Swarm optimized energy efficient clusters for MANET

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Abstract - In MANET, topology changes frequently due to the continues movement of mobile nodes with battery drainage. Here, use of efficient energy and mobility acknowledgement are the major problems. In this paper, these two problems will be discussed to increase network lifetime by using Particle Swarm Optimization(PSO)to develop a clustering algorithm with multiagent stochastic parallel search method.By selecting the long time survived cluster head , the condition of mobility, residual energy and node degree can be improved. Cluster formation is done by many objective function based on particle swarm optimization.

Keywords : MANET, Clustering, PSO, Mobility.

1 Introduction

MANET is a wireless network in which mobile nodes can communicate dynamically in absence of any infrastructure within limited transmission range[1]. Due to the continuous movement of the nodes, it becomes more complicated to manage network stability. For this, group of nodes are formed known as clusters that improve the robustness, durability and scalability of the network [2].Each possible solution in an optimization algorithm is derived in two ways, that is, deterministic and stochastic. All deterministic algorithms are generally covered by a certain mathematical formula and the search proceeds in only one direction; that is, these are unidirectional searches guided by certain rules. The stochastic algorithms are non-traditional algorithms to solve multimodal problems having many optima. Particle swarm optimization (PSO) is a robust stochastic optimization technique based on the movement and intelligence of swarms, that is, group (birds flocking or fish schooling) [1, 2]. In this paper, PSO has been used for optimizing the multiobjective problem of clustering in MANET.
A MANET is established very easily and each node is considered as router which further transfer the data but there is some limitations on bandwidth and battery power also continues topology change due to the movements of nodes .

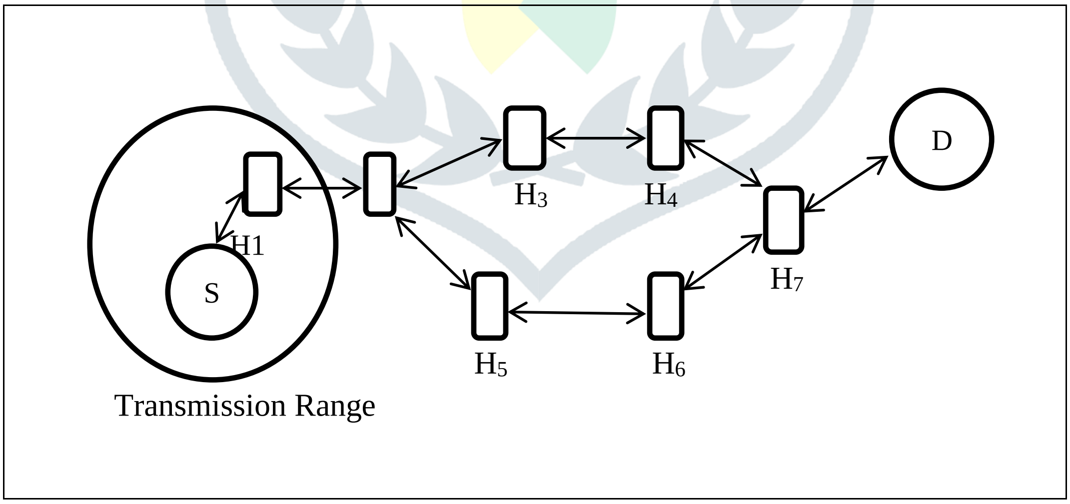

Fig 1.
A Mobile Adhoc Network

To overcome such inefficiencies several clustering algorithms and routing protocols have been introduced in previous researches. Three types of protocols are Proactive,Reactive and Hybrid[3]. Proactive remains activate and makes available route information all the time from source to destination even in the absence of data while reactive protocols makes route information available only on the request which reduces power consumption and hybrid protocol works on both proactive and reactive protocol's principals. But clustering is used for the large network to reduce data traffic, improve stability of network and bandwidth reusability, reduce consumption of battery power [7]. Clustering is a set of clusters in which each cluster contains the group of nodes and all clusters are connected to each other through gateway. There are mobile nodes, cluster head,cluster member and cluster gateway in a cluster.There is only one mobile node which is considered as a cluster head having the responsibility of forwarding the data from source to destination and all member nodes inside a cluster are managed by it. Cluster members are normal nodes which communicate with each other through cluster head and cluster gateway also the member node which connects two or more clusters so that those clusters can access each other data.

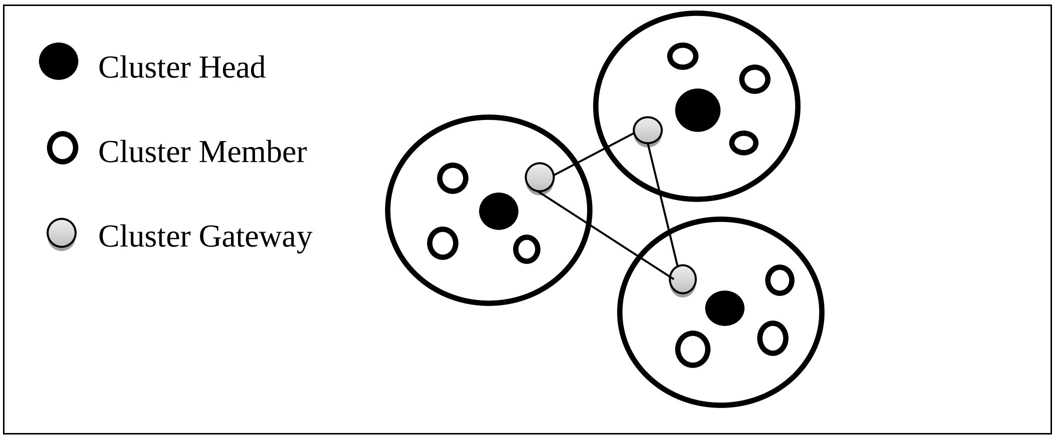

Fig 2. Clustering in MANET

Due to the dynamic nature of MANET, as network size increases network performance decreases. Clustering is better solution for increasing network scalability and also makes resources reusable to improve network capacity. The solution for different optimization problems (routing and clusering) can be improved by using nature based technique. Some of bio based computing applications are used for optimization algorithm to solve the problem either by deterministic or stochastic method. Deterministic algorithms are unidirectional search process based on mathematical formulas while stochastic algorithms are multiobjective based optima such as birds flocking. This paper consists the technique of stochastic optimization i.e particle swarm optimizationthat optimize multiobjective problems of MANET clustering[12].

Fig 3. Birds Flocking Behaviour

As a mobile adhoc network is formed due to interconnected multiple hosts using wireless links [6], so there is no fixed infrastructure of this network. Management scalability and energy efficiency are the main issues of this network. Here, Clustering approach is used in which CH selection and cluster is formed on the basic of communication dynamic movements and natural social behaviour of birds in this paper. Cluster Head (CH) is selected on the basic of longer time duration connectivity with another nodes in a cluster. Clusters are formed according to swarm movement and intelligence under bio inspired PSO search technique. Swarm is formed with number of agents known as particles[5]. Each particle gives the solution of a problem by adjusting its flying according to the another particles flying with mutual experience. According to fitness function which is used for proposed algorithm a node gets associated to a CH that is having the maximum fitness value and average distance from its neighbors should be minimum. The main focus of the proposed work is (i) To improve cluster stability. (ii) To balance the loads on CHs using PSO based clustering. (iii) working on fitness function for increasing the lifetime of both cluster head and members. (iv) simulation of result. The work in this paper is organized as follows: Section 2. describes applied models and PSO search technique.

2. Applied Models with PSO Search Technique

As model consistsmobile nodes which move randomly within the fixed area and each node has its unique ID. A neighbor information table is maintained by each node which contain all information about its neighboring nodes using MAC layer protocol and vice versa. [2].

Table 1. Neighbor Information Table

NEIGHBOR_ID	LINK_STATUS	ROLE
Nbr 1	bi/unidirectional link to clusterhead?	Is 1 a clusterhead?
Nbr 2		Is 2 a clusterhead?
: Nbr N	: bi/unidirectional link to clusterhead?	: Is N a clusterhead?

The transmission through wireless links is possible only when all nodes are within the fixed area of transmission range. The proposed work is formulated as :

(a) Assume N= {n_1, n_2, n_3,………, n_l} is a set of mobile nodes.
(b) H ={ch_1, ch_2,ch_3, ………, ch_m} is a set of CHs as (l>m).
(c) R_{trans} (ch_a) is transmission range of a CH i.e ch_a.
(d) W(n_i) is the weight of any one node n_i .
(e) C(n_i) is the cardinality of any one node n_i
(f) D(n_i, n_j)is the distance between nodes $n_i$and n_j.
(g) S (ch_a) is strength of a CH i.e ch_a.

2.1 Energy Consumption Model(ECM)

This model represents attributes of mobile nodes in wireless network. This is basic model used in proposed algorithm to analyse energy of nodes in NS2 at simulation time[4]. The considered attributes are :

Initial Energy - Energy of a node at the beginning stage.
rp Power - Energy consumed in receiving a packet.
tp Power – Energy consumed in transmitting a packet.
Sleep Power – Energy consumed in sleep state.
Idle Power – Energy Consumed in idle state.

Energy Consumption is calculated as:

$$E_{cons}(n_i, \Delta t) = E_{residual}(n_i, t_0) - E_{residual}(n_i, t_1) \quad (1)$$

Here n_i - A node.
Δt – time interval
$E_{residual}(n_i, t_0)$ - residual energy of node $n_i$at time t_0.
$E_{residual}(n_i, t_1)$ - residual energy of node $n_i$at time t_1.

2.2 Stability Model

On the basis of combined weight of parameters , the most suitable node is considered as CH from set of nodes. CH reelection depends on mobility of nodes. To check the suitability of CH, relative mobility,neighboring nodes distances and direct communicating nodes within the transmission range are considered [10].The strength of received signals between two successive “HELLO” packets is inversely proportional to distance between them. Relative mobility[$M_{ni}^{Rel}(nj)$] depends on signal strength which is calculated from node $n_j$to n_i.

$$M_{ni}^{Rel}(nj)=10\log_{10}\frac{RxPr_{nj}^{new}}{RxPr_{nj}^{old}} \quad (2)$$

Here $RxPr_{nj}^{new}$ *and* $RxPr_{nj}^{old}$ are considered as new and old receiving power of packetfrom node $n_j$to n_i.Relative Mobility is negative when $RxPr_{nj}^{new}<RxPr_{nj}^{old}$, means $n_j$is moving away from $n_i$and relative mobility is positive when $RxPr_{nj}^{new}>RxPr_{nj}^{old}$, means $n_j$is coming closer to n_i as shown in Fig.4.

Transmission Zones - If the mobility of a node is positive, it means that node is in the transmission range zone and coming closer to CH for calculating its weight [11]. A circle having radius r with k nodes is known as transmission range of $n_i$node. There is two types of transmission range: -

- Risked Zone - If the mobility of a node is negative, it means that node is in the risked zone and moving away from Cluster Head(CH) such node is not considered for weight calculation as it will get away from the transmission range of CH. The outer circle with (α_2-α_1)r is risked zone.

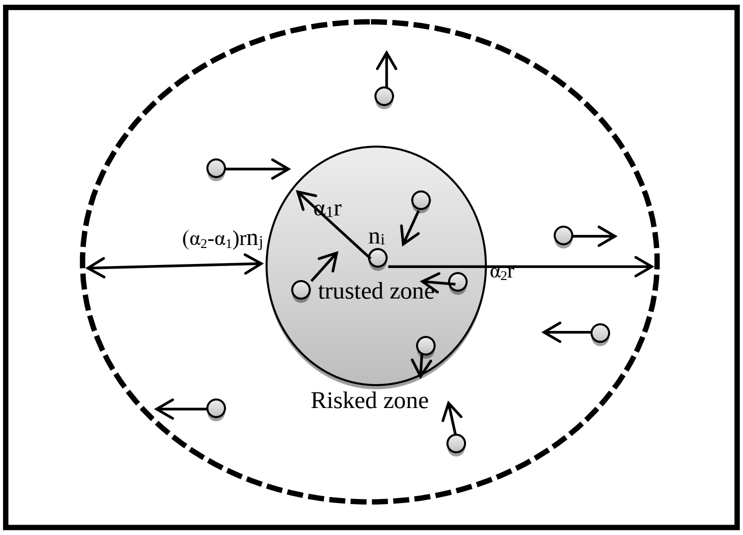

Fig 4. Node Zones with mobility

- Trusted Zone–when a node is in trusted zone but is moving away [8], then the contribution of that node in the finding range indicator is calculated on the basis of distance and relative mobility from CH as shown in this equation :

$$R_{Ind}(n_j , n_i) = \begin{cases} 0, & \text{if } \alpha 1r < dist(ni, nj) \leq \alpha 2r \wedge M_{ni}^{Rel}(nj) < 0 \\ 1, & if \ dist(ni, nj) \leq r \wedge M_{ni}^{Rel}(nj) > 0 \\ 1 + \frac{dist(ni + nj) - \alpha 1r}{(\alpha 2 - \alpha 1)r} & dist(ni, nj) \leq \alpha 1r \wedge M_{ni}^{Rel}(nj) < 0 \end{cases} \quad (3)$$

This shows that node priority in trusted zone is reduced in proportion of distance.The inner circle having radius $\alpha_1 r$ is trusted zone.

Now stability deviation ($STD(n_i)$) of node n_i is calculated on basis of range indicatorR_{Ind} (n_j , n_i) ,distance dist(ni , nj) and nodes cadinality $C(c_i)$ i.e

$$STD(ni) = \frac{\sum_{j=1}^{k} RInd\,(nj, ni) \times dist(ni, nj)}{C(n_i)} \quad (4)$$

2.3 Particle Swarm Optimization(PSO) Technique –

It is a search techniquewhich is used to solve problem by using social interaction concept. There are number of particles (agents) in this technique that are grouped(swarm) together in predefined size Np that moves around in the search space of dimension D trying to find the best solution [12]. Particle P_i ,($1 \leq i \leq Np$)is considered a probable solution that is evaluated by the fitness function having fitness value. Each particle have the position $X_{i,d}$,, $1\leq d\leq D$ and velocity $V_{i,d}$ of a particle adjusts its flying according to its own flying experience.

Here $Pbest_i$- own flying experience of particle
$Gbest_i$- flying experience of other particles

The position of each particle can be modified by itself with the following factors :

(i) Current position
(ii) Current velocity
(iii) Distance between current position and $Pbest_i$
(iv) Distance between current position and $Gbest_i$.

$$V_{i,d}(t+1) = w \times V_{i,d}(t) + c_1 \times rand_1 \times (Xpbest_{i,d} - X_{i,d}(t)) + c_2 \times rand_2 \times (Xgbest_{,d} - X_{i,d}(t)) \quad (5)$$

$$X_{i,d}(t+1) = X_{i,d}(t) + V_{i,d}(t) \quad (6)$$

Here w- inertial weight
c_1,c_2– constant acceleration factors
$rand_1$, $rand_2$– random numbers between 0 and 1

The iteration goes until Gbest value is obtained.

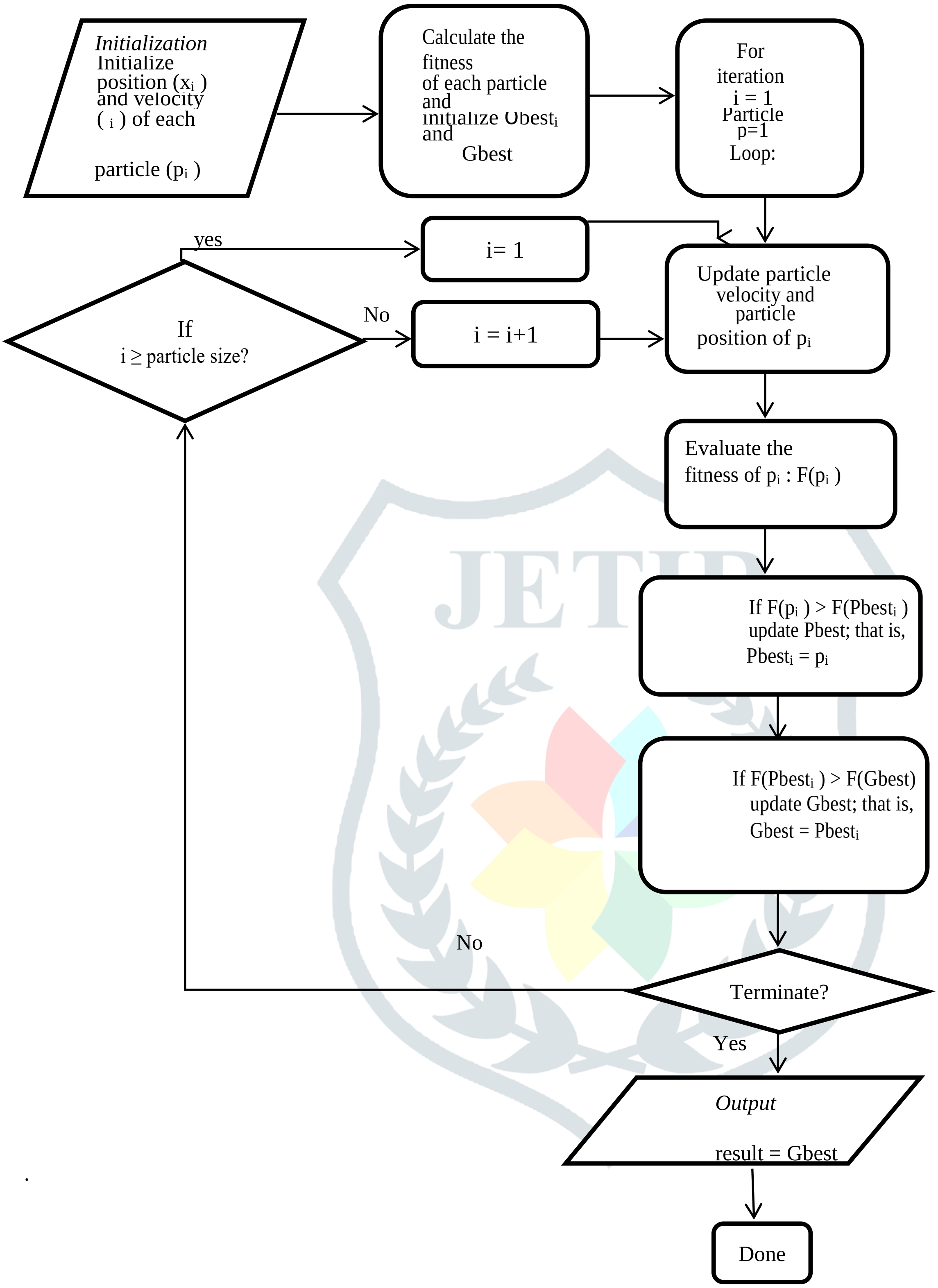

Fig 5. Flowchart of particle swarm optimization

3. Cluster Head Election(CHE) Algorithm

As we are considering two challenging issues mobility and energy of the mobile nodes so CHE algorithm works on both these factors to improve network lifetime. For cluster formation, a clustering approach with bio- inspired particle swarm optimization technique is also introduced. The network is setup in two steps:

3.1 Cluster Head Election - The best CH is selected based on amount of energy consumed by it, mobility, degree of connectivity and distances with all its neighbours and to increase the lifetime of CH, stability deviation (equ. 4) and energy consumption of that node should be less[13]. The combined weight of a node is calculated on the basis of stability deviation(STD(n_i)) and energy consumption(EC(n_i)). Here $W_1+W_2 = 1$ such that $W_1$and $W_2$are two weighing factors[9].

$W(n_i) = W_1 \times STD(n_i) + W_2 \times EC(n_i)$ (7)

From equ.7, a node having minimum weight is elected as CH in a cluster and inform itself to all other nodes in cluster about CH election.

Cluster Head Election Algorithm

Input: A set of nodes, N= { $n_1, n_2, \ldots, n_i$ }, weighing factors 1 and 2.
Output: A set of elected CHs, $\Psi = \{ch_1, ch_2, \ldots, ch_m\}$.
Begin:
Step 1:***for*** **i**= 1 to l $\forall n_i \in N$ ***do***
(1.1) each node n_i broadcast and receive "HELLO" message to and from all its one hop neighbors.
(1.2) estimate the total number of one hop neighbors.
(1.3) find STD(n_i) and ED(n_i).
(1.4) calculate weight, W(n_i)using Equation (7) and broadcast it to all its one-hop neighbors.
Step 2: set f lag = 1
Step 3:***while***(flag== 1∧ n_i is receiving **W**(n_j)$\forall n_j \in T_{range}(n_i)$)***do***
(3.1) ***if*** W (n_j) <W(n_i)***then***
(3.2) gives up the competition for CH election
(3.3) set flag = 0
end if
end while
Step 4:***if***(flag == 1)***then***
(4.1) declare itself as CH and broadcast CH advertisement message with its ID and weight, W(n_i)to $n_j \forall n_j \in T_{range}( )$
(4.2) ***else*** is an isolated node, so declare and advertise itself as a CH after timeout.
end if
Stop.

Algorithm 1.CH election algorithm

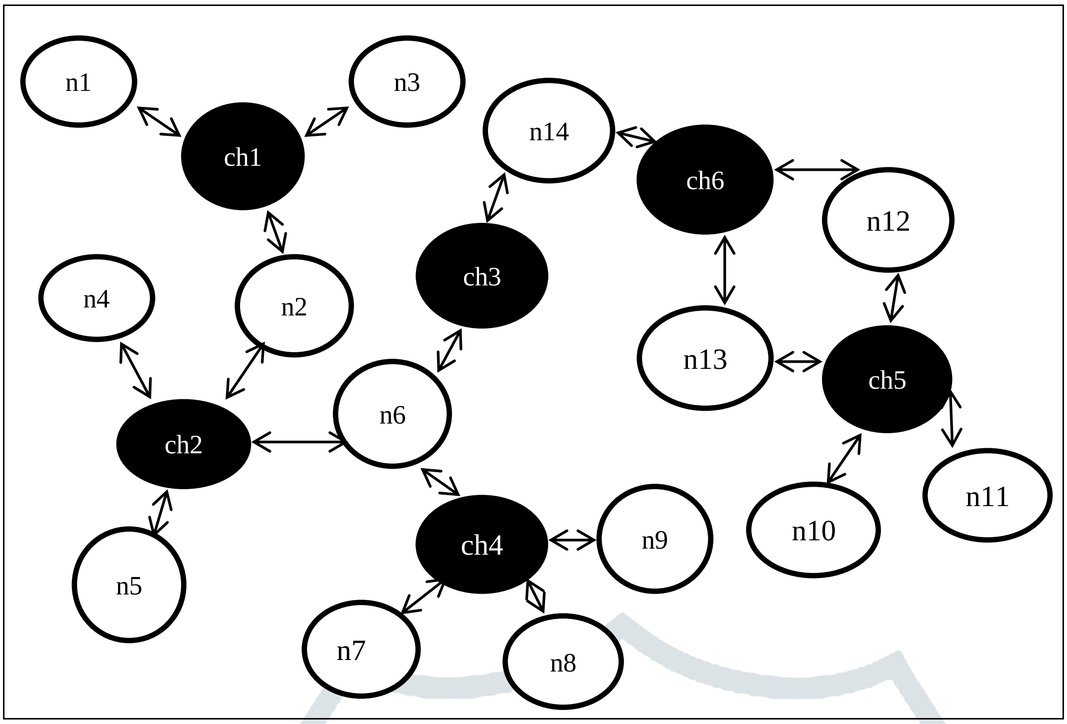

Fig 6.Network topology with elected CHs

4. Proposed Cluster Formation Based on PSO

After CH selection, cluster based on PSO is formed in MANET. Here initialization of a swarm of particles, fitness function evaluation, position and velocity of the particles are considered. The position and velocity of particles are updated according to search **dimension** range. From equ. 5 and 6 ,velocity and position of particles respectively can be find out by using present velocity, self progression factor and social interaction factor of the particle [15].

4.2.1 Initializing Swarm Particle

Initializing the particles in a dimension equal to number of nodes leaving set of elected CHs in MANET i.e $P_i$is a set where i = 1,2,3,………,k where K is total number of non cluster head nodes i.e K = N – Ψ. $P_i$is a particle of generation G having random values between 0 to 1 i.e $0 < rand(0,1) \leq 1$.

4.2.2 Fitness function Evaluation

Each particle performance is measured by fitness function which is based upon two objectives : a) to optimise CHs strength. b) to minimize intracluster distance between nodes and CHs.

a) Optimise CH strength – To improve the stability of clusters in MANET, PSO based clustering is used that also improve strength of CHs. On the basis of CH selection,there is no confirmation about any effect of clustering in network where data transmission from source to destination is done by CHs.CHs have different amount of laods so heavily loaded CH consumes energy very early. This problem leads link failure then selection of new CH or reclustering take place [14]. So clustering effectiveness depends upon well structured cluster in which assignment of nodes to CH is checked. CH strength is considered by optimizing parameters that depends on residual energy and and stability deviation of CH.A CH having high residual energy with least stability deviation is considered a good strength CH so the aims are : 1)To maximize the minimum strength of a CH 2) To minimize the average distance

$$S(ch_a) = \frac{E_{residual}(ch_a)}{STD(ch_a)} \quad (8)$$

Here $S(ch_a)$ – strength of a CH i.e ch_a

$E_{residual}(ch_a)$ - remaining battery energy

$STD(ch_a)$ – stability deviation of ch_a that is calculated by using equ 4.

Aim 1: Maximize $S = \min \{S(ch_a) \mid \forall\ ch_a \in \Psi\}$ (9)

i.e Fitness $\propto$ S(10)

b) Optimise intraclusture distance between nodes and their respective CHs - The fading of signal strength is also a characterstics of wireless channel which is directly proportional to distance between transmitter and receiver i.e

$$P_{Rec}(d) = \frac{P_{Trans}}{d^{\beta}} \quad (11)$$

$P_{Rec}(d)$ – received signal amplitude from a sender to receiver at a distance d.
P_{Trans}- strength of transmitted signal
d – distance between transmitter and receiver
β – path loss factor

As the energy consumption increases nodes die quickly that decreases network lifetime. So second aim to minimize average distance between nodes and their respective CHs as calculated:

$$AvDist = \frac{\sum_{i=1}^{k} dist(n_i, ch_a) \forall n_i \in T_{range}(ch_a) \wedge ch_a \in \Psi}{|k|} \quad (12)$$

Here |k| - nodes cadinality
$T_{range}(ch_a)$ – transmission range of ch_a
Ψ – set of elected CHs

$$Fitness \propto \frac{1}{AvDist} \quad (13)$$

Aim 2 : to minimize AvDist by combining equ (10) and (13)

$$Fitness \propto \frac{S}{AvDist} \quad (14)$$

i.e

$$Fitness = K \times \frac{S}{AvDist} \quad (15)$$

Here K =1 i.e proportionality constant. So

$$Fitness = \frac{S}{AvDist.} \quad (16)$$

PSO based clustering is to maximize fitness value(16). The more fitness value of a particle the more lifetime of CH and hence overall network lifetime increases. Pbest and Gbest are updated according to fitness functions evaluation.

4.2.3. Updation of velocity and position of particles - After fitness function evaluation velocity and positions are calculated by equ. (5) and (6) and updated after each iteration which finds best solution. During iteration current fitness value of particle is compared with its personal best value. When better fitness value is obtained, personal best, $PBest_i$ is replaced by current value and global best ,$GBest_i$ is replaced by current global best value. Iteration process will continue until termination criteria is satisfied(Algorithm 2). As the clustering algorithm is completed nodes are assigned to optimised CHs with minimum distance from respective CHs through which more balanced clusters are achieved [13].

Algorithm 2: Cluster formation based on PSO

Input: (1) A set of nodes = {1, 2,..., }. (2) a set of elected CHs Ψ = {ch1,ch2, ... ,ch }. (3) swarm size .
Output: An assignment*A:* → Ψwith maximized objective function.
Begin:
Step 1: Initialize swarm particles P_i ∀ $P_i \in N_p \wedge 1 \le i \le N_p$
Step 2:*for* = 1toN_p *do*
(2.1) Find Fitness ( )using Equation (17)
(2.2) set Pbest =
end
Step 3:*if*Fitness(Pbest) =max{Fitness($Pbest_i$) ∀i: 1 ≤ i≤ N_p }
set Gbest = Pbest
end if
Step 4:*while*(Not Terminate)*do*
for = 1toN_p *do*
(4.1) Each particle update its velocity and position using Equations (5) and (6) respectively.
(4.2) Find new Fitness(P_i) using Equation (17)
(4.3) if Fitness(P_i) > Fitness($Pbest_i$)*then*
(4.4) set $Pbest_i$= P_i
end
(4.5) *if* Fitness(Pbest) > Fitness(Gbest)*then*
(4.6) set Gbest = $Pbest_i$
end
end
end
Step 5: Assign noden_i∀i∈ N to the CH ch_a∀a∈Ψin its Transmission range with maximum fitness value i.e Gbest.

Stop.

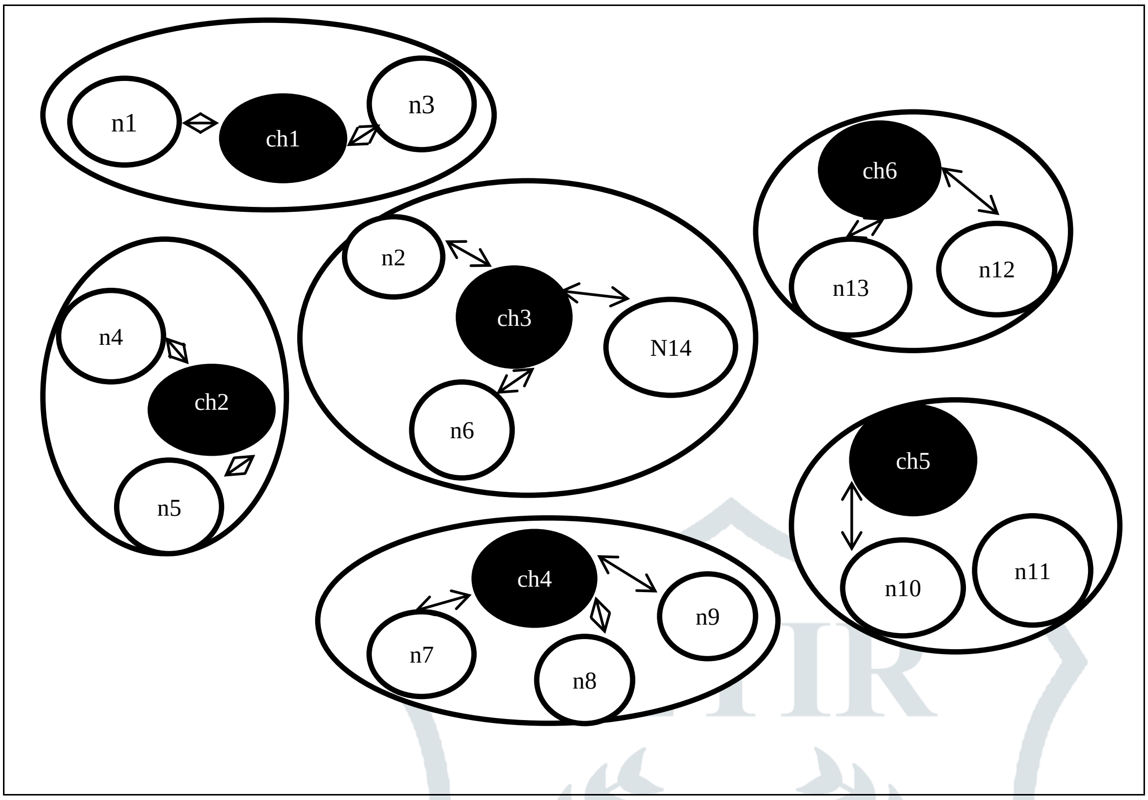

Fig 7. Cluster formation after execution of PSO based clustering

Explanation - After formation of compact and balanced clusters[16], a component of particle P_i with dimension d i.e ($CP_{i,d}$) maps association of nodes to CH. From fig. 6, there are 6 elected CHs and 14 non CHs nodes in the network. From Table 2(coloumn 4) ,element of ith particle ($CP_{i,d}$) are initialized between 0 and 1 randomly. CHs cardinality $|G_r|$ is in direct communication of each node. The number obtained by multiplication of particle component value and cluster heads cardinality is that number with which node is affiliated with CH. Nodes are assigned to cluster heads as shown in Fig 7 where clusters are formed after execution of PSO based clustering.

Table2: Assignment of nodes to CHs

Node #(n_i)	Possible CHs(G_r)	$\lvert G_r \rvert$	$CP_{i,d}$	[$G_r \times CP_{i,d}$]	Assigned CH
1	ch1	1	0.24	1	ch1
2	ch1,ch2,ch3	3	0.89	3	ch3
3	ch1	1	0.13	1	ch1
4	ch2	1	0.31	1	ch2
5	ch2	1	0.28	1	ch2
6	ch2, ch3, ch4	3	0.39	2	ch3
7	ch4	1	0.68	1	ch4
8	ch4	1	0.35	1	ch4
9	ch4	1	0.79	1	ch4
10	ch5	1	0.28	1	ch5
11	ch5	1	0.85	1	ch5
12	ch5,ch6	2	0.48	2	ch6
13	ch5,ch6	2	0.64	2	ch6
14	ch3,ch6	2	0.41	1	ch3

5. Conclusion- This paper considered mobility and energy consumption of nodes which are two main challenges. Particle Swarm Optimized energy efficient clustering is proposed for controlling these two challenges in MANET. A node having less stability deviation and less energy consumption is elected as best CH.In PSO based clustering, a fitness function is used which is based on CHs strength and average distance(AvDist) of nodes from its respective CHs. For better clustering that also improves network lifetime CHs strength is optimized and AvDist. is minimized.

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