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An Enhanced Forecast Weighted Clustering Algorithm for Reducing Overheads in Mobile Ad-hoc Networks

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Abstract - In this paper, we propose an enhanced forecast weighted clustering algorithm (EFWCA) which can reduce the computational overhead by electing the right candidate for the cluster head. This novel approach can handle enormous traffic and makes the network more stable. Wireless mobile ad-hoc networks (MANET) are prone to having routing issues due to their variable nature and resource constraints. Routing is an essential approach in ad-hoc networks for data transmission because every node serves as a router in the absence of a central router. Several routing schemes have been advised in order to discover route, many of which use the flooding method. The flooding method offers to discover routes through flooding of routing packets in the network. In this method routing packets are traversing throughout the network infinitely and unnecessarily consume resources such as battery power and bandwidth and cause throughput degradation. To solve the noted problem, clustering and efficient flooding methods are some of the alternatives. To form clusters and elect a cluster-head for a homogenous network, several techniques have been suggested by the researchers. Here, the suggested algorithm is simulated in network simulation and its performance is evaluated in the context of various parameters.

Keywords - Mobile Ad-hoc Network (MANET), Clustering, EFWCA, Routing

1. Introduction

A wireless network is a group of wireless devices connected by radio waves, such as laptops, wherein each device is capable of forwarding data packets to each other and can communicate over a wide range of networks. Each device works as a router as well as the host and reconfigured them self when needed. With regard to mobile ad-hoc networks, routing is an essential approach for data transmission. To make routing efficient in a highly unpredictable network, clustering mechanism is adopted. The motive behind clustering is to reduce the routing overhead occurred due to flooding of routing packets by generic routing protocols. Clustering works by splitting the network perimeter into logical regions. Each logical region is created by some criteria such as 1-hop and k-hop neighbor. The whole control of constructed region is given to one capable device that is designated as the cluster- head. In clustering, nodes are designated as cluster-heads, gateways and members or ordinary nodes according to their roles and responsibilities. Cluster-head election is one procedure in clustering, which is accomplished by following several processes and maintaining different criteria. Ordinary nodes or member nodes send packets to the cluster head or forward packets to the gateway node. Gateway nodes then forward the packets further to other clusters. This paper presents a comparative study of some of the prominent cluster-head election techniques. To ensure effective and efficient routing, it requires finding some alternate ways such as discovery of a good neighbor and logical splitting of network perimeter that is advantageous in terms of route stability and good performance. [1]

1.1 Clustering in Mobile Ad hoc Networks

The Process of dividing the whole network into sub networks or substructures which are interconnected is called clustering. The clustering technique begins with defining three important types of nodes in the network which are called Cluster head, Cluster member and Gateway node. Election of the cluster head is done by other member nodes on the specific measurements or combination of measurements such as degree of nodes, mobility of nodes, weight of nodes, etc. A cluster head serves as a coordinator for the cluster and maintains important information related to clustering algorithm which further helps nodes to exchange information for building a path. Cluster gateway is a common node between clusters, which is responsible for conveying information regarding routing from one cluster to another. Cluster members are the remaining nodes that are neither selected as the head nor the gateway of the cluster. Member nodes send packets to the head node or forward them to the gateway node. [2]

1.2 Cluster Heads Election Algorithms in MANET

In mobile ad-hoc networks, multiple algorithms have been proposed for the selection of cluster head: Highest-Degree, Lowest-id, Distributed clustering algorithm, Weighted Clustering Algorithm, Distributed Weighted Clustering Algorithm, Mobility Based Clustering and Power Based Clustering. Connectivity-based or Highest Degree algorithm is based on the total number of neighbors of a given node in which each node calculates its degree according to the number of IDs received.[3] The node having the maximum degree becomes the cluster-head. But there is no restriction on the number of nodes a cluster can serve which leads to high energy consumption and degrades the throughput and overall performance of the system. In Identifier based or Lowest-id algorithm every node is appointed with a unique ID in the network. Each node broadcasts its ID to its direct neighbors and then compares its own network ID with that of the neighbors. This algorithm performs better then Highest Degree but leads to faster battery drainage of the smaller ID nodes. In Distributed Clustering, highest weighted node according to decided parameters is chosen to be the head of the Cluster. In Weighted Clustering, the weight of each node is calculated for the election of the cluster head. All nodes must know the weight of other nodes before starting the process, which results in a high overhead. In Mobility Based algorithms, Cluster head is chosen based on the mobility of the nodes. The node with the lowest mobility is chosen to be the cluster head. In Power Based algorithms, the node having the highest battery power is elected to be the cluster head. [4]

2. Literature Review

Mobile ad-hoc networks are specified kind of networks that can easily be placed or installed without pre-existing infrastructure or centralized management systems. MANETs have a challenging environment due to the dynamic nature of mobile nodes, minimum battery power and limited bandwidth. As the nature of the nodes is dynamic, these can be grouped into clusters to reach greater stability. Each cluster has space for a number of nodes. One of the nodes is elected as the cluster head (CH) according to a system or a standard of measurement.

Mirjeta Alinci and Evjola Spaho surveyed weighted clustering algorithms. In weighted clustering algorithms, combined weight is calculated based on certain parameters like degree of nodes, distance, speed etc. Cluster head election is based on the weight of each node. Due to mobile nature of the nodes, sometimes nodes move away from the current region which in result affects the whole system. All nodes must have to know the weight of all the other nodes and have to maintain their routing tables before starting the process of clustering which thereby leads to a high overhead. [5]

Abdul Rahman and Amer Salem proposed flexible weighted clustering algorithm based on battery power which is an enhancement over WCA. This algorithm leads to a high degree of stability and limited number of clusters. It reduces the overhead by keeping a node with weak battery power for cluster-head election. Performance evaluation of the algorithm depends on a number of parameters such as total number of clusters formed, total number of cluster-head changes, re-affiliation frequency, stability, and the lifespan of a node. Simulation results of this algorithm show that it performs better then original WCA and also improves load balancing, but network traffic increases during cluster head election process which results in decreased overall performance. [6]

R. Pandi Selvam and V.Palanisamy, designed a stable and flexible weight based clustering algorithm to enhance the performance of the network. The weight of each node is considered for the election of the cluster head. Degree difference (Dv), summation of distances (Pv), mobility (Mv) and cumulative time (Tv) are the parameters for calculating the weights. After the weight calculation, each node compares its weight with that of its neighbors within two hops for cluster head election. The number of clusters can be greatly reduced by 2 hops weight based clustering algorithm. The node which has the largest weight will declare itself as the cluster head. This algorithm performs better than traditional and existing LID, HD, and WCA and is suited for different application and environments. [7]

Piyalikar, Pritam Kar, and Mrinal Kanti Deb Barma explained about the Forecast Weighted Clustering in MANET. In this cluster-based routing protocol, a cluster head is responsible for the routing process and maintains certain information like cluster membership and cluster links, based on which it is possible to dynamically discover the inter cluster routes. FWCA takes into account previous values of weights of nodes and selects the most eligible node as the cluster-head and thereby reduces the total incurring overhead. FWCA performs better than Weighted Clustering Algorithm, but overhead increases due to storing all previous values for the nodes. [8]

V.V. Neethu and Awadhesh Kumar Singh presented mobility aware clustering algorithm for a heterogeneous MANET. Higher transmission range and lower mobility are the key elements for a stable cluster-head selection that leads to lower maintenance overhead. Nodes with a high transmission range are selected as cluster heads which results in fewer numbers of clusters because a large area is covered by a single cluster-head and hence allows comparatively longer lifetime of clusters. [9]

3. Problem Definition and proposed Solution

In ad-hoc networks each node is allowed to move within the network without needing synchronization. There are many functions that can reduce network performance affecting the extent of end to end communication. In networking, there is no criterion for uniform distribution of cluster head elections. However, WCA often leads to wrong cluster-head election. This problem is solved by FWCA keeping previous weighted values of nodes apart from the current value. FWCA offers correct cluster head election but requires more memory to keep previous values. It also leads to high computational overhead and is not suitable for heterogeneous MANET environment.

To sort out this problem with FWCA and to make it effective in a heterogeneous environment, a novel approach is proposed to elect the cluster head. Unlike FWCA, this approach will keep previous values for only the nodes that did not receive a new weighted value. So it requires less memory to store data and also reduces computational overhead. Weight of each node is calculated by using weighted clustering algorithm in the following manner -

$$W_i = w_1 \cdot SS_i + w_2 \cdot TP_i + w_3 \cdot ST_i + w_4 \cdot TR_i$$

Where, SS= signal strength

TP= Transmission power

ST = Stay time

TR= Transmission range

w1, w2, w3 and w4 are the weight factors for the corresponding system parameters.

3.1 Algorithm

An algorithm is designed to understand the working of the proposed approach which is defined in pseudo code form. Designed algorithm works in a chronicle order that initiates declaration of variables to define an array of nodes, signal strength, transmission power, stay time and transmission range. The algorithm uses certain functions such as 'send' and 'receive'. The algorithm is illustrated below where node i sent a hello packet to node j and repeated to n number of nodes and discovery of neighbors is made by each node. Afterword, election process will start to elect cluster head on the basis of minimum weighted value. The node with the lowest weight is chosen as the cluster head. Weight value is calculated by each node based on the certain parameters which are Signal strength, Transmission power, Stay time and Range of neighboring nodes. At the last, a decision is made for the cluster head and algorithm is terminated.

```
Algo CHE (N [ ], id)
{
DECLARE i, j, SS, TP, ST, TR, W;
Repeat i=1 to n
    {
      Send (hello, Node[i], Node[j]);
      For all nodes
     (Node[j] ==id) in receive (hello, id)
     NB1 (Node[i], Node[j]) =1
    //Calculate signal strength, transmission power, stay time and range of neighbor's nodes.
//Determine weighted value of each node using conditional formula.  Elect cluster head with lowest weighted value.
        If (Node[i] -> receive (hello)! =NULL) {
           Wi = w1*SSi + w2*TPi + w3*STi + w4*TRi
}
           Else
           {
EFW = αWcurrent + (1 − α)* EFWprevious
           Wi = w1*SSi + w2*TPi + w3*STi + w4*TRi
           }
}
```

3.2 Simulation and Result Analysis

NS is a discrete event simulator for networking research. NS supplies widespread support for simulation of TCP, routing protocols over wired and wireless (local and satellite) networks. A simulator model in real-world system is essentially a simplification of the real-world system itself. This explanation describes some of the boundaries of the simulation model personified in the current release of NS-2. Simulation network scenario and proposed approach with several parameters is considered which are given in table1.

Parameters Name	Value
Number of nodes	40-100
Dimension of simulated area	1000×1000
Simulation time (seconds)	50
Radio range	100m
Traffic type	CBR, 3pkts/s
Packet size (bytes)	512
Routing Protocol	DSR
Connection Type	TCP

Table 1 Network Parameters and Values

3.3 Simulation Scenario: Proposed approach is simulated using table 1 parameters that creates simulation scenario shown in figure 1 and 2

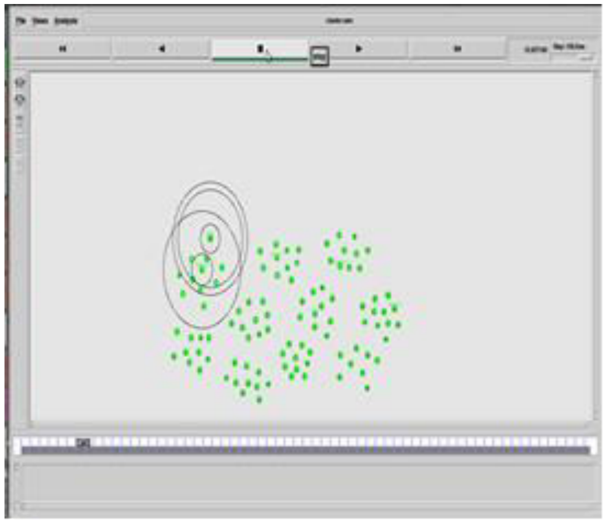

Figure 1 Simulation Scenario

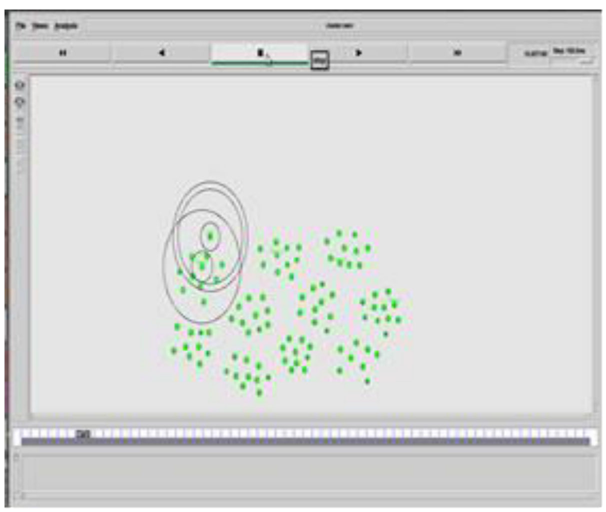

Figure 2 Simulation Scenario

3.4 Result Analysis: The result analysis of proposed approach is calculated on various parameters .Computational overhead reduction and proper cluster head selection is the motive of the approach. The network performance is evaluated by considering following evaluation parameters.

- Throughput
- Routing Overload
- Residual Energy

Throughput - Successful Data units received in form of bits, bytes or packets per unit time are known as throughput. Throughput = Number of packets received / Unit time The different values resulted and shown in the upccoming figures are according to time scale of 10,20,30,40 and so on.

Figure 3 shows the throughput of proposed method of cluster head election in which throughput is determined in bytes/sec with respect to time.

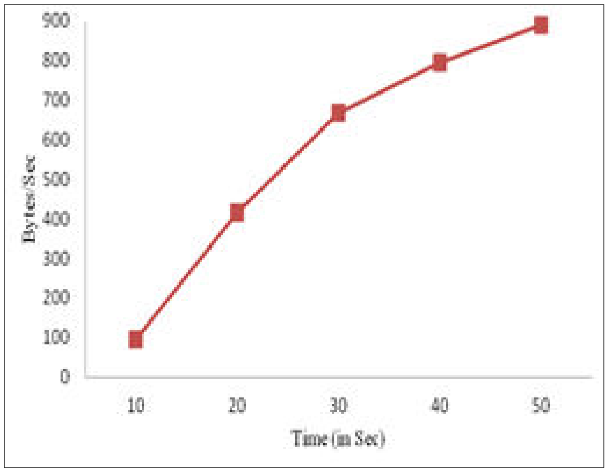

Figure 3 Throughput Graph

Figure 4 shows the throughput of generic method of cluster head election in which throughput is determined in bytes/sec with respect to time.

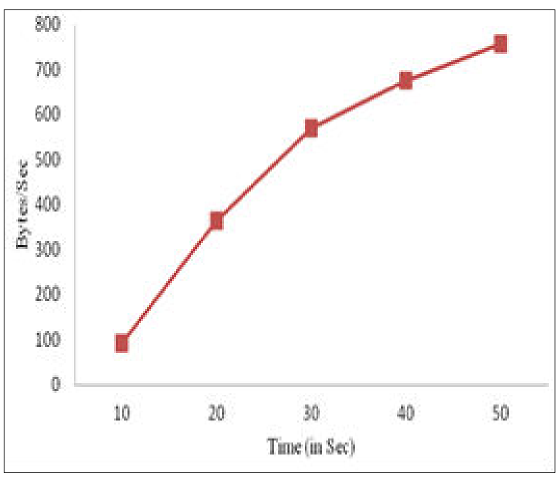

Figure 4 Throughput Graph

Figure 5 shows the throughput of both generic methods of cluster head election in which throughput is determined and compared in bytes/sec with respect to time.

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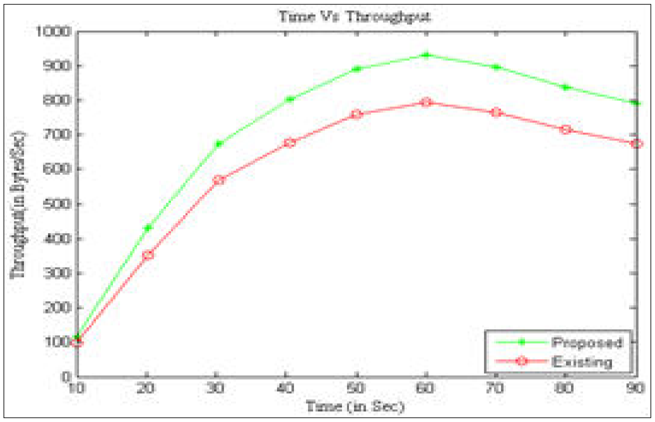

Figure 5 Throughput Graph

Routing Overload - Routing overhead is define by number of routing packets transmitted in network during route discovery and maintenance.

Figure 6 shows the routing overhead of the proposed method of cluster head election in which overhead is determined in number of routing packets with respect to time.

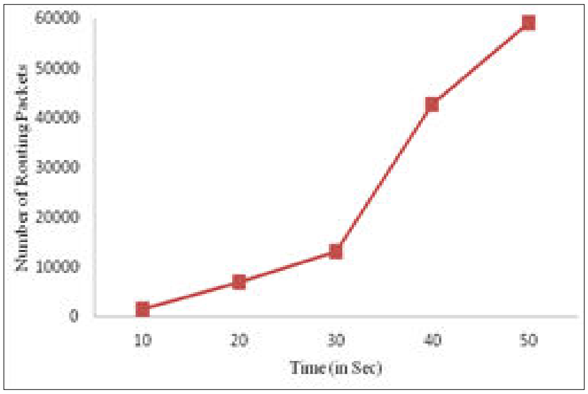

Figure 6 Routing Overhead Graph

Figure 7 shows the routing overhead of generic method of cluster head election in which overhead is determined in number of routing packets with respect to time.

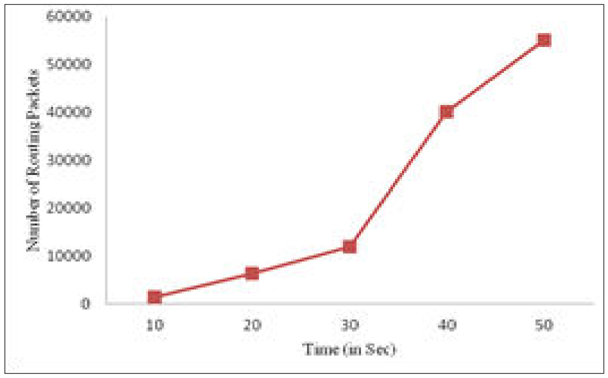

Figure 7 Routing Overhead Graph

Figure 8 shows the routing overhead of both methods of cluster head election in which overhead is determined and compared in number of routing packets with respect to time.

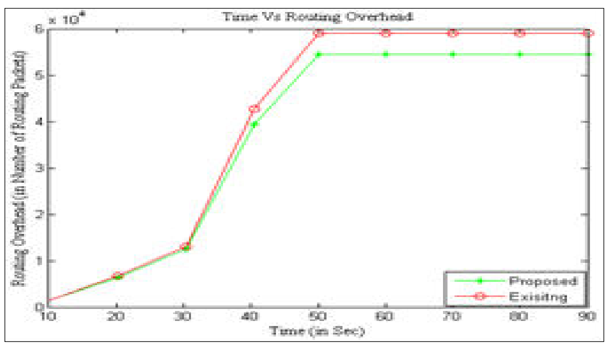

Figure 8 Routing Overhead Graph

Residual Energy- The remaining energy of network nodes after the network functioning is called residual energy.

Figure 9 shows the residual energy of proposed method of cluster head election in which it is determined as energy of each node left after the complete transmission and is represented in Joule unit with respect to node number. The different values of energy is resulted according to node number such as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.....39.

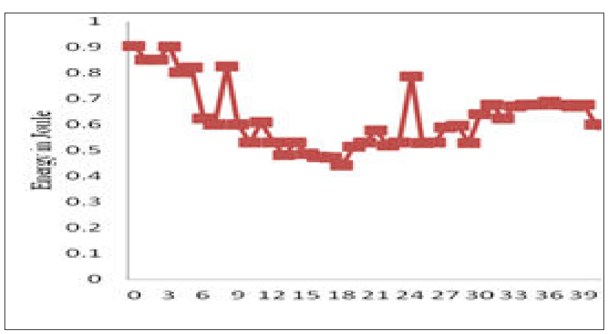

Figure 9 Residual Energy Graph

Figure 10 shows the residual energy of generic method of cluster head election in which it determines as energy of each node left after the complete transmission that represented in joule unit with respect of node number. The different values of energy are resulted according to node number such as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.....39.

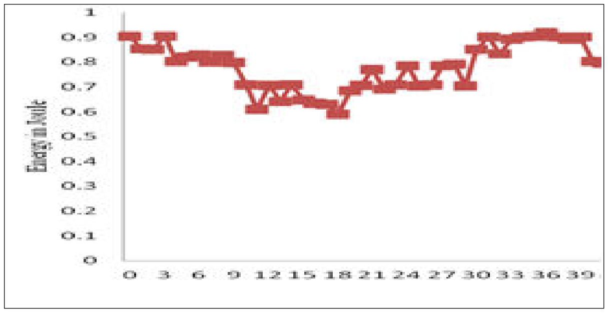

Figure 10 Residual Energy Graph

Figure 11 show the residual energy of both methods of cluster head election in which it is determined and compared as energy of each node left after the complete transmission and is represented in Joule unit with respect to node number. The different values of energy are resulted according to node number such as 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.....39.

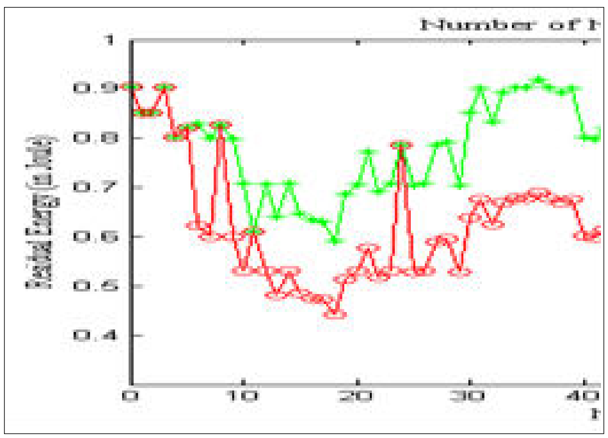

Figure 11 Residual Energy Graph

Figure 5, 8, 11 shows the comparison of the previous algorithm (FWCA) and the proposed algorithm (EFWCA) with different parameters. The simulation results are conducted in terms of Throughput, Routing Overhead and Residual Energy of the nodes. Results show that our Enhanced Forecast Weighted Clustering Algorithm give better results and reduced overhead in a heterogeneous environment.

4. Conclusion

Clustering is a key technique for organizing a mobile ad-hoc network. Clustering helps to process routing efficiently and reduce complexity of the network. Numerous clustering algorithms have been studied which helps to establish MANETs in a hierarchical manner and their main properties are presented. By analyzing it is seen that a cluster-based MANET has many significant issues to observe, such as cluster structure stability, regulate overhead of cluster construction and conservation, energy consumption of mobile nodes with dissimilar cluster-related status, traffic load supply in clusters. Hence a solution is needed which confirms the selection of a consistent cluster head which can handle extreme traffic while maintaining stability. To do this, an approach is proposed to select a proper cluster head to reduce computational overhead and to improve network performance.

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