



# AN IMPROVED CLUSTER BASED ROUTING PROTOCOL WITH BACKUP CLUSTER HEAD FOR MANETS

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## ABSTRACT

Mobile ad hoc network (MANET) is a reconfigurable network of mobile nodes connected by multi-hop wireless links and capable of operating without any fixed infrastructure support. In order to facilitate communication within such self-creating, self-organizing and self-administrating network, a dynamic routing protocol is needed. The routing protocol performance suffers due to resource constraints and mobility of the nodes. The existing routing challenges in MANETs clustering based protocols suffer frequently with cluster head failure problem, which reduces the cluster stability. This paper proposes, Improved CBRP, a method to develop the cluster stability and in-turn enhances the performance of traditional cluster based routing protocol (CBRP), by electing better cluster head using weighted clustering algorithm and considering some vital routing challenges. Also, proposed protocol suggests a backup cluster head for each cluster, to increase the stability of the cluster in case of unexpected failure of cluster head.

**Keywords:** CBRP, MANETs, cluster head, WCA, backup cluster.

## 1. INTRODUCTION

Mobile ad-hoc networks (hereinafter, MANETs) are infrastructure less self-organizing networks, formed randomly by mobile hosts using wireless links, and the union of which forms a communication network. Routing protocol offers communication outside the physical wireless range of nodes by relaying on intermediary nodes [1]. Due to the mobility of nodes, the network topology changes often, hence, nodes do not familiar with topology of their network. Each node studies about neighbor nodes by listening announcements (using broadcasting of packets) of other nodes [2]. Due to the existing constraints of MANETs, routing should be resource saving.

Clustering is one approach to reduce traffic during the routing process, and several authors proposed cluster based routing protocols [3], [4], [5]. All the nodes are grouped into clusters and each cluster has one cluster head in addition to many gateways; the cluster head is responsible for its cluster member, whose rebroadcast can cover all nodes in that cluster.

One of the leading protocols in MANET is Cluster Based Routing Protocol (CBRP), proposed by [6]. CBRP is an on demand routing protocol, where nodes are separated into clusters. Initially each node in the network has unsure state.

Node starts timer and broadcasts HELLO packet. If it receives a Hello reply from any cluster head then sets its state as cluster member else it makes itself as cluster head but only when it has bidirectional links with one or more neighbor nodes. Otherwise it repeats the procedure with sending HELLO packets.

Clustering is the process that divides the network into interconnected substructures, called clusters. Each cluster has a cluster head and act as a coordinator within the substructure. Each cluster head, in other terms acts as a

temporary base station within its zone or cluster and communicates with its peers. Clustering algorithm used in CBRP is a variation of simple "lowest ID" clustering algorithm in which the node with a lowest ID among its neighbors is elected as the Cluster head. Each Node maintains neighbor table and cluster adjacency table which help to has knowledge of network topology. This paper proposes a new method for electing cluster heads by considering metrics viz., node mobility, power, distance and node degree, and also suggests a backup cluster head [7] which progresses the performance of CBRP, to make the system fault tolerant. The rest of paper is organized as follows: section II presents related work on routing protocols. Section III & IV describes the proposed Improved CBRP (hereinafter, ICBRP) algorithm and section V presents ICBRP evaluation and results analysis. Finally section VI concludes with future work.

## 2. RELATED WORKS

Ref. [8] suggested a new approach to improve cluster stability, namely Smooth and Efficient Re-Clustering (SERC) protocol. In SERC, every cluster head known as primary cluster head (PCH). Each PCH elects secondary cluster head (SCH). When PCH no longer be a cluster head SCH will be cluster head. Since SCH known to all cluster members, the cluster leadership will be transferred effortlessly. Each node has four battery power levels when battery power of PCH at critical threshold it transfers its responsibilities to SCH. This approach progresses cluster stability and reduces cluster communication overhead.

Ref. [9] suggested Vice Cluster Head on Cluster Based Routing Protocol (VCHCBRP) by enhancing CBRP specifically designing self-healing of clusters. To enable self-healing they introduced a vice cluster heads concept.



In this, after election the cluster head the cluster head sends a notification to each node about this vice cluster head. If the primary cluster head dies for some reason, then vice cluster head advertises itself as cluster head, which reduces the frequency of calling cluster formation algorithm due to mobility/crash of cluster head. So it increases the performance of clustering.

Ref. [1] suggested Cluster Based Trust-aware Routing Protocol (CBTRP), which is a reactive protocol. CBTRP aimed to work in presence of malicious nodes. In CBTRP each node establishes trust among them and maintains it in a trust table. When establishing a route CBTRP ensure that all nodes in the path are trust worthy. If any node detected as malicious, then it will be isolated from the network such that no packets are forwarded through or from it. As mentioned earlier, one of the problems with any cluster based protocol is cluster head failure, which causes frequent execution of cluster formation algorithm. To avoid frequent execution of cluster formation algorithm one solution is to keep backup cluster head. Once primary cluster head fails the backup cluster head takes primary cluster head responsibilities. CBTRP uses local cluster formation algorithm to increase the cluster stability. In local cluster formation algorithm whenever a cluster head detected as malicious the next best dependable node in cluster, will be elected as cluster head. This algorithm considers only malicious cluster heads case. But there are other chances to cluster head failure which yields to frequent execution of cluster formation algorithm like cluster head moved away from the cluster and died due to lack enough energy. Therefore, ICBRP handles cluster head failure caused by node mobility and due to lack enough energy.

### 3. IMPROVED CLUSTER BASED ROUTING PROTOCOL (CBRP)

CBRP is a source routing protocol that works based on dynamic source routing. The main idea of CBRP is to divide the network into overlapped or disjoint clusters. Initially each node starts timer and broadcasts HELLO message, which carries neighbor table and cluster adjacency table. Neighbor table contains information about neighbor nodes id, status and link status, where cluster adjacency table has information about adjacent cluster head id and gateway nodes to reach that cluster head.

In CBRP, routing has mainly two phases: Route discovery and Data packets transmission. When source node wants to send data to destination node, source node broadcasts route request (RREQ) packet to cluster heads. After receiving RREQ packet it checks whether destination node is in its cluster or not. If destination node available sends request directly to it else broadcasts to neighbor cluster heads. Before broadcasting each node adds their node id to packet so it may drop packets with its id. When destination node receives RREQ packet it reply to source with route reply (RREP) packet through the nodes which are recorded in RREQ packet. If source doesn't receive RREP from destination within some time

period, it tries to send RREQ again. When source receives RREP it starts sending data packets.

Many researchers concentrated their studies on CBRP to progress its performance in different factors. The challenges for any routing in MANETs are mobility, resource constraints. Because of these issues the Cluster head may move away from the cluster or die lack of sufficient energy. So, original cluster head election algorithm of CBRP may not gave a better solution to the problem. Hence, this paper presents Improved CBRP (ICBRP) algorithm planned to provide a better solution for this problem. Main motivation for this research is to achieve significant impact in the performance of CBRP by improving the cluster stability. This proposed method significantly improves the performance of clustering algorithm than in Cluster based Routing Protocol.

### 4. WEIGHTED CLUSTERING ALGORITHM (WCA)

ICBRP makes use of Weighted Clustering algorithm (WCA) for selecting cluster heads [10] adopts a combined weight metric that takes some parameters like ideal node degree, transmission power, mobility and the battery power of the nodes to elect cluster heads. Each node calculates its weight as follows:

$$W_v = w_1\Delta v + w_2D_v + w_3M_v + w_4P_v \quad (1)$$

Parameter  $\Delta v$  represents degree-difference for every node  $v$ . Degree of the node is nothing but number of neighbors of that node (i.e., nodes within its transmission range),  $D_v$  is sum of the distances with all its neighbors. The running average of the speed for every node till current time  $T$  gives a measure of mobility and is denoted by  $M_v$ .  $P_v$  implies how much battery power has been consumed.

In equation 1, the first component,  $w_1\Delta v$ , helps to avoid MAC layer problems because it is always desirable for a cluster head to handle up to a certain number of nodes. The second component is related to energy consumption because to communicate for a longer distance it requires more power. Hence, it would be better if the sum of distances to all neighbors of a cluster head is less. The third component, mobility of the node, a cluster head having less mobility shows grater improvement on stability of cluster. Last component,  $P_v$ , is the total (cumulative) time a node act as cluster.

Battery drainage will be more for cluster heads comparing to cluster members. WCA also provides the flexibility to adjust the weighting factors according to our network requirements.

Initially each node in undecided state and calculates its weight  $W_v$ , then broadcasts their ids along with  $W_v$  values. When a node received it, it checks for the node with smallest  $W_v$  in its list and sets it as its cluster head and makes itself as cluster member. All nodes broadcast their weights along with ids in Hello message. Before every broadcast a node should calculate its weight. Every time a cluster head received a broadcast message from an undecided node, it will reply with a Hello message immediately. After receiving reply from a cluster



head, the unsure node changes its status as cluster member. When a node elected as cluster head it checks for next best node (i.e. node with smallest  $W_v$ ) among cluster members, and broadcasts it as secondary cluster head to cluster members. So when a cluster head dies for some reason, backup cluster head takes responsibilities of primary cluster head and improves the cluster stability by avoiding frequent execution of cluster formation algorithm. When two cluster heads move next to each other, then one of them will lose its cluster head position. i.e., whenever a cluster head receives a broadcast message from another cluster head, it checks its own weight with that of the other cluster head's. The one with smaller weight will be cluster head and another one with larger weight makes itself as a cluster member. If any node falls under the transmission range of two cluster heads, then the node joins to the cluster, which having a cluster head with smallest weight ( $W_v$ ). Each cluster is identified by its cluster head id.

Every node maintains data structures to store information about network. Each node has two tables: Neighbor table and Cluster Adjacency table. Neighbor table contains the information of neighbor node id and status (i.e., cluster head or cluster member), whereas cluster adjacency table consists of neighbor cluster id, ids of the gateway node through which the neighboring cluster head could be reached. Note that there may be many gateways to reach neighbor cluster. These tables are updated periodically by Hello messages.

While coming to route discovery and transmission of data, the process is same as CBRP. ICBRP differs with CBRP when a routing failed because of cluster head failure. In CBRP, while transmitting data from source to destination, if route error occurred because of some reason (i.e., the next node in the path may die or moved away from the transmission range of the node which is currently forwarding the packets), the node which found route error will try to recover the route. Otherwise, it generates route error packet and tells to source. But in ICBRP, if route error occurred, the current node first checks whether the next node is cluster head or not. If it is a cluster head, then in the path the cluster head will be replaced by the secondary cluster head of that cluster.

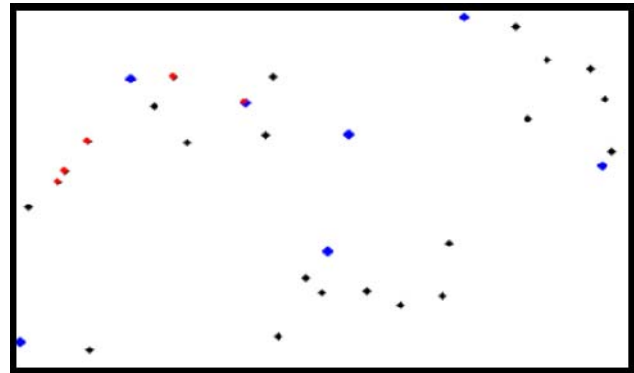
## 5. SIMULATION AND RESULTS

In this section, the proposed protocol is evaluated using NS-2 Simulator and compared with CBRP. This phase of research is mainly concentrated in the packet delivery ratio (PDR) of the network to measure the network performance. PDR is defined as the ratio of the number of packets received at the destination to the number of packets sent by the source. In this paper, authors adopted the weighing factors from WCA [10] to compute Equation (1), as follows:  $w_1 = 0.7$ ,  $w_2 = 0.2$ ,  $w_3 = 0.05$  and  $w_4 = 0.05$ .

Assumed that all nodes initially having equal power and power of the node will be reduced when a node transmits (sending its own packets or forwarding) packets and all nodes are having bidirectional links. We have

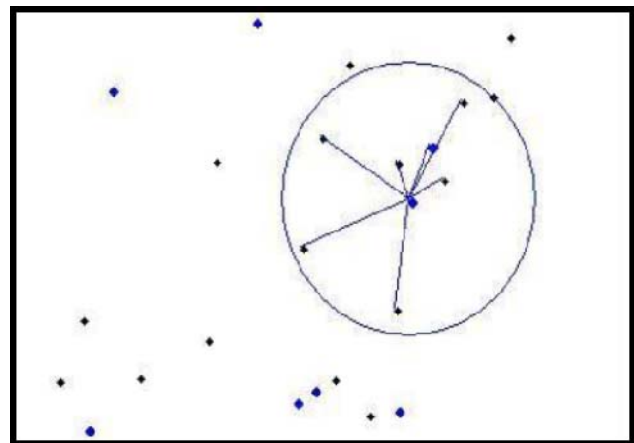
simulated a wireless ad hoc network with 60 nodes in general but nodes may vary up to 120 in some tests. The area of simulation is 500mX500m and the transmission range of the node is assumed as 100m. During the simulation the source and destinations were randomly chosen among all the nodes in the network. While coming to node mobility, destination position of each node selected randomly and moves toward the destination with 40mps with 120sec of pause time.

Figure-1 shows the test framework, where nodes are distributed randomly and cluster heads and cluster members are represented with blue and black colors respectively, and the dead nodes are represented with red color.



**Figure-1.** Randomly distributed nodes.

As discussed earlier, initially each node calculates its weight using equation 1, and broadcasts it along with their ids. The node having minimum weight will be elected as cluster head and next best one is secondary cluster head, which will be announced by cluster head. Figure-2, shows that a node broadcasting its weight to other nodes which falls within its transmission range.

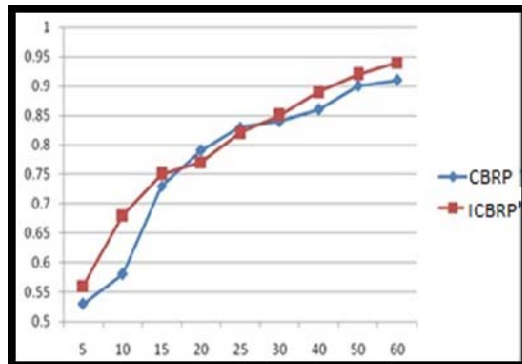


**Figure-2.** A node broadcasting its weight ( $W_v$ ).

The test results obtained with ICBRP are compared with the results (PDR) of CBRP, for various numbers of nodes



(from 5 to 60), which is presented in Figure-3. For each data point in the result, 5 simulation results were performed, then the average value is computed. From Figure-3, one can observe that the Improved CBRP performs well than the CBRP at all cases, its due to increase of cluster stability and implicitly reducing the process of cluster reformation.



**Figure-3.** Results of increasing number of nodes to packet delivery ratio.

## 5. CONCLUSIONS

The proposed Improved Cluster Based Routing Protocol (ICBRP) method, designed to progress the performance of CBRP. It makes use of the Weighted Clustering algorithm; ensures the selection of best cluster head and progresses the cluster stability by replacing cluster heads with the help of backup cluster heads, leading to infrequent execution of recreation of clusters. As the performance of network is firmly attached with the frequency of cluster reorganization, the proposed algorithm aids to reduce the occurrence of cluster reorganization and surges the network performance. The Test results show that the Improved CBRP performs better than traditional CBRP. To support Intrusion Detection System (IDS), The IDS running is carried by backup/secondary cluster head to overcome the burden on cluster head.

## REFERENCES

- [1] Safa H., Artail H. and Tabet D. 2010. A cluster-based trust-aware routing protocol for mobile ad hoc networks. *J. Wirel. Netw.* 16, pp. 969-984.
- [2] SECAN lab- Cluster Based Routing Protocol, <http://wiki.uni.lu/secanlab/Cluster+Basd+Routing+Protocol.html>.
- [3] Liu W., Chiang C., Wu H. and Gerla C. 1997. Routing in Clustered Multihop, Mobile Wireless Networks with Fading Channel. In: *Proc. IEEE SICON'97*, pp. 197-211. IEEE Press, Piscataway.
- [4] Jiang M., Li J. and Toy Y.C. 1999. Cluster Based Routing Protocol (CBRP) Functional Specification

Internet Draft. IETF Draft  
<http://tools.ietf.org/html/draft-ietf-manet-cbrp-spec>.

- [5] Gerla M. and Tsai J. T. C. 1995. Multicluster, mobile, multimedia radio network. In *J. Wireless Networks*, 1, pp. 255-265.
- [6] K. L. Pang. 2006. "Cluster head based routing algorithms and performance study for ad hoc wireless networks," School of EEE, Nanyang Technological University, Singapore.
- [7] Yuan Xue and Klara Nahrstedt. 2003. "Fault tolerant routing in mobile ad hoc networks," *Proc. IEEE Wireless Communications and Networking Conference (WCNC)*, New Orleans, Louisiana, March.
- [8] Al-kahtani S.M., Mouftah H.T. 2005. Enhancements for clustering stability in mobile ad hoc networks. In: *Proceedings of the 1<sup>st</sup> ACM international workshop on Quality of service & security in wireless and mobile networks*, pp. 112-121. ACM, New York, USA.
- [9] Yassein M.B. and Hijazi N. 2010. Improvement on Cluster Based Routing Protocol by Using Vice Cluster Head. In: *NGMAST '10 Fourth International Conference on Next Generation Mobile Applications, Services and Technologies* IEEE Computer Society, pp. 137-141. IEEE Computer Society, Washington.
- [10] Chatterjee M. Das S.K. and Turgut D. 2002. WCA: A Weighted Clustering Algorithm for Mobile Ad Hoc Networks. *J. Cluster Computing*, 5, pp. 193-204.