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Implementation of Source Routing Protocol in Hierarchical Mobile Ad Hoc Networks

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ABSTRACT

A mobile ad hoc network is characterized by constraints such as limited bandwidth, energy constraints, less memory and processing capabilities. Also MANET's are required to be deployed under scalable conditions for some applications. A novel self-organizing hierarchical architecture is proposed for improving the scalability properties of ad-hoc wireless networks. This paper focuses on the evaluation of routing protocols applicable to this class of hierarchical ad-hoc networks. The performance of a hierarchical network with the popular Dynamic Source Routing (DSR) protocol is evaluated and compared with that of conventional flat ad-hoc networks using an NS-2 simulation model. The results for an example Mobile Ad hoc NETwork (MANET) scenario show significant capacity increases and reduction in control overhead with the hierarchical architecture. Simulation results using NS-2 show that our proposed scheme achieves good performance.

Keyword- *Manet, Clustering, Routing, Dsr, Hierarchical, Overhead, Energy Efficient.*

1. INTRODUCTION

Mobile Ad Hoc Networks (MANET) is an autonomous system formed by mobile nodes without any infrastructure support. Routing [1] [2] in MANET is challenging because of the dynamic nature of the network topology. A MANET is usually assumed to be homogeneous, where each mobile node shares the same radio capacity [3]. However, a homogeneous ad hoc network suffers from poor scalability. Building a physically hierarchical ad hoc network is a very promising way to achieve good scalability. In this paper, we present a methodology to build a hierarchical ad hoc network using clustering algorithm. Each group elects a cluster-head to be a backbone node (BN). Then higher-level links are established to connect the BNs into a backbone network. Following this method recursively, a multilevel hierarchical network can be established. Then, we propose a modified Dynamic Source Routing (DSR) protocol to operate the physical hierarchy efficiently.

2. ROUTING PROTOCOLS

The routing protocols for MANETs are generally categorized as *table-driven* and *on-demand driven* based on the timing of when the routes are updated. With table-driven routing protocols, each node attempts to maintain consistent, up-to-date routing information to every other node in the network. This is done in response to changes in the network by having each node update its routing table and propagate the updates to its neighboring nodes. Thus, it is *proactive* in the sense that when a packet needs to be forwarded the route is already known and can be immediately used.

As is the case for wired networks, the routing table is constructed using either *link-state* or *distance vector* algorithms containing a list of all the destinations, the next hop, and the number of hops to each destination. Many routing protocols including *Destination-Sequenced Distance Vector (DSDV)* [4] and *Fisheye State Routing (FSR)* protocol [5] belong to this category, and they differ in the number of routing tables manipulated and the methods used to exchange and maintain routing tables.

With on-demand driven routing, routes are discovered only when a source node desires them. *Route discovery* and *route maintenance* are two main procedures: The route discovery process involves sending route-request packets from a source to its neighbor nodes, which then forward the request to their neighbors, and so on. Once the route-request reaches the destination node, it responds by unicasting a route-reply packet back to the source node via the neighbor from which it first received the route-request. When the route-request reaches an intermediate node that has a sufficiently up-to-date route, it stops forwarding and sends a route-reply message back to the source. Once the route is established, some form of route maintenance process maintains it in each node's internal data structure called a route-cache until the destination becomes inaccessible along the route. Note that each node learns the routing paths as time passes not only as a source or an intermediate node but also as an overhearing neighbor node. In contrast to table-driven routing protocols, not all up-to-date routes are maintained at every node. *Dynamic Source Routing* (DSR) [8] and *Ad-Hoc On-Demand Distance Vector* (AODV) [9] are examples of on-demand driven protocols.

3. ROUTING IN HIERARCHICAL NETWORKS

Routing is critical to operate such a hierarchical structure efficiently. Most routing protocols in MANETs are designed for a homogeneous wireless network, where all nodes share the same radio capacity. It has been proven that current routing protocols works well in small size networks. However, recent study also reported that the "flat" ad hoc network structure has limited capacity. As the size of network increases, the overall network capacity decreases substantially, especially when current routing schemes [12] [15] are applied. Current routing schemes usually need to propagate certain routing packets throughout the whole network. Data packets are usually routed through "long hop" paths. The "long hop" paths in large-scale network are prone to break. All these features prevent the "flat" ad hoc network structure from scaling to large scale. Its performance will degrade quickly along with the increase of network size. However, the large-scale ad hoc networks are more and more desired in many application scenarios, especially the mobile military networks [11].

An emerging promising solution to remove the performance bottleneck of an ad hoc network in large scale is to build hierarchical network architecture. A general picture of a two level hierarchical ad hoc network is demonstrated in Figure 1. It is referred as an ad hoc network with mobile backbones (MBN). Among the mobile nodes, some nodes, named backbone nodes (BNs) or cluster heads [16], have an additional powerful radio to establish wireless links among themselves. Thus, forming a higher-level network called the backbone network. Since the backbone nodes are also moving and join or leave the backbone network dynamically, the backbone network is exactly an ad hoc network in a different radio level.

Routing is critical [14] to effectively and efficiently operate such a hierarchical ad hoc network. So far, several routing schemes [17] [18] targeting the physically hierarchical structure have been proposed. All of them are simply the extension of popular routing schemes originally designed for "flat" ad hoc networks. A homogeneous routing protocol is applied to support routing. In this paper, a new idea of designing routing schemes for a hierarchical ad hoc network is presented. Mobile nodes are grouped into local subnets and routing protocols are applied in the backbone network and in local subnets.

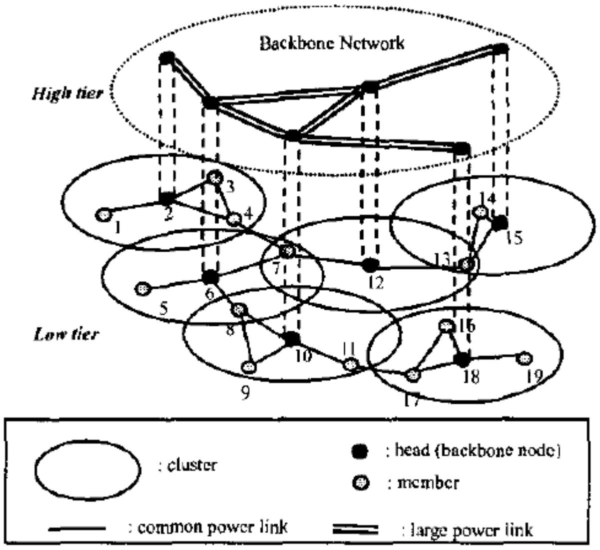


Figure 1. General Model of a two-tier hierarchical network

3.1 Hierarchical Routing Protocol

The Dynamic Source Routing (DSR) protocol is modified to operate a two level hierarchical MANET that is proposed as Hierarchical Dynamic Source Routing (HDSR) protocol. In HDSR, only the cluster head handles control packets and manages the routing table of inter-cluster routing. Therefore, HDSR can reduce the number of the control packets and mitigate the overhead of each node in comparison with flat routing protocols. This section describes the procedures of the data packets forwarding, the route creation, and the route maintenance in HDSR.

In order to forward data packets in Hierarchical Dynamic Source Routing Protocol - HDSR, the intra-cluster routing and the inter-cluster routing are used.

Intra-Cluster Routing: In the intra-cluster routing, each data packet is forwarded using the cluster head-based tree within the cluster. When a node sends a data packet to the destination node, the node forwards it to the cluster head along the cluster head-based tree. Then, the cluster head which received it sends the data packet to the destination node using the cluster head-based tree if the cluster head has the destination node in the cluster member list. However, if the cluster head does not have the destination node in the cluster member list, the cluster head forwards the data packet to one of the neighbouring clusters based on the routing table for the inter-cluster routing.

Inter-Cluster Routing: When the destination node is not in the cluster, the cluster head which received the data packet checks the routing table for the inter-cluster routing. If the cluster head does not have the routing information for the destination node, it discovers the route for the destination node. At this time, the data packet is stored in the buffer.

The data packet stored in the buffer is transmitted as soon as the route is constructed. If the cluster head has the routing information, it forwards the data packet to the next hop cluster for the destination node. HDSR forwards the data packet from the source node to the destination node by repeating the operations of the intra-cluster routing and the inter-cluster routing.

3.2 HDSR- Route Discovery

In order that each cluster head creates the routing table, HDSR uses the RREQ (Route Request) and RREP (Route Reply) . Each route entry of the routing table consists of {destination node ID, destination cluster ID, next hop cluster ID, hop count}. The destination node ID is a destination node of the route entry. The destination cluster ID is a cluster ID to which the destination node belongs. T

The hop count is the number of clusters between this cluster and the destination cluster. In Figure 2, the route discovery scheme in HDSR is explained. Given that source node S is in cluster A and destination node D is in cluster F. When source node S sends a data packet to destination node D, node S sends it to cluster head A along the cluster head-based tree which is used for the intra-cluster routing. Cluster head A checks the routing table for the inter-cluster routing. If cluster head A does not have node D in the routing table, it broadcasts a RREQ to all of the neighbouring clusters. Each cluster head that received RREQ (cluster heads B and E) adds source node S to the routing table, and rebroadcasts RREQ. Then, the route entry in cluster head B and E is {S, A, A, 1}. Similarly, cluster head C adds the route entry {S, A, B, 2} to the routing table and rebroadcasts RREQ.

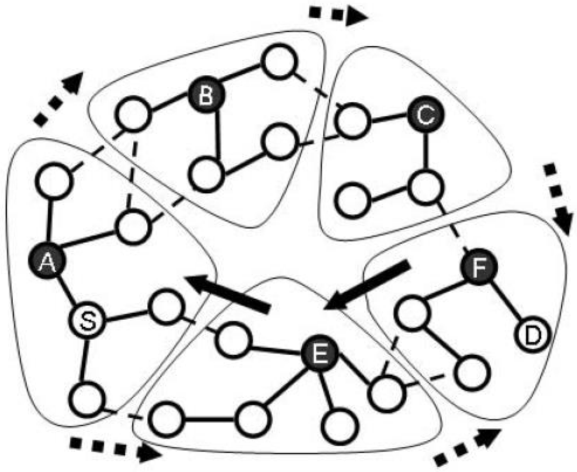


Figure2. Route discovery in HDSR

When cluster head F receives RREQ, it adds source node S to the routing table. And, it adds routing information of destination node D {D, F, F, 0} to the routing table because destination node D exists in the cluster F. After that, cluster head F sends RREP back to source node S. RREP is forwarded based on the routing table which was created when RREQ is broadcasted from destination node D to source node S. When the cluster head A receives RREP, it starts to send data packets based on the routing table of each cluster head.

3.3 HDSR Route Maintenance

In HDSR, if the cluster ID of the intermediate cluster between the source cluster and the destination cluster is changed, the route between the intermediate cluster and its upstream cluster becomes invalid. The cluster head in the upstream cluster stores the data packet into the buffer and invokes the route repair to find a new route to the destination cluster. The condition which the route repair invokes is described as follows.

The first case is that the source node left from the cluster to which it had belonged or the cluster ID of the cluster to which the source node belongs is changed. In this case, if the cluster head in the new source cluster has the routing table for the destination node, the source cluster sends the data packets according to the routing table. Otherwise, it invokes the route discovery to find a new route.

The second case is that the link between an intermediate cluster and the next hop cluster to which the intermediate cluster should forward data packets breaks. Regardless of the hop count from the destination node to the cluster head in the intermediate cluster, the cluster head invokes the route repair to forward the data packets to the destination cluster. At the same time, the cluster head sends a RERR (Route Error) message back to the source cluster. The third case is that the destination node left from the current destination cluster which the source cluster had found out by the route discovery. In this case, the destination cluster invokes the route repair to find a new destination cluster to which the destination node currently belongs.

4. SIMULATION SETUP AND RESULTS

The experiments are executed with NS2.26 [13] network simulator with CMU Monarch Wireless extension. All simulations carried out with 20 nodes and simulated for 20 seconds of real time. The radio model for each node is similar to Lucent Technologies wave LAN product, which is shared –media radio with a raw capacity of 2Mbps and a 250m normal communication range. The distributed coordination functions (DCF) protocol of the IEEE 802.11 for wireless LANS is used as the MAC layer. The node communication is modelled using constant bit rate (CBR) traffic sources sending data in 512 byte packets at a rate of 4 packets per second.

Random Waypoint mobility model is used and nodes are spread in a square region, having dimension of 500 X 500 m. In this model each node picks a random location in the simulated area and proceeds there at a speed chosen uniformly from Zero to 20 m/s. When the node reaches this point, it remains stationary for a fixed time (known as pause time) after that picks another location to move to and repeats the cycle. Pause time controls the degree of mobility by making each node remain stationary for a definite period of time, before it moves to the next position. The snapshots of Nam file and trace file are shown in Figure 3 and in Figure4. respectively.

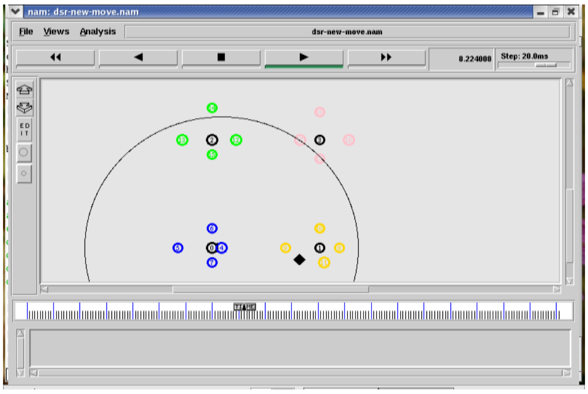
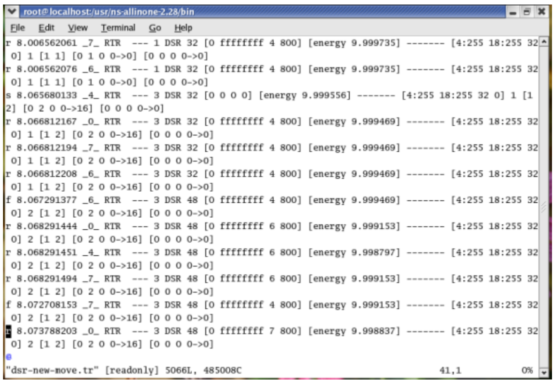


Figure 3 Nam File



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r 8.006562061 _7_ RTR  --- 1 DSR 32 [0 ffffffff 4 800] [energy 9.999735] ------- [4:255 18:255 32
 0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
r 8.006562076 _6_ RTR  --- 1 DSR 32 [0 ffffffff 4 800] [energy 9.999735] ------- [4:255 18:255 32
 0] 1 [1 1] [0 1 0 0->0] [0 0 0 0->0]
s 8.065680133 _4_ RTR  --- 3 DSR 32 [0 0 0 0] [energy 9.999556] ------- [4:255 18:255 32 0] 1 [1
2] [0 2 0 0->16] [0 0 0 0->0]
r 8.066812167 _0_ RTR  --- 3 DSR 32 [0 ffffffff 4 800] [energy 9.999469] ------- [4:255 18:255 32
 0] 1 [1 2] [0 2 0 0->16] [0 0 0 0->0]
r 8.066812194 _7_ RTR  --- 3 DSR 32 [0 ffffffff 4 800] [energy 9.999469] ------- [4:255 18:255 32
 0] 1 [1 2] [0 2 0 0->16] [0 0 0 0->0]
r 8.066812208 _6_ RTR  --- 3 DSR 32 [0 ffffffff 4 800] [energy 9.999469] ------- [4:255 18:255 32
 0] 1 [1 2] [0 2 0 0->16] [0 0 0 0->0]
f 8.067291377 _6_ RTR  --- 3 DSR 48 [0 ffffffff 4 800] [energy 9.999469] ------- [4:255 18:255 32
 0] 2 [1 2] [0 2 0 0->16] [0 0 0 0->0]
r 8.068291444 _0_ RTR  --- 3 DSR 48 [0 ffffffff 6 800] [energy 9.999153] ------- [4:255 18:255 32
 0] 2 [1 2] [0 2 0 0->16] [0 0 0 0->0]
r 8.068291451 _4_ RTR  --- 3 DSR 48 [0 ffffffff 6 800] [energy 9.998797] ------- [4:255 18:255 32
 0] 2 [1 2] [0 2 0 0->16] [0 0 0 0->0]
r 8.068291494 _7_ RTR  --- 3 DSR 48 [0 ffffffff 6 800] [energy 9.999153] ------- [4:255 18:255 32
 0] 2 [1 2] [0 2 0 0->16] [0 0 0 0->0]
f 8.072708153 _7_ RTR  --- 3 DSR 48 [0 ffffffff 4 800] [energy 9.999153] ------- [4:255 18:255 32
 0] 2 [1 2] [0 2 0 0->16] [0 0 0 0->0]
r 8.073788203 _0_ RTR  --- 3 DSR 48 [0 ffffffff 7 800] [energy 9.998837] ------- [4:255 18:255 32
 0] 2 [1 2] [0 2 0 0->16] [0 0 0 0->0]
@
"dsr-new-move.tr" [readonly] 5066L, 485008C                                    41,1          0%
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Figure 4. Trace File

The performance of DSR protocol for a flat network and the modified DSR protocol for a hierarchical network is compared for various network parameters such as control overhead, end to end delay, throughput and node energy drain rate.
The performance of the proposed protocol is evaluated on the following metrics.

- Control Overhead: The total number of routing packets transmitted during the simulation. For packets sent over multiple hops, each transmission of the packet (each hop) counts as one.
- Energy Depletion Rate: The energy resources of a node on the path may be depleting quickly.
- Throughput: Fraction of the number of received packets over the sent ones. This metrics actually tells us how much reliable our ad hoc network is. The greater the ratio, the more reliable the network will be.
- Average End-To-End Delay: The time taken for the data packet to travel from source to destination. The lesser this delay, the better the performance of ad hoc network.

The Control overhead is measured in terms of the amount of control messages generated by the routing algorithm. Figure 5 shows the control overhead generated in HDSR and DSR architectures in the networks for different mobility scenarios. From these results it is clear that HDSR significantly reduces the topology control overhead from that of the flat DSR mechanism.

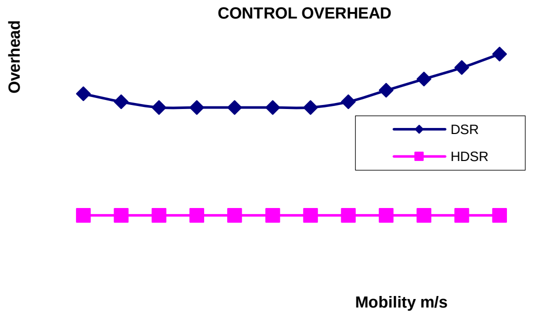

Fig 5. Control overhead Vs Mobility

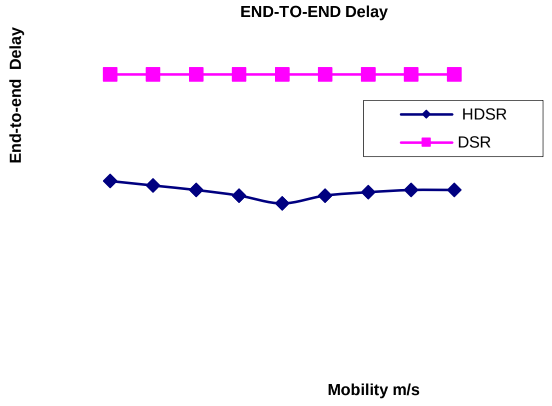

Fig 6. End to end delay Vs Mobility

On the average HDSR achieves a reduction of control messages up to 78.57%.The performance improvement of HDSR over flat DSR can be explained by the fact that the flat structure of DSR requires that topology control messages must be sent through all the wireless interfaces. By contrast, HDSR achieves a reduction of control overhead, as the mobile nodes are grouped into distinct hierarchical clusters and the propagation of topology control messages are restricted to each cluster. The approach used by HDSR prevents the topology control messages from flooding the entire network.

The end to end delay of HDSR architecture compared to DSR architecture is less by 44.44% for a mobility of 7 m/s. The end to end delay measurements of the HDSR in comparison with DSR is shown in Figure 6. From these results it is clear that under HDSR architecture it is possible to achieve a lower end to end delay metric than under a flat DSR architecture. HDSR delivers data packets more quickly and efficiently than it is done in the flat DSR, because under HDSR, the generated control overhead is much lower than that of DSR, reduced traffic in wireless media allows the HDSR to realize a shorter queuing delay, resulting in shorter end to end delays for data packet transfers between different clusters. Thus, unlike with flat DSR, HDSR capitalizes on higher capacity wireless links for data transmission and thus more efficient in data packet delivery.

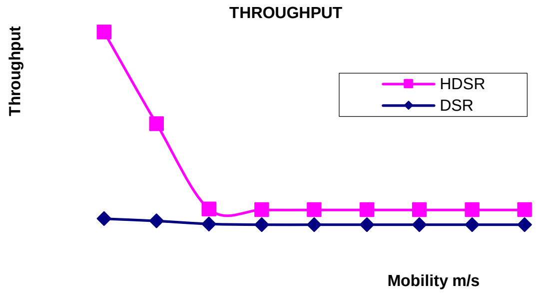

Fig 7. Throughput Vs Mobility

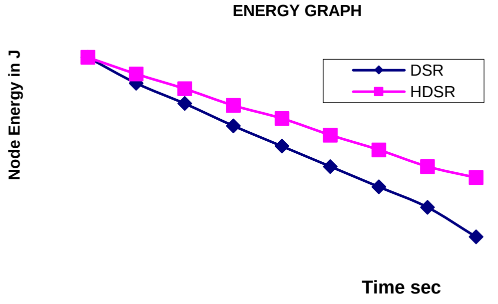

Fig 8. Node energy Vs Time

Figure.7 shows the throughput results for the HDSR and DSR protocols for different mobility scenarios. From the result it is clear that the throughput of HDSR protocol is 66.67% greater than that of flat DSR protocol. This result can be explained in terms of the network overhead due to the control messages generated by the DSR protocol. It is clear that the DSR mechanism generates a greater amount of control messages than does the HDSR mechanism [11]. While testing the HDSR and DSR protocols, node energy is measured over a period of simulation time.

Figure8 shows the node energy depletion rate with simulation time for HDSR and flat DSR architectures [12]. The average energy saving in HDSR is up to 40%. In HDSR, the nodes have longer lives. So the nodes are capable of transmitting their own packets and they are able to forward packets for a longer period of time.

5. CONCLUSIONS

In this paper, we discussed major critical issues involved in building a hierarchical ad hoc network with mobile backbones. We first analysed the optimal number of backbone node needed. Then, a new stable clustering scheme is proposed to deploy the BNs. We also proposed an extension of DSR routing to operate such a network efficiently. Backbone links are automatically selected by the routing scheme if they can reduce hop distance to remote destinations. On the average HDSR achieves a reduction of control messages up to 78.57%. In essence, the proposed scheme combines the benefits of “flat” DSR routing and physical network hierarchy. Simulation results show that our proposed schemes can establish and operate a mobile backbone network effectively and efficiently. It can improve the network performance significantly and is robust to failures.

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