CBE-ABR: A CLUSTER BASED ENHANCED ROUTING PROTOCOL FOR AD HOC MOBILE NETWORKS

Shafinaz Buruhanudeen[1] , Mohamed Othman[1] , Borhanuddin Mohd Ali[2], Mazliza Othman[3]

[1]Faculty of Computer Science and Info Technology, [2]Faculty of Engineering, University Putra Malaysia, Malaysia,
43400 UPM Serdang, Selangor D.E., Malaysia
[3]Faculty of Computer Science and Info Technology, University Malaya,
50603 Kuala Lumpur, Malaysia
effynn@gmail.com, mothman@fsktm.upm.edu.my

ABSTRACT

A wireless ad hoc network is a collection of two or more devices with wireless communications and networking capabilities that communicate with each other without the aid of any centralized administrators. The network topology is dynamic, because the connectivity among the nodes may vary with time due to node mobility, departures and new arrivals. Hence, the need for efficient routing protocols to allow the nodes to communicate. In a flat topology, all nodes are of the same level and functionality, thus making it simple and efficient for smaller networks. However, when the network is large with sparse nodes, the routing information becomes more complex. This is when cluster-based techniques become useful to tackle such situations. In a cluster-based routing, all nodes in the network are dynamically organised into partitions called groups or clusters. These clusters are then combined into larger partitions to help maintain a relatively stable network topology.

KEYWORDS

Mobile Ad hoc Network, Routing Protocols, Clusters, Associativity Based Routing (ABR), Load Balance.

1. INTRODUCTION

A Mobile Ad Hoc Network is a collection of wireless nodes communicating with each other in the absence of any fixed infrastructure. MANET is a developing area of research. Efforts have been taken for achieving efficient and reliable routing in mobile ad hoc networks. Mobile ad hoc networking is an efficient way of exchanging peer-to-peer information among devices such as fixed, portable and wireless nodes. Each node in the network also acts as a router; forwarding data packets for other nodes, which in such a network move arbitrarily, thus network topology changes frequently and unpredictably. Moreover, bandwidth, energy and physical security are limited.

Most of the ad hoc routing protocols are based on flat topology, thus giving making it only practical for smaller network with packed topology. In most of the ad networks, having a dense topology might be a great weakness as many of these routing protocols might not work well at all, since there are lesser nodes to act as intermediary to forward packets from one point to another. Clustering of mobile nodes are mostly done in bigger networks, as a means to organise the nodes and make the packet forwarding task becomes more efficient. This proposal is based on the underlying Associativity Based Routing (ABR)[1] protocol with other refinements.
The organization of the paper is as such: Section 2 discusses the existing clustering techniques used in ad hoc networks followed by the load balancing approached used for mobile ad hoc

networks in section 3. The design of CBE-ABR will be covered in section 4. Section 5 talks on the future work and simulation and lastly, conclusion in section 6.

2. RELATED WORK: EXISTING CLUSTERING TECHNIQUES USED FOR AD HOC ON-DEMAND ROUTING

Since not many MANETs have been deployed, most of this research is simulation based. In a multihop mobile ad hoc network, mobile nodes move freely and communicate with their neighbouring nodes (peers) via wireless links. These nodes are basically powered by batteries, which get exhausted over a period of time, thus the amount of computations should be kept to a minimum to avoid nodes from falling off the network prematurely.

This section discusses a few cluster based routing protocols used in MANET (Mobile Ad Hoc Networks).

2.1. Densed Cluster Gateway Based Routing (DCG)

DCG is a technique used to determine clusters for ad hoc mobile networks using the k-tree core approach [2]. Connectivity between nodes are determined by the wireless range of broadcast signal. First, a distributed spanning tree, which is the sub graph of the network topology is constructed and the root is selected towards the centre of the network as possible. During the construction, the edges of the trees are monitored and tracked. These edges are categorised by colors- yellow edges and green edges. The use of color attribute in DCG determines the role of the edge on the tree formed. It uses a two-tier hierarchical routing scheme which combines the optimality of the shortest path algorithms and at the same time restricts flooding of control packets utilising the low overhead of the on-demand algorithms. Cluster heads and gateways are used as special nodes which have added responsibilities over the ordinary participating nodes in the network. A cluster head keeps track of all the members (nodes) in a cluster, and the routing information needed. The gateways are the nodes at the border or edge of a cluster and communicate with the gateways of neighboring clusters.

2.2. Associativity Based Clustering (ABC)

Associativity Based Clustering (ABC) is a strategy proposed using the ABR protocol as its base to support location based routing protocol [3]. ABC presents framework for dynamically organizing mobile nodes and electing a dominating set in a highly spontaneous large scale mobile ad hoc networks. A node is selected as the cluster head based on nodes having associativity states that imply periods of spatial, temporal and stability. The results of simulation show that it is more dynamic, distributed and adaptive. ABC considers mobility of nodes as main criterion in the cluster head election process thus ensuring stable cluster formation. A cluster head us elected based on spatial associativeness and based on the notion of virtual-clusters. The location information maybe then obtained using Global Positioning Systems (GPS) or other self positioning algorithms. Existing solutions to this problem are based on the heuristic (mostly greedy) approaches and none attempts to retain topology of the network.

2.3. Adaptive Clustering for Mobile Wireless Networks

Adaptive Clustering in this paper takes advantage of network locality [4]. This particular work presents an architecture for multimedia support in a multihop mobile network [4]. The algorithm works as such each node only broadcasts one cluster message before the algorithm stops, and the time complexity is O(|V|) where V is the set of nodes. The clustering algorithm converges rapidly and in the worst case, the convergence is linear in the total number of nodes.

2.4. Mobility Based Framework (α,t) for Adaptive Clustering

This work presents a novel framework for dynamically organizing mobile nodes in wireless ad hoc networks into clusters, in which the probability of path availability can be bounded [5]. The objective of this (α,t) is to maintain an effective topology that adapts to the node mobility so that routing can be more responsive and optimal when mobility rates are low and more efficient when they are high. This is made possible by using a simple distributed clustering algorithm using probability model for path availability as the basis for clustering decisions. The algorithm efficiently maintains the cluster topology with very little additional processing or internodal coordination.

3. Load Balancing in Mobile Ad Hoc Networks

Fair route relaying load (load balancing) is also important as no one particular mobile node should be heavily/ unfairly burdened to support many routes and to perform many packet relaying functions. This is about fairness for all nodes in the network, and even route relaying load can alleviate the possibility of network congestion in an ad hoc mobile network. The key argument lies on the fact that selecting a route based on shortest path is useless if the path is going to be broken in the next instance due to nodes mobility or power run-down. Hence, it makes sense to select nodes to form a route that is likely to last over time and at least at the lifetime of a connection. If one can transmit all information quickly throughout the active time of the connection, then performance would be worth it. In ad hoc networks, only ABR considers the load as the metric. ABR, however, uses the routing load as the secondary metric. Furthermore, the load is measured in the number of routes a node is a part of, and hence the protocol does not account for various traffic loads of each data session.

Reference [6] presents Dynamic Load-Aware Routing (DLAR) protocol. DLAR considers the load of intermediate nodes as the main route selection metric and monitors the congestion status of active routes to reconstruct the path when nodes of the route have their interface queue overloaded.

A new protocol to enhance path reliability and realise load balancing in mobile ad hoc networks was introduced in [7]. These goals are achieved through fully exploiting the presence of multiple paths in mobile ad hoc networks in order to jointly attack the problems of frequent route failures and load balancing. The system assumes the use of the on demand routing protocol and the basis of the system is lightweight path monitoring mechanism for handling route failures proactively. Another study on load balancing is done in [8]. The protocol introduced is a multipath routing protocol with a load balance policy. The simulation results from this work show significant improvements in terms of connection throughput and end-to-end delay when compared to single path routing. Another contribution of the paper is a theoretical analysis allowing to compare reactive single path and multi path routing with load balance mechanism in ad hoc networks, in terms of overheads, traffic distribution and connection throughput. The results reveal that using multipath routing using a load balance policy provide better performance than reactive single path routing in terms of congestion and connection throughput.

The common belief is that multipath routing distributes the load significantly better than single path routing. However, this is not always the case. Authors in [9] introduce a model for evaluating the load balance under multipath routing and show that unless there is a very large number of a path (which is costly and therefore infeasible) the load distribution is almost the same as single path routing.

CBE-ABR algorithm considers a queuing theory model, where among metrics involved (within a cluster) includes number of load in the cluster, number of load for each node in the cluster, number of packets in service, and the time taken for each task in queue within a cluster. Packets

or jobs arriving will be in random arrival pattern or Poisson Arrival process. No one particular cluster or node should be highly burdened in the mobile network, as mostly, the centre clusters would cause a bottle neck situation.

For each node, a simple M/M/1 queue is included in the CBE-ABR algorithm. Figure 1 shows the queuing concept suggested within each cluster. For each node, there is a simple M/M/1 queue, and if the queue at node a is full, the packet/ task is forwarded to node b in the same cluster, or otherwise, be in the queue again until the previous task has finished being forwarded to the next intermediate node.

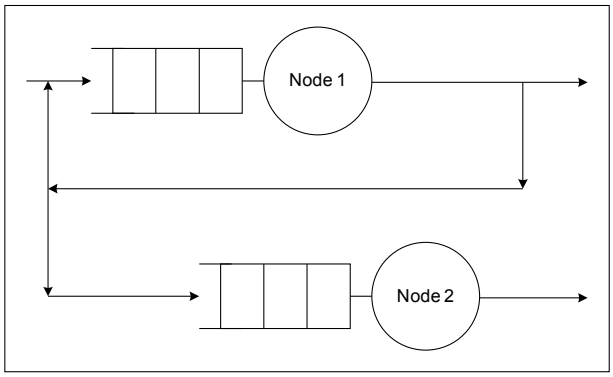


Figure 1: A Simple M/M/1 Queue

4. CBE-ABR DESIGN

Having studied the work done on wireless ad hoc cluster based routing and taken into account the drawbacks and deficiencies of other approaches, the proposed cluster based routing protocol tackles these issues in terms of i) cluster head selection, ii) neighbourhood discovery iii) load balancing within clusters and iv) route reconstruction/ maintenance phase.

4.1. Further Subsections

The objective of clustering is to partition the network into several groups of clusters. Cluster size is determined by the tradeoff between channels, delay, load relaying load, transmission power and geographical layout. For the cluster algorithm, assumption that the transmission power if fixed and uniform across the network is necessary. Within clusters, nodes can communicate (via wireless radio range) with each other in at most two hops. These clusters are constructed based on node ID, load serving at each node and other metrics specified in the ABR protocol especially the Associativity Stability known as associativity ticks. Each cluster would be equally distributed with nodes having high and low associativity ticks- high ticks shows that nodes are stable and are of lesser probability to move away. Lower associativity ticks denotes that nodes might be mobile within the cluster or might even move out of the cluster. However, in a cluster based protocol, even when an intermediate node is moving out, if it is still moving in the same cluster, then, it is still used to relay packets to reach destination. Only when it moves out of its cluster, a new node in a nearby cluster will be chosen.

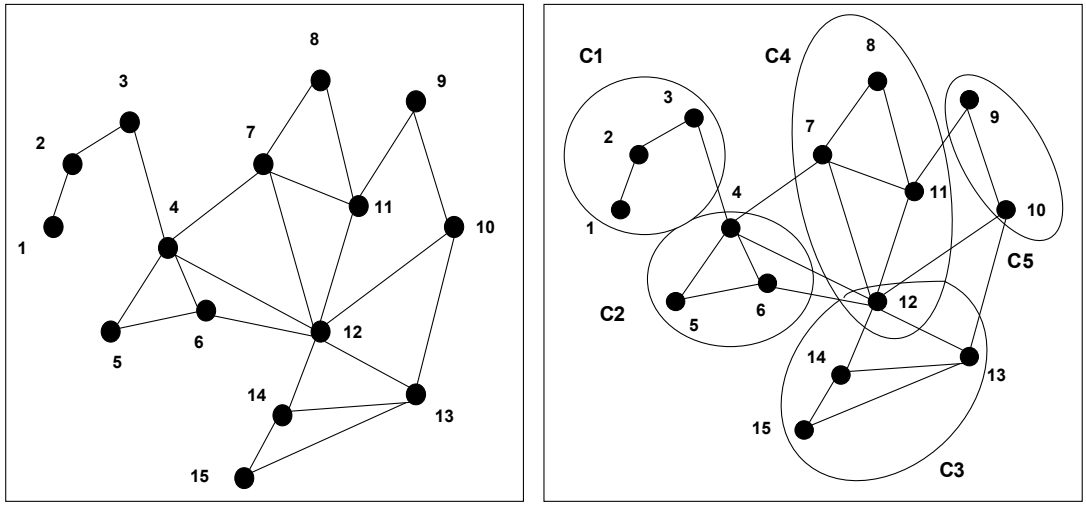
The algorithm suggested would make it possible to partition the multihop network into some clusters- and these clusters could also be overlapping each other to the maximum number of 3 nodes. This means, each node can also be a member of 1, 2 or maximum 3 clusters- and each cluster will have a cluster head who would determine the routing decision within each cluster.

The following operational assumptions are made:

i. Every node in the network has a unique ID. If a node shares more than 1 cluster, it would still use one ID for all the clusters it is a member of.

ii. A message sent by a node is received correctly within a finite time by all it's 1-hop neighbours. After this allocated time, the message will be timed out and a new request will be broadcast within the network (be it new broadcast or a local repair broadcast).

iii. Network topology maintains the same- no increase or decrease of network size during the algorithm execution. However, nodes leaving and entering the network is allowed as long as the network size maintains the same. There is a max nodes number within the network, in which, exceeding this number is not allowed.



a. Before clustering

b. After clustering

Figure 3a: Network topology with 15 mobile nodes
Figure 3b: Clustering of mobile nodes with 5 clusters

The proposed algorithm was designed with 2 objectives in mind, which is i) to achieve a stable and efficient cluster topology and ii) cluster topology should be achieved with minimal cost overhead and minimal complexity.

The algorithm covers node activation (whether or not node has a neighbour and a cluster already), link activation (if node has no cluster, than, whether or not it will join any clusters or it should be left without one-orphan), link/ cluster failure, local route reconstruction within clusters and also a set of algorithm to determine the routing procedure given that each cluster has their own loads. The algorithm details will be discussed in future work with the simulation results of this algorithm.

4.2. Cluster Head Selection

It is important for each cluster to have a cluster head- to maintain and control the mobility and also to control the routing decisions. Cluster head is also responsible to make sure non of its nodes in the cluster is overly burdened, as it might result in high cost and routing overhead (as a result of node movement, node failure or packets lost).

Once a node is elected as a cluster head, it is desirable that the node becomes the head up a maximum specified amount of time to meet the characteristics of the system such as battery life of individual nodes, associativity ticks, load relay, and location of the cluster head node within the cluster. The cluster head would also have the intelligence to organise route forwarding and

route maintenance procedure. When a cluster head is about to 'resign or retire', it will send out a 'check_for_new_cluster_head' message along with the radius value to its neighbouring nodes in search of a new head.

4.3. Maintenance Phase

The maintenance phase is mainly concerned with the local route reconstruction mechanism which was introduced in the ABR protocol. For this enhanced cluster based protocol suggested, a cluster based local route repair mechanism is proposed. The state machine diagram below shows the transitions occurred during a route reconstruction phase.

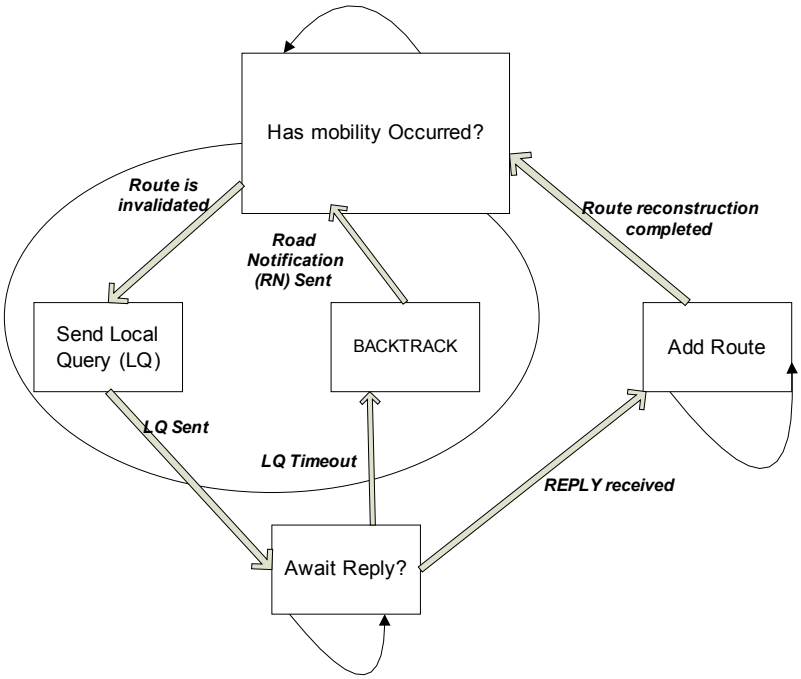


Figure 4: CB-ABR Maintenance Phase

The shaded partition is the area where enhancements and modifications are done in the CBE-ABR. The backtracking procedure and the local route reconstruction methods proposed by previous work will be modified in order to achieve better overhead and overall reliability and efficiency. Instead of repairing node by node, this suggested scheme would repair local clusters instead. In the event that an affected node moves out of the cluster, then, another node within the cluster would be selected. This scheme also employs the multipath route selection method.

Since the proposed CBE-ABR takes the notion of inter-clusters, in the case of the destination cluster (the particular destination node where resides in the cluster, called destination cluster) moves out of range, then, the following mechanism applies.

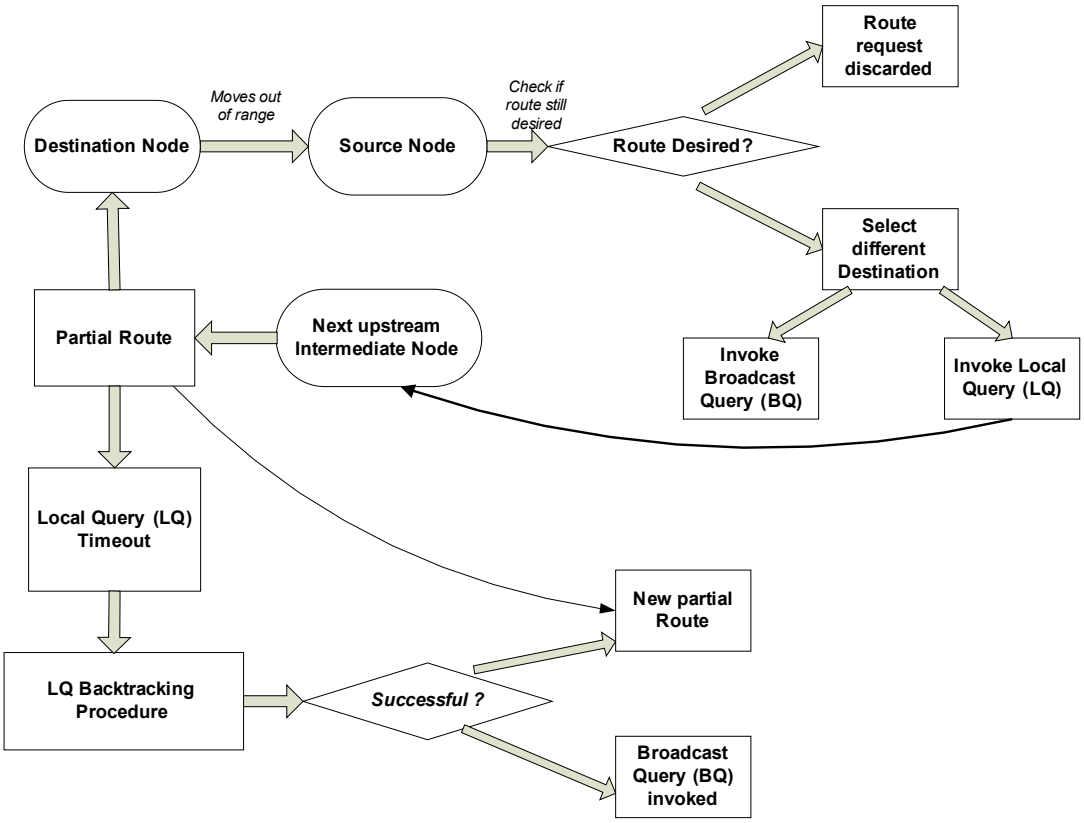


Figure 5: Processes involved when the destination cluster moves out of range

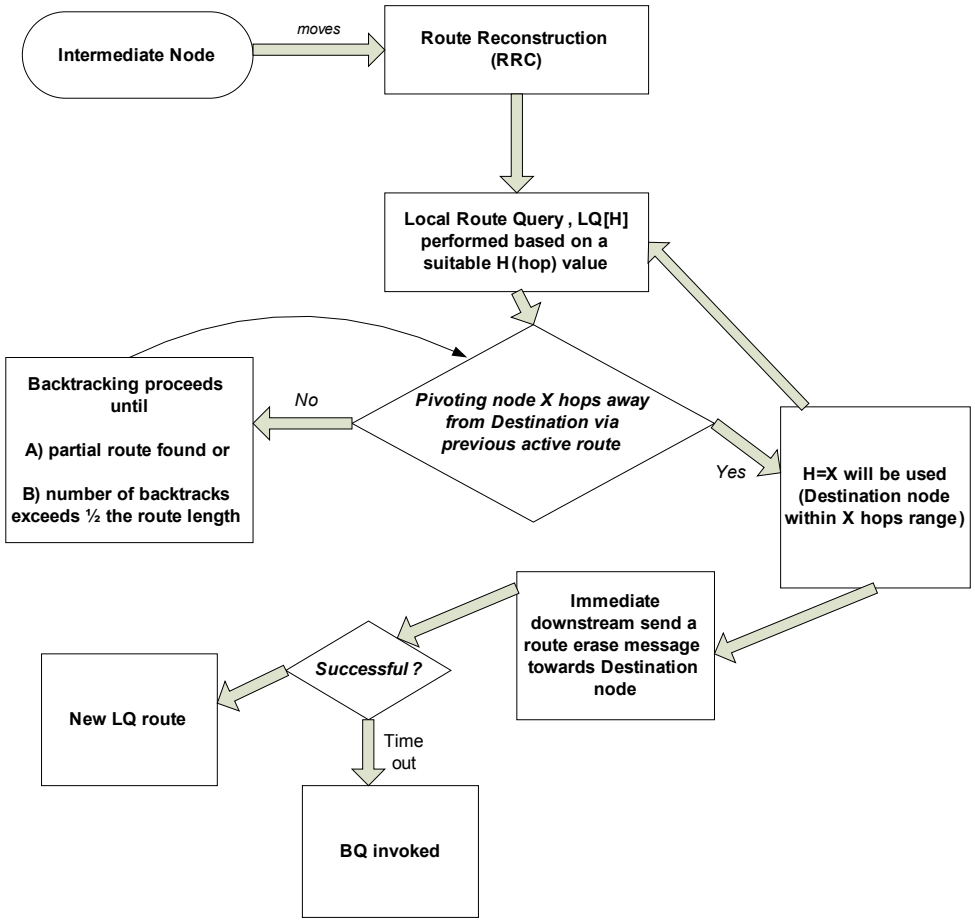


Figure 6: Processes involved when the Intermediate cluster moves out of range

In all these diagrams, movement between nodes refers to the inter clusters, where each cluster contains the mobile nodes.

4.4. Routing Algorithm

The routing algorithm of CBE-ABR is based on on-demand ad hoc multiple routing based on clustering techniques. Unlike the original ABR, CBE-ABR would find multiple routes which have the advantages of easy recovery from route failure and thus making it more robust and reliable. Source node would usually have the advantage to select the best route among the multiple available routes. The multipath routing protocol proposed here seeks to reduce the number of route discoveries and average end-to-end delay by providing alternative routes between source and destination nodes. Several route selection criteria was used to find the most effective method used in the creation of multipath routes. The selection criteria include cluster based node-disjoint, cluster based partial node-disjoint and cluster based intermediate node-disjoint. Results from previous researchers show that the most effective technique is partial node-disjoint multipath routing.

5. SIMULATION

The proposed algorithm, CBE-ABR will be simulated using Java. The mobility model used will be the freeway model and the ad hoc and cluster based broadcasting techniques will be assigned

to the simulation. Among parameters of interest include control packet overhead, route discovery time, data throughput and end to end delay.

6. Conclusions and future work

This proposed study would have the potential of adding a novel protocol into the MANET family which is comprehensive of all aspects of importance in a MANET network. From this research, an improvised version of ABR will be developed incorporating features which are not readily available in the original version of ABR. The proposed protocol, IABR would benefit a lot of mobile networking enthusiasts into implementing the protocol in their respected fields of interests. It is expected that IABR would be both efficient and effective compared to the existing ABR protocol and would cover a wider range of possibilities in terms of its routing metrics. It is expected to give a higher route establishment rate with lesser route breakage. On top of that, it is also expected to balance the load in the mobile network thus producing higher throughput and better overall performance.

Future work includes simulating the proposed algorithm to determine the effectiveness and the robustness of the proposed cluster based ad hoc routing algorithm and comparing it with the non-cluster based ABR. Besides that, the efficiency and reliability of this proposed algorithm will also be compared to the other cluster based protocols suggested by other researchers.

References

[1] C.K.Toh, (1997) "Associativity Based Routing for Ad Hoc Mobile Networks", *Wireless Personal Communications Journal, Special Issue on Mobile Networking and Computing Systems,* vol. 4 issue 2, pp 103-139.

[2] R.K.Ghosh, V. Garg, M.S. Meitei, S.Raman, A.Kumar, N.Tewari, (2006) "Dense Cluster Gateway Based Routing Protocol for Multihop Mobile Ad Hoc Networks", *Ad Hoc Networks Journals,* vol. 4 issue 2, pp 168-185.

[3] Y.Choi, D.Park, (2002) "Associativity Based Clustering and Query Stride for On Demand Routing Protocols in Ad Hoc Networks," *Journal of Communications and Networks (KICS),* vol. 4 issue 1, pp 4-13

[4] C. R. Lin, M.Gerla,(1997) " Adaptive Clustering for Mobile Wireless Networks," *IEEE Journals on Selected Areas in Communications,* Vol 15 Issue 7, pp 1265-1275

[5] A.B.McDonald, T.F.Znati, (1999) "A Mobility-Based Framework for Adaptive Clustering in Wireless Ad Hoc Networks," *IEEE Journal on Selected Areas of Communications,* Vol.17 Issue 8, pp 1466-1487

[6] Sung-Ju Lee, Mario Gerla,(2000) "Dynamic Load-Aware Routing in Ad Hoc Networks," *Proceedings of The Third IEEE Symposium on Application-Specific Systems and Software Engineering Technology.*

[7] Antonios Argyriou, Vijay Madisetti, (2006) "Using a new protocol to enhance path reliability and realise load balancing in mobile ad hoc networks," *Journal of the Ad Hoc Networks,* vol.4 Issue 1,pp: 60-74.

[8] Peter P.Sham, Sylvie Perreau, (2004) "Increasing the network performance using multi-path routing mechanism with load balance*," Journal of the Ad Hoc Networks,* vol.2 issue 4, pp: 433-459.

[9] Yashar Ganjali, Abtin Keshavarzian, (2004) "Load Balancing in Ad Hoc Networks: Single-path Routing vs. Multi-path Routing," *INFOCOM 2004. Twenty-third Annual Joint Conference of the IEEE Computer and Communications Societies,* Vol. 2, pp. 1120-1125.