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An Enhanced Energy-Efficient Clustering Routing Protocol (Eeecrp) For Heterogeneous Mobile Ad Hoc Networks

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Abstract: A mobile ad hoc network (MANET) is dynamic in nature and is composed of wirelessly connected nodes that perform hop-by-hop routing without the help of any fixed infrastructure. A Mobile Ad hoc Networks shortly called as MANET simply consists of a set of wireless mobile nodes that can quickly organize into a network, without the need for an infrastructure and start communicating using their wireless links. The nodes randomly move in a given region; as a result, the network topology keeps on changing. These ad hoc networks have found numerous applications in civil and military domains. The main requirements of a Mobile Ad hoc Network (MANET) is the efficiency of energy. Energy efficiency increases the lifetime of the network. In this research, inter-cluster and intra-cluster traffic is maintained by the cluster-head mobile nodes. The research takes into consideration the velocity of the mobile nodes, transmission range and battery power consumption of the mobile nodes. These solutions are achieved through the proposed routing. Simulations are performed using NS-2. The comparison is to be made between the proposed algorithm in the research and Weighted Clustering Algorithm (WCA).

Keywords: Ad hoc networks, Routing, Energy, Power, Clustering, WCA

I. INTRODUCTION

A mobile ad hoc network (MANET) is a dynamic and self adapting network in which no centralized control exists. It has a set of dynamic nodes that can move freely. The nodes that are present in mobile ad hoc network have limited processing speed, battery, storage, and communication capabilities. The features of MANET bring many new problems and challenges for the researchers in the field of computer science, engineering, technology etc., Clustering is a means of categorizing objects into meaningful groups with respect to their similarities. The purpose of clustering in MANETs is to recognize the groups of nodes in such a way that the identified groups are exclusive and any instance in the network belong to a single group. The special type of nodes called as cluster-heads (CHs) are accountable for the formation of clusters, maintenance of the network topology, and the resource allocation to all nodes belonging to their clusters. Since the configuration of the cluster- heads is constantly changing due to the dynamic nature of mobile nodes, minimizing the number of cluster-heads becomes essential. The neighborhood of a CH is the set of nodes that lie within its transmission range. Since energy efficiency is an important requirement of a MANET, which increases its lifetime, clustering can provide an energy-efficient solution as only few nodes are involved in doing the main operations in the network such as routing, management, data aggregation, etc.

Optimization refers to finding one or more solutions of a problem, which correspond to extreme values of one or more objectives. It has been an active area of research as many real world optimization problems have become increasingly complex. Therefore better optimization algorithms are always needed. Evolutionary algorithms paradigm is very suitable to solve Multi-Objective Problems (MOPs) since they are population based and can generate a set of solutions in one run. In multi-objective problems multiple criteria are considered.

II. LITERATURE STUDY

In [1] the authors have proposed a comprehensive learning particle swarm optimization based clustering algorithm for mobile ad hoc networks. It finds the optimal or near-optimal number of clusters to efficiently manage the resources of the network. The cluster-heads are used for routing network packets within the cluster or to the nodes of other clusters. It takes into consideration the transmission power, ideal degree, mobility of the nodes and battery power consumption of the mobile nodes. It is also a weighted clustering algorithm that assigns a weight to each of these parameters of the network. Each particle contains information about the cluster-heads and the members of each cluster.

In [2] the authors have proposed the weighted clustering algorithm. It elects cluster heads according to their weights. The weights are computed by combining a set of parameters such as battery power, mobility and transmission range. This was the first weighted clustering algorithm proposed for MANETs. The time required to identify the cluster-heads depends on the diameter of the underlying network. The non-periodic procedure for the selection of cluster heads is invoked on-demand and is aimed to reduce the computation and communication costs.

In [3] the authors have proposed the lowest-ID, known as identifier-based clustering algorithm. It assigns a unique ID to each node and chooses the node with the lowest ID as a cluster-head. It means that whenever a new node with a lowest ID appears, it will become the cluster-head.

In [4] the authors have proposed the highest connectivity algorithm for clustering. It is multi-cluster, multi-hop packet radio network architecture for wireless adaptive mobile information systems. In this technique the degree of nodes is calculated, which describes the number of neighbours of a given

node. Each node broadcasts its identifier for the election procedure. After computing its degree, the node having the maximum degree becomes the cluster-head. A genetic algorithm based clustering algorithm was proposed in [5]. Genetic algorithm was used to optimize the number of clusters in an ad hoc network. It

is a weight-based clustering algorithm, which assigns a weight to each objective of the problem and is set by the user.

Another clustering algorithm based on d-hops has been proposed in [6]. It forms variable diameter clusters based on mobility pattern of the nodes in MANETs. A new metric is used to find the variation of distance between nodes over time in order to estimate the relative mobility of two nodes.

The authors also estimate the stability of clusters based on relative mobility of cluster members. The diameter of clusters is not restricted to two hops as other clustering algorithms do. The diameter of clusters is flexible and determined by the stability of clusters. Nodes are grouped into one cluster, which have similar moving pattern.

III. PROPOSED WORK

PSO can handle both continuous as well as discrete variable problems. The implementation of PSO is very easy and few lines of code are required for implementation. It is also computationally inexpensive in terms of memory as well as speed and is suitable for multi-objective optimization. These features suggest that PSO is a potential algorithm for optimizing clustering in a mobile ad hoc network.

In this research work, a multi-objective particle swarm optimization algorithm to solve the problem of clustering in a mobile ad hoc network is used.

Each particle in MOPSO represents coordinates of N number of cluster-heads. MOPSO starts with population P0 of N randomly generated cluster-heads vector T, which has a unique ID in the network. Each vector T covers the whole network for communication. It is important to note that each of these particles has the following characteristics:

a) completeness, and
b) uniqueness.

It means that each particle covers the whole network as well as has the unique cluster-heads. For each solution the objectives are calculated using the respective equations. First of all we find the neighbors of the cluster-head, which is at first position in the cluster-heads vectors T and calculate the energy consumption of that cluster-head, mobility, and transmission range. In the same way we calculate all objectives for all cluster-heads.

The degree difference is calculated for each cluster-head by the equation (1)

$$\Delta = \left| d - \delta \right| \text{ - (1)}$$

In the same way we calculate the objectives for all cluster-heads in a single solution in the population. After that we sum up all the values of each objective of cluster-heads.

These summations are the overall objective values of a single solution in a population.

$$V_{id} = wv_{id} + c1r1(P_{id} - x_{id}) + c2r2(p_{gd} - x_{id}) \quad (2)$$

$$x_{id} = x_{id} + v_{id} \quad (3)$$

In the same manner we calculate the objectives of all the population. After finding the objective values, the comparison of current objective values and old objective values is taken place to find the personal best cluster-heads vector. Non-domination sorting is used for optimal Pareto front, which is used for global best cluster-heads vector.

Velocity of each individual is calculated using (2) with the help of current positions using (3), personal best positions of the cluster-heads of the current individual and the positions of global best cluster-heads vector positions.

The current positions and the velocity of each cluster head in the current vector are used for new cluster-heads vector.

After comparison an individual is selected from new cluster-heads vector or the current cluster-heads vector.

```
Randomly initialize the positions of all the nodes, the
velocity of each node and, the general parameters of PSO
FOR each particle
 DO
      (a) WHILE whole network is not covered
   DO
     i. Randomly select a cluster head
     ii. Find the neighbours of the cluster head
      (b) Remove the cluster head  and its neighbours for
next cluster head
selection process
      (c) END WHILE
END FOR
Evaluate each of the particles
Store the best cluster heads vectors
Find the global cluster heads vector from the repository
WHILE maximum number of cycles not reached
   DO
 i.    Compute the velocity (VEL) of each cluster heads vector
 ii.   Compute the new cluster heads vectors from the previous
       step
 iii.  Evaluate each of the particles in POP
 iv.   Update the contents of REP
 v.    particle's position is updated
 vi.   Increment the loop counter
END WHILE
```

IV. SIMULATION SETTINGS

100 mobile nodes starting from IP address 192.168.1.1 to 192.168.1.100 move in a 1500 x 1500 meter region for 100 seconds simulation time. The channel capacity of mobile nodes is set to the value ranging between 0.5 to 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs. It has the functionality to notify the network

layer about link breakage. We assume each node moves independently with the different mobility speed between 0.5 m/s to 3 m/s. All nodes have the different transmission range ranging between 100 to 250 meters. The simulated traffic is Variable Bit Rate (VBR) with varying initial energy between 1.75 to 2.5 joules. Since the real-time ad hoc networks are heterogeneous, in this simulation the optimum level of heterogeneity in configuring the mobile nodes is done. The simulation settings are also represented in tabular format as shown in Table.1.

Table I. Simulation Settings

No. of Nodes	100
Terrain Size	1500 X 1500 m
MAC	802.11b
Radio Transmission Range	100 to 250 meters
Simulation Time	100 seconds
Traffic Source	VBR (Variable Bit Rate)
Packet Size	512 KB
Mobility Model	Random Waypoint Model
Speed	0.5 m/s to 3 m/s

V. PERFORMANCE METRICS

a. Throughput
b. Energy consumption
c. Overhead
d. Packet delivery ratio
e. No. of Clusters formed

The above said performance metrics will be simulated using NS2 under following two major heterogeneous environments namely,

a. Mobility speed and
b. Transmission range

VI. RESULTS

Simulations are done using NS2. From the Figure1 and Figure2 it can be inferred improvement in throughput of the proposed routing protocol.

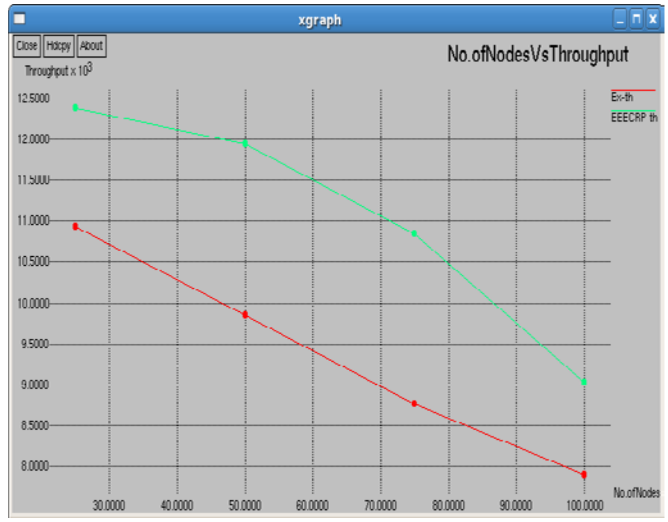

Figure 1. No.of Nodes Vs Throughput

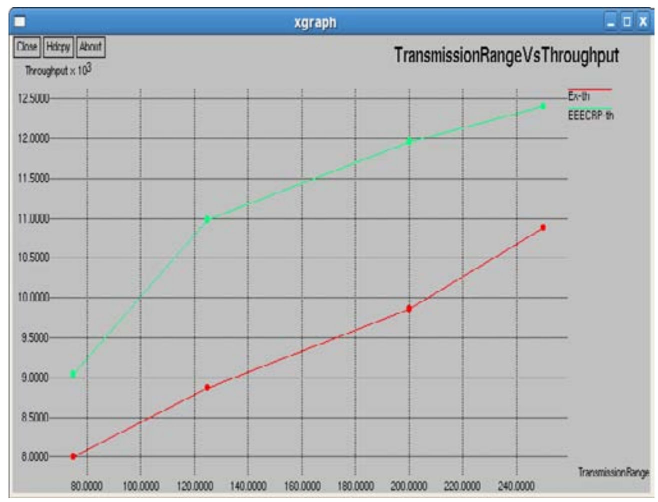

Figure 2. Transmission Range Vs Throughput

From Figure 3 and Figure 4 it can be observed the reduction of energy consumption of the proposed routing protocol.

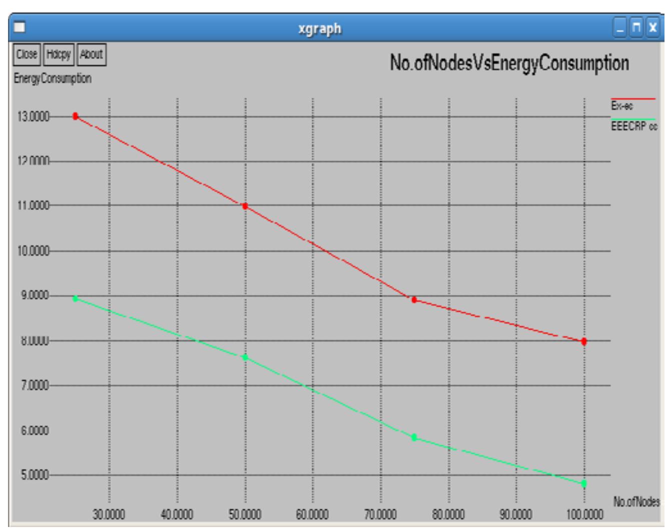

Figure 3. No.of Nodes Vs Energy Consumption

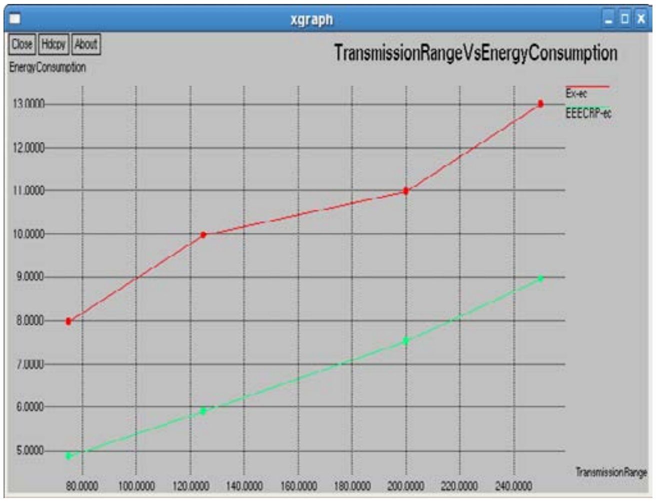

Figure 4. Transmission Range Vs Energy Consumption

The comparison on overhead packets performance is depicted Figure 5 and Figure 6. From the graphs it is shown clearly that the proposed routing protocol has reduced overhead packets that the existing routing mechanism.

Figure 5. No. of Nodes Vs Overhead

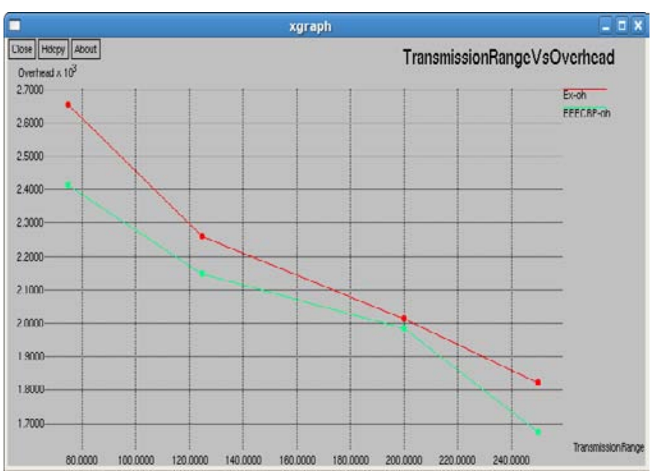

Figure 6. Transmission Range Vs Overhead

The performance of number of clusters formed is shown in Figure 7 and Figure 8. It can also be observed that the proposed routing protocol has reduced number of clusters formation and is most preferable for clustering mechanism.

Figure 7. No.of Nodes Vs No.of Clusters Formed

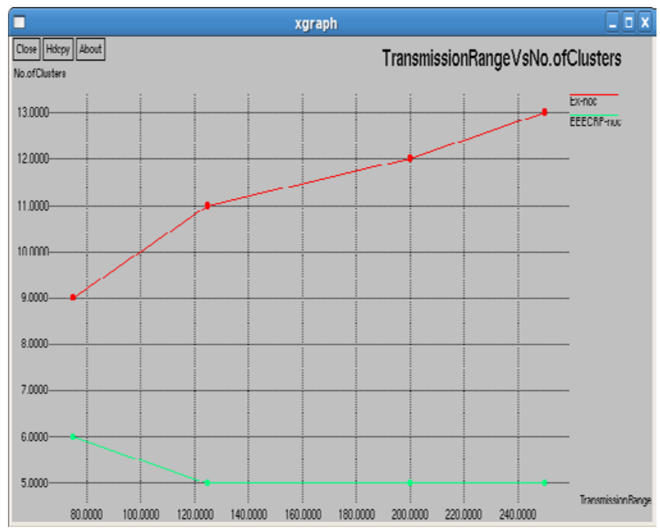

Figure 8. Transmission Range Vs No.of Clusters Formed

From the Figure 9 and Figure 10 the packet delivery ratio performance of the proposed routing protocol and existing routing mechanism is compared and it is inferred that the proposed routing protocol performs better in terms of packet delivery ratio.

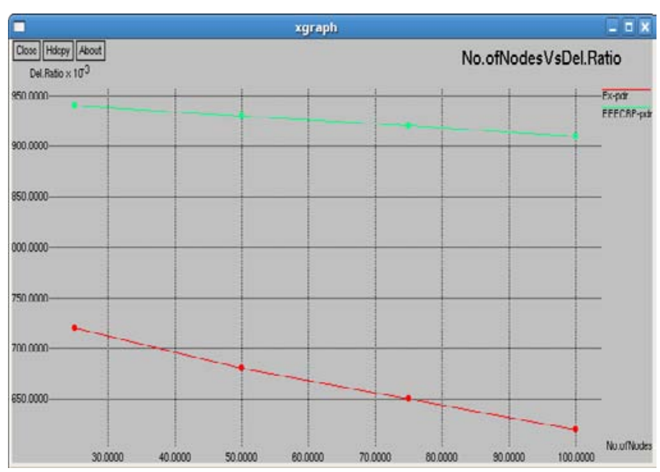

Figure 9. No.of Nodes Vs Delivery Ratio

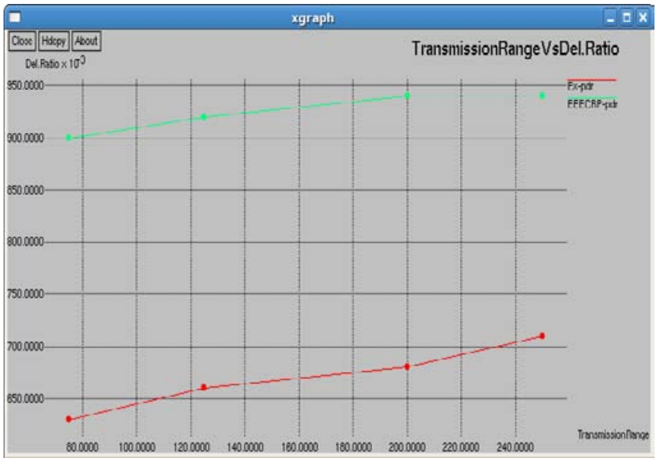

Figure 10. Transmission Range Vs Delivery Ratio

VII. CONCLUSION

In this research work an enhanced multi-objective particle swarm optimization algorithm for energy-efficient clustering in mobile ad hoc networks (MANETs) is implemented. The main constraint of MANETs is the limited battery power which leads to the computer science developers to make these networks energy-efficient as much as possible.

In the proposed research clustering is done for providing the energy-efficient solution. Furthermore, the research has the ability to find out multiple optimal solutions, which provides the flexibility of the solutions. The users can choose a solution according to their needs. By minimizing the number of clusters the routing cost of a packet will be reduced.

The proposed routing mechanism makes the energy-efficient routing because less number of nodes is involved for routing a packet. The evolutionary capability of the algorithm allows it to search large search space. It also has the advantage of dynamically adjusting objective function values instead of specifying by the user.

The simulation results that are gained from NS2 show that it is an effective and flexible approach. The results are compared with well-known clustering algorithms, i.e., WCA. The proposed EMOPSO-based approach outperforms WCA algorithm in finding optimal number of clusters as well as providing multiple options for the user.

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