A CLUSTER BASED STABLE ROUTING PROTOCOL USING BINARY PARTICLE SWARM OPTIMIZATION TOWARDS SERVICE DISCOVERY IN MOBILE AD HOC NETWORK

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ABSTRACT

A Mobile Ad hoc Network consists of active nodes that can be in motion freely. These networks can be improved by the use of clusters because of huge congestion in the whole network. In such a system, the performance of MANET is improved by splitting the whole network into various clusters. The performance of clustering is improved by the cluster head selection and number of clusters. In this paper, we have designed a new protocol, Cluster based Stable Routing protocol (CSR) based on Binary Particle Swarm Optimization (BPSO). The proposed algorithm shows how BPSO can be useful in enhancing the performance of service discovery in MANET. This algorithm is to select the best cluster head and minimum number of clusters. Experiments were performed to prove that the proposed method is an efficient method for clustering in MANET. Also the path stability is combined with clustering with use of remaining battery power of the nodes.

KEYWORDS

Mobile Ad hoc Network, stable routing protocol, Binary particle swarm optimization, clusters, cluster head.

1. INTRODUCTION

Mobile ad hoc networks (MANETs) play a critical role in today's wireless ad hoc network research. A MANET consists of wireless nodes which can communicate with each other over a wireless medium. Such a network can be formed spontaneously whenever devices are located within transmission range. New nodes can join or leave an existing node dynamically, because of the mobility in wireless networks. MANETs provide unforeseen applications in some new fields.
One such problem is how to create an organizational structure amongst these nodes . The MANETs is the capability to organize them in an ad hoc method, as it is not feasible to arrange these nodes into groups. For this reason, we need to group nodes into clusters[1],[2]. The clustering phenomenon, as we shall see, plays an important role not just in organization of the network but also can dramatically affect network performance. There are several key limitations in MANETs that clustering schemes must consider, such as limited energy, network lifetime, mobility and stability.

Different existing algorithms for the creation of clusters are limited in many routing protocols, as well as clustering algorithm, such as (i) lowest-ID (ii) node-weight heuristic.

Lowest-ID [3] is known as identifier based clustering. In this algorithm, ID is assigned to each node. Periodically, every node broadcasts the list of nodes so that it can be heard. Among the neighbors, the node with minimum ID is selected as a cluster head. The drawback of this algorithm leads to battery drainage of certain nodes. Furthermore, it does not try to balance the load equally across all the nodes.

Weighted clustering algorithms (WCA) [4] depend on the weight of the nodes in the network. In these algorithms, the node with lower weight among the neighbors is selected as a cluster head. Although it can increase the stability of clusters, it cannot obtain the optimal number of cluster heads. Furthermore, calculation and storage of the weight are costly and the overhead induced by WCA is very high.

In [5] this research, the main objective is towards maximizing the lifetime of wireless ad hoc networks through energy efficient routing. Furthermore, the factors that control the reduction of energy in ad hoc networks are shown and the method for load balancing, which is considered as important factor in MANETs, is proposed. But as in many researches, the proposed method for load balancing is the theoretical one and hence the correctness of the method is not guaranteed since there are no results of simulation.

Li Q, Aslam J, Rus D [6] describes Online Power-aware Routing in Wireless Ad-hoc Networks. This paper describes online power-aware routing in large wireless ad-hoc networks for applications where the message order is not known. The main purpose of this research is to optimize the lifetime of the network. Here an approximation algorithm called max-min z P_{min} that has a good empirical competitive ratio is proposed. To ensure scalability, a second online algorithm for power-aware routing is introduced. This hierarchical algorithm is called zone-based routing.

In this paper, we propose a routing protocol towards service discovery protocol for MANET, cluster based stable routing protocol (CSR) based on binary particle swarm optimization (BPSO). The main objective is to minimize the number of cluster, election of cluster head with efficient energy consumption and maximizing the network lifetime. The rest of this paper is organized as follows. Section 2 consists of power aware routing that includes the nodes which are having the optimized power in the path. Section 3 introduces definitions and models like system model, energy model and transmission range. Section 4 provides the proposed work with Novel Binary Particle swarm optimization is applied to optimize the cluster head election procedure. The simulation results have demonstrated its performance improvement in terms of packet delivery ratio and network lifetime is explained in section 5.

2. POWER AWARE ROUTING

Commonly routing is the very important part in MANET. Until now, so many protocols have been proposed for routing. The working of each protocol is different from each other and each has their own benefits and limitations.The purpose behind this method is to send the message as quickly as possible. But this should not be considered as the best path at all times. Because if the battery power of any node in the selected path is very low then the message cannot be transmitted through that path at any cost because in the middle of the transmission, the link may get broken down due to insufficient power. In the network shown below, consider the path 1-6-3 as the shortest path. In Fig 1, node1 starts transmission then the power gets depleted to some extent.

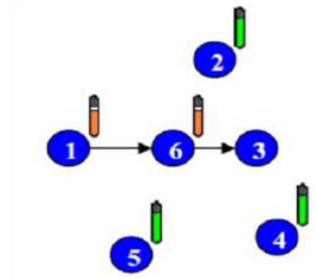

Fig. 1. Status of power during initial transmission

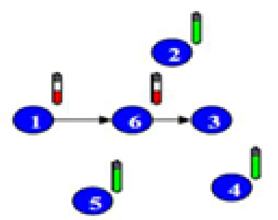

Fig. 2. Status of power after first transmission

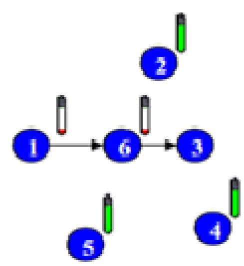

Fig. 3. Status of power before final transmission

So this problem has to be resolved by the following ways

(a) The path has to reconstructed
(b) The message has to be retransmitted.

But here the power of the nodes got wasted unnecessarily. Now all these problems occur because of the instability of the selected paths. Hence, the lasting battery power of the nodes in the network should be taken into account during the route discovery process in MANETS to avoid such link breakage during the message transmission. This is the concept of power aware algorithm proposed so far.

3.System Model and Definitions

3.1.System Model

We consider a distributed heterogeneous wireless network where data tends to be correlated in both time and space and nodes are assumed to be time synchronized. The nodes are organized into clusters based on power calculation and distance based and spatial correlation. Each cluster has an aggregator or cluster head denoted as CH_i and a set of nodes as Z_k Є C_i. The network topology is modeled as an undirected graph G where G = (C, E). C represents clusters in the network and E represents an edge which connects two nodes within a cluster. Within a cluster C_i, each cluster head CH_i has k spatially correlated neighboring nodes. The k spatially associated nodes in C_i are represented by Z_k = { Z_k ;k=1…n}, i.e., $N(C_i)$ = { Z_k Є C_i |(Z_k, CH_i) Є E}U{ CH_i }An example of $N(C_i)$ cluster is shown in Figure 4. The clusters are formed such that all the clusters are connected.

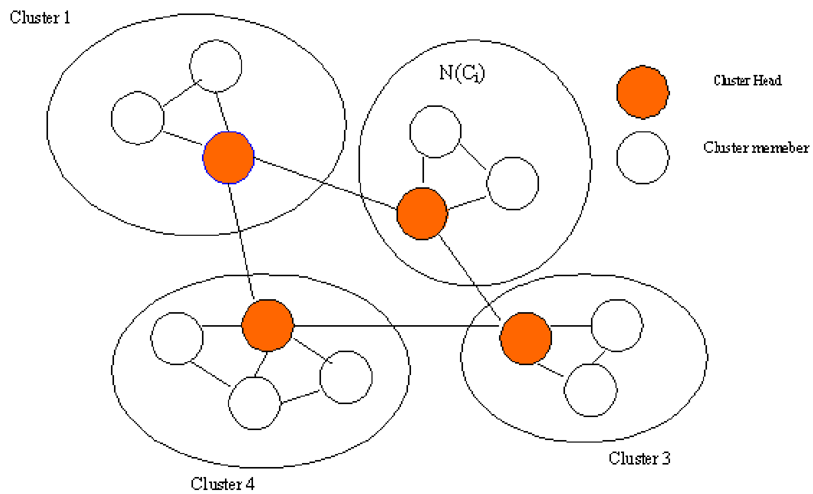

Fig. 4. Example of cluster with its member $N(C_i)$

3.2 Energy Model

All the nodes in the given area have same transmit power and each node selects a threshold energy level (E_{th}) and each node must maintain the value in their routing table to select the nodes during route discovery. The residual battery energy value can be obtained to the network layer where it is stored in the routing tables to make routing decisions based on the battery energy. When the residual energy is less than threshold energy value, that node is avoided in the route selection by the destination. On receiving the RREQ the intermediate nodes calculates the received signal (r(t)) strength which holds the following relationship for two-ray propagation model:

$$P_R = P_T\, G_T\, G_R \left(\frac{h_t h_r}{d^2} \right)^2 \qquad (1)$$

Where P_T and P_R are transmitter power and receiver power respectively, λ is the carrier wavelength, d is the distance between the senders and the receiver and G_T G_R are the unity gain of the transmitting and receiving antenna respectively. Hence the node calculates the path loss using

$$\text{Path loss} = P_T - P_R \qquad (2)$$

The receiver sensitivity, the minimum received power necessary for a signal to be correctly detected is, P_{Rmin} as from (1). The receiver strength is the only one parameter which decides the correct reception of signals. The sender uses this P_R as P_{Rmin} for further transmissions.
The total amount of energy consumed per transmitted packet is written as

$$\alpha = P_T * L/R_b \quad (3)$$

Where

α = transmitted energy

P_T = transmitter power

L = packet length

R_b = data rate or bandwidth

The total amount of energy consumed per received packet is written as

$$\beta = P_{R_{min}} * L/R_b \quad (4)$$

where, β, P_{Rmin} are the energy consumed in received packets and minimum receiving power respectively.

The node then calculates the residual energy E_R using the following parameters:

Σ – Initial energy taken by the node
α – Energy consumed in transmitting packets
β – Energy consumed in receiving packets
γ – Energy consumption in idle state.

$$E_R = \Sigma - (\alpha + \beta + \gamma) \quad (5)$$

3.3.Transmission Range

Distance and the transmission power are generated randomly for the nodes. Average distance and mean transmission power are calculated. Max distance of the nodes generated is taken as the radius for coverage area in transmission range. Average transmission range is computed with distance of the nodes.

$$TR_{tx} = \sqrt{\frac{P_t G_t G_r}{P_{R\ min}}} (C/4\pi f_c)^2 \quad (6)$$

This transmission range is taken as the parameter to decide the cluster head. If a node has this value with all other nodes, that node will be selected as the cluster head.

4.PROPOSED WORK

4.1.Problem Statement

In this proposed work, the remaining battery power of the node is calculated and then routing decision will be made. And identify the nodes those are having the higher capacity. Based on the power of the node cluster head (CH) is elected then the clusters are formed based on the transmission range that is calculated as per equation (6). BPSO is applied to optimize the number of clusters as well as manage the load among the clusters.

4.2.Method Overview

In this method, during route discovery, the remaining battery power of each node is first calculated and then it is compared with a pre determined threshold value. A node is approved only if it is greater than threshold value (E_{th}) to make sure that there is enough power for the node to forward the packets to its neighbours. In fig 5, the power of node 6 is compared with the threshold and it is low.

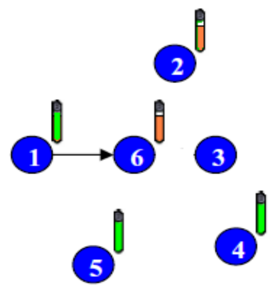

Fig. 5. Checking power condition for the first neighbor of source

So remove all the paths involving 6 and move to next neighbour which is node 2 as shown in fig 5

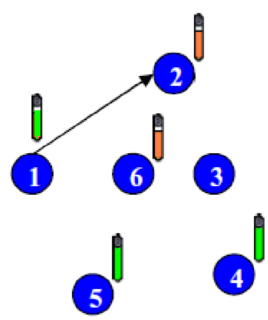

Fig. 6. Checking power condition for the next neighbor of source

Node 2 also fails, and node 5 satisfies the condition and now move to its neighbour node 4 as shown in fig 6.

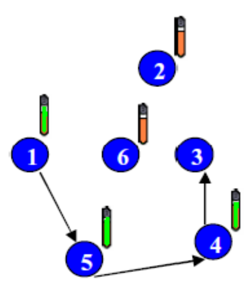

Fig. 7. Situation in which all the nodes of a path satisfies the power condition

If the condition fails, then that node can be simply removed from the consideration, not only the node but also all the paths in which the node gets involved. So by this method, the entire route discovery process is simplified by considering only one-third of the total number of nodes. In addition to this, a special case has been dealt even though it is very rare. The following pseudo code describes the steps about, when none of the nodes in the network meet the situation, then the threshold value is decreased by half and the procedure is repeated until a node which satisfies the condition is identified. As a result the stability of the paths in which the message has to be transmitted gets increased and also it avoids unnecessary power reduction, which is one of the very limited resources in MANETS.

```
/****** pseudo code for path stability *****/
Begin
     BPi ← initial power of nodes;
     for each node 'n' in the network
        calculate BPi;
L:
 for  i ← 0 to n
   if(BP[Ni] >THi)
      Forward to adja(Ni)
   Else
      Remove(Ni)
   While(BP[Ni] != NULL)
      THi =  THi/2;
i++;
GoTo L;
```

Improve the path stability by avoid power depletion;

4.3.Novel Binary Particle Swarm Optimization

Kennedy and Eberhart proposed a discrete binary version of PSO for binary problems [3].In the binary PSO, the particle's personal best and global best is modernized .The difference is that velocities of the particles. This velocity must be controlled within the range of [0, 1]. The velocity of each particle is obtained using the equation:

$$\left\{\begin{array}{l} v_{i,j}(t+1)=\eta\left(\begin{array}{l} v_{i,j}(t)+c_1r_1\left(p_{ibest,j}(t)-x_{i,j}(t)\right) \\ +c_2r_2\left(g_{ibest,j}(t)-x_{i,j}(t)\right) \end{array}\right) \\ x_{i,j}(t+1)=x_{i,j}(t)+v_{i,j}(t+1) \end{array}\right\} \quad (7)$$

where $v_{i,j}$ is the velocity of particle, $x_{i,j}$ is the position of the particle, t is the number of iterations, c1, and c2 are two positive constants, referred to as the cognitive and social acceleration factors respectively, r1 and r2 are random numbers within the range [0,1], and w is the inertia weight. The particle's best position (pbest) is denoted as p_{ibeset},j,the best position among all particles in the swarm is denoted as g_{ibeset},j.

$$\left\{ h(v_i(t+1)) = \eta \begin{pmatrix} v_{max}, & if \quad v_i(t+1) > v_{max} \\ v_i(t+1), & if \quad |v_i(t+1)| \leq v_{max} \\ v_{min}, & if \quad v_i(t+1) < v_{min} \end{pmatrix} \right\} \quad (8)$$

Here v_i depends on the sigmoid function

$$sig(v_i) = \frac{1}{1+\ell^{-v_i}} \quad (9)$$

Then the position of the particle is updated as[9]

$$x_i(t+1) = \begin{cases} 0, & if \quad r3(t) \geq sig(v_i(t+1)) \\ 1, & if \quad r3(t) < sig(v_i(t+1)) \end{cases} \quad (10)$$

$$v_{i,j} = \begin{cases} v_{i,j}^{1}, if \cdots x_{i,j} = 0 \\ v_{i,j}^{0}, if \cdots x_{i,j} = 1 \end{cases} \quad (11)$$

Where r3 is a random number within the range [0,1].

$$\begin{array}{l} if \quad p_{ibest}^{\ j} = 1 \quad Then \quad d_{i,j}^{\ 1},1 = c_1 r_1 \quad and \quad d_{i,j}^{\ 1},1 = -c_1 r_1 \\ if \quad p_{ibest}^{\ j} = 0 \quad Then \quad d_{i,j}^{\ 0},1 = c_1 r_1 \quad and \quad d_{i,j}^{\ 0},1 = -c_1 r_1 \\ if \quad p_{gbest}^{\ j} = 1 \quad Then \quad d_{i,j}^{\ 1},2 = c_2 r_2 \quad and \quad d_{i,j}^{\ 1},2 = -c_2 r_2 \\ if \quad p_{gbest}^{\ j} = 1 \quad Then \quad d_{i,j}^{\ 0},2 = c_2 r_2 \quad and \quad d_{i,j}^{\ 0},2 = -c_2 r_2 \end{array} \quad (12)$$

$$v_{i,j}^{\ 1} = wv_{i,j}^{\ 1} + d_{i,j}^{\ 1},1 + d_{i,j}^{\ 1},2 \quad (13)$$

$$v_{i,j}^{\ 0} = wv_{i,j}^{\ 0} + d_{i,j}^{\ 0},1 + d_{i,j}^{\ 0},2 \quad (14)$$

4.4.Cluster Formation

The proposed algorithm is a fully distributed algorithm as in section 3.1. All nodes in the mobile network share the same responsibility and act as a cluster head. The proposed protocol takes rounds where each round begins with a setup phase at the time cluster is formed. At the starting phases, all the nodes share their energy level as per the energy model in section 3.2, to its neighbor node. To ensure that only node with sufficient energy and transmission range are selected as a cluster head (CH) as per section 3.3. The node with an energy above the threshold value is suitable to be a cluster head for this round. During second phase, Novel Binary particle swarm optimization is used to improve the performance of the cluster head election procedure. The aim is that the numbers of clusters are minimized while the load in the network is balanced among the clusters.

4.4.1.Cluster head election procedure.

For each particle in the population every dimension of the particle is traversed according to the order of their experience. Cluster head election procedure is not a periodic and it is invoked at starting and rarely when the network node joins in the cluster or moves away from the cluster

4.4.2.Initialize cluster head.

Cluster head candidate have the possible to become the cluster head for the cluster in the current round. Cluster head candidate is selected based on the threshold energy (E_{th}) and based on the transmission range as per equation (8).

$$f1 = \max \left\{ \sum_{\forall Z_{j \varepsilon C_{pn}}} d_{Z_{j \varepsilon CH_{pn}}} \Big/ |C_{pn}| \right. \quad (15)$$

$$\vdots \quad n = 1,2..N$$

where z_j member of the node in the cluster

CH_p cluster head of the particle

$|C_{pn}|$ Number of nodes that belongs to cluster c_n of particle p.

$$d_{Z_{j\varepsilon CH_{pn}}} = \left\{ ((CH_{pn} - z_j)^{\tau s^{-1}} (CH_{pn} - z_j))^{1/2} \right\}$$

$$f2 = \sum_{i=1}^{N} E(z_i) \Big/ \sum_{n=1}^{N} E(CH_{pn}) \quad (16)$$

$$f3 = \begin{cases} 2\pi r & if\ d(u,v) < TR_{tx} \\ out\ of\ range & if\ d(u,v) > TR_{tx} \end{cases} \quad (17)$$

Where,

TR_{tx}-Transmission Range based on the distance.

In this approach, a local lbest is found for each swarm member selected from the 'closest' two swarm members. The distance between each particle and its neighbour's particle that computed the proximity depends on the first function, f1. Consequently, the preference of local optima among the neighbours of a particle is based upon the second function, f2. The Third function f3 describes the optimal function for the transmission range through the nodes distance. In the next sub-section, the steps of the algorithm will be described in detail.

/*Algorithm for cluster formation*/

1. Initialize swarm X_i, the position of the particles are initialized. Elements of Xi are randomly selected from the binary values o and 1.
2. Initialize the randomly selected z_k among the eligible cluster head candidate.
3. Particles position using the equation(7)
4. for each X_i in swarm find the function,
5. Assign each node n_i, i =1,2……N in the network to the closest cluster head CH.
   a. Assign each node n_i,i=1,2……N in the network to the Closest cluster head CH.

b. Calculate the function f1, f2, f3 using (15)(16)(17).

6. Evaluate the performance of each particle to its best presentation.

if(f1(X_i(t+1)<f1(P_{ibest})and(f2(X_i(t+1)<f2(P_{ibest})and f3

f1(P_{ibest})= f1(X_i(t+1))

f2(P_{ibest})= f2(X_i(t+1))

f3(P_{ibest})= f3(X_i(t+1))

P_{ibest} = X_i(t+1)

7. Compare the performance of each particle to the Gbest particle.

if(f1(X_i(t+1)<f1(G_{ibest})and (f2(X_i(t+1)<f2(G_{ibest})

f1(G_{ibest})= f1(X_i(t+1))

f2(G_{ibest})= f2(X_i(t+1))

f3(G_{ibest})= f3(X_i(t+1))

G_{ibest} = X_i (t+1)

8. Apply the velocity update on all particles $\vec{v}^0{}_j$ *and* $\vec{v}_j^1$
9. Apply the binary position update using (10)(11)
10. Calculate the velocity change of the bits $\vec{v}^c{}_j$.
11. Generate the random variable r_{ij} in the range (0,1).Move each particle to new position using (12).
12. Reinitialize M.
13. Repeat steps 2 to 11 until the maximum iteration is reached.

5.SIMULATION AND RESULTS

In this section, we evaluate the performance of our proposed technique via simulations. We The network simulation model was built using MATLAB. The BPSO starts with a “swarm” of nodes randomly generated. As shown in Figure 8 is a randomly deployed network with equal initial energy of 0.25 J. A linear decreasing inertia weight value w is 0.8 and coefficients c1 and c2 both are set to 2 as proposed in [7]. r1 and r2 are random numbers within the range [0,1]. In the simulation wireless network composed by 400 nodes, for optimization, we have used 20 particles, which are denoted by all nodes coordinates, for our experiment nodes are randomly distributed in a 300m x300 m area square mobile ad hoc network shown in figure(8), and the maximum number of iterations we are running is 6000. The transmission range of each node in the network and the maximum speed (velocity) of the particle is set as 5 units and 50.Initially cluster head candidate is selected based on the Residual energy (E_R) which is calculated from the Eq. (5) and based on the transmission range as per equation (7).Based on the transmission range nodes are moved and located in their final position. For optimizing the clusters functions are calculated.

The nodes are organized into clusters by the cluster head candidate. Each particle will be estimated by the functions in equations (15) (16) (17) in each iterations. Our purposed work is to find the optimal location of cluster heads. As can be seen in Figure 9, our proposed algorithm CSR-BPSO locates minimum number of clusters (3 clusters) in the whole network than SEP[8],LEACH[9], PSO-C in the 300 x 300 m area with a transmission range of 35. The proposed algorithm CSR-BPSO mechanism better than the other algorithms in terms of produce the average number of clusters. The reason to find the best solution is that the total fitness value should be minimal. The proposed work results confirm the network with minimum number of clusters that can decrease the routing cost of the network.

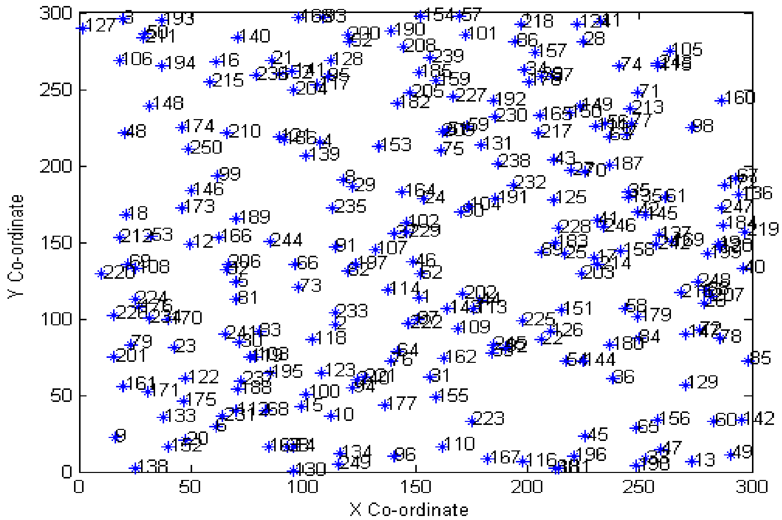

Fig. 8. Node Deployment

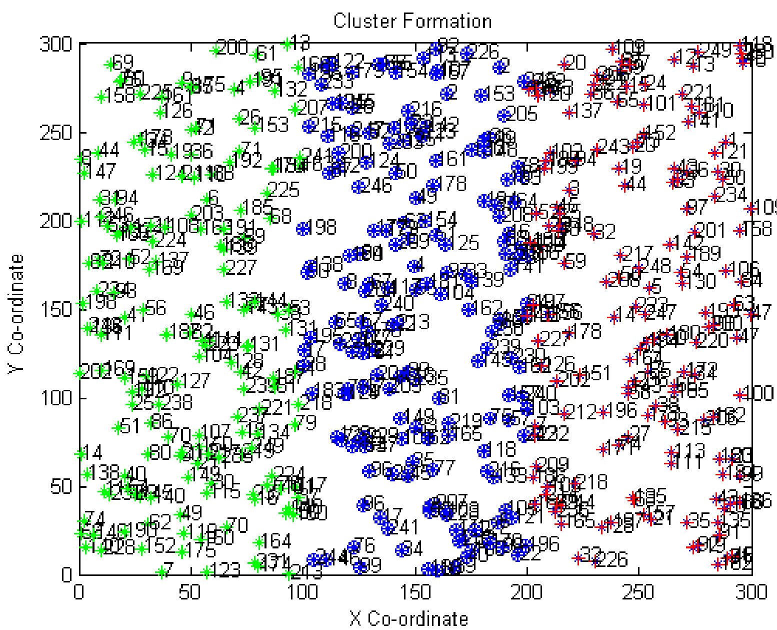

Fig. 9.optimized cluster formation

For the current paper, Life time of a node is maximized and the number of cluster heads and number of clusters are optimized. Our analysis focuses the energy efficiency and network life time. Initially the required power is set as the threshold and the route is discovered by checking the power of each node with the threshold. If it fails, all the paths involving that node will be considered as failed paths. If no paths available, the threshold is reduced by half and the process is repeated. Then the message is transmitted via the discovered path with enough power. It is useful to reduce the number of hops and the delays of packets transmitted in a cluster environment. The clusters are huge when the transmission ranges of nodes are little. The evaluation results show that the proposed method performs better than other algorithms in a mobile ad hoc network environment.

The simulation results have been compared with various existing protocols. Table I describes the Life Time of the node for different amount of energy and it also shows the comparisons of SEP, LEACH, PSO-C with our proposed protocol CSR-BPSO algorithm. It shows when the first node lost their energy during different energy levels 0.25J, 0.5J, 1J. Our proposed CSR-BPSO algorithm has the highest lifetime compare to the other protocols.

Table 1 Lifetime of the Node

Protocol	First Node Dies	Last Node Dies	Energy(J)
SEP	590	1654	0.25
LEACH	420	806	
PSO-C	801	1809	
CSR-BPSO	1011	2010	
SEP	1001	2715	0.5
LEACH	934	2951	
PSO-C	1501	3001	
CSR-BPSO	1901	3125	
SEP	1983	4100	1
LEACH	1851	3961	
PSO-C	2002	4510	
CSR-BPSO	2251	5805	

The performance of the CSR-BPSO algorithm is compared with the well known algorithm LEACH, SEP and PSO-C. In every round a set of new cluster heads is selected and the member nodes send packet to their connected cluster head.

Figure 10 demonstrates the lifetime of the nodes in the clusters. The Number of nodes that stay on active after each round. Initial energy is assigned as 0.25J.This figure shows that the network life time for CSR-BPSO increases considerably compared to PSO-C, LEACH, and SEP. This development is based on the following reasons, Firstly considerable energy saving is achieved by CSR-BPSO algorithm through the use of dynamic clustering with the proposed functions. By using the proposed dynamic clustering method, the CSR-BPSO algorithm can attain the minimum number of clusters all the way through the simulations which leads to minimum energy. Secondly, the functions can generate improved network partitioning with smallest amount network energy dissipation. Here the total energy efficiency is raised nearly 48% than the PSO-C, LEACH, SEP. After 5805 rounds only the proposed algorithm nodes are in dead situation, but in the case of PSO-C, LEACH, SEP all the nodes are lost their energy nearly 806 rounds itself.

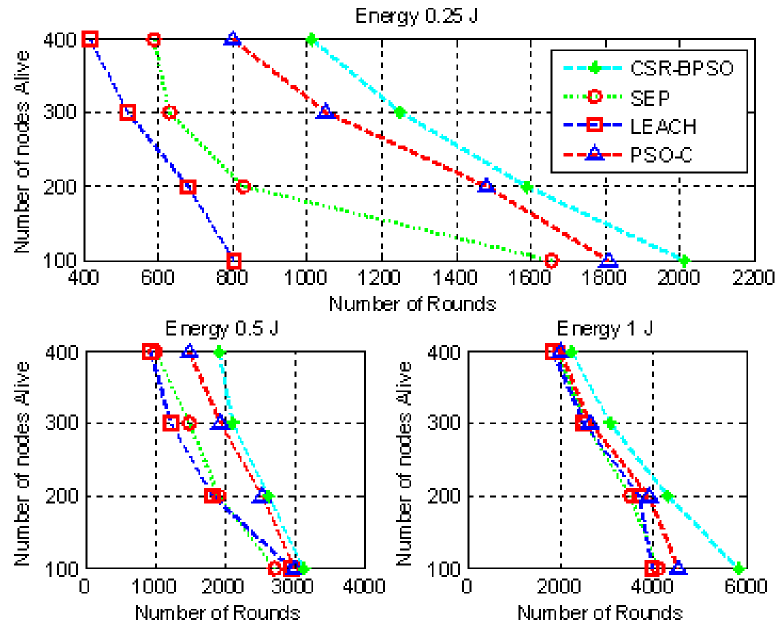

Fig. 10. Lifetime of the nodes

Figure 11 gives the results of amount of packet delivered in the network. Equation (18) shows the ratio between number of packets received and number of packets transmitted. This parameter finds the fraction of successful packet reception. In figure 11, the ratio of packet delivery in the cluster for various numbers of nodes in Ad hoc network environment. In our algorithm, the ratio of packet delivery is high by maintaining a stable route by considering residual energy and transmission power taken from PHY and MAC layers. It reduces the rate of packet loss due to link break by choosing an alternate path according to residual energy and transmission power.

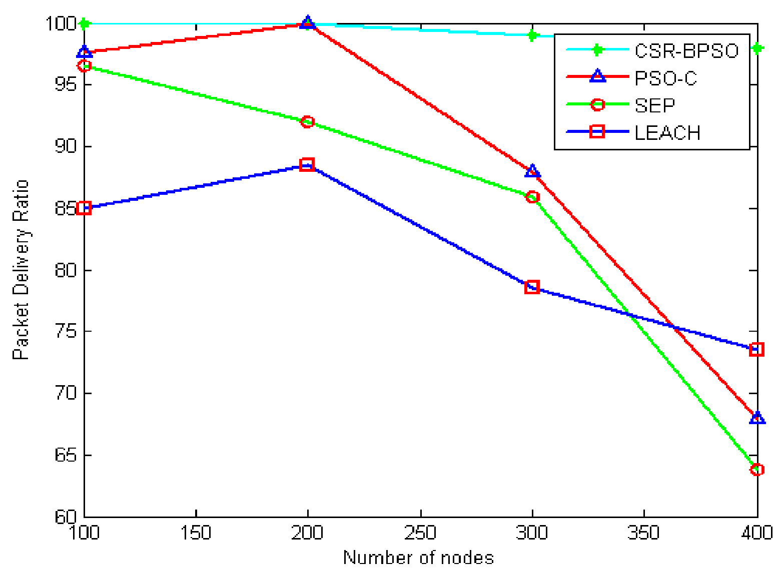

Fig. 11. Packet Delivery Ratio vs Number of Nodes

$$\text{Packet delivery ratio} = \frac{\text{number of packets received}}{\text{number of packets transmitted}} \quad (18)$$

Furthermore, we also observed in the above Figures that the network lifetime increased to a certain length in the cluster formation scenario. In our proposed work network life time will be increased when compare to the LEACH, SEP, PSO-C. With this increase, the Network lifetime was further prolonged when compare to the other cluster formation technique. This scheme can produce results close to the optimal result.

6.CONCLUSION

In this paper, we have proposed a CSR-BPSO algorithm for routing towards service discovery using a binary particle swarm optimization algorithm. Our algorithm improves the routing function by taking into account of number of clusters and load among the clusters. It tries to minimize the number of clusters as well as cluster heads.

The Performance results show a minimum number of clusters in every round during simulation. Furthermore, the proposed algorithm gives the network lifetime is 84.34% and packet delivery ratio is more compared to other algorithms such as LEACH, SEP, and PSO-C.

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