id, dominant set based, energy efficient, load balancing, and mobility aware , low maintenance and weight based clustering has been proposed. Most recent clustering is weight based clustering and modification to these clustering has been presented.

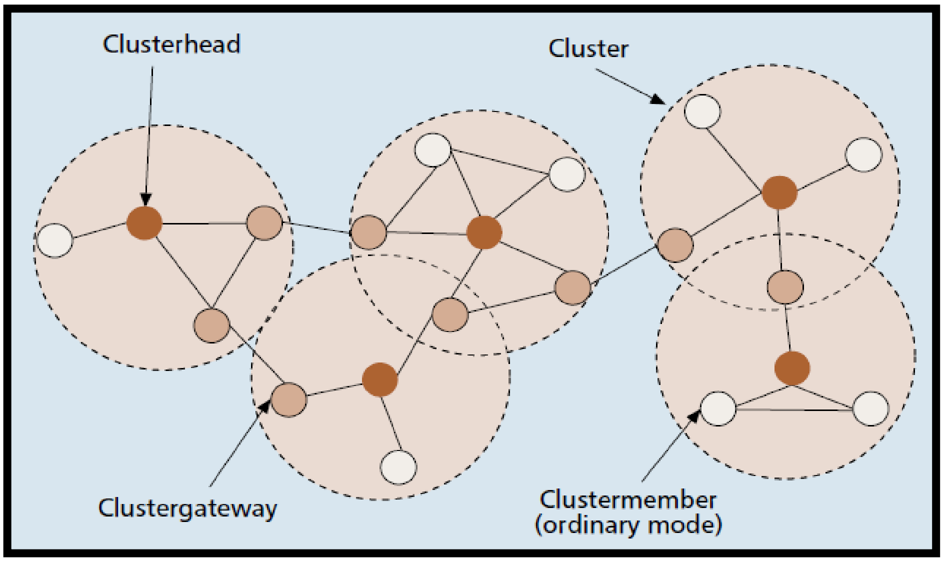

Figure1:- Cluster Architecture

A typical cluster structure is shown in Fig. 1. It can be seen that the nodes are divided into a number of virtual groups (with the dotted lines) based on certain rules. Moving from flat topology to hierarchy topology there was cost to handle the clustering. These costs plays important role to form and maintain the clustering. These costs also represent either constraints or flexibility of the clustering. Cost of clustering is (a) explicit control message for clustering (b) ripple effect of re-clustering (c) stationary assumption for cluster formation (d) Constant Computation round (e) Communication (message) complexity.

It has been shown that cluster architecture guarantees basic performance achievement in a MANET with a large number of mobile terminals. A cluster structure, as an effective topology control means, provides at least three benefits. First, a cluster structure facilitates the spatial reuse of resources to increase the system capacity. With the non-overlapping multicluster structure, two clusters may deploy the same frequency or code set if they are not neighbouring clusters. Also, a cluster can better coordinate its transmission events with the help of a special mobile node, such as a clusterhead, residing in it. This can save much resources used for retransmission resulting from reduced transmission collision. The second benefit is in routing, because the set of clusterheads and cluster gateways can normally form a virtual backbone for inter-cluster routing, and thus the generation and spreading of routing information can be restricted in this set of nodes. Last, a cluster structure makes an ad hoc network appear smaller and more stable in the view of each mobile terminal. When a mobile node changes its attaching cluster, only mobile nodes residing in the corresponding clusters need to update the information. Thus, local changes need not be seen and updated by the entire network, and information processed and stored by each mobile node is greatly reduced.

Weighted Clustering algorithm has been dominated in manet over the years and several modification proposed in this including entropy based weighted clustering algorithms.

2. LITERATURE REVIEW

Earlier with the flat topology, scalability and energy consumption was limited and improved with clustering of mobile nodes. This clustering has cost to pay in terms of explicit control messages for clustering, ripple effect of re-clustering, stationary assumption for clustering, constant computation round and communication complexity. Many clustering algorithm proposed incrementally and showed improvements over others. Some of the clustering algorithms are dominant set based clustering, low maintenance clustering, mobility aware, energy efficient, load balancing and combined metrics based clustering. Combined metrics based clustering includes node dynamics such as degree difference, mobility and power of the mobile nodes. Weighted clustering algorithm is one such metrics based clustering algorithm.

2.1 WEIGHTED CLUSTERING ALGORITHM

The **Weighted Clustering Algorithm** (WCA) was originally proposed by M. Chatterjee et al. which obtain 1-hop clusters with one cluster-head. The election of the cluster-head is based on the weight of each node. This algorithm performs with four admissible factors for the cluster head election and maintenance. The four factors are degree difference (Dv), summation of distances (Pv), mobility (Mv) and cumulative time (Tv). Although WCA has proved better performance than all the previous algorithms, it is also has few drawbacks to know the weights of all the nodes before starting the clustering process and CHs rapidly Changing difficulties. As a result, the overhead induced by WCA is very high. The weight value associated to a node 'v' is defined as,

$$Wv = {}_{W1}Dv + {}_{W2}Pv + {}_{W3}Mv + {}_{W4}Tv$$

A CH algorithm finishes once all the nodes become either cluster head or a member of cluster head. A cluster head consumes more battery power than ordinary node. This algorithm depend few conditions i.e. the distance between members of CH must be less or equal to the transmission range between them. WCA assumption is that a node can support up to δ nodes for better MAC functioning.

2.2 CLUSTER FORMATION PROCESS

Step 1: Find the neighbours of each node *v* (i.e., nodes within its transmission range) which defines its *degree*, *dv*, as

$$dv = |N_{(v)}| \qquad (1)$$

Step2: Compute the ***degree-difference***,

$$\Delta v = |dv - \delta|, \text{ for every node } v. \qquad (2)$$

Where δ is maximum nodes supported by mobile nodes for better physical layer functioning.

Step3: For every node, compute the ***sum of the distances***, *Dv*, with all its neighbours, as

$$Dv=\sum \{dist(v,v')\} \qquad (3)$$

Step4: Compute the running average of the speed for every ***node v*** till current time *T.* This gives a ***measure of mobility*** and is denoted by *Mv*, as

$$Mv = 1/T \sum sqrt[(X_t - X_{t-1})^2+(Y_t - Y_{t-1})^2], \text{ Coordinates}(X_t, Y_t) \text{ and } (X_{t-1}, Y_{t-1}) \text{ at time } t \text{ and } t\text{-}1 \text{ for node } v \text{ respectively} \qquad (4)$$

Step 5: Compute the cumulative time, *Pv*, during which a node *v* acts as a cluster head.

Step 6: Calculate the *combined weight Wv* for each node *v*,

$$Wv = w1\Delta v + w2Dv + w3Mv + w4Pv, \quad (5)$$

Where *w*1*, w2, w3* and *w*4 are the *weighing factors* for the corresponding system parameters

Step 7: Choose that node with the smallest *Wv* as the cluster head. All the neighbours of the chosen cluster head are no longer allowed to participate in the election procedure.

Step 8: Repeat steps 2–7 for the remaining nodes not yet selected as a cluster head or assigned to a cluster.

Minimum weight *Wv* among the nodes will be elected as cluster head in the cluster of mobile nodes. In the next section of related work, it will be analyzed that the weights associated with the **node dynamics [Δ*v, Dv, Mv, Pv*]** plays important role to elect the best suited role of cluster head which must be stable in the network. Sum of intermediate weights **[w_1, w_2, w_3, w_4]** associated with the dynamics must satisfy below condition:

$$W1+W2+W3+W4=1 \quad (6)$$

Intermediate weights must satisfy equation 6 but distribution of intermediate weights on dynamics must be well balanced so that better cluster head election must take place.

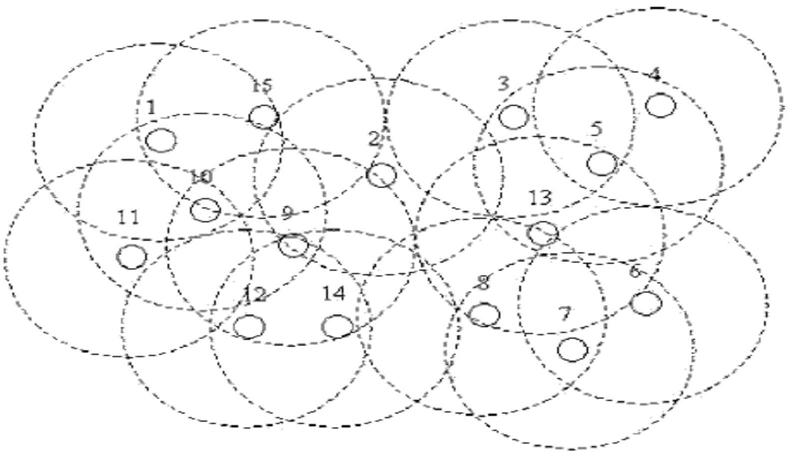

Figure 2:- Initial Configuration of Nodes

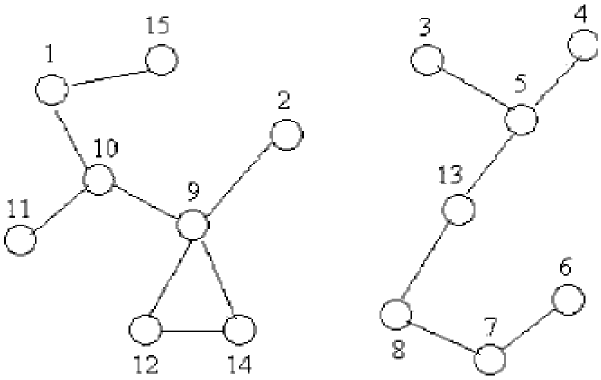

Figure 3:- Neighbours Identified

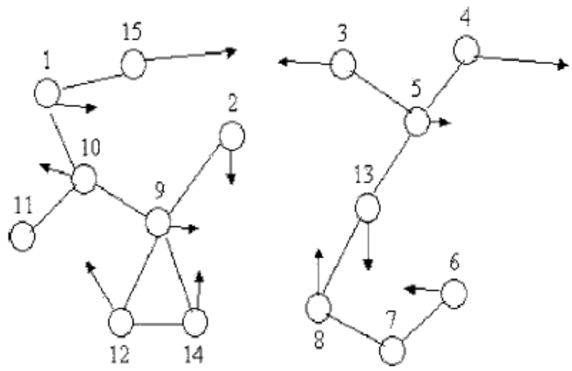

Figure 4:- Velocity of the Nodes

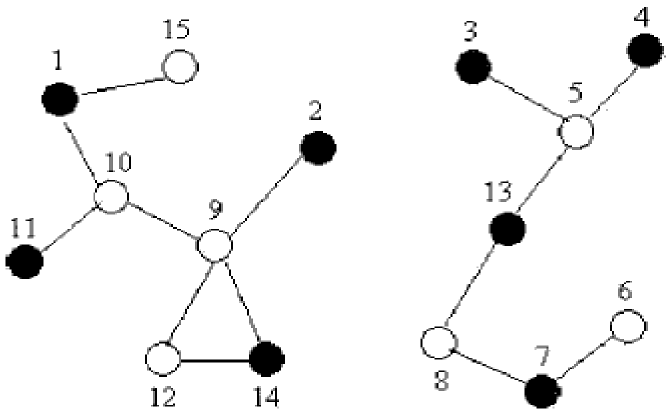

Figure 5:- Cluster Heads Identified

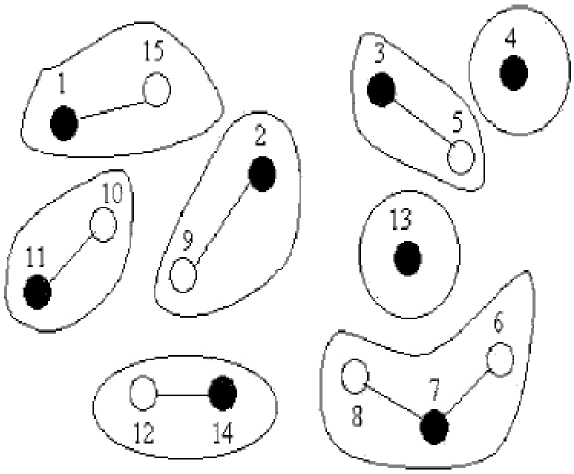

Figure 6:- Clusters Identified

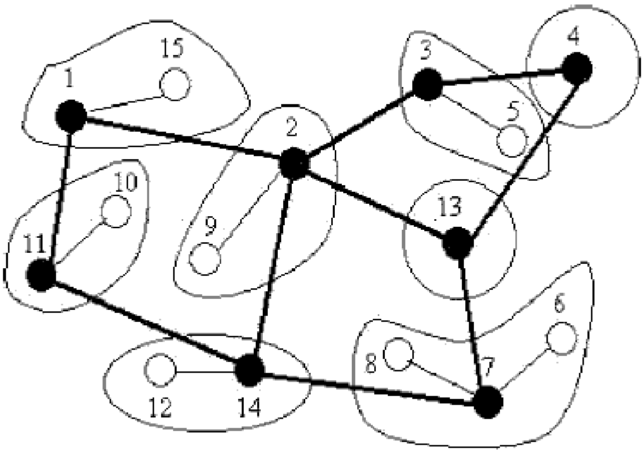

Figure 7:- Connectivity Achieved

Node id	d_v step 1	Δ_v step 2	D_v step 3	M_v step 4	P_v step 5	W_v step 6
1	2	0	6	2	1	1.35
2	1	1	4	2	2	1.70
3	1	1	3	3	1	1.50
4	1	1	3	4	2	1.60
5	3	1	9	1	4	2.75
6	1	1	3	2	2	1.50
7	2	0	6	0	0	1.20
8	2	0	7	3	3	1.70
9	4	2	13	2	6	4.40
10	3	1	12	2	7	3.55
11	1	1	3	0	1	1.35
12	2	0	5	3	4	1.35
13	2	0	7	3	2	1.65
14	2	0	5	2	0	1.10
15	1	1	3	4	3	1.65

Table 2.2.1:- Execution of Weighted Clustering Algorithm

2.3 CLUSTER MAINTAINANCE PROCESS

On system boot up every node transmit their id in the range, as can be seen from figure 2.It is assumed that based on signal strength distance of one node to another can be measured. Other technique to measure distance is through GPS. But GPS can bring cost of deployment on the mobile node. Signal strength can help measure the distance of one node to another. These neighbouring nodes are in the range of each other but not necessary that they belongs to the same cluster. Clustering algorithm identifies the cluster head after finding the neighbours, as illustrated in figure 5 and figure 6.It can be noted that the mobility factor and the battery power would be the same for all the nodes when the system is initialized. Each node has identified with their role either cluster head or cluster member. Due to the dynamic nature of the system considered, the nodes as well as the clusterheads tend to move in different directions, thus disorganizing the stability of the configured system. So, the system has to be updated from time to time. The update may result in formation of new clusters and possible change of point of attachment of nodes from one clusterhead to another within the existing dominant set. This is called *reaffiliation*. The frequency of update and hence reaffiliation is an important issue. If the system is updated periodically at a high frequency, then the *latest* topology of the system can be used to find the clusterheads which will yield a good dominant set. However, this will lead to high computational cost resulting in the loss of battery power or energy. If the frequency of update is low, there are chances that current

topological information will be lost resulting in sessions terminated midway. All the nodes continuously monitor their signal strength as received from the clusterhead. When the mutual separation between the node and its clusterhead increases, the signal strength decreases. In that case, the mobile has to notify its current clusterhead that it is no longer able to attach itself to that clusterhead. The clusterhead tries to hand-over the node to a neighbouring cluster (existing clusterhead in the dominant set). The clusterhead of the re-affiliated node updates its member list. If the node goes into a region not covered by any clusterhead, then the clusterhead election algorithm is invoked and the new dominant set is obtained.
Objective of clustering scheme is to maintain the cluster structure as long as possible to maintain the network topology and mobile node roles. Other goal is to avoid frequent cluster formation in the network. But when the situation arises that the cluster cannot be maintained then the invocation of cluster formation is needed and new cluster structure is formed. Clustering scheme consider degree difference, sum of distances, mobility and power of the mobile node with weighted factors associated with them. These are node dynamics and changing with the time. Electing the cluster head depends on the minimum weight obtained with the weights and node dynamics.
Weights of each node are shared among the mobile nodes in neighbours, minimum weigh node elected as cluster head and nodes associated with this cluster head are members of the nodes.

2.4 LOAD BALANCING

The load handled by a clusterhead depends on the number of nodes supported by it. A clusterhead, apart from supporting its members with the radio resources, has also to route messages for other nodes belonging to different clusters. Therefore, it is not desirable to have any clusterhead overly loaded while some others are lightly loaded [1]. At the same time, it is difficult to maintain a perfectly load balanced system at all times due to frequent detachment and attachment of the nodes from and to the clusterheads. To quantitatively measure how well balanced the clusterheads are, we introduce a parameter called *load balancing factor* (LBF). As the load of a clusterhead can be represented by the cardinality of its cluster size, the variance of the cardinalities will signify the load distribution.
We define the LBF as the inverse of the variance of the cardinality of the clusters.

$$\mathrm{LBF} = n_c / \sum (x_i - \mu)^2$$

Where n_c is the number of clusterheads, x_i is the cardinality of cluster i, and $\mu = (N - n_c)/n_c$, (*N being* the total number of nodes in the system) is the average number of neighbours of a clusterhead. Clearly, a higher value of LBF signifies a better load distribution and it tends to infinity for a perfectly balanced system.

3. PROPOSED WORK

Adhoc clustering in MANET is to divide mobile nodes into different virtual groups. Mobile nodes are allocated geographically adjacent in the cluster. Clustering is done by some rule specific in the network. In this proposed work, we have concentrated to modify weight based clustering algorithm to improve the performance in this wireless technology. By slight improvement in existing weight based clustering algorithm reduction in cluster as well as cluster head can be observed through experiment. Proposed Algorithm specifies relaxing the weight criteria for isolated cluster head nodes in range of other cluster head as well as reconsidering the nodes in the range which is already participated in cluster formation. Reconsidering the participated node again in clustering formation could help in creation of better cluster, forming better routes as well as in conserving the cluster head energy.

Wireless Adhoc Networks are infrastructure less networks which configures itself for communication. Proactive and Reactive on demand routings are applied on the network for data and packet routings. Node arrangement in network associated with its coverage of the mobile nodes and its range. Arrangement of node generally kept dense to maximize the efficiency of the network. Dense mobile node arrangement in the network ascertains that communications between nodes are continuous in nature and does not disconnect for certain time period. With the dense arrangement of the nodes, loss of data and packets are minimized. Drop of packet and data depends on capacity on the network and node compatibility factors such as queuing mechanism for message and frequency of processing of the messages. Early invention of wireless network for mobile nodes only dealt with routing and its arrangement on the network but it suffer the scalability problem over the large area network. It also suffer from the dynamic nature of the mobile nodes such as mobility, support of mobile nodes, power of mobile nodes and the coverage of mobile nodes. All the dynamic factors become bottle neck for communication protocols. In order to bring scalability over the mobile adhoc network different network topology has been given. In its early invention flat topology for routing has been done and correspondingly supported routing methods has been proposed. In quest of scalability, hierarchical structure has been proposed for mobile nodes arrangement. This brings more stability, better routing methods, energy and bandwidth consumption has been minimised, load over the network has been optimised. Clustering is one of the methods in hierarchical structure where nodes are allocated in the neighbourhood and it is done by applying some rule. Each node in the cluster perform different roles such as cluster head, cluster member and gateway nodes. There can be many small to large range cluster present in the network. Cluster head performs the routing and data forwarding role for intra cluster as well as for inter cluster through gateway nodes. Intention of this proposed work is to study and experiment on load balancing act on weighted clustering algorithm. Further generic modification and theory has been proposed to balance load by modifying algorithm for cluster formation and maintenance process. Network stability can be enhanced by balancing the algorithm and changing maximum threshold node criteria for both cluster formation as well as cluster maintenance process.

Clustering in mobile adhoc network is technique to group mobile nodes based on their attribute such as mobility, degree, energy and other absolute and relative attributes. Mobile nodes are located geographically adjacent to each other and relative communication configures the cluster for intra and inters communication with mobile nodes. Communication between mobile nodes depends on the strength of the signal between them. Cluster communication takes place either one hop or multi hop using associates mobile nodes, also known as gateway nodes. In this proposed work focus is on reducing communication overhead during cluster formation by using greedy approach. Mostly greedy approach has been used to select cluster head. Reducing communication overhead benefits in faster cluster formation and avoiding other communication delay such as packet transfer, handover of resources and other useful communication messages other than clustering information related messages.

Each cluster family have different members with different assigned roles such as cluster head, cluster members, gateway members and ordinary nodes which can perform roles of any three mentioned roles as the time progresses based on absolute and relative attribute information. Absolute attributes of mobile nodes can be mobility, energy consumed and entropy of the mobile node. Relative attributes can be considered as neighbour information and sum of distances of neighbours etc. Relative attributes are the information based on neighbourhood and absolute information which can be extracted from measuring its own system parameters locally. Weighted clustering scheme uses both the information for calculating weights and delay the clustering formation process. In this proposed work we choose to apply greedy approach for cluster head selection and absolute weighted information for clustering to reduce the communication round which results in fast clustering formation process.

Mobile Ad hoc network has taken the lead in the field of wireless communication. MANET has supported mobility, scalability and extendibility of the network over the air. Connectivity in wireless medium has several costs for communication. Costs such as life of connections, packets routing, information delay, security over the air and trusted source and receivers needs extra care in communication. Initially a flat topology has been proposed considering the life of connection i.e. how long connectivity is present between mobile nodes. Flat topology was not able to support scalability of the mobile nodes in the wireless network. To overcome this, hierarchy topology has been proposed which overcome the scalability problem. One of the hierarchy topology can be consider as clustering. Clustering of mobile nodes solves basic three problems which are (a) expanding the network (b) communication stays within the cluster so that other neighbouring cluster remains unawares of the communication and (c) maintenance of routing become much easier. This proposed work mainly concentrates on one of the clustering scheme known as weighted clustering scheme. Clustering has mainly two processes which are (a) cluster formation and (b) cluster maintenance. Weighted clustering algorithm has both the processes well defined. Weighted clustering has some constraints such as (a) Dynamic nature of relative (such as degree difference and sum of distance) and absolute attributes (Mobility and Power) (b) Non scaled threshold of maximum supporting node (δ) and (c) Distributed weight configuration for selecting stable cluster head. This proposed work has described the constraints on weights which is fixed and not varying with the dynamics [Degree Difference Δv, Sum of Distances Dv, Mobility (Mv) and Power (Pv) of the nodes] of the mobile node in the network. Weights play major role to select the best stable cluster head as it defines and support the dynamics of the mobile nodes. Algorithm depends on the minimum weight among the mobile nodes, which become the cluster head. Choosing cluster head is an important task of the clustering which takes in cluster formation and also in maintenance phase as well.

Choosing a cluster head is an NP-hard Problem in algorithm domain and mostly follows greedy approach. Choosing the proper weights for supporting the dynamics has not been described much in earlier research and could be important factor while selecting a cluster head. This proposed work describes the dynamic weight adjustments by using method of soft computing. Soft computing has non-deterministic algorithm such as fuzzy logic and neural networks.

Weight based clustering algorithm shows the nature of artificial neural network with fuzzy behaviour on their node dynamics. Since less computation and fast clustering is goal of any clustering based algorithm, so proposed work is intended to select the best clusterhead by choosing the appropriate weights for mobile nodes with less computation overhead. Network model for weight correction based on neural network has been proposed which has less overhead and apply fast computation method.

Proposed work has been divided in five different sections; with some objective inclusive or exclusive but focus on making network more stable by applying correction in weight based clustering algorithms. Proposed work is very generic and can be applied to any clustering algorithm or can be included as a tweaking the existing algorithm to maintain the cluster as stable as possible with minimum cost of clustering.

3.1 RELAXING WEIGHTED CLUSTERING ALGORITHM FOR REDUCTION OF CLUSTERS AND CLUSTER HEAD.

In this section, weight based clustering algorithm has been studied and modified for reduction of cluster as well as reduction of cluster head. We will analyze two scenario of clustering where modification can result in efficient clustering as well as energy can be saved

Scenario (a): Isolated cluster formation due to minimum weight selection among the nodes.

Step 7 of weighted clustering algorithm could result in isolated cluster. Consider nodes arrangement in table 3.1.1. Weight has been taken arbitrary but similar situation also arises while executing in real environment or in network simulation. Range of nodes may or may not be same for this scenario. Assume maximum delta a node can support is (δ) 4.

Node ID	Weight(Wv)	Nodes in range
1	4	3,4,5
2	3	5,7,6,8
3	7	-
4	8	-
5	9	-
6	12	2
7	10	2
8	2	-

Table 3.1.1

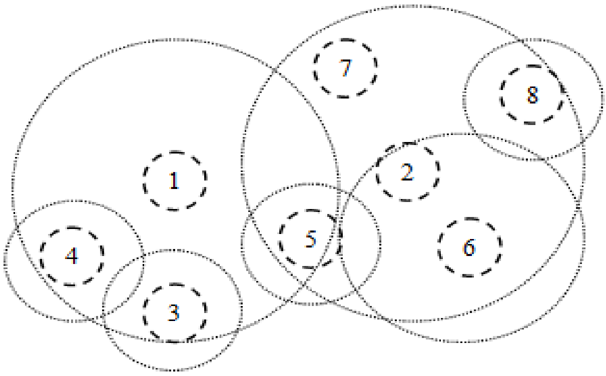

Fig 8:- Cluster architecture before cluster formation.

Running the WCA on above network structure, clustering shown in Fig 9 has been formed for cluster creation process. Cluster head, Member Nodes and gateway nodes are shown in Fig 9. Node_8 has the minimum weight and becomes the cluster head. It has no members in the range so it becomes an isolation node. Node_2 becomes the cluster head after Node_8 since it has more weight than the node_8.Node_1 becomes the next cluster head and node_3 and node_4 becomes its member. Similarly Node_2 serves node_5, node_6 and node_7. Node_8 has no neighbours in the range and hence become isolated cluster as shown in Fig 3.

We also assumed that cluster head can serve up to four nodes. In this case no cluster head is serving the maximum threshold. Here there are two problems isolated cluster head as well as maximum threshold has been not served. Both of the problems can be solved if relaxation is made in minimum weight criteria.

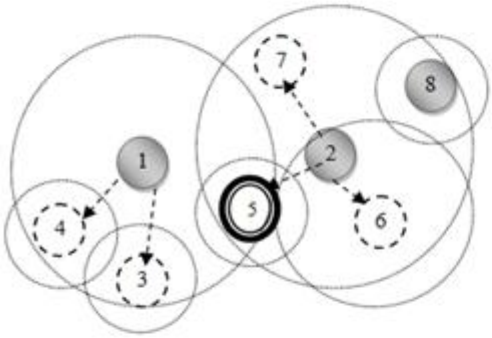

Fig 9:- Cluster Formation with weighted clustering algorithm

Relaxing the already formed isolated cluster head (Node_8) minimum weight criteria and including it in cluster formation again by checking that the cluster head (Node_8) has no neighbours associated and current cluster head node (Node_2) is under threshold, isolated cluster head node (Node_8) becomes member of the next cluster head (Node_2) selected. Since isolated cluster node (Node_8) is not serving any node so there is no need to be a cluster head. Isolated Cluster (Node_8) must be in the range of the next incoming cluster head (Node_2).It is not necessary that immediate node (node_2) with minimum weight in the range elect isolated node as member node. It may take time and turn of next minimum node could be late in cluster head election process due to minimum weight. It will be an exception in the network with minimum weight having no neighbours become a member nodes instead a cluster head. Now the cluster formed will be shown in Fig 10.

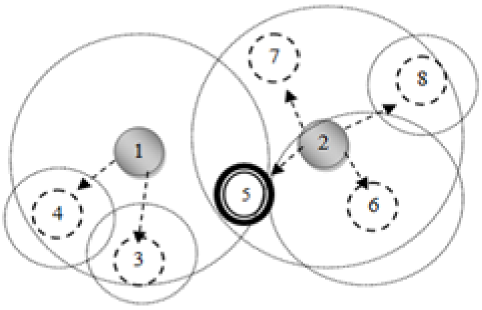

Fig 10 Cluster Formation after relaxing the minimum weight criteria for isolated nodes.

Such adjustments in the network can help in minimizing the hop count while routing. It reduces the cluster head as well as number of clusters in the network. Less number of clusters in dense network reduces the hop count and intern traffic in the network which is already proven fact.

Scenario (b): Cluster Change of the ordinary or member node if its distance and weight is less than the newly selected cluster head node and become member of new cluster formed.

Energy consumption is more if the node distance is more in communication range. So to save energy already selected member node can be re elected in the cluster formation. Slight change in algorithm can help in achieving the task.

Each node can support maximum threshold to 4 nodes. Node_1 has minimum weight and become cluster head. Neighbour (node_3, node_4, node_8 and node_6) nodes become cluster member. After this cluster Node_7 becomes cluster head according to next minimum weight shown in Fig 11. Once cluster member become part of one cluster it cannot participate in the next cluster head election process but it can be in the neighbourhood of other cluster head and it hears the request of cluster election procedure. Small calculation by this member node (node_4) while hearing Node_7 cluster head request can join the new cluster formed by node_7 cluster head. Node_4 need to check the distance of previous cluster head (node_1) to the new cluster head (node_7) that it's less or more. If node_4 has less distance from node_7 and node_7 can satisfy the maximum threshold as well as node_4 has more weight than Node_7, node_4 joins the cluster formed by Node_7 shown in Fig 12.

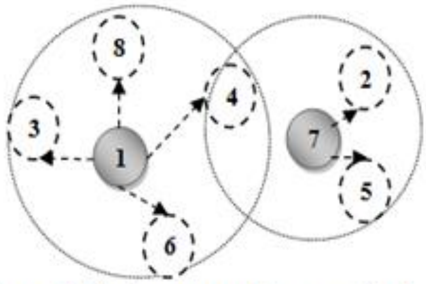

Fig11:- Initial cluster according to weighted clustering algorithm

Node ID	Weight(Wv)	Nodes in range
1	1	3,4,6,8
2	9	7
3	10	1
4	8	7
5	9	7
6	5	1
7	4	2,4,5
8	12	-

Table 3.1.2

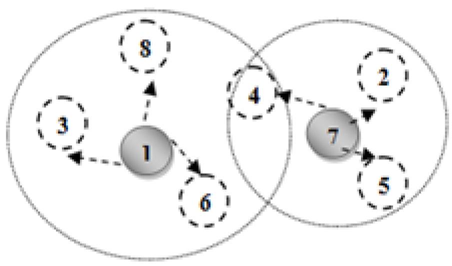

Fig12- Node_4 join the cluster formed by Node_7

3.2 LOAD BALANCING BETWEEN CLUSTER FORMATION AND MAINTENANCE PROCESS TO ACHIEVE NETWORK STABILITY IN WEIGHTED CLUSTERING ALGORITHM FOR MOBILE AD HOC NETWORKS.

Cluster formation for weighted clustering algorithm steps has been defined for a dense network and handling with some of exceptions are also proposed. Load balancing for WCA depends on the nodes supported by cluster head. Quantitatively how well balanced a cluster head is measured by load balancing factor. Supported nodes δ by a cluster head is the source of load balancing. For the update policy in weighted clustering algorithm, dynamics of the mobile nodes has been considered. The term frequency of updates in the network and reaffiliation of nodes is the measure of stability for the network. Reaffliation of node means separation from one cluster and joining another cluster i.e. movement of nodes from one cluster to another. If cluster member reaffiliate then only it needs to join the other cluster. Separation from the previous cluster has been detected by the signal strength. Once the signal strength become weaker the handover process for the node begins to join the new cluster. Both the cluster heads updates the information related to affiliated node. This has been generic update policy has been described in WCA. System activation i.e. invocation of weighted clustering starts again when any node went out of the range of any cluster head or it is unable to join any cluster in the network. This demands new cluster formation or dominant set to cover all the nodes in the network. Such updates propagate all over the network till the completion of clusters or after stabilisation of cluster formation process. There are many exception cases which also can invoke the weighted clustering algorithm again such as movement of cluster head so that it came one hop to another cluster head, what if any node become dead? Deactivation of the node can be detected on it energy criteria. Once it reaches near to minimum threshold of energy it can leave the cluster and consequently cluster head update the information. What if a dead node comes to alive and tries to join the cluster or cluster head? This node can send join request in the neighbourhood. On the basis of the node who is serving as cluster head from the neighbourhood, it will join the cluster. But what about the delta δ the maximum threshold node that a cluster head can support? If the cluster head is already at maximum threshold then system invocation is required i.e. again cluster formation required in the network. If such cases happened frequently in the network then network can be termed as unstable network. But if there are many nodes which are showing behaviour as (a) dead or alive nature (b) reaffiliation (c) out of the range from all the clusters or cluster head (since it's a one hop clustering algorithm) but in the range of some member nodes and (d) in a dense network maximum threshold delta δ that a cluster head can support has been already achieved, now it cannot serve further alive or affiliated nodes. All four factors are well capable of invoking the system updates which always cost more, make network unstable and unreliable. Network is overloaded with update messages and no productive operation takes place. Energy of mobile nodes get wasted along with many network operations get delayed.

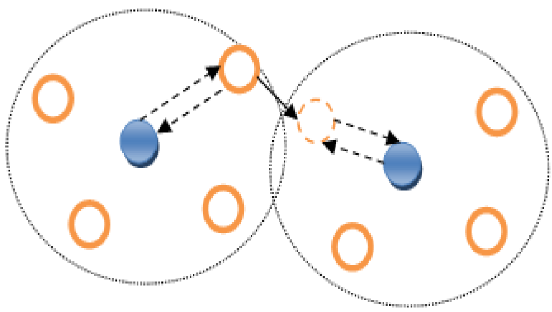

Fig 13:- Reaffliation of cluster member

Figure 13 shows general reaffiliation process where node moves from one cluster to another. It sends the join request to neighbourhood cluster head. In WCA, a one hop clusters are formed so in this case it directly can communicate to next cluster. Handover concept is generic as done for mobile adhoc network. In this case either cluster head will give all the occupied resources to the affiliate node or it will handover to neighbour cluster head through gateway nodes.

Figure 14 shows a dead node scenario in the cluster and probably become alive in future. This will have strong probability that it will invoke the clustering formation algorithm. If maximum delta δ constraint is not present then only join request to cluster head is enough to maintain the cluster and broadly comes under cluster maintenance process.

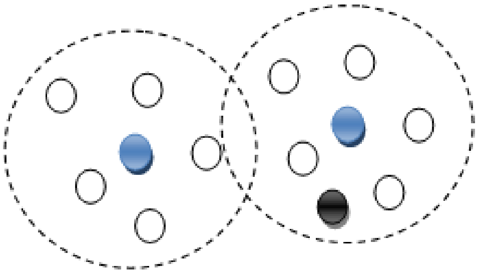

Fig14:- Dead Node and Cluster Head supporting maximum delta δ =5

Cluster maintenance, includes updating the messages with in the cluster (intra cluster) and outside cluster (inter cluster / neighbourhood cluster). Affiliated nodes which joins or leave also required to be maintained by the cluster head.

Figure 15 where node send join request to the neighbouring cluster head but it gets denial message due to maximum threshold has been reached for supporting the nodes. This situation has highest probability that it invokes the cluster formation process.

Statement of probability is due to dynamics of the node. It may be possible that some of the cluster nodes moves to other cluster during reaffiliation and cluster formation do not arise as maximum threshold criteria might satisfied during reaffiliation.

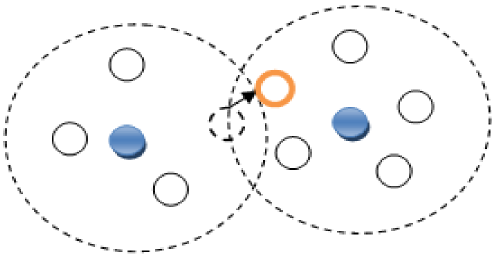

Fig15:- Member node sends join request to neighbourhood Cluster head with δ = 4

Proposed work deals with load balancing in cluster formation and cluster maintenance process by redefining the criteria of maximum threshold δ which a node or cluster head can handle. Load balancing in WCA is defined by the number of nodes handle by cluster head over the network. It will be always difficult to balance the load due to dynamic nature of the node. But handling the use cases, algorithm can be modified for the situation mentioned in figure 14 and figure 15 specifically changing maximum threshold δ criteria. Load balancing in cluster formation and maintenance by relaxing the maximum threshold δ criteria can be achieved. Later on we will analyse the impact by changing the criteria.

We already seen two scenarios where cluster formation or system invocation for clustering can be called (a) dead node comes to alive and vice-versa (b) any member node which has been affiliated from one cluster two another. This has been already experimented and analysed that invoking the clustering mechanism frequently can make network unstable and network bandwidth will be engaged for unnecessary clustering formation messages, along with it useful network operation get delayed.

Avoiding two scenarios for some instant of time, network stability can be prolonged. The proposed method only can prolong the invocation of network stability but concept can be extended to different clusters within the network i.e. concept can be applied to the different cluster in the same network based on probability of two scenarios mentioned.

Maximum threshold δ can be divided in two parts to support the cluster formation and cluster maintenance. Threshold division [δ-n] and [n] can be done based on the networks node density. Suppose a node can support maximum δ = 5 nodes, so one can divide it in [δ-1] and [1] i.e. 4 nodes in cluster formation and 1 node for cluster maintenance. Idea can be extended to any clustering algorithm for load balancing for mentioned two situations or added situation related to this. Dividing the supporting node criteria can have extra buffer to support the nodes which can prolong the network stability. These criteria can be imposed (a) on whole network or (b) specific to the clusters. [δ-n] and [n] can be scaled for any n ϵ R^+ (positive real numbers). Further study has been presented for two conditions.

Consider cluster structure shown in figure 16 with equal range for all nodes and maximum threshold for supporting node is **[δ]** 3. Invoking cluster formation for structure shown in figure 16 by applying WCA will result the cluster shown in figure 17. Node_1, Node_4 and Node_7 will serve as cluster head and rest nodes will be serving the cluster head as cluster members. Three clusters have been formed after running the WCA with above data mentioned in the table 3.2.1. Algorithm chooses minimum weight first (node_1) then assign its role to cluster head and neighbour belonging to (node_1) cluster head become its member node and do not participate further in clustering algorithm. Algorithm runs for all the nodes, nodes either become cluster head or cluster member. Gateways nodes depends on the hearing capability of other cluster identity. Nodes arrangement was perfectly balanced, as it forms only three cluster, also supported node δ = 3 satisfy properly and fortunately maximum nodes in the range is three, this is due to arrangement of nodes. But if any likely cluster head had more than three nodes in the range then it could have left those nodes. Those left node again need to participate in the cluster. Consider maximum threshold for supporting nodes are δ = 2 then there will be more cluster in the network.

Node Id	Weight (Wv)	Nodes in range
1	5	5,6,12
2	8	3,7
3	9	2,7,10
4	6	8,9,11
5	10	1,9,12
6	11	1,5,12
7	7	2,3,10
8	12	4,11
9	13	4,8,11
10	15	3,7
11	16	4,8,9
12	17	1,6,5

Table 3.2.1

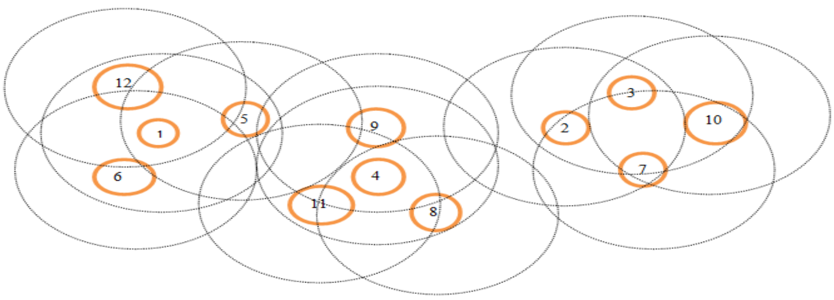

Fig 16:- Initial Cluster with maximum threshold is δ = 3

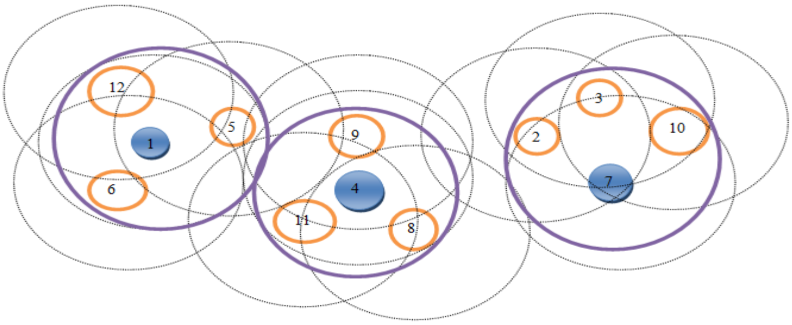

Fig 17:- Performing WCA Cluster formation with maximum threshold is δ = 3

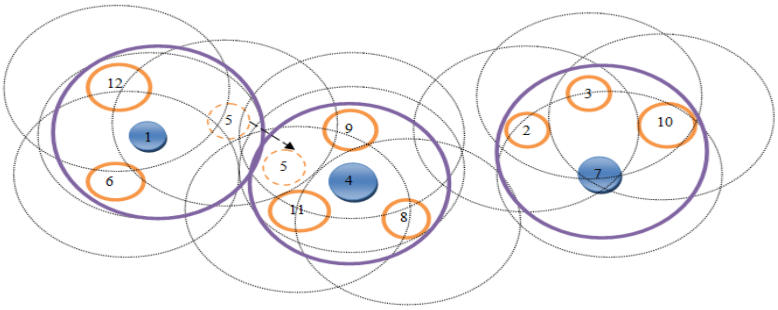

Fig 18:- Reaffiliation of node_5 with maximum threshold δ = 3

Now consider the reaffiliation of node_5 in the neighbourhood cluster as shown in figure 18. Due to network dynamics weight (Wv) changes over the time. It is certain that affiliated node_5 weight changes since mobility and energy consumption have been taken place. For other nodes weight parameter also changes if the nodes are not idle. Consider that weight of other nodes changes slightly and form table 3.2.2 based on the current dynamics. In WCA algorithm weight calculation takes place initially at the time of cluster formation. Since this is the case of invocating the cluster formation, weight of each node recalculated again and WCA run over to form cluster.

Node Id	Weight (Wv)	Nodes in range
1	6	5,6,12
2	10	3,7
3	9	2,7,10
4	7	8,9,11
5	14	1,9,12
6	11	1,5,12
7	8	2,3,10
8	12	4,11
9	17	4,8,11
10	15	3,7
11	16	4,8,9
12	20	1,6,5

Table 3.2.2

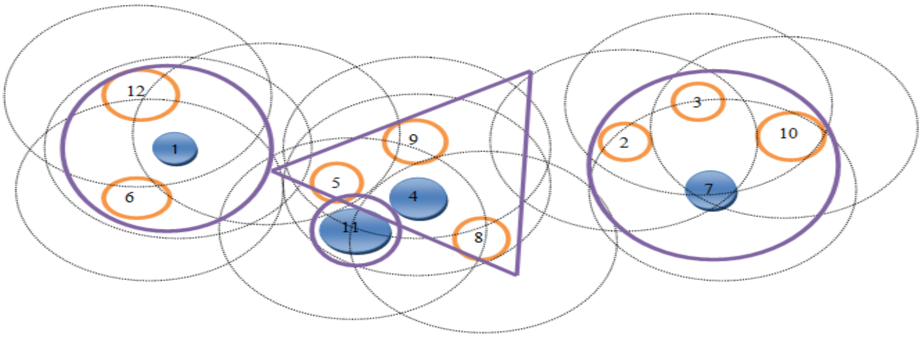

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Fig 19:- Cluster Formation Invoked with maximum threshold δ = 3

This was the case when maximum threshold was [δ] 3, instead maintaining the cluster, cluster formation has been called and whole network get configured again.

Now reconsider the figure 16 cluster architecture and table 1 configuration with maximum threshold δ-n = 2 in cluster formation and n = 1 for cluster maintenance process, figure 20 represent the cluster with δ-n = 2 cluster representation. Compare to figure 17 number of cluster has been increased from three to six. This has been doubled for this network architecture but it's possible that it might be less depends upon the network scenarios or on the arrangement of nodes. Increasing number of cluster or cluster head also increases the hierarchy of routing but in the dense network with more cluster heads, overall load on the cluster head decreases. Node_10, node_11 and node_12 are isolated nodes but it's possible that there might be some nodes in the neighbourhood. So with the current proposal the number of cluster will increase as well as cluster head but it also ensures that cluster head is properly balanced in the network and can handle the reaffiliation of the node. In figure 21 node_5 starts moving and join to node_4 which was assigned as cluster head. It's also possible that it joins node_11 depends on the communication which was taken first. Once node_5 has been assigned to any cluster or designated as cluster member, cluster maintenance process stops. Node_4 was well capable of receiving one more node request. This prevented the cluster formation process and helped to maintain the cluster architecture as well as stability. This process certainly delayed the cluster formation process. For both cases figure 19 and figure 21 it's possible that node_5 joins node_11 and in that case also cluster formation won't be invoked.

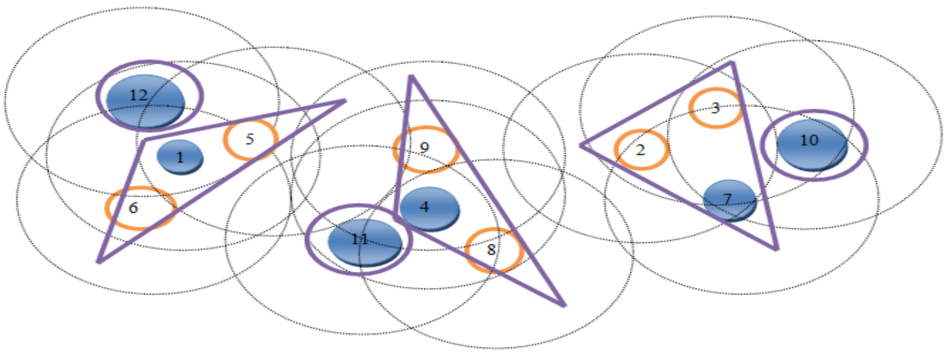

Fig 20:- Performing WCA Cluster formation with maximum threshold is δ = 2

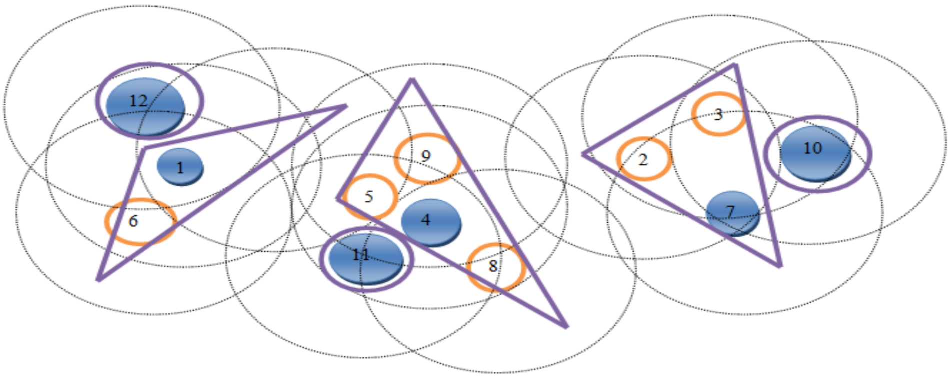

Fig 21:- Reaffiliation of node_5 with maximum threshold (δ -1 = 2) [formation] + 1 [maintenance] = 3

Scaling of maximum threshold can be done during cluster formation and can be utilized during cluster maintenance phase. Consider figure 22 where cluster formation using WCA has been already performed and shown in the figure 22 is the current network scenario. Cluster 3 has one dead node and one reaffiliating node in scenario. When cluster has been created in the formation phase, maximum threshold was decided to be 4 that a cluster head can support. Figure 22 is however generic method and scenario for maintaining the node. Further addition of node in cluster 4 can invoke the cluster formation process. Figure 23 shows cluster after reaffiliation and activation of dead node in the neighbourhood applied on figure 22. Figure 24 shows the distributed delta method which is for every cluster formed, division has been made between [cluster formation (δ – n), cluster maintenance (n)] cluster formation with current nodes threshold and cluster maintenance threshold nodes. Total results in the maximum supported delta. In figure 24, cluster formation has been called with 3 (δ – n) nodes and one node (n) has been left for cluster maintenance process. Scaling of maximum threshold goes up and down between cluster maintenance and cluster formation process.

Dividing the delta or maximum threshold δ between cluster maintenance and formation proves that cluster formation can be delayed and stability of the network can be maintained. Further experiment is done for extending the concept of delta distribution over different cluster. Till now we consider that delta [δ] is divided uniformly over the network. Number of nodes to be kept for cluster maintenance was constant for all the clusters.

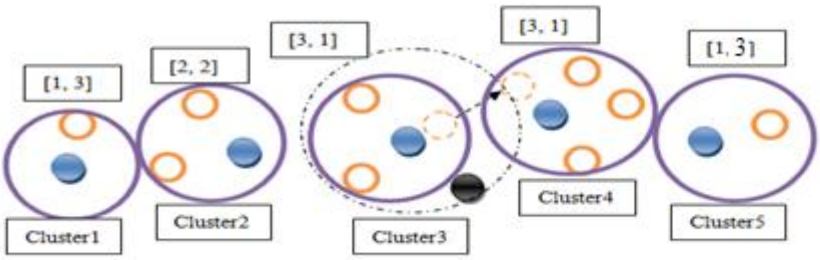

Fig 22:- Cluster with maximum threshold δ = 4

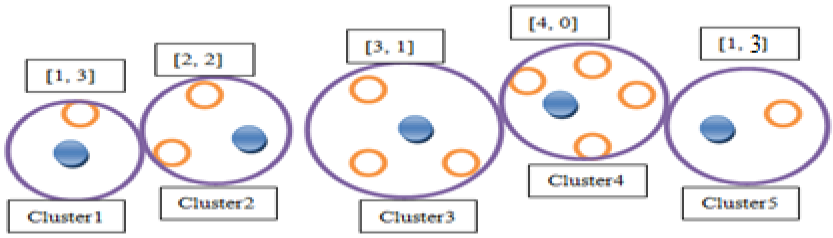

Fig 23:- Cluster after reaffiliation and dead node activation

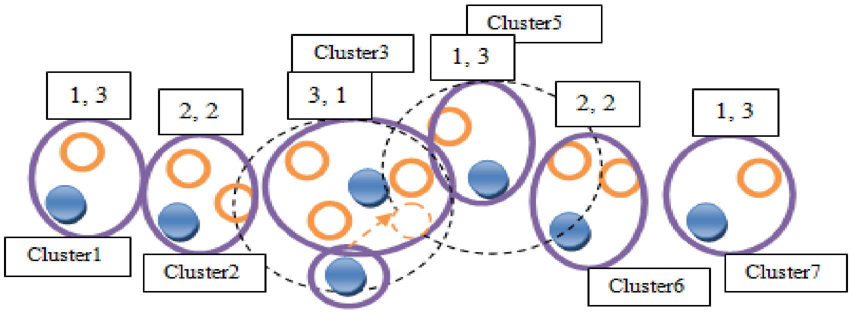

Fig 24:- Cluster formed with 3 maximum supported nodes [δ-n = 3]

Scaling concept can be extended with different threshold between the clusters. It is possible that nodes can support different delta among the cluster or over the network scenario. Effectiveness of diving nodes [δ-n, n] can be seen from network scenario mentioned in figure 25. Maximum supporting nodes which cluster head can maintain are different for clusters mentioned. For C1 total δ are 5, C2 its 4 and so on. Study of reaffiliation and node activation after dead period gives better result in this scenario. Figure 26 shows maintenance of the network is enough to handle the situation of reaffiliation and activation of nodes. Cluster formation gets delayed for some more period of time and maintains the stability.

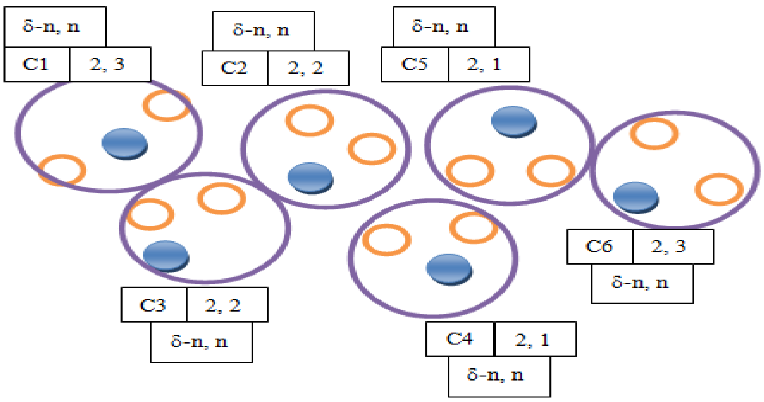

Fig 25:- Cluster formed with 2 maximum supported nodes [δ-n = 2]

Cluster	Maximum Supporting Node for Cluster Head [δ]
C1	5
C2	4
C3	4
C4	3
C5	3
C6	5

Table 3.2.3

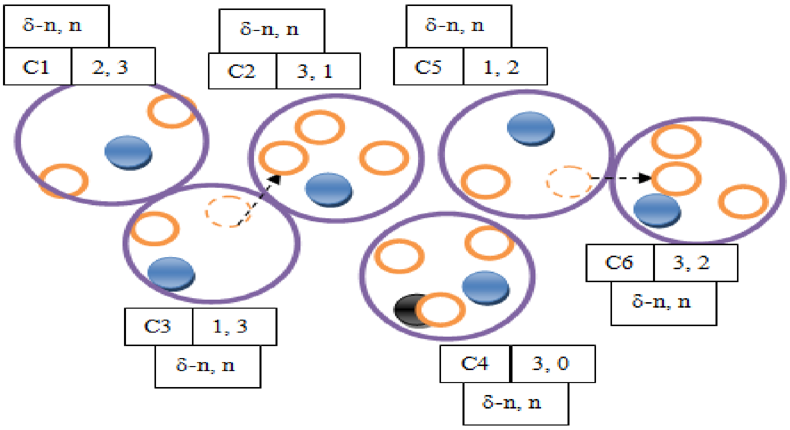

Fig 26:- Maintaining the cluster formed

Cluster 3 has an affiliated node, after affiliation it changes [δ-n, n], similarly change occurred in cluster 2, cluster 4 and cluster 6. Cluster 4 shows a dead node comes alive at some instant of time and send join request to the cluster head. Distribution of threshold among nodes and changing the criteria to support node over network time period support the maintenance process. Problem with original WCA applied was that maximum supported threshold was always fixed. The scenario in figure 25 and 26 is a valid scenario in the network. Suppose we assumed that a node can support maximum up to 5 nodes. This is the highest limit of supporting node by a cluster head. As the time progresses the cluster head looses it energy in serving the nodes so now it cannot support the maximum threshold and require division of the threshold in timely manner.

From table 3.2.3, C1 and C6 has the maximum strength to support but strength of C2 and C3 degraded to 4 along with C4 and C5 which has been degraded to 3. When cluster formation has been run over this network, assumption made that only two nodes can be supported by the cluster head. Cluster head strength to support may again reach to 5 which is maximum if attains the threshold energy.

To support the concept there are two cases have been studied so far. First is when maximum threshold node supported by cluster head kept constant and division made on that threshold. Second case when maximum threshold is not constant and degraded over the time period. For both the cases distributed division of delta proves that it can delay the cluster formation process. All the cases definitely depend on the network scenarios. Dynamic nature of the network can result in the scenarios mentioned so far.

Summary for proposed work is as follow:

(a) Divide maximum supported node criteria between cluster formation and cluster maintenance process for network stability.
(b) This is the technique to delay the cluster formation process and keep network stable as much as possible.
(c) Load of supporting node can change due to dynamic behaviour of the network. So maximum threshold criteria can be relaxed over the time.
(d) Considering the assumption that cluster head can always support the maximum threshold may or may not be valid over network time period.
(e) Based on point (d) changing the maximum threshold of supporting node is a good option to prolong the network lifetime.
(f) Point (a) gives option to maintain the node easily. It also stops frequent updates and frequent cluster formation process.
(g) Approach is similar to Divide and Conquer for optimum result. This gives one of the good options for network configuration policy.
(h) Invocation of cluster formation considering the node strength to support other nodes to form a cluster can help in making healthy cluster with prolonged lifetime and can handle dynamics nature of the nodes such as mobility and energy depletion.
(i) Main goal is how to balance cluster formation and cluster maintenance so that network stability can be increased.
(j) Scaling of maximum threshold δ can be done after cluster formation process. Scenarios mentioned in figure 14 and 15, changes δ when dynamics of mobile node changes.
(k) Maximum threshold δ can be scaled to constant limit and further decrease or increase to lower and upper threshold limit.

Mathematically:

Maximum threshold division range: $C_{lower} < \delta <= C_{upper}$; $\delta \in (C_{lower}, C_{upper}]$

Cluster formation division: $C_{lower} < \delta - n <= C_{upper}$; $n \in R^+$

Cluster maintenance: $n <= C_{upper}$; $n \in R^+$

3.3 REDUCTION OF COMMUNICATION ROUND FOR FASTER CLUSTER FORMATION PROCESS BY GREEDY APPROACH OF ROLE SELECTION FOR MOBILE NODES INMANET FOR WEIGHTED CLUSTERING ALGORITHM.

Weighted Clustering Algorithm, calculate the weight of each mobile node and starts the algorithm by electing minimum weighted node as cluster head and neighbourhood node of cluster head selected as member nodes. WCA also take maximum node supported [δ] by a cluster head into consideration. This algorithm is perfectly balanced for dense mobile nodes. Clustering algorithm must not only well balance but also take less time. Timing analysis for clustering is difficult as it also depends on network operations but considering only clustering time an approximation can be done. WCA has been taken for analysis purpose. Analysis can be made on WCA regarding the communication taken based on the cluster formation algorithm steps. Intention is to analyse how much communication or message exchange has been taken to form a cluster.
Clustering step 1 invokes first round of communication to find the degree which depends on the neighbourhood mobile nodes. Step 2 and 3 can be computed in one round of communication. Step 4, 5 and 6 are absolute measure and does not require the relative information or round of communications. For steps 7, second round of communication is required to share the weight information. Based on comparison of weights members can decide about their own roles either it turns to cluster head or cluster member. Round 3 is optional round to perform completion of weight sharing information. If any neighbour defer in sharing invoke the round 3.
Round 4 of communication required by cluster head to notify that it has been elected as cluster head and other members can save the cluster head node identification for further communication.

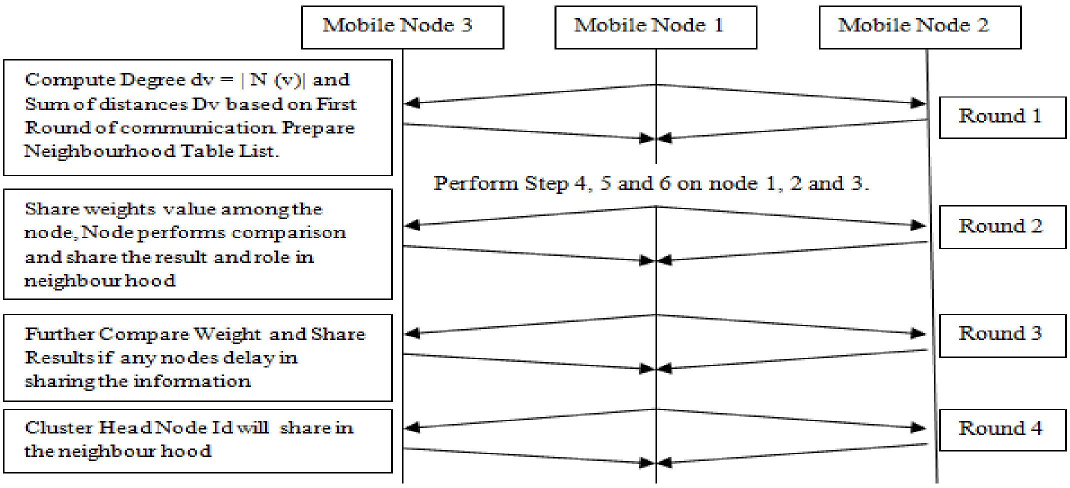

Fig 27:- Cluster Formation Communication Round

Figure 27 illustrate the rounds in cluster formation process and functions during operations. Overall computation in cluster formation operation is difficult but modification in algorithm step can reduce the computation cost by applying greedy approach and make cluster formation faster.
According to Weighted Clustering Algorithm all nodes must participate and either becomes a cluster head or cluster member. Further in algorithm cluster head only can support maximum threshold of nodes. But this algorithm doesn’t give information about the initial state of the node. Initially there are no roles assigned to the mobile nodes.

Proposed work intended to assign initial role to the mobile nodes and further this modification in algorithm reduce the round of communication and results in faster cluster formation.

Section 1: Weighted Clustering Formation Communication Operations

Every mobile node has potential to serve as either cluster head or cluster member. This consideration is also the goal of weighted clustering algorithm. At the end of WCA, each mobile node will be either cluster head or cluster member and those who listen more than one cluster member of different clusters become gateway nodes.

Receiver Node ID	Role	Sender ID	Message
MN1	Undecided	MN2,MN3	"Neighbour2 and Neighbour 3"
MN2	Undecided	MN1	"Neighbour 1"
MN3	Undecided	MN1	"Neighbour 1"

Table 3.3.1:- Round 1 Communication Control Packet

Table 3.3.1 shows first round communication where communication only informs the presence of the node in the neighbourhood. This information helps in performing cluster formation step 1 and 2. Table 3.1.1 is approximated control packet and has very basic information but it can have more information in the packets. MN1 has two neighbours MN2 and MN3.

Receiver Node ID	Role	Sender ID	Message
MN1	Undecided	MN2,MN3	Weight (2), Weight (3)
MN2	Undecided	MN1	Weight (1)
MN3	Undecided	MN1	Weight (1)

Table 3.3.2:- Round 2 Communication Data Packet

Table 3.3.2 shows the data exchange packet, mobile nodes share their weights after computation for further election of cluster head among nodes. All mobile nodes compare the weight and communicate further with their roles shown in table 3.3.4s.

From Table 3.3.1 every mobile node has prepared the neighbourhood list. It's possible that assignment of role get delayed until all the weights received from the neighbours. Round 3 are dedicated to these delay operations or just an informing messages to the neighbourhood about their role which they can take. Table 3.3.3 shows the round 3 shared results but role is still in undecided stage.

Receiver Node ID	Role	Sender ID	Message
MN1	Undecided	MN2,MN3	"Cluster Member 2 and Cluster Member 3"
MN2	Undecided	MN1	"Cluster Head 1"
MN3	Undecided	MN1	"Cluster Head 1"

Table 3.3.3:- Round 3 Communication Control Packets

In round 3 it can be decided that which node will take what roles in the network. But mobile node waits for confirmation from cluster head so that they can change the role.

Receiver Node ID	Role	Sender ID	Message
MN2,MN3	Cluster Member	MN1	"Cluster Head1"
MN1	Cluster Head	MN2,MN3	"Cluster Members 2 and 3"

Table 3.3.4:- Round 4 Communication Control Packets

Round 4 shown in table 3.3.4 completes the cluster formation process. Table 3.3.1, 2, 3 and 4 are part of the control packets. Packets are not illustrated in its original form, but it's sufficient to proof the concept.

Section 2: Initial Role Consideration for Faster Cluster Formation

As initially stated that the goal of every mobile node is either to become cluster head or cluster member. So further assumption is role assigned to each and every node is either cluster head or cluster member. Table 3.3.5 assumes the role that assigned to each node is cluster head at the beginning of cluster formation process.
Table 3.3.5 shows the first round of communication which performs step 1 and 2. Each mobile node shares their neighbourhood presence. Each node also tabulates the role send during sharing.

Receiver Node ID	Role	Sender ID	Message
MN1	Cluster Head	MN2,MN3	"Neighbour2 and Neighbour 3"
MN2	Cluster Head	MN1	"Neighbour 1"
MN3	Cluster Head	MN1	"Neighbour 1"

Table 3.3.5:- Round 1 Communication Control Packet

Step 7 of weighted clustering algorithm requires round 2 of communication where calculated weights has been shared among the neighbourhood. Once this has been shared, role has been changed for MN2 and MN3 from table 3.3.6.

Receiver Node ID	Role	Sender ID	Message
MN1	Cluster Head	MN2,MN3	Weight (2), Weight (3)
MN2	Cluster Member	MN1	Weight (1)
MN3	Cluster Member	MN1	Weight (1)

Table 3.3.6:- Round 2 Communication Data Packet

Mobile nodes are already aware of which node was cluster head in round 1 from table 3.3.5. From table 3.3.6 MN2 and MN3 knew that MN1 was cluster head, since their weight was more, MN2 and MN3 need to change their role to cluster member. MN1 also known by the weight calculation that MN2 and MN3 will be member nodes only as MN1 weight is less than MN2 and MN3 and changes the role of MN2 and MN3 to cluster members.

As earlier described that round 3 of communication shown in figure 27 is not compulsory so adding this in section 2 it produces overall three rounds of communication to complete cluster formation.

From section 1 "Weighted Clustering Formation Communication Operations" total round performed was four considering the optional round.

From section 2 "Initial Role Consideration for Faster Cluster Formation" total rounds reduced to three from four rounds from the original.

One round where cluster head needs to notify about the election result need not to notify now. Already winner has been announced as cluster head in the neighbourhood.

Assumption of initial role to cluster head reduced the cluster formation communication cost and further help in making cluster formation faster.

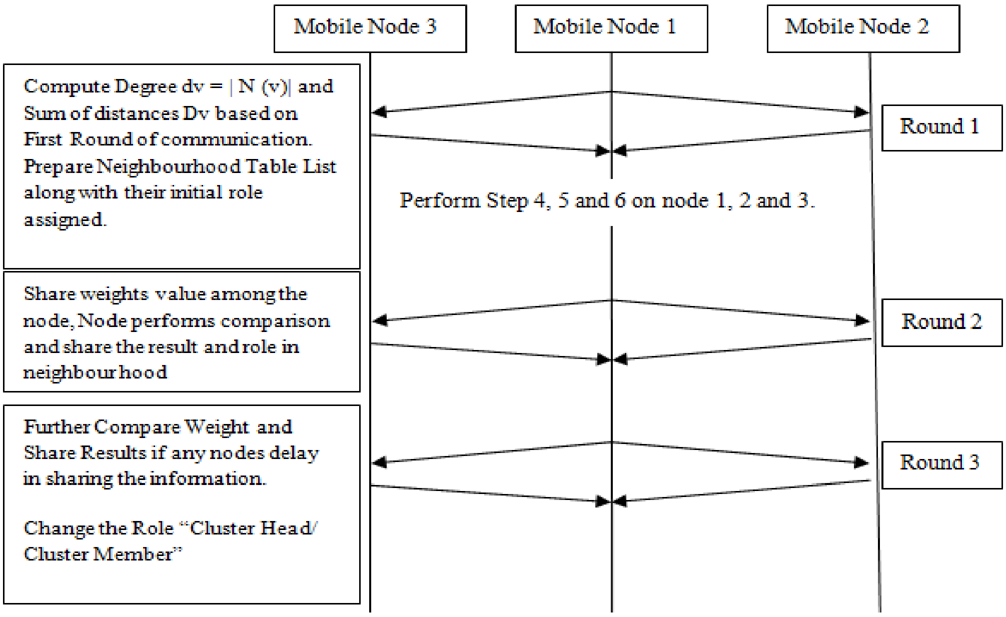

Fig 28:- Cluster Formation Communication Round Considering Initial Role

Figure 28 shows the cluster formation reduction steps of rounds. Comparing to figure 2, one round of communication has been reduced by greedy approach of declaring all nodes as cluster heads.

3.4 MODIFICATION IN WEIGHTED CLUSTERING ALGORITHM FOR FASTER CLUSTERING FORMATION BY CONSIDERING ABSOLUTE ATTRIBUTES OF MOBILE NODES AND GREEDY METHOD FOR ROLE SELECTION OF MOBILE NODES IN MANET.

Weighted Clustering Algorithm depends on absolute and relative attributes of the mobile nodes. Steps for clustering formation for WCA demands communication round for relative attributes such as degree difference and sum of distances. One round of communication to find number of neighbours along with the position of the mobile node in the neighbourhood can help in finding sum of distances. Whereas mobility and power consumed does not require communication round.

Symbols	Terms	Meanings	Attributes	Communication Round Requirements
Δ_v	Degree Difference	Difference between total number of neighbours and maximum node supported by mobile nodes	Relative attributes as information related to actual presence of neighbourhood required	Yes
D_v	Sum of Distances	Sum of all mobile nodes present in neighbourhood	Relative attributes as information required from the neighbours	Yes
M_v	Mobility	Position of mobile node at discrete time	Absolute attribute as it require its own position information at discrete time. Relative to itself	No
P_v	Consumed Battery Power	Power consumed by mobile node at discrete time	Absolute attribute as it is measure of power at mobile node end	No
Tx-Rx	Authentication	Authorised Mobile Node	Relative Attributes	Yes
Tx-Rx	Reaffiliation	Joining of other cluster	Relative Attributes	Yes
H(s)	Entropy	Entropy of cluster	Relative attributes as disorder measures required mobile nodes information from neighbourhood	Yes
E(s)	Entropy	Entropy of Mobile Nodes	Absolute attributes [Mobility, Power] required to measure disorder behaviour of mobile nodes locally	No

Table 3.4.1:- Attributes and Communication Round Information

Table 3.4.1 explains about the attributes for parameters and communication round availability for them. From above table it can be understood that relative attributes can delay the actual operations between the mobile nodes and cluster formation can take time with the addition of relative attributes. Other communications such as authentications, de-authentication, reaffiliation, association and disassociations of mobile nodes in network can be considered as relative attributes and required communication round.

Weighted Clustering Algorithm for cluster formation calculate weights for each node and minimum among weights wins the cluster head election, neighbour nodes become cluster member and do not participate further in the algorithm. Equation 1 is the weighted formula used in cluster formation.

$W_v = w_1\Delta_v + w_2D_v + w_3M_v + w_4P_v$, where w1, w2, w3 and w4 are the weighing factors………………………. (1)

It's clear with equation 1 that weighted clustering scheme is combination of absolute and relative attributes for cluster formation. Relative parameters can delay network operations and consume time in cluster formations due to mutual communication.

In this section, modification of weighted clustering algorithm based on absolute attributes such as mobility, power consumed and entropy of the mobile has been proposed. Further modification by greedy approach can help in reducing the communication round in cluster formation for faster clustering formation.

Overall proposal is to faster clustering formation for minimum delay in network operations by considering greedy selection of cluster head and only considering absolute attributes for calculating weights of the mobile node. Relative attributes results in communication round and greedy selection of cluster head can reduce overall cluster formation time. Clustering algorithm which is faster helps network appears stable, communication overhead and delays are comparatively low.

$W_v = w_1Mv + w_2P_v$, where w_1 and w_2 are the weighing factors………………………………………………… (2)
$W_v = w_1P_v - w_2H_v$, where w_1 and w_2 are the weighing factors…………………………………………………. (3)
$w_1 + w_2 = 1$; weights sum equals to 1……………………………………………………………...… …….…...(4)

Mobility, Power Consumed and Entropy of mobile node is better factors to consider while applying clustering process. Equation 2 and 3 are representation of absolute weighted parameters based on mobility, consumed power and entropy based clustering [10]. Equation 4 describes the weight factor whose sum must be equals to one. These equations have no relative parameters and do not require communication between neighbourhood mobile nodes.

Minimum weights among them will be elected as cluster head and as weighted clustering algorithm also deals with maximum supported nodes [δ] can be considered for this too. Once cluster head and cluster members are defined they will not participate further in clustering formation process [1].

Cluster formation step through greedy approach of cluster head selection to reduce communication overhead and faster clustering formation has been demonstrated further. Combined effect of selecting absolute attributes and greedy approach can result in faster and effective clustering.

Cluster Formation Steps:

Step 1: Set Up Initial Configuration

Greedy Approach for Mobile Nodes: - Initial Configuration

Received Node ID	Role	Sender Node ID	Message
MN1	Cluster Head/Cluster Member	-	-
MN2	Cluster Head/Cluster Member	-	-
MN3	Cluster Head/Cluster Member	-	-

Table 3.4.2

Initial mobile node configuration considers all mobile nodes are capable of either cluster head or cluster member. Consider case when all mobile nodes are cluster members of some arbitrary cluster. Table 3.4.2 shows the initial configuration for three mobile nodes.

Step 2: Calculate weights [W_v] according to equation 2 or 3. Suppose Mobility and Power is the absolute attributes considered for this illustration. Calculation for Mobility and Power Consumed steps has been described in weighted clustering algorithm.

Step 3: Perform first round of communication to share weights. One round is duplex communication among nodes. Sender shares its weight and receiver compares the weight to change the role. Receiver shares this message and role. Sender remains or change its role based on shared information.

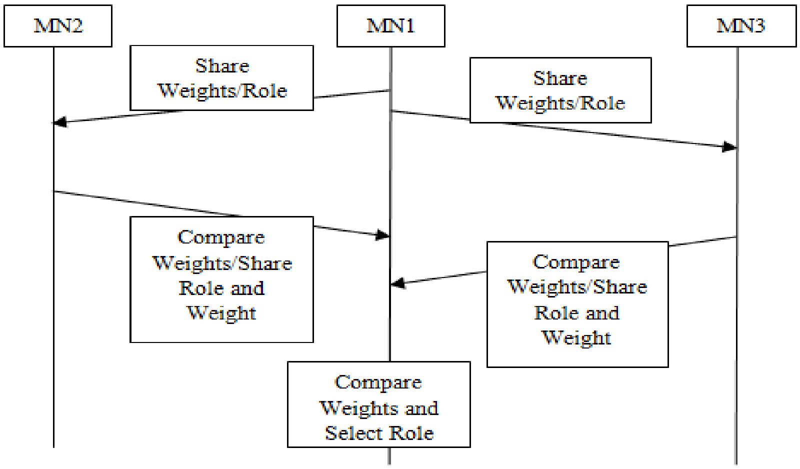

Fig 29:- Communication Round

Node ID	Weights
MN1	3
MN2	5
MN3	6

Table 3.4.3

Received Node ID	Role	Sender Node ID	Message
MN1	Cluster Head	MN2, MN3	CM2,CM3 (cluster members)
MN2	Cluster Member	MN1	CM1
MN3	Cluster Member	MN1	CM1

Table 3.4.4

Figure 29 explains the communication between mobile nodes. Mobile node 1 shares its weight with mobile node 2 and 3 along with its role. Assumed weight calculated has been shown in table 3.4.3. Mobile node 2 and 3 compares this weight and found it is less than mobile node 1 and remain as cluster member as initial consideration of role. Table 3.4.4 shows MN2 and MN3 received message from MN1 as CM1 (as initial assumption was all nodes are cluster member). MN1 receives CM2 and CM3 along with their weights shown in figure 2 after comparison made by MN2 and MN3. MN1 change its role based on this information and become cluster head shown in table 3.4.4. MN1 remains cluster member if it receives other than cluster member message i.e. either of MN2 or MN3 will be cluster head. When MN2 and MN3 receives CM1 message along with MN1 weights from figure 2 and table 3.4.4, comparison made with the weights and decides their role further this role shared with MN1.

One round of communication decides about the election of cluster head and cluster member in neighbourhood. Although one optional round to inform others about the final role by cluster head can be performed to ensure who is the cluster head elected currently. Since greedy approach already made other nodes aware about probable cluster head, it’s really optional to do so. Table for further communication or neighbours table can be prepared in this round only. Clustering formation process is distributed over the network and already participated nodes will not take part in clustering. For knowing the members who has been already participated, a participation ticket flag can be introduced or assigned to the mobile nodes.

Step 4: Repeat step 2 and step 3 for all nodes till either mobile nodes become cluster head or cluster member or assigned to a cluster.

Combined effect, by (a) considering absolute attributes and (b) greedy approach for reduction of communication round relaxes clustering formation process. Mixed of result can be expected on clustering with original weighted clustering schemes in terms of cluster head selection but this method ensures that clustering formation will be faster. There were many clustering schemes which are stand alone based on mobility and power of the mobile nodes. Considering degree difference and sum of distances demands relative information of neighbourhood and do not have high significance in clustering which can be neglected. If the clustering algorithm is based on highest degree it cannot be considered as very good clustering algorithm as possibility of frequent updates can make cluster unstable.

Node ID	W_v
1	3
2	5
3	6
4	9
5	2
6	10

Table 3.4.5

Table 3.4.5 illustrates nodes and their calculated weights using equation 2 or 3. Figure 3 shows initial configuration on the network.

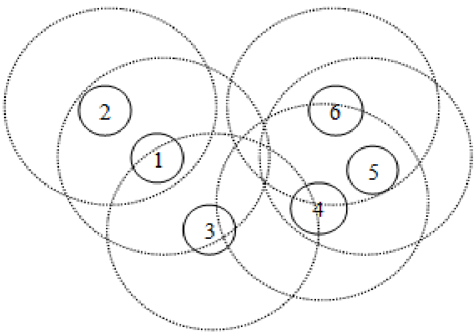

Fig 30:- Initial Mobile Nodes in the Network

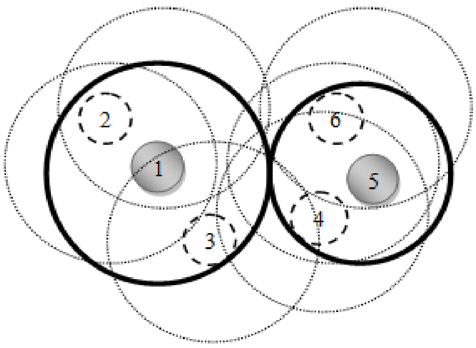

Fig 31:- Cluster formation for clustering

Figure 31 shows cluster after cluster formation process. Figure 30 and 31 is the result of cluster formation steps performed in the mentioned proposed algorithm. Cluster head election is similar to the original weighted clustering algorithm which chooses minimum weighted node as cluster head.

Difference between original weighted clustering algorithms and this proposed algorithms are as follow:

(a) Steps for cluster formation have been reduced from the original algorithm.
(b) This ensures that cluster formation become faster.
(c) Relative attributes (degree difference and sum of distances of neighbours) have been removed from weight calculation.
(d) Greedy approach applied for selection of cluster head and members for faster cluster formation.
(e) Communication round has been reduced so that cluster formation become faster.

Results of proposed algorithm depends on network environment, it's possible that network has large congestion and band width uses that election itself get delayed. Such situation cannot be controlled but simulation must perform better result from the existing one practically as well as theoretical.

3.5 PROLONGING NETWORK LIFETIME BY ELECTING SUITABLE CLUSTER HEAD BY DYNAMIC WEIGHT ADJUSTMENT FOR WEIGHTED CLUSTERING ALGORITHM IN MANET.

This section describes the weight selection on the mobile nodes based on dynamic consideration of the network. Goal of clustering algorithm is to select the best possible cluster head which shows stability in terms of defining its dynamics. Network has dynamic behaviour and best clustering algorithm wins to show preferred clustering. As described earlier, clustering goal is to scale the network, stability of the cluster and consequently best suited for best network configurations such as best routing, less packet drop, less delay in communication and less battery consumption for mobile nodes. Main issue here is that weight distribution for node dynamics consideration is static and based on assumption on the importance of the node dynamics **[Δv, D_v, M_v, P_v].** It is presumption that which dynamically changing parameters need to be given priority. Weights distribution to calculate overall weights from given equation 5 is much dependent on the node dynamics. Weights here are the tuning parameters for finding overall weights so that best cluster heads can be chosen. To gain understanding the effects of tuning the weights analysis on the network variation i.e. node dynamics consideration is important.

Let's consider the below initial configuration shown to analyse the weight effects on cluster formation process for weighted clustering algorithm.

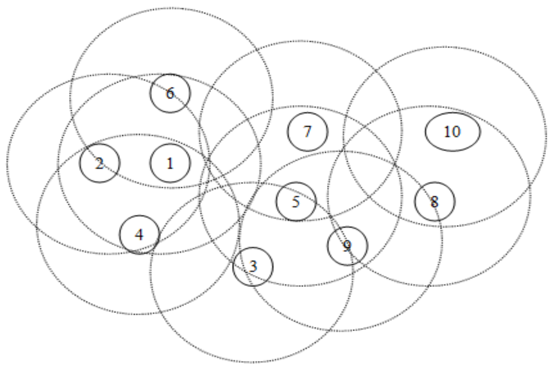

Figure 32:- Mobile Nodes Arrangement with Equal Range

Figure 32 shows the nodes arrangements in the network with equal range. Figure 32 shows ten nodes with their ranges where maximum node supported by cluster head is 2. Cluster formation is about to take place based on the overall weight calculation.

Node_id	Pv	Mv	Dv	Δv	w_1	w_2	w_3	w_4	W_v
1	20	15	5.19	1	0.05	0.05	0.7	0.2	14.81
2	20	15	5.19	1	0.05	0.05	0.7	0.2	14.81
3	20	15	3.46	0	0.05	0.05	0.7	0.2	14.60
4	20	15	3.46	0	0.05	0.05	0.7	0.2	14.60
5	20	15	5.19	1	0.05	0.05	0.7	0.2	14.80
6	20	15	3.46	0	0.05	0.05	0.7	0.2	14.60
7	20	15	1.73	1	0.05	0.05	0.7	0.2	14.62
8	20	15	3.46	0	0.05	0.05	0.7	0.2	14.67
9	20	15	5.19	1	0.05	0.05	0.7	0.2	14.80
10	20	15	1.73	1	0.05	0.05	0.7	0.2	14.62

Table 3.5.1: Initial Weight Calculation (δ= 2)

Initial Assumptions:

(a) All nodes are 1 unit of distances
(b) All have same energy and relative movements are negligible.
(c) Maximum cluster head can support two ($\delta = 2$) mobile nodes.
(d) $W_v = w_1 * \Delta v + w_2 * Dv + w_3 Mv + w_4 * Pv$
(e) Maximum Power = 20 J/Sec
(f) Minimum Mobility = 15 m/sec
(g) Higher Value of Mobility shows highly mobile (<50)
(h) Degradation of Power Value shows power consumed over the time by mobile node (>5)
(i) Highest weighing factors [w_1, w_2, w_3, w_4] will be varied for examples.
(j) Combination of weighing factors must satisfy equation 6.

Table 3.5.1 shows the initial data when mobile nodes are alive i.e. ready to participate for the cluster formation process. Initial communication has been taken place so that the neighbourhood information can be retrieved. Cluster head election procedure has been mentioned earlier and result of cluster formation has been shown in the figure 33.

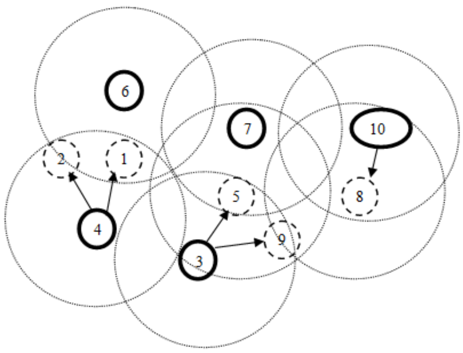

Figure 33:- Cluster Formation Process Result

Starting with minimum weights node_4 has been selected as cluster head (marked in dark black line) and associated neighbours which are in the range node_1 and node_2 (marked in dotted lines) becomes cluster members. This forms one cluster and further clustering process for other mobile nodes repeated. In figure 33 there are five clusters and consequently five cluster heads are present. From table 3.5.1, it can be observed that highest weighing factor has been given to mobility which is 0.7. This has impacted the selection of cluster head or instead defining factor for selecting the cluster head.
Consider another example where node dynamics [P_v,M_v] has been changes and same weighing factors has been applied.

Node_id	Pv	Mv	Dv	Δv	w_1	w_2	w_3	w_4	w_v
1	18	20	5.19	1	0.05	0.05	0.7	0.2	17.90
2	15	22	5.19	1	0.05	0.05	0.7	0.2	18.70
3	14	23	3.46	0	0.05	0.05	0.7	0.2	19.07
4	16	24	3.46	0	0.05	0.05	0.7	0.2	20.17
5	13	25	5.19	1	0.05	0.05	0.7	0.2	20.40
6	10	26	3.46	0	0.05	0.05	0.7	0.2	20.37
7	16	27	1.73	1	0.05	0.05	0.7	0.2	22.23
8	17	28	3.46	0	0.05	0.05	0.7	0.2	23.17
9	12	29	5.19	1	0.05	0.05	0.7	0.2	23.00
10	10	30	1.73	1	0.05	0.05	0.7	0.2	23.13

Table 3.5.2: Initial Weight Calculation (δ= 2)

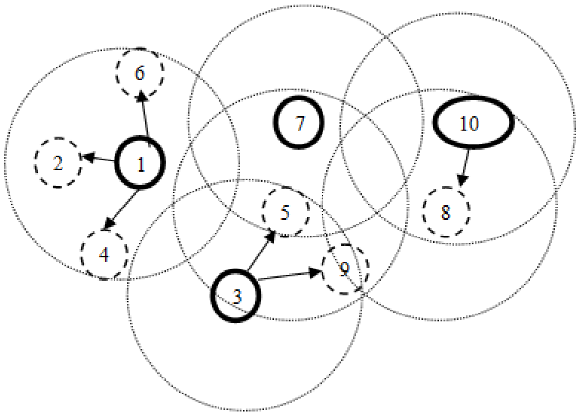

Figure 34:- Cluster Formation Process Result

From table 3.5.2, weighing factor is still higher for mobility but node dynamics [P_v,M_v] has been changed. Considering that deflection or mobility from the original position does not affect the ranges defined in figure 32. Node_1 has the minimum weight which is selected as cluster head and neighbouring nodes node_2, node_4 and node_6 becomes the cluster member with node_1 as cluster head. Member nodes further cannot participate in the clustering process for next cluster round as per weighted clustering algorithm. There are four clusters with consequently four cluster head. Cluster and cluster heads are directly proportional. In figure 33 there were five clusters which reduced to four clusters as compared to figure 3. Weights factor were same but node dynamics [P_v,M_v] changes. Here point to observe is with the cluster head node_10 and cluster member node_8. Node_10 power has been just halved of the initial value and mobility is also high as compare to node_8 but overall weight for node_10 has lower than the node_8. Since overall weight is less node_10 become the cluster head but after some time node_10 may lose more energy and become guilty for invoking the cluster formation process again. Cluster formation process is very costly operation in terms of message overhead. This is very unwanted situation in the clustering process. Weighing factor which has been given higher for mobility is not the suitable choice here but tuning the weighing factor is also very tricky.

Consider another example where weighing factors [w_3, w_4] has been interchanged. Node dynamics [P_v,M_v] has been maintained as table 3.5.2.

Node_id	Pv	Mv	Dv	Δv	w_1	w_2	w_3	w_4	w_v
1	18	20	5.19	1	0.05	0.05	0.2	0.7	16.90
2	15	22	5.19	1	0.05	0.05	0.2	0.7	15.20
3	14	23	3.46	0	0.05	0.05	0.2	0.7	14.57
4	16	24	3.46	0	0.05	0.05	0.2	0.7	19.40
5	13	25	5.19	1	0.05	0.05	0.2	0.7	14.40
6	10	26	3.46	0	0.05	0.05	0.2	0.7	12.37
7	16	27	1.73	1	0.05	0.05	0.2	0.7	16.73
8	17	28	3.46	0	0.05	0.05	0.2	0.7	17.63
9	12	29	5.19	1	0.05	0.05	0.2	0.7	14.50
10	10	30	1.73	1	0.05	0.05	0.2	0.7	13.13

Table 3.5.3: Initial Weight Calculation (δ= 2)

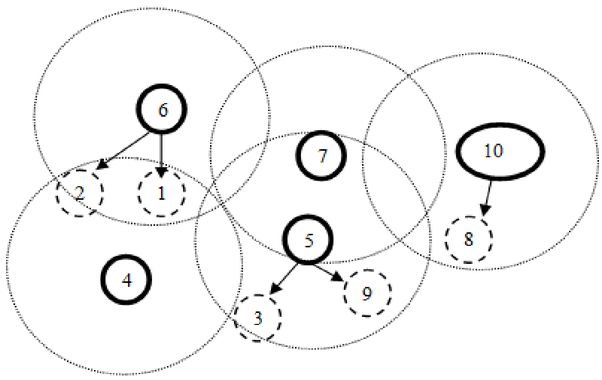

Figure 35:- Cluster Formation Process Result

Table 3.5.3 shows the intermediate node configuration where weighing factors [w_3, w_4] has been interchanged. Figure 35 is the resultant of cluster formation process. Node_6 has the minimum weight and chosen as cluster head for neighbouring nodes node_1 and node_2. Important observation here is that node_6 has power reduced to half of the initial and node_1 and node_2 has still power higher than the node_6 but not elected has the cluster heads. Reason is the weighing factor [w_4] which is set higher for power. In this power has been considered as important parameter but weighing factor has shown the adverse effect. Once the power reaches to lowest threshold node_6 will trigger the cluster formation process. Possible that node_6 become dead and do not participate in cluster formation process which affects the overall network configuration or in routing of data packets.

Further experiment by example shown in table 3.5.4 where weighing factors [w_3, w_4] has been distributed to find the best suited cluster head. Overall Weights [w_v] has been calculated which is responsible in defining the cluster head role.
Minimum weight in table 3.5.4, after calculation of overall weights [w_v] comes for node_6 so it is selected as cluster head and neighbour nodes, node_2 and node_1 becomes the cluster member. Node_1 and node_2 will not participate further in the clustering process so algorithm selects the next minimum weights which come for node_3. Node_3 becomes the cluster head and correspondingly node_5 and node_9 becomes the cluster member.

Important note to make here is distribution of weighing factor [w_3, w_4] has been selected best cluster head among node_3, node_5 and node_9. From table 3.5.4 it can be observed that power for node_3 is more than node_5 and node_9 and also the mobility for node_3 is lower than its neighbouring nodes.

Node_id	Pv	Mv	Dv	Δv	w_1	w_2	w_3	w_4	w_v
1	18	20	5.19	1	0.05	0.05	0.5	0.4	17.50
2	15	22	5.19	1	0.05	0.05	0.5	0.4	17.30
3	14	23	3.46	0	0.05	0.05	0.5	0.4	17.23
4	16	24	3.46	0	0.05	0.05	0.5	0.4	18.57
5	13	25	5.19	1	0.05	0.05	0.5	0.4	18.00
6	10	26	3.46	0	0.05	0.05	0.5	0.4	17.17
7	16	27	1.73	1	0.05	0.05	0.5	0.4	20.03
8	17	28	3.46	0	0.05	0.05	0.5	0.4	20.97
9	12	29	5.19	1	0.05	0.05	0.5	0.4	19.60
10	10	30	1.73	1	0.05	0.05	0.5	0.4	19.13

Table 3.5.4: Initial Weight Calculation (δ= 2)

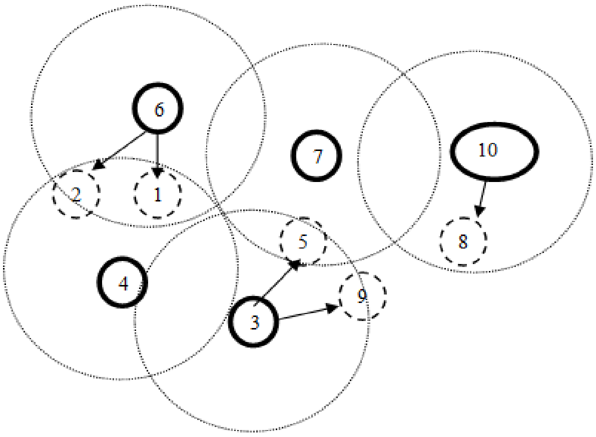

Figure 36:- Cluster Formation Process Result

Figure 36 is the resultant of cluster formation process and it is the best configuration achieved so far among the experiments based on tables or data presented in mobile adhoc network.

This proves that the changes of weighing factor [w_1, w_2, w_3, w_4] are equally important as node dynamics **[Δ*v*, *Dv*, *Mv*, *Pv*]**.

So far experiments do not elaborate about the selection of weighing factors. Weighing factors selection could be consider as static parameters which needs adjustments when node dynamics changes.

All above experiments and data presented shows that tuning of weighing factor is as much important as node dynamics are. There must be some association of node dynamics with the weighing factors which can be self-adjusted or self configured. Clustering is the process which configures their nodes in dynamic environment which forms a hierarchy of nodes with stability. Choosing best cluster head is an NP-hard problem and only best possible configuration can be achieved by varying parameters.

Proposed work is related to the tuning of the weighing factors in the network dynamics which also associates itself with the node dynamics **[Δ*v*, *Dv*, *Mv*, *Pv*].** Mobile adhoc network must show the behaviour of self adjusting or self configuring. Weighing factors must also self configure with changing node dynamics in the network.

Dynamic weight adjustment model is required which can sense the network's node dynamics and consequently adjust itself to support the node dynamics and help in electing the best cluster head.
This section of work demonstrates and presents the theory for distributing the weighing factors dynamically. Node dynamics **[Δ*v*, *Dv*, *Mv*, *Pv*]** and weighing factors must be correlated so that on changing the node dynamics, weights for each node dynamics must get self configured. The point here is to choose the correct weight when node dynamics changes and also weighted clustering algorithm retains its original form on every cluster formation and maintenance process.

Many researchers have presented their work to choose cluster head based on fuzzy logic. Fuzzy logic has been applied on the node dynamics to select the best cluster head. Many inferences mechanism have been built to select the cluster head based on the variation of mobile nodes.

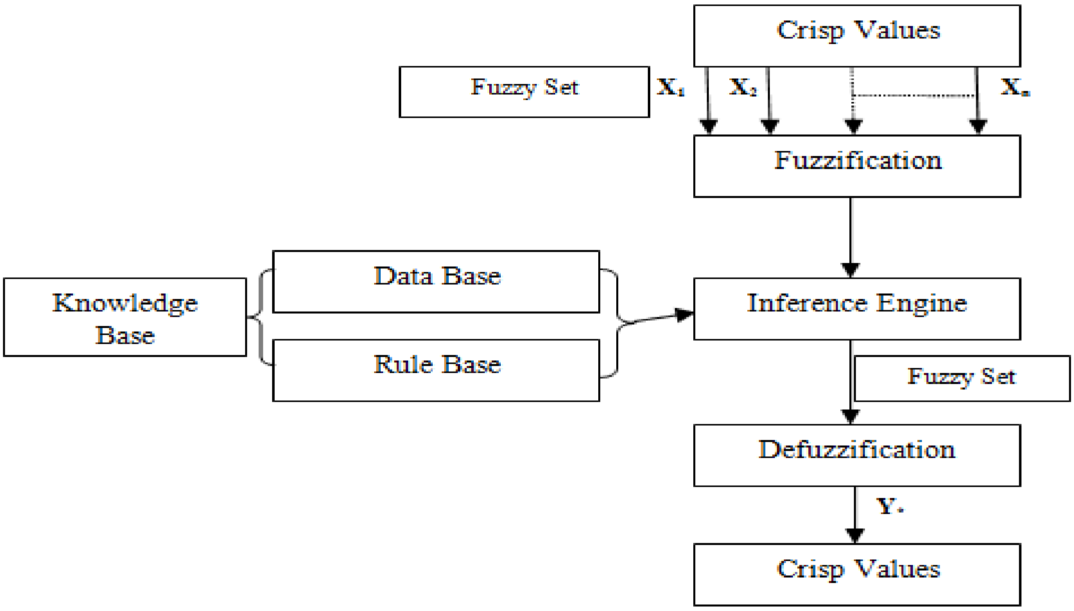

Figure 37:- Fuzzy Logic Model

Figure 37 illustrates the generic fuzzy logic models. Fuzzy sets describe the ranges the set which must be set of values in between [0, 1]. Consider set A = [X_1, X_2 ……X_n] where X_1, X_2 are crisp value or members of the fuzzy set in between [0, 1] i.e. $0 \le X_n \le 1$. Sets [X_1, X_2 ……X_n] are resultant of membership functions which further processed for the inference engine. Inference engine helps to decide the fuzzy set which defined the vagueness of the real world applications. Outputted fuzzy set from inference mechanism fed to the defuzzification model which results the final signal output as crisp value.

Figure 38 illustrates the concept of fuzzification and defuzzification on the mobile node dynamics. All the dynamic parameters of mobile node fed to the fuzzy system and crisp output for node dynamics after defuzzification multiplied with the weighing factors and further summed up for final weights for each node.

Model illustrated in the figure 38 do not describe about the weights which also needs the adjustments according to the defuzzified output. Further figure 39 describes the individual node dynamic [*Mobility (Mv)*] fuzzy logic implementation. Later in the section, discussion has been presented for dynamic weight adjustments.

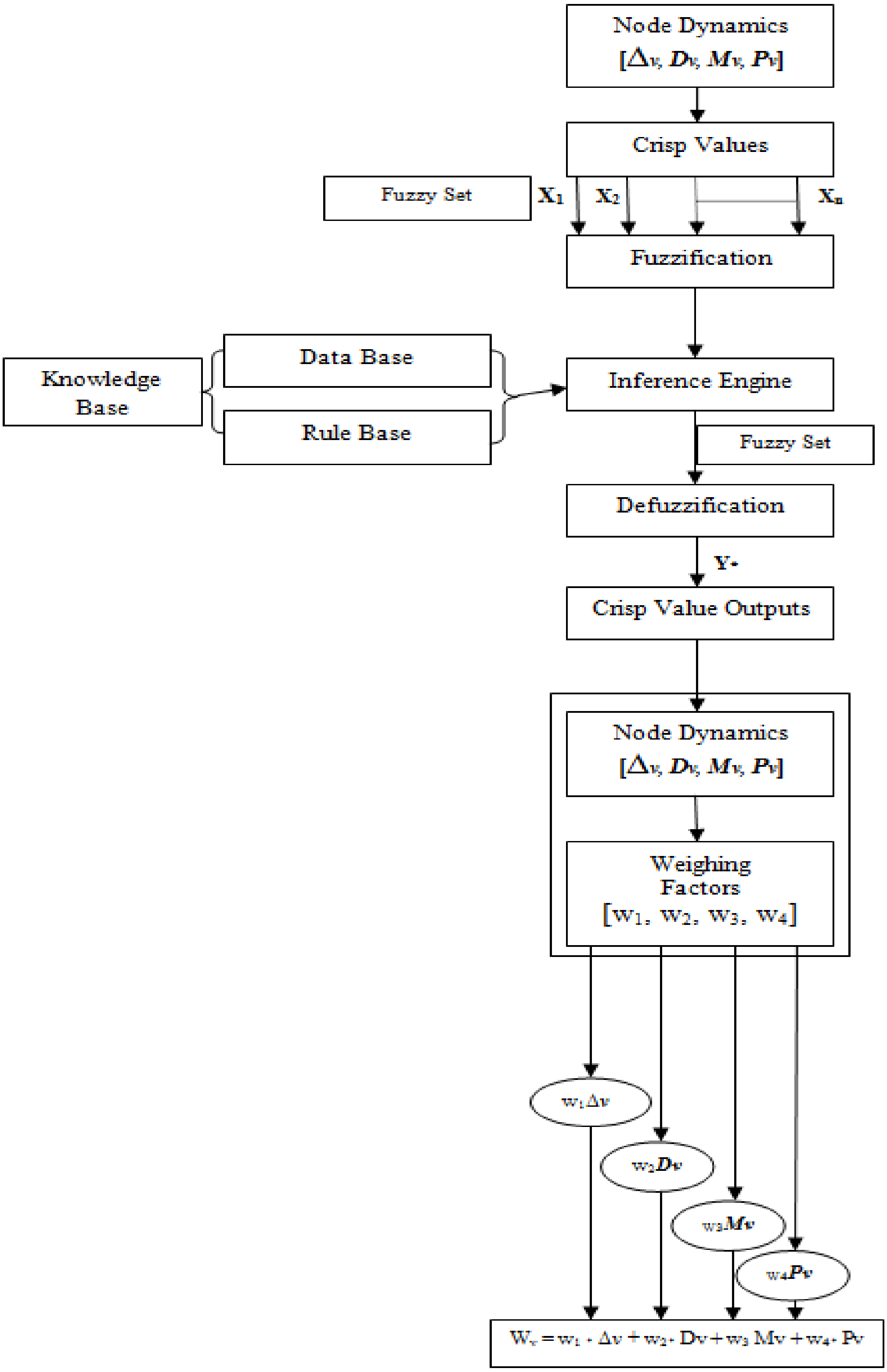

Figure 38:- Fuzzy Logic Model for Node Dynamics

Figure 38 and figure 39 shows the fuzzy logic model proposed without considering the adjustments for weights. Weights have been taken random or analysis based on crisp out from defuzzification helps to select appropriate weight for the calculation of overall weights.

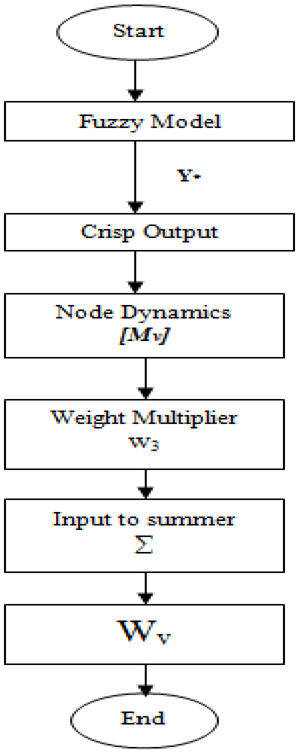

Figure 39:- Fuzzy Logic Model for Specific Node Dynamics [Mobility]

Figure 40 present the complete picture of dynamic weight adjustments model. Figure 38 and figure 39 only present that the node dynamics has been passed to the fuzzy model and output has been multiplied with the correlated weights. Figure 40 has the *"**weight sets**"* corresponding to the node dynamics with defuzzified output i.e. crisp output of node dynamics. Weights need to learn or supervised itself for correct weight. Weight correction model is based on supervised learning and represent a feed forward networks [23]. Feed forward network properties are (a) flow of information is unidirectional (b) information is distributed and (c) information processing is parallel. Supervised learning i.e. where teacher is required to explain how to process the input to the model. Crisp outputs for node dynamics can be consider as input to the weight set which adjusts the weights based on the input quality of crisp output.

In figure 9 weight sets are shown individually but further simplification has been presented in the figure 10. Weighing factors must be adjusted in such a manner that equation 6 get satisfy any number of iteration. For this case there are four crisp outputs in terms of node dynamics **[Δ*v, Dv, Mv, Pv*]** and correspondingly four weighing factors.

Proposed model is not only valid for weighted clustering algorithm but it can be extended to another weight based algorithm proposed in mobile adhoc networks or in sensor networks. Weight distribution or correction model can be having "n" node dynamics and correspondingly "n" weighing factors.

Mathematically,

Node Dynamics Parameters can vary for each node: $1 < N_v [P_v, M_{v \dots} X_n] < n, n \epsilon R^+$,
N_v – Node v, X_n – Node dynamics.
Associated Node Weighing Factors can vary for each node: $1 < w_m < n, n\epsilon R^+$, w_m – weighing factor

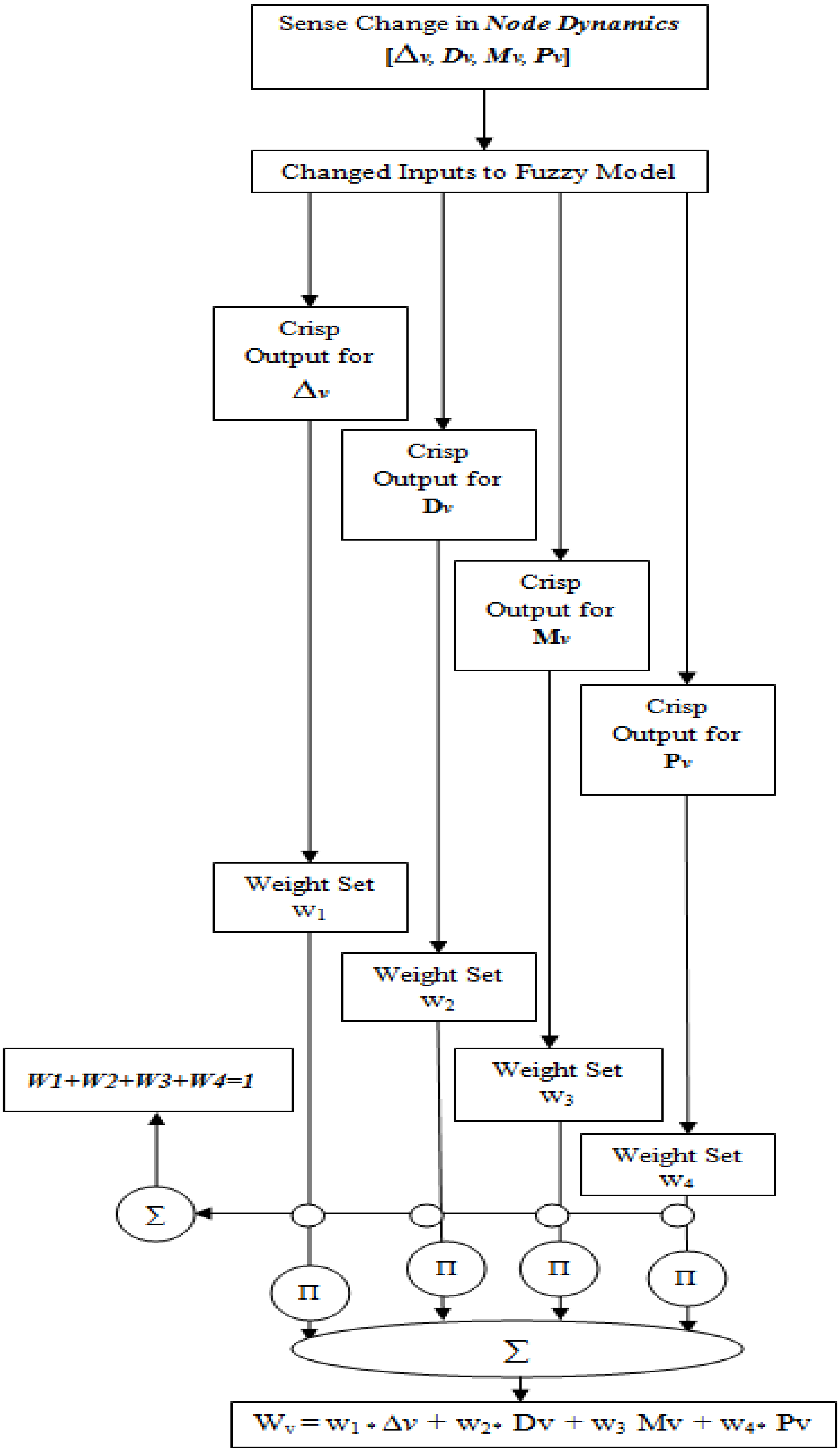

Figure 40:- Weight Correction Model

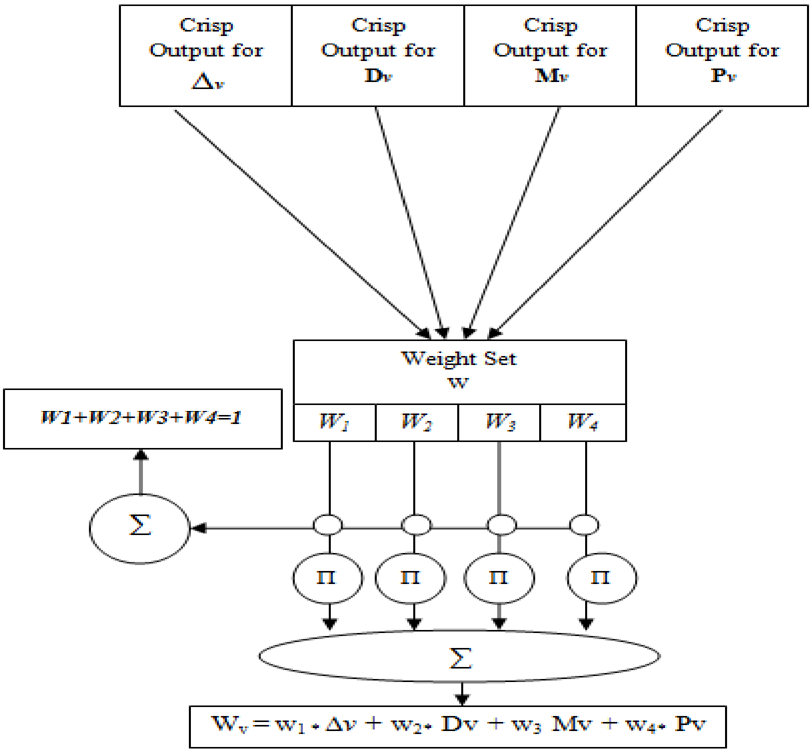

Figure 41:- Simplified Weight Correction Model

Till now figure 40 and figure 41 represented the weight correction model through supervised learning. Further discussion defined the supervised method for weights to adjust themselves to crisp output of node dynamics. Crisp output for node dynamics are four and different sixteen combinations can be derived from the fuzzy model.

Δv	Dv	Mv	Pv
LOW	LOW	LOW	LOW
LOW	LOW	LOW	HIGH
LOW	LOW	HIGH	LOW
LOW	LOW	HIGH	HIGH
LOW	HIGH	LOW	LOW
LOW	HIGH	LOW	HIGH
LOW	HIGH	HIGH	LOW
LOW	HIGH	HIGH	HIGH
HIGH	LOW	LOW	LOW
HIGH	LOW	LOW	HIGH
HIGH	LOW	HIGH	LOW
HIGH	LOW	HIGH	HIGH
HIGH	HIGH	LOW	LOW
HIGH	HIGH	LOW	HIGH
HIGH	HIGH	HIGH	LOW
HIGH	HIGH	HIGH	HIGH

Table 3.5.5: Crisp Output for Node Dynamics

[Δv] – {(LOW, Difference of neighbourhood nodes and Maximum supported nodes are less), (HIGH, Difference of neighbourhood nodes and Maximum supported nodes are high)}

[Dv] – {(LOW, Sum of distances is less in value), (HIGH, Sum of distances is high in value)}

[Mv] – {(LOW, Relatively less mobile), (HIGH, Relatively high mobility)}

[Pv] – {(LOW, Less power consumed with respect to time), (HIGH, high power consumed with respect to time)}

From table 3.5.5, it can be observed that sixteen different combinations have been offered in terms of node dynamics. This is a fuzzy approximation and totally dependent upon the membership function consideration for crisp interval i.e. there could be more possible crisp output on node dynamics. Here sixteen combinations have been formed considering that node dynamics has only two crisp interval [LOW, HIGH]. It is possible that there could be more crisp intervals such as [LOW, MEDIUM,HIGH] in that case more combination could be formed through defuzzification process. This consideration has been taken for fast processing and computation on mobile node must not take much time to make decision in fuzzy logic model.

Weight set offer different combination which suits for the combination achieved through defuzzification process. Weight set have infinite combination to offer to the crisp outputs of node dynamics.

Δv	**Dv**	**Mv**	**Pv**
LOW	LOW	LOW	LOW
HIGH	HIGH	HIGH	HIGH
w_1	w_2	w_3	w_4
.25	.25	.25	.25

Table 3.5.6: Weight Set for Bounded Output

Δv	**Dv**	**Mv**	**Pv**
LOW	LOW	LOW	HIGH
w_1	w_2	w_3	w_4
.3	.3	.3	.1
.25	.25	.4	.1
.2	.2	.4	.2

Table 3.5.7: Multiple Weights Set for One Output

Δv	**Dv**	**Mv**	**Pv**
LOW	HIGH	HIGH	LOW
w_1	w_2	w_3	w_4
.1	.4	.4	.1
.2	.3	.3	.2
.15	.35	.35	.15

Table 3.5.8: Multiple Weights Set for One Output

Δv	**Dv**	**Mv**	**Pv**
HIGH	HIGH	LOW	LOW
w_1	w_2	w_3	w_4
.5	.4	.05	.05
.35	.35	.15	.15
.45	.25	.15	.15

Table 3.5.9: Multiple Weights Set for One Output

Table 3.5.6, 7, 8 and 9 shows different weighing factors for all crisp outputs but selecting the best weight combination comes under the learning mechanism.

Δv	Dv	Mv	Pv
LOW	LOW	LOW	LOW
LOW	LOW	LOW	HIGH
LOW	LOW	HIGH	LOW
LOW	LOW	HIGH	HIGH
LOW	HIGH	LOW	LOW
LOW	HIGH	LOW	HIGH
LOW	HIGH	HIGH	LOW
LOW	HIGH	HIGH	HIGH
HIGH	LOW	LOW	LOW
HIGH	LOW	LOW	HIGH
HIGH	LOW	HIGH	LOW
HIGH	LOW	HIGH	HIGH
HIGH	HIGH	LOW	LOW
HIGH	HIGH	LOW	HIGH
HIGH	HIGH	HIGH	LOW
HIGH	HIGH	HIGH	HIGH

Time stamp	w_1	w_2	w_3	w_4
10	.5	.4	.05	.05
25	.35	.35	.15	.15
15	.45	.25	.15	.15

Figure 42:- Time Stamp recording for different weight sets

Figure 42 explains the learning of best weight based on time stamp recording process for the same crisp output. For the first time when specific crisp output occurs [HIGH, HIGH, LOW, LOW] select the arbitrary weight set prepared [refer table 3.5.9]. When demand of same weight set i.e. if the crisp output in the next iteration i.e. either cluster formation or in maintenance phase demands or results the same crisp output then time stamp can be recorded for the earlier chosen arbitrary weigh set. For next iteration choose the weights which has unrecorded time stamp and process similar steps for next iteration. In figure 42 there are three weight set prepared for particular crisp output and all the weight sets has been iterated for cluster formation or cluster maintenance phase for particular node in the mobile adhoc network.

Method of recording the time stamp for the weight set is nothing but the learning for the weight set that which weight set has effectively helped the node to prolong the network lifetime. Time stamp with value “25” is suppose to be the best weighing distribution for particular mobile node and can be consider as best weighing distribution for other nodes as well. Crisp output is for particular node where node dynamics is valid for each and every node in the network. Table 3.5.5 is the possible outputs for a particular node in the network and also for all the nodes in the networks. Similarly weight set is also valid for all nodes in the network.

Once the selection of best weighing distribution has been found for particular crisp output, same can be applied to all mobile nodes in the network for particular crisp output [refer table 3.5.5]. Weight set can be prepared in the cluster formation process and carried forward in cluster maintenance process. Variation can be present to the timestamp field. Once for particular network time all the timestamp can be reset and further recording of timestamp can be invoked. Addition to invocation of timestamp recording, weight sets for particular crisp output can be changed or added to the table 3.5.5.

New timestamp recording for the iteration and addition of weight sets are possible combination for finding the right weights and learning the best timestamp could find the best weight distribution for mobile node and for its dynamics.

Fuzzy model and weight correction model is implemented for all mobile nodes in the network so for specific crisp output weights on the mobile nodes can vary. Mobile node selects the best suited weight set for specific crisp out which helps to prolong the network lifetime.

4 SIMULATION RESULTS AND ANALYSIS

A. Introduction

Network Simulator 2 (NS2) is a discrete event simulator targeted at networking research. It provides support for simulation of TCP, routing and multicast protocols over wired and wireless networks. Currently DARPA, NSF and ACIRI support the development of NS. It contains three types of discrete event schedulers: list, heap and hash based calendar. NS2 also provides default implementations for network nodes, links between nodes, routing algorithms, transport level protocols and some traffic generators. Adding functionality to these objects can extend the simulator. NS2 also contains some useful utilities which include Tcl debugger used to debug Tcl scripts and it might become necessary if one is using large scripts to control a simulation. Tcl-debug is not however installed automatically with NS2 but it can be installed later. The major drawback of using Tcl-debug is that it is dependent on used Tcl version and also NS2 version.

B. Simulation Study

In simulation N was chosen to 30 nodes and arrange randomly with X and Y specified. Transmission ranges have been considered in the range of 50 to 100m.

Parameters	Meaning	Value
N	No of nodes	30
X*Y	Simulation Area	650X500
R	Transmission Range	50-100
Mobility Model	Random Way Point	-
Duration	Simulation time	50Sec
MD	Maximum Displacement	300-400

Table 4.1

4.1 RELAXING WEIGHTED CLUSTERING ALGORITHM FOR REDUCTION OF CLUSTERS AND CLUSTER HEAD.

4.1.1 Simulation Results and Discussion

Arrangement of thirty nodes has been done with specifying the coordinates on network simulator. Nodes have been distributed in range of 50 and 100. Weighted Clustering Algorithm has been implemented first; its arrangement in the network area is such that out of 30 nodes 20 nodes become the cluster head and correspondingly 20 clusters. Maximum threshold node to be supported is 4 but none of the cluster head serves maximum threshold. It could be because of arrangement of nodes. Further modified weighted clustering algorithm which includes scenario (a) and scenario (b) on the same network reduce the cluster head to 15 and correspondingly 15 clusters. Result will be variable since it depends on node distribution on the network. It could be possible that network doesn’t have isolated node i.e. all nodes are in the range of each other. If the nodes are isolated and fall under scenario (a) definitely could result in reduction of cluster. Scenarios (b) don’t reduce the cluster head and cluster size. Its logic is only for better energy conservation or for saving the energy for cluster head since in this case cluster member changes its cluster head identification. Fig 43 and Fig 44 shows the comparison between WCA and WCA with addition of scenario (a) and scenario (b). Since the network is designed randomly such scenarios are likely to take place. This research work has been focused on such issues and further modification to the algorithm for better result in some extra computation time. Computation cost will increase slightly but stability of cluster will increase too. In this WCA computation could have been taken place for avoiding the nodes which has been already participated i.e. already selected cluster member and cluster head will not participate in the cluster formation process but this computation is necessary so that nodes can be added to the cluster. Scenario (a) and (b) could replace this computation for adding in the cluster. So there is minimum cost of computation here or stay same as original computation cost.

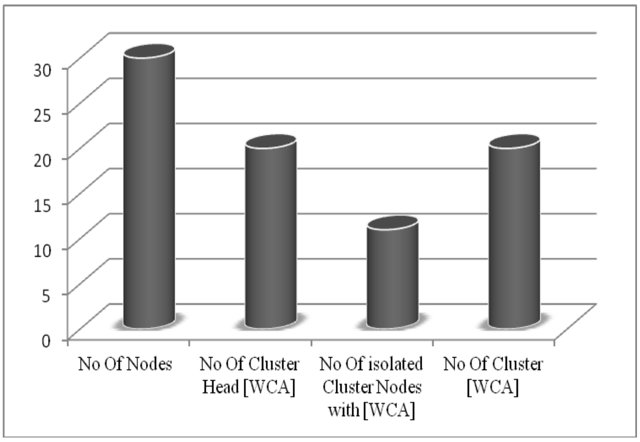

Fig 43:- WCA implementation result

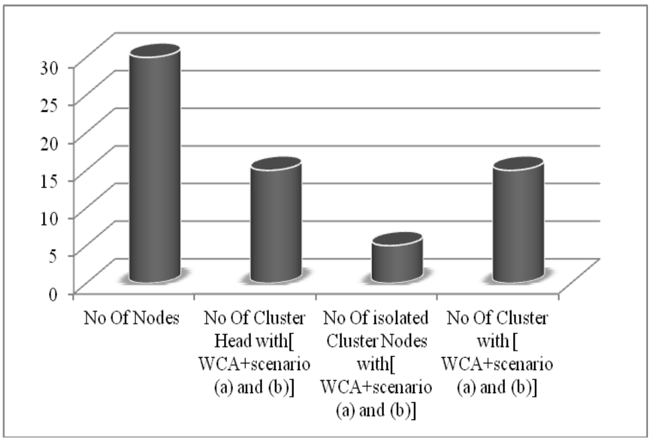

Fig 44:- WCA implementation result after adding scenario(a) and scenario(b)

4.2 LOAD BALANCING BETWEEN CLUSTER FORMATION AND MAINTENANCE PROCESS TO ACHIEVE NETWORK STABILITY IN WEIGHTED CLUSTERING ALGORITHM FOR MOBILE AD HOC NETWORKS.

4.2.1 Simulation Results and Discussion

Simulation has been performed on network simulator ns-2.35 and table 4.1 shows the network environment of simulation along with it network parameters have been described.WCA has been implemented with considering thirty nodes in network area. Maximum threshold has been experimented with δ = 4 and 3. Observation has been made with arrangement of different network scenarios. Figure 45 gives comparison on network stability with threshold. Network stability improves slightly on the same network scenario comparing with two threshold values 4 and 3. Figure 46 shows improvement over invocation of cluster formation. All the simulation has been performed on different scenarios after changing threshold supported by cluster head performing 25 rounds of simulation.

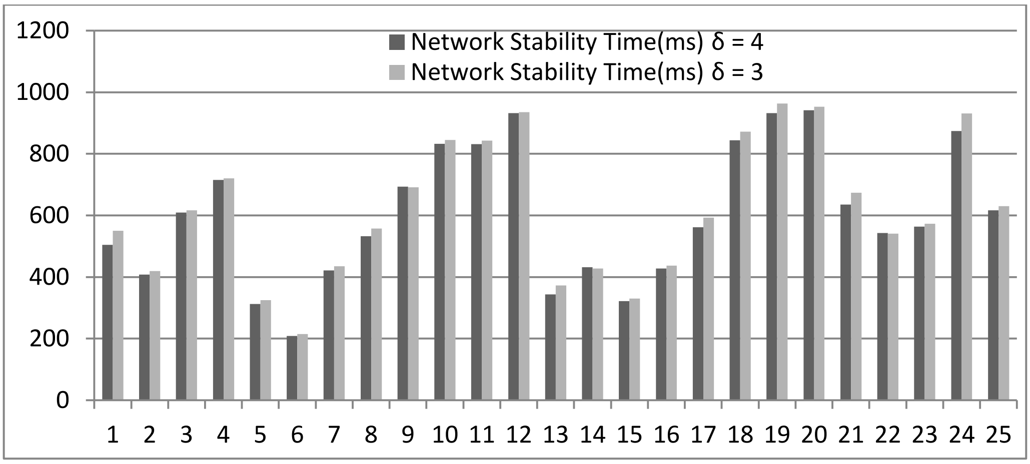

Fig 45:- Clustering Algorithm Comparison with Threshold

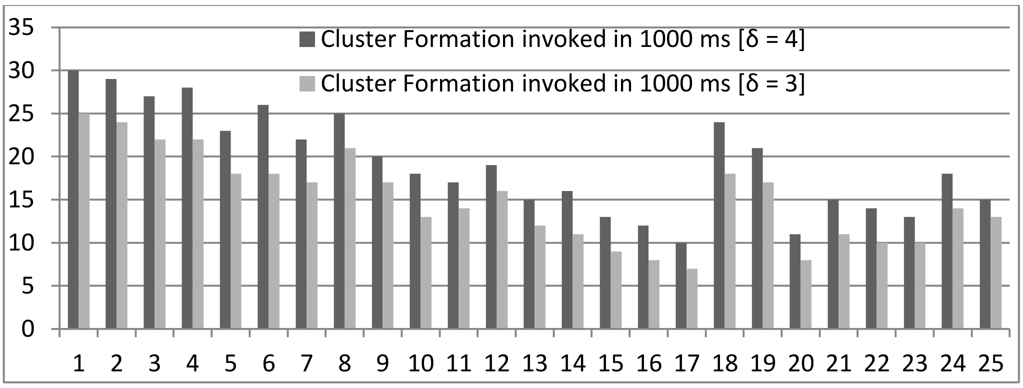

Fig 46:- Invocation of Cluster Formation

4.3 REDUCTION OF COMMUNICATION ROUND FOR FASTER CLUSTER FORMATION PROCESS BY GREEDY APPROACH OF ROLE SELECTION FOR MOBILE NODES IN MANET FOR WEIGHTED CLUSTERING ALGORITHM.

4.3.1 Simulation Results and Discussion

Figure 47 shows the result of comparison with two different assumptions about the role. This shows that greedy approach in cluster formation process also can help reducing the communication overhead and results in faster cluster formation.

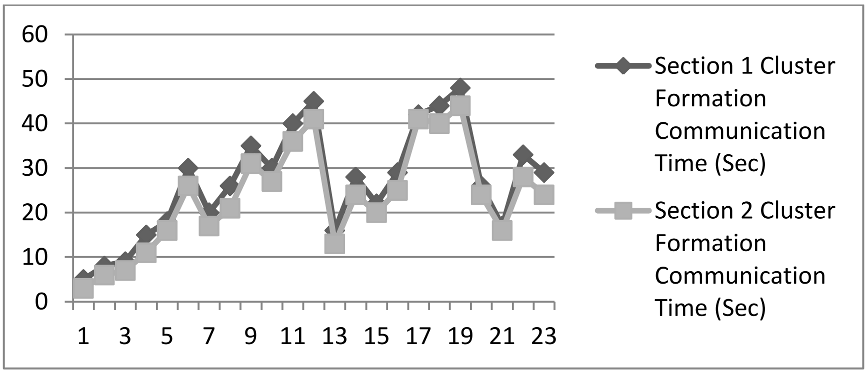

Fig 47:- Timing Comparison for Cluster Formation

4.4 MODIFICATION IN WEIGHTED CLUSTERING ALGORITHM FOR FASTER CLUSTERING FORMATION BY CONSIDERING ABSOLUTE ATTRIBUTES OF MOBILE NODES AND GREEDY METHOD FOR ROLE SELECTION OF MOBILE NODES IN MANET.

4.4.1 Simulation Results and Discussion

Figure 48 shows significant reduction in time for cluster formation process in modified scheme. Comparison has been made by choosing different network scenarios over time. Mobile nodes are distributed over the network and algorithm started on distributed nodes simultaneously. Mobility of nodes is also considered and nodes out of range of the nodes remains cluster members with unallocated cluster. In weighted clustering algorithm nodes which are out of range become cluster head. Modified clustering with greedy approach chooses to be cluster member so there is change in result from original WCA but if cluster head chosen as greedy approach then it will be same as original weighted clustering algorithm.

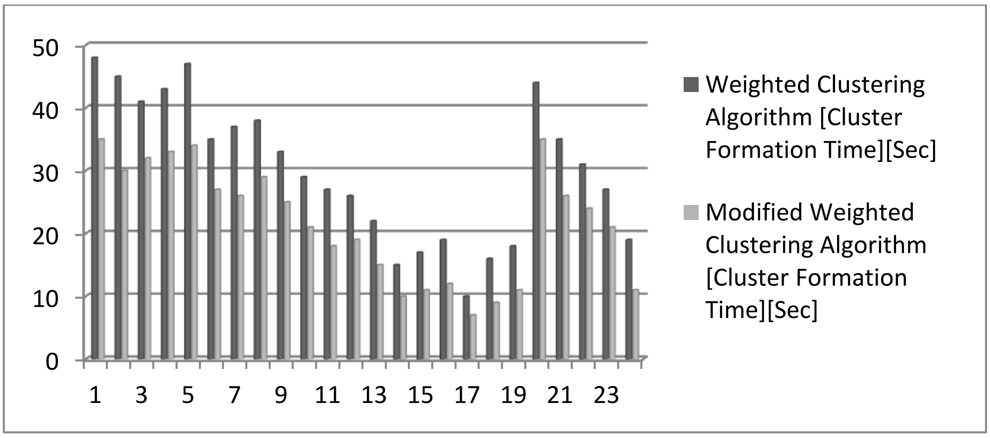

Fig 48:- Timing Comparison for Cluster Formation

4.5 PROLONGING NETWORK LIFETIME BY ELECTING SUITABLE CLUSTER HEAD BY DYNAMIC WEIGHT ADJUSTMENT FOR WEIGHTED CLUSTERING ALGORITHM IN MANET.

4.5.1 Simulation Results and Discussion

Simulation has been performed on network simulator ns-2.35 and table 4.1 shows the network environment of simulation along with it network parameters. Figure 49 present the comparison between the original weight based clustering algorithm and with weight correction model. Appropriate weight set can prolong the network lifetime but it could have cost of computation. Intelligence of adding time stamp could help in learning best weight distribution. Method used to achieve network lifetime is the first mobile node which become dead in the network.

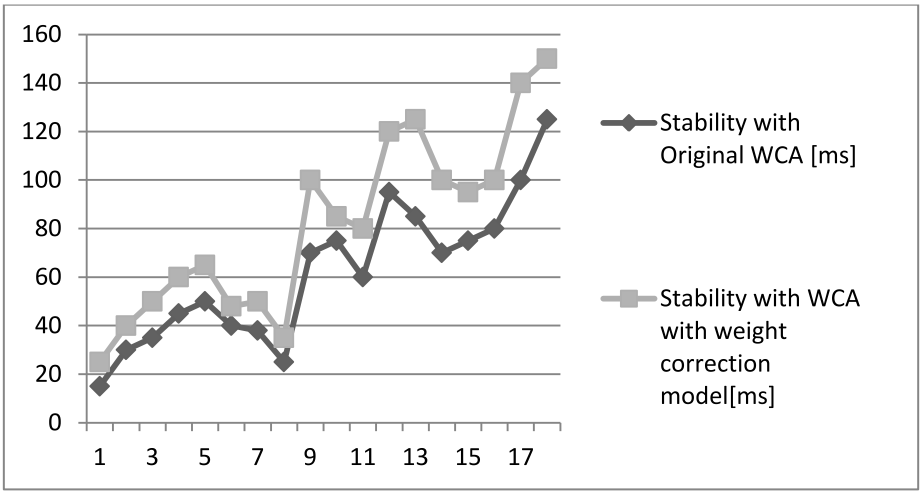

Figure 49:- Stability of Network Lifetime

5 CONCLUSION AND FUTURE WORK

This report intended to present the modification on the constraints for weighted clustering algorithm in mobile adhoc network. In this report generic weight based algorithm for clustering has been described. Chapter 3 section 3.1 dealt the modification by relaxing two criteria of weighted clustering algorithm for network stability and reduction of cluster and cluster head. Constraints such as minimum weight cluster head can be isolated cluster head even it is in the range of other cluster or cluster member. Other constraint that a cluster member cannot participate further in algorithm has been also relaxed and made available to join another cluster.

Chapter 3 section 3.2 deal with the load balancing by considering “distributed delta” technique. Another constraint was that a cluster head can support maximum threshold nodes in the neighbourhood. But due to dynamics of the mobile nodes, it is not possible to support maximum delta. New concept has been developed to scale the delta value up and down over the network time for supporting the maximum threshold value.

Other work related to clustering is to identify absolute and relative attributes of mobile nodes and modifying algorithm according to it [Chapter 3 section 3.3]. Applying greedy approach to select cluster head to reduce the communication delays in the network and achieving faster clustering scheme is enhance work in the modification of algorithm.

Greedy approach for selecting cluster head and reducing the round to decide cluster head and cluster members of the cluster can reduce the effort of clustering. Further identifying absolute and relative attributes of the mobile nodes and modifying the algorithm according to this help in reducing communication round to form clusters [Chapter 3 section 3.4].

Combination of greedy approach and modifying algorithm according to absolute attributes of mobile node further reduce communication round and form faster clustering. Faster clustering and easy maintenance is the prime objective of any clustering algorithm.

Till chapter 3 section 3.4, we solved the problem on constraints of mobile nodes participation and applied greedy approach to select the cluster head for reducing the communication for election process. Weighted clustering algorithm has weight which has been distributed to the node dynamics and also major components in election of cluster head.

Chapter 3 section 3.5 deals with this factor and proposes the method for dynamic selection of weights for specific output of node dynamics from the fuzzy system. Weighted clustering algorithm shows behaviour of feed forward network with supervised learning. Time stamp and weight sets help mobile network in learning process and chooses best suited weights for mobile nodes.

Proposed model of weight correction helps find suitable cluster in worst case also. Future scope for tuning weight sets and variation of the model could take place. It is important that calculation overhead is minimal which consume less battery power. Computation for weight distribution must be intelligent and fast.

Future scope is to reduce the clustering messages in clustering formation process, minimising the cost of clustering, increasing the lifetime of the cluster by modifying the clustering algorithms, saving mobile node battery by using less communication messages, scaling the network and its life span over the time, effective load balancing among the nodes by sharing the loads, jobs and roles can be achieved.

Any clustering algorithm goal must be reducing the cost of clustering associated in cluster formation and cluster maintenance processes. Saving energy, faster clustering, electing the best cluster head, network stability and scalability must be optimised through clustering.

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