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Load Balancing Performance of Clustering Algorithms for Mobile Ad-hoc Networks

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***Abstract**: Mobile ad hoc networks (MANETs) are collection of distributed nodes which communicate using multi-hop wireless links with frequent node mobility. The frequent mobility of nodes leads network partition and futile communication. So, there need an interconnection technique that should guarantee network connectivity, efficient routing and maintain network performance in MANET. Clustering has become an important approach to manage MANETs. This paper proposed Weighted Cluster Based Distributed Spanning Tree (WCBDST) routing technique and its performance analysis with existing clustering algorithm Cluster Based Routing Protocol (CBRP), Highest Connectivity Clustering (HCC) and Weighted Clustering Algorithm (WCA) in terms of node-reaffiliation, node re-election, number of cluster heads and cluster stability to improve load balancing. We assumed a predefined threshold for the number of nodes to be included in a cluster head to improve the load balancing.*

***Keywords**:* MANET*; WCBDST; CBRP; HCC; WCA; Node-reaffiliation; Node-reelection; Cluster Stability*

I. Introduction

Routing is a very challenging task in mobile ad-hoc networks due to their peculiar characteristics like dynamic mobility, frequent disconnections, low bandwidth, low battery power, etc. Hence traditional routing protocols like RIP [1] cannot be used in mobile ad-hoc networks. Various routing protocol schemes have been proposed for mobile ad hoc networks like table driven, source initiated on demand and hybrid protocols like AODV [2], DSDV [3], DSR [4], TORA[5], ZRP [6], CBRP[7], WCA[8], HCC[9], LAR[10]. Cluster based routing scheme provides a solution to routing schemes for MANETs by organizing the nodes into clusters to reduce communication overhead. Thus a virtual network infrastructure is created which resembles fixed network infrastructure. The number of nodes of a cluster is smaller than the number of nodes of the entire network. Each node only stores fraction of the total network routing information. Therefore, the number of routing entries and the exchanges of routing information between nodes are reduced.

II. Clustering Algorithms for Manets

A. Cluster Based Routing Protocol (CBRP)

Cluster Based Routing Protocol (CBRP) [11] is a routing protocol designed for use in mobile ad hoc networks. The protocol divides the nodes of the ad hoc network into a number of overlapping or disjoint 2-hop diameter clusters in a distributed manner. A cluster head is elected for each cluster to maintain cluster membership information. Inter-cluster routes are discovered dynamically using the cluster membership information kept at each cluster head. By clustering nodes into groups, the protocol efficiently minimizes the flooding traffic during route discovery and speeds up this process as well. Limitation of this protocol is that selection of lowest ID node as cluster head is that certain nodes are prone to power drainage due to serving as cluster heads for longer periods of time.

B. Highest Connectivity Clustering (HCC)

The Highest connectivity clustering [12] uses the degree of a node as a metric for the selection of cluster heads. The degree of a node is the number of neighbor nodes. The node with maximum degree is chosen as a cluster head. Any tie is broken by the node identifiers. As the number of nodes in a cluster is increased, the throughput drops. The reaffiliation count of nodes is high due to node movements and as a result, the highest-degree node (the current cluster head) may not be re-elected to be a cluster head even if it loses one neighbor. All these drawbacks occur because this approach does not have any restriction on the upper bound on the number of nodes in a cluster.

C. Weighted Clustering Algorithm (WCA)

WCA [13][14] selects a cluster head according to the number of nodes it can handle, mobility, transmission power and battery power. To avoid communications overhead, this algorithm is not periodic and the cluster head election procedure is only invoked based on node mobility and when the current dominant set is incapable to cover all the nodes. To ensure that cluster heads will not be over-loaded a pre-defined threshold is used which indicates the number of nodes each cluster head can ideally support. WCA selects the cluster heads according to the weight value of each node. WCA drawback is 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 high.

III. Weighted Clustered Based Distributed Spanning Tree (WCBDST)

A number of clustering algorithms have been proposed and based on some criteria to choose cluster head such as speed and direction, mobility, energy, position and number of neighbors of a given node. These works present advantages but some drawbacks as a high computational overhead. WCBDST systematize MANETs into a hierarchy of groups of nodes with weighted clustering. The nodes are put together in group's recursively. This systemization is built on top of routing tables allows effective routing in MANETs.

A. Formation of Cluster

Initially each node is assigned a unique ID value. It broadcasts its ID value to its neighbors and builds its neighborhood table. Each node calculates its own weight based on the following factors:
i) Number of neighbors (nN): The number of nodes that can communicate directly with the given node i.e. that are in its transmission range.
ii) Node energy (nE): The power currently left in each node. The energy is consumed by sending and receiving of messages.
iii) Mobility (nM): Running average of speed of each node. If mobility is less, the node is more suitable to become cluster head CH.
iv) Distance (nD): Sum of distance of the node from all its neighbors.
Initially, each node broadcasts a beacon message to notify its presence to the neighbors. A beacon message contains the state of the node. Each node builds its neighbor list based on the beacon messages received. The cluster-heads election is based on the weight values of the nodes and the node having the lowest weight is chosen as CH. Each node computes its weight value based on the following algorithm:

B. **Cluster Weight Algorithm**

Node weight (nW) is computed according to the number of neighbor nodes with in transmission range (nN), average node mobility (nM), battery power consumed (nE) and sum of distance with neighbor nodes(nD). These parameter is multiplied by some coefficient to normalized the factors and sum of these coefficient are equal to 1. Minimum weight node is elected CH

$$\mathrm{nW} = (\mathrm{w1} \times \mathrm{nN}) + (\mathrm{w2} \times \mathrm{nE}) + (\mathrm{w3} \times \mathrm{nM}) + (\mathrm{w4} \times \mathrm{nD}) \quad (1)$$

Where sum of coefficients w1+w2 + w3 +w4 = 1
Compute the running average of the speed for every node till current time T. This gives a measure of mobility and is denoted by nM as

$$\mathrm{nM} = \frac{1}{\mathrm{T}} \sum_{t=1}^{\mathrm{T}} \sqrt{(\mathrm{X}_t - \mathrm{X}_{t-1})^2 + (\mathrm{Y}_t - \mathrm{Y}_{t-1})^2} \quad (2)$$

Where (X_t, Y_t) and (X_{t-1}, Y_{t-1}) are the coordinates of the node n at time t and (t-1), respectively.
Similarly sum of distance is computed

$$\mathrm{nD} = \sum_{i=1}^{m} \sqrt{(\mathrm{X}_n - \mathrm{X}_i)^2 + (\mathrm{Y}_n - \mathrm{Y}_i)^2} \quad (3)$$

Where m is number of neighbor nodes, n is the node, (X_i, Y_i) is coordinate of i^{th} node, (X_n, Y_n) is coordinate of n^{th} node.
The WCBDST Algorithm uses five procedures. Firstly WCB*DST_initialize()* is a procedure which initializes WCBDST by creating Cluster Head (CH) and the procedure creates an array on each CH to hold its MN details. Each CH is provided with unique Priority Number (PN) to provide write priority among the CHs. WCB*DST_initialize()* also set CH id field of node as their own id and then it calls the procedure WCB*DST_probe()*[15][16].

IV. Simulation Process

We have considered CMU Monarch extension to NS-2, because it is targeted for ad-hoc network. Extensive simulations are carried out using NS-2. The NS-2 written in C++ and a script language called Object Tool Command Language (OTCL). A traffic generator named *cbrgen* is developed to simulate constant bit rate (CBR) sources. A mobility generator named *setdest* is to be developed to simulate node movement. Event type: s send, r receive, d drop, f forward. We have done simulation using NS-2 with following parameters in the given table I.

TABLE I: Simulation Parameters

Parameter	Value
Ad-hoc routing protocol	CBRP, HCC, WCA and WCBDST
MAC type	IEEE 802.11 DCF
Energy model	Node attribute: initial energy, tx Power = 0.6mW and , rxPower = 0.3mW
Antenna type	Omni directional
Simulation time	900 seconds
Terrain dimension	670m x 670m
Transmission range	250 m
Node speed	0 – 20 m/s in steps of 5 m/s
Node pause time	0-900 s in steps of 100s
Traffic type	CBR (UDP)
Data payload	512 bytes/packet
Packet arrival rate	4 packets/sec
Node pause time	0 - 900 s in steps of 100s
Bandwidth	2 Mbps
Traffic sources	10 to 50 in steps of 10
Propagation model	Two-ray ground reflection
Mobility model	Random waypoint
Interface queue type	Drop Tail/Priority Queue
Interface queue length	50 packets
Maximum number of nodes	150

V. Results and Discussion

We have compared our proposed WCBDST scheme with existing cluster based algorithms with following performance parameters.

A. Node Re-affiliation

In the cluster formation phase, cluster heads are selected for every node. By the virtue of mobility, either the cluster head or the cluster member may go out of range of each other. Node re-affiliation is very much required to retain the node connectivity in the network. CBRP results in an overall good performance among other algorithms in achieving the cluster population, re-affiliation overhead and number of reelections as shown in the figures. But the identification based weight calculation criteria biases the lower ID nodes to become the heads all the time. This may cause faster resource drainage or even node failure to such lower ID nodes.

B. Node Re-election

In the dynamic topology of MANET, cluster head may move or its raise life down signal need re-election of the cluster head. Similarly HCC succeeds in minimizing the number of clusters as shown in figure 3 so that the routing delay is minimized due to reduced number of routing heads. But at the same time the re-elections and the number of reaffiliations are compromised as shown in figures 2 and figure 1 which does not encourage a designer to choose this algorithm for implementation. In WCA initial cluster setup is delayed due to the weight calculation. However, the on demand reelection enhances the cluster stability by reducing the number of reelections in figure 2. They also provide lowest re-affiliation overhead in figure 1. In a nutshell, WCA can be better option if cluster setup delay is compromised.

Figure 1: Comparison for Frequency of Re-affiliation for 50 nodes

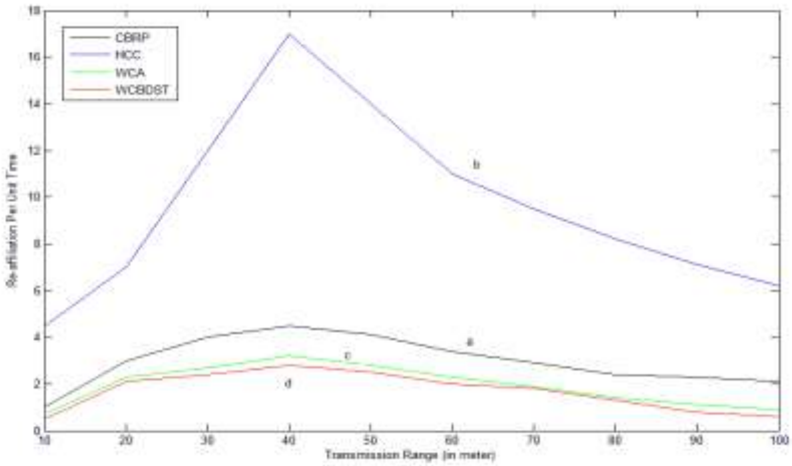
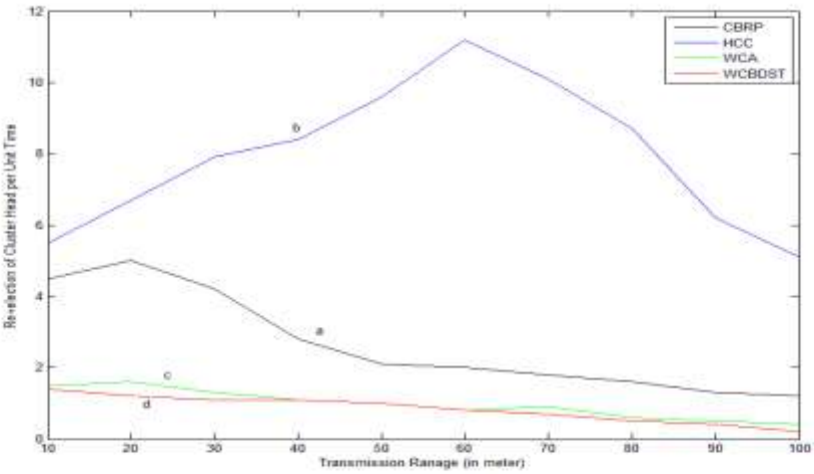


Figure 2: Comparison for Frequency of re-election for 50 nodes



C. Average Number of Cluster Heads

That means the total number of clusters that are formed in network space. Every cluster is headed by a single cluster head. This is defines the number of the dominated set and it ranges between 1 and N, where N is the number of node in the network. This parameter decides the length of communication backbone. To reduce the end-to-end delay in communication, the number of hops in the virtual back bone should be as less as possible.

Figure 3: Average number of cluster heads vs. transmission range

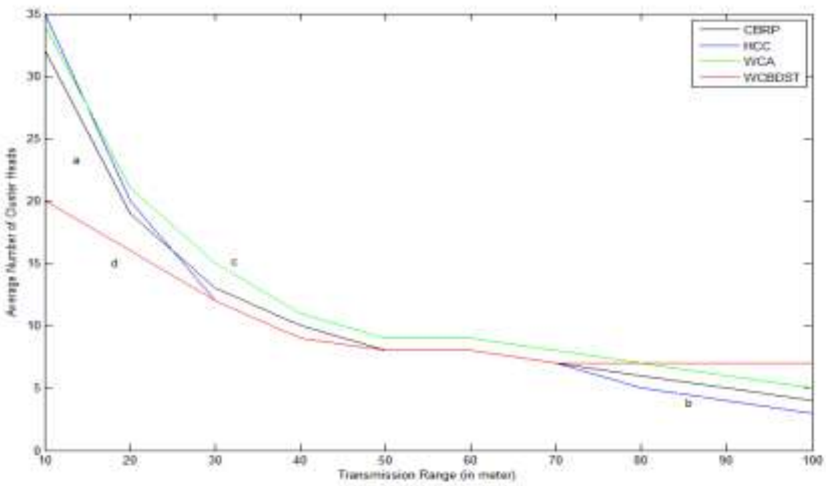
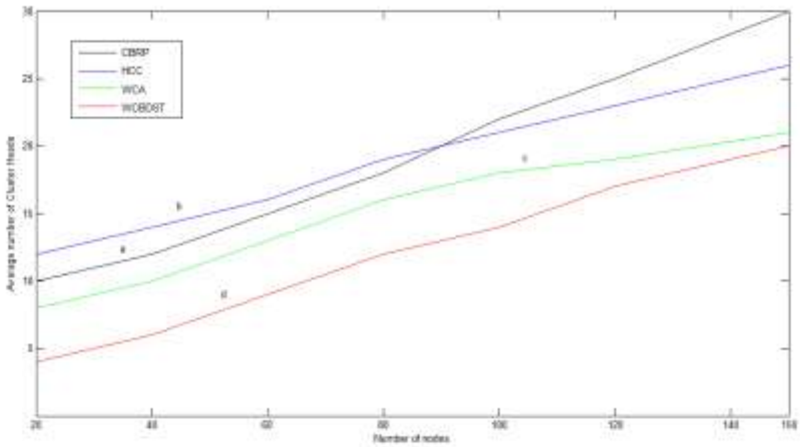


Figure 4: Average number of cluster heads vs. number of nodes



WCBDST also suffer initial cluster setup delayed as WCA. But it limited the Cluster Head re-election only when CH move or its life down falls to threshold. Average number of CHs also restricted due to stability of the head which make virtual backbone of the network.

D. Cluster Stability

The mean time for which once a node is elected as a cluster head, it stays as a cluster head. This statistic is a measure of stability the longer the duration the more stable the system. Cluster stability means the number of nodes which will be remaining in the cluster during the simulation time. The stability is decremented when a node is moved out from the current cluster and attached to another cluster. WCBDST is 20 to 30% more stable as compared to other algorithms. Stability lies between nodes 60 to 140.

Figure 5: Average number of cluster heads changes vs. transmission range

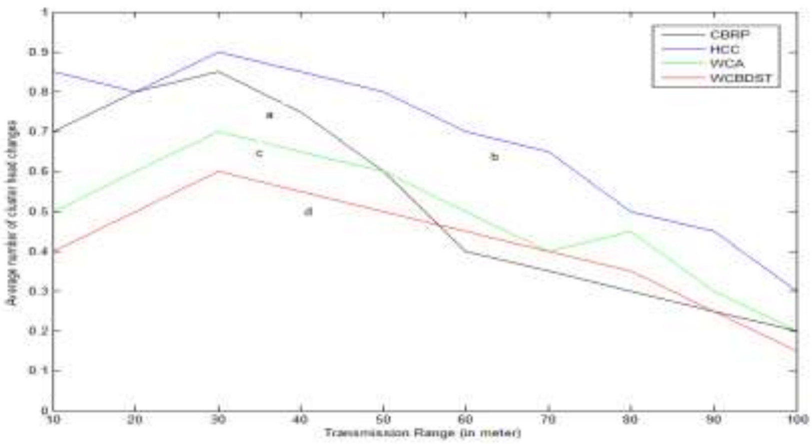
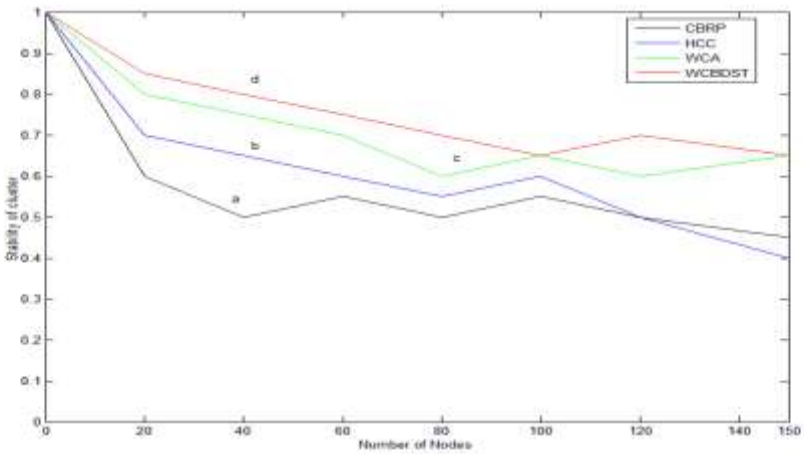


Figure 6: Comparison for cluster stability vs. number of nodes



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