# A Mobility Tolerant Cluster Management Protocol with Dynamic Surrogate Cluster-heads for A Large Ad Hoc Network

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**Abstract.** It is not a trivial job to maintain clusters in a highly mobile ad hoc scenario where changes in node activity status cause frequent and unpredictable topological changes. It requires continuous and efficient management protocol for frequent up-dation and re-clustering which are costly in a resource-poor environment. In this context, we describe a convenient cluster management protocol that incurs very little communication overhead for maintaining a stable cluster structure. Our protocol defines a geographical boundary for each cluster using GPS information that enables the mobile nodes to get alarmed while crossing the cluster boundary. Here a cluster-head is also free to leave the cluster after delegating the leadership to a member-node, which will then act as a surrogate cluster-head of the cluster. The simulation results indicate that this mechanism reduces as much as 30% of the overhead traffics involved in cluster maintenance.

## 1 Introduction

The clustering is always of significant importance for network management, routing methods, QoS, resource allocation, topology update effect and in this context, they should be maintained and managed efficiently. This task becomes complicated in a highly mobile scenario and results in much overhead with increase in cluster size [2, 3, 4]. Existing periodic trigger based clustering management protocol incorporates large intra and inter-cluster traffic that degrades the performance of the network as a whole.

Here we describe a convenient and a low cost cluster management protocol for large mobile networks. We assume that the locations of the nodes are available directly using GPS (Global Positioning System). Clusters are formed initially using a modified Max-Min-D-cluster formation algorithm [1] and we propose to construct a static geographical boundary for each cluster using GPS of the boundary nodes. In this protocol the nodes are free to move from one cluster to another keeping the cluster structure entirely stable within the defined region boundary. This boundary information is available with all the members of a cluster. Our technique enables all the nodes of a cluster to get alarmed while crossing the cluster boundary and is able to generate a timely request for unbind and bind with old and new cluster-head respectively.

This paper also proposes a novel optimistic cluster head-surrogating scheme for achieving efficiency in mobile cluster management process. In this scheme a cluster-head is also free to leave its cluster after delegating the leadership to any member-node of its current cluster. This member-node now will act as a surrogate cluster-head of the cluster. The process actually duplicates a copy of headship program and related member information list to the selected surrogate-head. This particular technique of defining the clusters with fixed boundaries has following advantages.

1. The cluster structure becomes robust in the face of topological changes caused by node motion, node failure and node insertion /removal.
2. Conventional beacon-based cluster management algorithms require the entire network to reconfigure continuously, while in GPS based cluster management protocol the impact of node mobility has been localized within the cluster and its immediate neighboring clusters.
3. The ability of surrogating cluster headship from a mobile cluster head to any of its neighbor.
4. Independent and autonomous cluster control and maintenance by the mobile members only.
5. No performance degradation of the network due to cluster management protocol.

## 2 GPS bounded Cluster Structure Algorithm

To obtain the initial set of clusters, we referred a leader election algorithm - Max-Min D–Cluster Formation algorithm proposed by Alan D. Almis, Ravi Prakash, Vuong Duong and T. Huynh [1]. There are several advantages for using Max-Min D–Cluster Formation algorithm over other existing clustering algorithms like the nodes can asynchronously run the heuristics so no need for synchronized clocks, we can customize the number of clusters as a function of d.

In our proposed GPS based clustering algorithm we have used the initial leader election part of the Max-Min D–Cluster algorithm in the first phase. In the second phase the elected leader or the cluster head will be able to recognize its boundary by getting the GPS information from all of its member nodes and will announce this boundary location values within d hop. Thus all the member nodes get alarmed about the current cluster boundary and will utilize this value while going out of this cluster. The cluster boundary algorithm can be explained in two phases.

**Phase I Max-Min D–Cluster Formation algorithm:**

1. At some common epoch each node initiates **2d** rounds of flooding of information exchange (**node id**) where d is the given heuristic. Each node maintains a logged

entry of two arrays, **WINNER** and **SENDER** to store the results of each flooding round.

2. Initially each node sets its winner to be equal to its own node id.
3. This is the phase for **FLOODMAX** where a node chooses the largest value among its own **WINNER** array and this process continues for d rounds.
4. This **FLOODMIN** phase follows **FLOODMAX** where a node chooses the smallest rather than the largest value as its new **WINNER** to reclaim some of their territory.
5. After these two d rounds of information exchange a node is able to determine its cluster- head.

The existing Max-Min D–Cluster Formation algorithm can be stopped here and as the head selection procedure is over we can now proceed to define a static geographical boundary for the clusters. This geographic boundary can be easily defined with the absolute coordinate position (GPS) of the nodes lying at the boundaries.

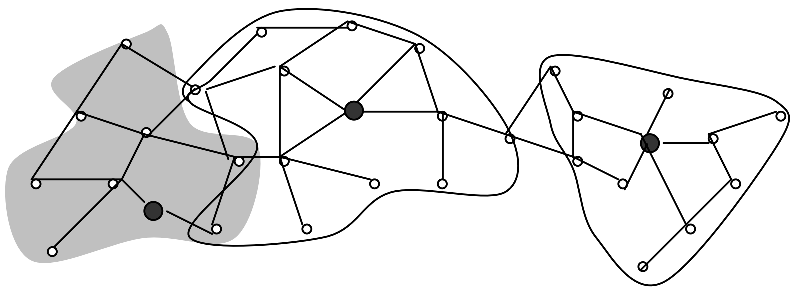


Fig. 1. Initial Cluster structures formed with Max - Min -D Clustering.

**Phase II : Cluster Boundary Formation algorithm:**

1. The cluster head broadcasts get**_Position_ forAll ( )** request message along with its own GPS to get percolated within d hop.
2. All member nodes in turn unicasts back the message **node_GPS ( )** to the cluster-head using geographical routing.
3. Cluster-head receives all the GPS values of its members and calculates the maximum limiting coordinates for Left, Right, Up and Down values to define its boundary.
4. The cluster head then broadcasts the message **get_Boundary_values( )** within the d hop transmission range to notify all the member nodes about the cluster boundary.
5. All the member nodes become alarmed about the rectangular cluster boundary information that can be verified while changing their positions.

Thus our GPS based clustering algorithm will partition the network into a number of geographically overlapping clusters. These cluster boundaries are static, and are not required to be redefined with the mobility of the boundary nodes. This boundary value will be once notified to all the members of a cluster and will remain fixed until all the nodes move away from this region. In that case only the cluster–head will recall the initial clustering algorithm to remain connected and the cluster boundary does not exists any more.

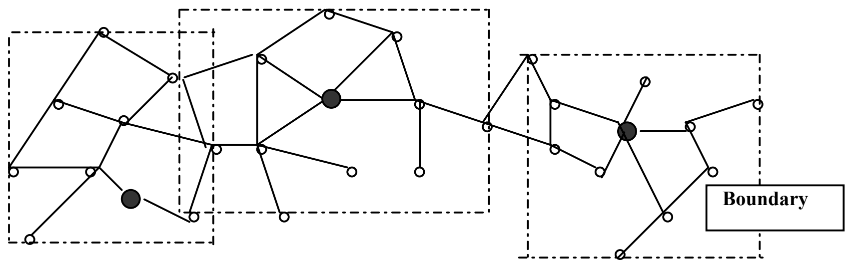



Fig. 2. Cluster boundaries formed with GPS of the boundary nodes

## 3. Cluster management Protocol

For periodic beacon based cluster maintenance protocols if a cluster member is moving out of the transmission range of the CH, the member node searches for the new head by detecting the new CH beacon signal. There is no other intelligent way to track the mobility of a member node. Here we have proposed a cluster maintenance protocol using GPS technology, which is able to maintain a stable cluster structure even in presence of high mobility incurring little overhead. In this protocol any node including the cluster head automatically gets alarmed while crossing the geographical boundary of a cluster using the program which continuously compares the current GPS value of the node with that of the boundary values. Thus it is quite easy for a departing node to make a timely arrangement for rebinding with a new CH and unbind with the old one.

## 4 Mobility Management of Cluster Heads through Selection of Surrogate Heads

The entire process of surrogating actually involves the transfer of cluster head information and re-announcement of new cluster head within the cluster. We have considered different schemes for selecting surrogate head considering different aspects of the network performance like number of cluster head change in the near future or the overhead traffic involved in transferring the headship.

We have found that if the surrogate head can be selected from the middle of the cluster then, the chance of this new cluster head to cross the cluster boundary gets reduced and as such the duration of a node to remain as cluster head increases remarkably. This particular scheme though yields better stability of a cluster [fig .4] but the traffic overhead involved for handover of headship is much higher due to multihop data transfer. In the second scheme, when the departing head can select any of its 1- hop neighbors as surrogate head and as such there is no need to concern about their positions. Here the initial overhead for head transfer is much less due to 1 hop data transfer. But as the surrogate head lies within the vicinity of cluster boundary the chance of change of cluster head in near future also gets increased.

## 5 Performance analysis and Simulation Results

We first analyze the communication overhead involved in cluster maintenance with varying the important clustering parameters like i) cluster size and ii) node mobility. It has been observed in all the graphs shown in the following fig [3a and 3b] that a significant amount of overhead traffic can be reduced for cluster maintenance using the GPS based cluster management protocol. For the periodic beacon based clustering algorithm [1] there is a gradual rise in the curves showing a rapid increase in communication overhead with cluster size and mobility.

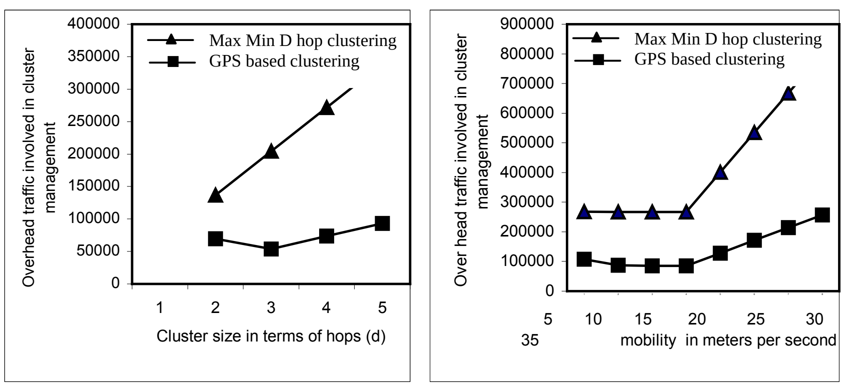
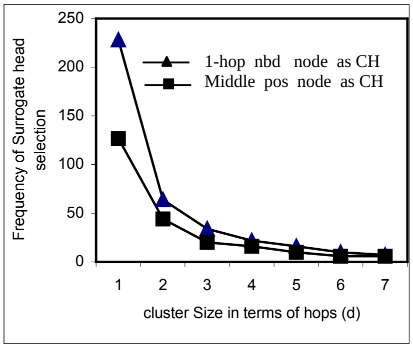



Fig. 3. Average overhead involved in cluster maintenance with a) varying cluster size b) varying node mobility.

The cluster topology stability can be measured by determining the number of times each cluster head has attempted and given up its role as cluster head. So in the second part of our simulation results we have tried to show the performance of the surrogate head selection schemes. We have counted the number of cluster changes with varying cluster size and varying the node mobility, and the results give the efficiency of selection scheme used.



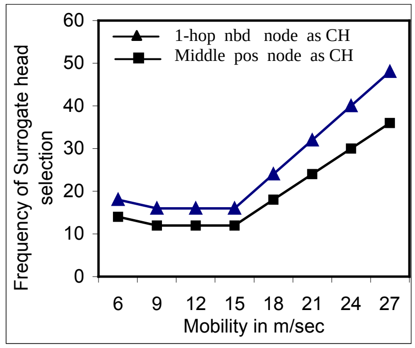




Fig. 4. Frequency of cluster head surrogating using the two selection schemes with a) varying cluster size b) varying node mobility.

## 6 Conclusion.

Here we have tried to minimize the frequency of re-clustering by proposing a GPS based stable cluster maintenance protocol. We have shown that using a one time absolute geographical boundary for a cluster, it can be kept stable over a region for a long period. In this protocol the mobility can be managed locally and as such the communication overhead gets heavily reduced. The cluster belonging ness can be determined once by using the deterministic GPS based approach and any further modifications in the member belongingness can be taken care locally without having a little impact on the rest of the network. This GPS based robust approach together with the support of Surrogate cluster-head makes this approach highly deployable in an extremely mobile environment.

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