Introducing a new idea of Routing via Novel Clustering Strategy for AdHoc Networks

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Abstract
Routing in wireless mobile adhoc networks should be time efficient and resource saving. One approach to reduce traffic during the routing process is, to divide the network into clusters. Until now, there have been several approaches on cluster-based routing. We propose a voting based clustering strategy to form network with spatial and temporal stability. The selection of cluster head and cluster size is done in a very efficient manner. We present algorithms for creation of clusters and their maintenance in presence of various network events. Our strategy outperforms existing and conventional clustering approaches in terms of number of hops required, at a little cost of overhead during topology updates. The strategy performs very well when density of nodes is very high. We have simulated the model in matlab to check the expected results.

I. INTRODUCTION
An adhoc network is a dynamic multi-hop wireless network established by a group of mobile nodes on a shared wireless channel without any infrastructure. Efficient clustering and routing in adhoc networks has been a topic of research in the past few years. The literature that deals with adhoc routing identifies two types of networks viz. hierarchical routed networks and flat routed networks. While the former creates a hierarchy among the nodes the latter treats all nodes equally. Most hierarchical clustering architectures for mobile radio networks are based on concept of cluster head (CH) [1,2,3]. In most of the proposed methods in hierarchical (clustered) networks, much thought has not been given for the selection of the CH. In order to design a stable network we need to look after features that the clusters should suffice. In [2] CH is selected based on a node identifier and thus may not be spatially and temporally suitable. The concept of associativity (relative stability of nodes) was used to get long live routes in routing [7]. Associativity provides temporal stability but not spatial. By up-to-date GPS system, location information is available to different mobile computing platforms [8]. Therefore, we intend to address the above-mentioned issues and propose to design a novel location-aware clustering strategy. The cluster formation scheme should form clusters based on the spatio-temporal stability of the mobile nodes forming the adhoc network. The node elected as the CH should be such that it should satisfy the following constraints:

1. Located centrally for spatial stability.
2. Should have high energy value relatively to other nodes in the cluster.

The cluster size also needs to be constrained and we are looking on achieving the following in our protocol design:
1. Overlap between clusters should be minimum, thus suitable for dense mobile adhoc networks
2. Should suffice the connectivity constraints.
• Intra and inter stability should be inherent.

• Has a maximum size (number of member) constraint.

In the view of above constraints, our clustering strategy tries to find an optimal location of the CH in a cluster using voting algorithm. Using this algorithm nodes in a cluster interact with each other and select a CH. We also have to address the different issues that may arise in management of a cluster and the necessary actions to be taken by the CH in this regard. The paper is organized as follows. Section II introduces system model and novel approach for cluster formation and maintenance using the proposed voting algorithm. Section III discusses the routing strategy for both intra and inter cluster routing. Section IV presents simulation results and section V concludes the paper.

II. SYSTEM MODEL
We consider a system in which all nodes have a prior information of their location. This is valid for adhoc networks as we can append nodes with devices like GPS. We will describe our model in two phases:

A. Cluster Formation:
The routing protocol we use takes cluster formation as its basis. Hence, efficient cluster formation is the crux of a routing protocol of this nature. The clusters should be formed in such a way that the resulting network is cluster-connected. A network is cluster-connected if it satisfies the following two conditions:

• The union of the clusters covers all the nodes.
• There is a path from each node to every other node through other clusters.

Routing from one node to another will consist of routing inside a cluster and routing between clusters. Here, we have assumed clusters, such that with in a cluster each node can directly communicate with the other member nodes. We assume that each node has a unique id (node id) which is its device address. Again each of them maintains a list of nodes in its cluster (node list). Also each of them has information about the location of various nodes in their cluster (node location list). As soon as a node is set on, it looks to join a cluster and follows the following procedure:

• Transmits a hello packet (Broadcast Packet) and waits for a reply for a fixed amount of time (reply timeout).
• If any of the CH is around and it listens to this hello packet, it replies to the request.
• If the node does not receive any reply before reply timeout, it will assume that no clusters are present around and will become a CH itself.
• If it receives a reply, it will send an ACK to the CH which replied.
• If it receives more than one reply, it will look for the one with the highest SINR value and will send an ACK to that CH.
• The CH after receiving the ACK, informs the newly joined node about the cluster. The cluster head informs the node about the cluster members’ id and their location.
Using the above procedure we get a basic clustered network. Note the above procedure may not yield optimal clusters. We use an algorithm where we will try to reach optimality by shifting the role of the CH to the most optimal node with time. Also we put constraints on the size of the clusters to get suitable clusters.

B. Cluster Maintenance:
Once a basic structure has evolved, next job is to optimally evolve the clusters. The mobility of the nodes introduces the need to device algorithms for Cluster fusion, Cluster division and Handoff. We consider all these features in detail later. Let us first look at how we can optimally assign the job of CH to the nodes in the cluster. To do this we propose Voting Algorithm as described below:

- Each node evaluates the best possible position using eqns.(1) and (2). This position is the weighted location with weights of various nodes inversely proportional to the SINR value for the Hello packets (Broadcast Packets) transmitted by corresponding nodes. These packets are transmitted periodically by various nodes and using these packets each cluster member updates other members about their latest location. Also nodes utilize these packets to estimate the channel conditions between the transmitting node and themselves and hence evaluate the weights above.

\[
x_{\text{optimal},j}^{(i)} = \frac{\sum_{k \in \text{cluster}(i)} x_{k} w_{j,k}}{\sum_{k \in \text{cluster}(i)} w_{j,k}} \\
y_{\text{optimal},j}^{(i)} = \frac{\sum_{k \in \text{cluster}(i)} y_{k} w_{j,k}}{\sum_{k \in \text{cluster}(i)} w_{j,k}}
\]

Where \( x_{\text{optimal},j}^{(i)} \) and \( y_{\text{optimal},j}^{(i)} \) are the optimal location of the CH as desired by \( j^{th} \) node. \( x_{k}^{(i)}, y_{k}^{(i)} \) are the \( x \)-position and \( y \)-position of \( k^{th} \) node in \( i^{th} \) cluster and \( w_{j,k} \) is the weight function between node \( j \) and \( k \) of a cluster. We have taken \( w_{j,k} = \frac{1}{\text{SINR}_{j,k}} \). The weight function can be modified to account for battery power, mobility etc.

- Each of the cluster members periodically votes for the best location of the CH for itself.
- CH receives votes from all the cluster nodes and evaluate their mean to estimate the position for the next possible CH. Thus the optimal CH location will be:
where $N^{(i)}$ is the number of nodes in $i^{th}$ cluster.

- If the new location is in CH's proximity, it continues to do the job of CH. It informs this to the members by broadcasting a result packet.
- If the optimal location is far away, CH looks for nodes in proximity to this location and elects the nearest.
- It informs the newly selected CH about its new role as a CH and waits for an acknowledgment.
- The newly selected CH sends an ACK packet to the old CH and then broadcasts to the cluster that it has taken over the job of the CH.

The voting algorithm above is timely executed and the new CH is chosen such that it confirms equally to all the nodes in the cluster. Next, we look at the other facets of cluster maintenance. As the nodes are mobile and so the clusters keep on drifting with time. They collapse into each other leading to cluster fusion. Again as the cluster grows and become bigger in size, they divide into child clusters. Also as the nodes are mobile some of them may move from one cluster to another. This phenomenon is termed as Handoff and we will discuss this later.

Snapshots of both Novel and Fixed clustering are shown in Figs. (1) and (2) respectively.
1) Cluster Fusion: The cluster fusion is a phenomenon of combining two clusters when they come close to each other. We have chosen two criterion’s for the fusion process to happen:

- A cluster completely moves inside another cluster.
- Around C⁻D8E of a cluster nodes are inside another cluster.

In any of the above two circumstances the following procedure is used to result in cluster fusion:

- The CH’s of the two clusters communicate with each other. The CH with less number of members updates the other CH about new members.
- Of the two combining clusters, the CH of the one with more number of nodes plays the role of the immediate CH of the fusion cluster.
- The CH thus broadcasts update packet with the information about the latest status of the cluster.
2) **Cluster Division**: The cluster division is a phenomenon of splitting a parent cluster into child clusters. This happens if the number of the members in the cluster goes above a fixed threshold (Max Num Cluster Members). The splitting results using the following algorithm:

- The CH sorts the location indices of the members via both the co-ordinates. The two sets thus obtained are used to determine the position of the CH’s in the child clusters.
- The CH evaluates the preferable positions for the new CH’s by taking the indices of their location as those of the elements in the (1/3) and (2/3) places of the sorted sets.
- Now the division of the members is done on the basis of their closeness to the newly formed CH’s.

3) **Handoff**: Due to mobility, the nodes keep on joining and leaving the clusters. We have worked out a procedure to smoothen out this process. There are two types of handoff we have looked for, namely, controlled handoff and forced handoff.

- Controlled Handoff: When a node moves away from its cluster and nears the maximum transmission range of the CH, the CH advertises about it to the neighboring CH’s. Hence before the moving node parts away from the parent cluster it is accepted as a member of another cluster, the one it is moving towards. Thus this is a Make before Break kind of situation.
- Forced Handoff: This occurs if the node crosses the maximum transmission range of the CH and there is no cluster around to accept this node as a member. In this situation the node is left on itself and the node becomes the CH on itself.

![Fixed Clustering: Red shows selected CH, Rectangles show cluster boundaries](image-url)
III. PROTOCOLS USED

A. Medium Access Control
We have used Carrier Sensing Multiple Access (CSMA) as MAC protocol in our analysis. Any CSMA-based medium access scheme has two important components, the listening mechanism and the back off scheme. The constant listen periods are energy-efficient, and the introduction of random delay provides robustness against repeated collisions.

B. Routing
The routing strategy has to take care of both intra and inter cluster routing. We have used existing protocols for both types of routing. We have used DSDV for intra cluster routing and AODV for inter cluster routing. These protocols are briefly described below:

1) DSDV: DSDV stands for Destination-Sequenced Distance Vector [10]. In our novel clustering strategy we have assumed that within a cluster every node is directly accessible from any other node. Thus any node can communicate to its cluster members in a single hop. The DSDV protocol requires each mobile node to advertise to each of its cluster members, about its own presence in the cluster for instance by hello packets (Broadcast packets). The position of the node may change fairly dynamically over time, so the advertisement must be made often enough to ensure that every mobile node can almost always locate every other mobile node of the cluster.

2) AODV: AODV stands for Ad-hoc On-demand Distance Vector [9]. This routing protocol uses a data structure called cluster adjacency table (CAT) to support the routing process. The CAT stores information about neighboring clusters. Route discovery is done by using source routing. In the routing protocol CH’s are flooded with route request package (RREQ). This strategy reduces the network traffic. Initially, node $S$ broadcasts a RREQ with its ID and containing the destinations address, the neighboring CH’s and the cluster address list which consists of the addresses of the CH’s forming the route. If the RREQ reaches the destination node $D$ it contains the loose source route $[S, C_1, C_2, \ldots, C_k, D]$. $D$ sends a route reply message (RREP) back to $S$ using the reversed loosed source route $[D, C_k, \ldots, C_1, S]$.

Every time a cluster head receives this RREP, it computes a strict source route, which then consists only of nodes that form the shortest path within each cluster.

IV. PERFORMANCE COMPARISON
We have used the standard models for the channel state and the mobility of the nodes. Below we describe each of them in detail:

A. Mobility Model:
We have chosen a mobility model suitable for urban and vehicular environments [6]. A number of vehicular users move around the simulated area and their initial directions in degree are generated by the uniform distribution $U[0,360]$. The velocity of users is fixed. After the negative exponentially distributed amount of time, with mean equal to 60 seconds, the direction of a user is changed. The new direction is generated by a Gaussian
distribution with mean equal to the user’s old direction and standard deviation 30 degrees.

**B. Channel Model:**
We have used the shadowing model for the radio propagation models. The overall shadowing model is represented by:

\[
\left[ \frac{P_r(d)}{P_r(d_o)} \right]_{db} = -10\beta \log\left( \frac{d}{d_o} \right) + X_{AB}
\]  

where \( X_{AB} \) is a Gaussian random variable with zero mean and standard deviation of 6.8\( dB \) (factory, obstructed environment) and \( \beta = 4 \) (urban environment). The model is also known as a log-normal shadowing model.

**C. Simulation Results:**
The simulation was carried in MATLAB. We have compared our Novel clustering strategy with Fixed clustering strategy. For a fair comparison, we decided to keep the number of clusters in both the strategy same. The constant parameters chosen for the simulation were:

- Number of nodes: 100
- Area of the network: 1000 x 1000 for 9, 16 clusters; 1000 x 750 for 12 number of cluster.
- Max Num Cluster Members: 15
- Velocity of a node: 10 m/sec
- Time for simulation: 2000 sec

![Plot for Throughput vs Load for 9 clusters](image-url)  
**Fig. 3.** Comparison of Throughput for varying load for 9 clusters
The simulation has been done to carry out a detailed comparison of performance of DSDV and AODV routing protocols when implemented with our Novel clustering strategy and existing Fixed clustering strategy. We have carried out the simulation by varying the number of clusters in both the strategies. This is done in order to have the routing overheads same in both.

Fig. 4. Comparison of Throughput for varying load for 12 clusters
the clustering strategies. We have compared the two strategies for cases of 9, 12 and 16 clusters. The performance parameters chosen are Throughput and Power spent per packet, i.e. number of hops required per hop, transmitted successfully normalized by transmission power of the node. The packet arrival process was taken as Poisson for varying values of load in Erlang’s. These parameters are evaluated for various load values in both the strategies. The plots giving performance comparison are shown below. It was observed during the simulation that number of CH swapping’s and Handoff ’s required were very less in Novel clustering than in Fixed, which is due to temporal and spatial stability achieved. The throughput performance is almost same in both the strategies Fig (3), (4), (5). Our strategy performs better at low load but performance coincides as load increases. Also, it doesn’t vary much with the number of clusters.

Fig. 5. Comparison of Throughput for varying load for 16 clusters
In case of power required per packet, Novel clustering surpasses rectangular clustering strategy when number of clusters are less (9 and 12) but performance deteriorate as number of cluster increases to very high value (16), shown in Fig. (6), (7), (8). Thus our clustering strategy works well when node density is high, since less number of clusters.
As the number of clusters increases, number of members per cluster is very less (≤ 5), hence clusters formed in our approach are not stable and hops required increases. Therefore, a simple approach of fixed clustering is more suitable for low density. On the other hand, when number of clusters is 9, 12 (approx. number of member per cluster are 11, 8 respectively), thus cluster formed are stable. We try to give an intuitive reasoning for the substantial power saving. For the same number of clusters, the Novel clustering strategy is able to cover the same area, with smaller cluster size required than the fixed clustering. Thus, comparatively less power is required while transmitting a packet. That’s why the advantage obtained goes off as number of clusters increase. Thus, Novel Clustering performs much better and is suitable for a network having high node density.

V. CONCLUSION
We have succeeded in achieving the goals for cluster framework stability and have showed that Novel Clustering Strategy outperforms fixed clustering strategy. We were able to achieve similar throughput performance and substantial power saving. We also succeeded in choosing optimal cluster head and suitable cluster size. The overhead involved during the voting process is an issue of concern.

REFERENCES