Hierarchically Segmented Routing Protocol for MANETs

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***Abstract-* With the rapid advances in wireless and semiconductor technologies mobile connectivity became cheap and ubiquitous. One of the major challenges facing Mobile Ad-Hoc Networks (also known as MANETs) is the absence of a proper routing protocol that provides good scalability, low overhead, low end-to-end delays, seamless connectivity and good quality of service. In this paper we propose a Hierarchically Segmented Routing (HSR) approach to solve this problem, based on the two well know routing protocols; the DSR and CGSR. The paper provides a comparative analysis of the proposed HSR protocol using a stochastic network simulation.**

I. INTRODUCTION

Wireless device are becoming ubiquitous, with the ever increasing advances in wireless and mobile computing. Improved protocols must be developed to support these new mobile devices/ MANETs and to see that these devices do not overload the existing infrastructure network. The aim of this endeavor is to provide anytime, anywhere connectivity for unlimited mobile devices without overloading the associated infrastructure networks.

Most protocols in place suffer from low quality of service and overload the network with a large percentage of overhead (control data) when compared to the data packets. Any improvement in the routing protocol should be an extendible architecture to support high number of mobile units and at the same time ensure a good quality of service.

Mobile routing protocols have been attracting the attention of a major section of the research community as is evident from the large number of ongoing projects at various universities and institutions on this topic. Numerous achitectures have been proposed such as the ExScal project in OSU [1], the Terminodes project in Switzerland [2], and the Roofnet project at MIT [3], the Waypoint Routing Protocol [4].

II. PREVIOUS WORK

Routing protocols form the heart of any MANET, which haven't evolved as much to support a large amount of mobile units. The performance of most routing protocols degrades with the increase in mobile nodes, leading to higher end-to-end delay, more dropped packets and low quality of service (QoS).

Existing routing protocols can be classified either by their behavior or by their architecture. The existing protocols can be broadly classified into three groups based on their behavior; reactive protocols (on-demand), proactive protocols (table driven) and hybrid protocols that are a combination of reactive and proactive protocols. If classified by architecture, the protocols are either flat or follow a hierarchy.

A. Reactive and Proactive Protocols

Reactive protocols are passive protocols that deliver the routing paths and topologies on-demand. Reactive protocols only take corrective measures on reported route failure. In contrast, proactive protocols issue topology and route information at regular intervals, therefore taking corrective measures before nodes encounter a dead end.

Studies have revealed that reactive protocols enjoy a higher throughput and efficiency when compared to proactive protocols. This is mainly due to the fact that the proactive protocols usually flood the network with control packets constantly issuing topology information. This causes a lot overload on the network without delivering much of the data. This has caused the research community to mainly concentrate their effort on reactive protocols more than the reactive ones.

The well known table driven (proactive) protocols are the Dynamic Destination-Sequenced Distance-Vector Routing Protocol (DSDV) [5], Wireless Routing Protocol (WRP) [6], Global State Routing (GSR) [7], Fisheye State Routing [8], Hierarchical State Routing (HSR) [10], Zone-based Hierarchical Link State Routing Protocol (ZHLS) [8], and Cluster Gateway Switch Routing Protocol (CGSR) [11].

Cluster based Routing Protocol (CBRP) [8], Ad hoc On-demand Distance Vector Routing (AODV) [12], Dynamic Source Routing Protocol (DSR) [13], Temporally Ordered Routing Algorithm (TORA) [15], Associativity Based Routing (ABR) [16, 17], Signal Stability Routing (SSR) [18] to name a few are reactive or on-demand protocols.

Also some hybrid protocols exist such as the Waypoint Routing Protocol [4].

B. Flat and Hierarchical protocols

In the case of flat routing algorithms, all the participating nodes have equal privileges and responsibilities. Flat routing algorithms are very well suited for small networks where the network is easily manageable by equal functionality nodes. But, as the size of the network increases flat routing algorithms fail to keep up and their performance degrades with increase in the number of nodes. This is because with the increase in the network size it becomes increasingly difficult to have updated routing tables. Examples of good flat routing protocols are Ad-hoc On-demand Distance Vector (AODV) [12] and Dynamic Source Routing (DSR) [13, 14].

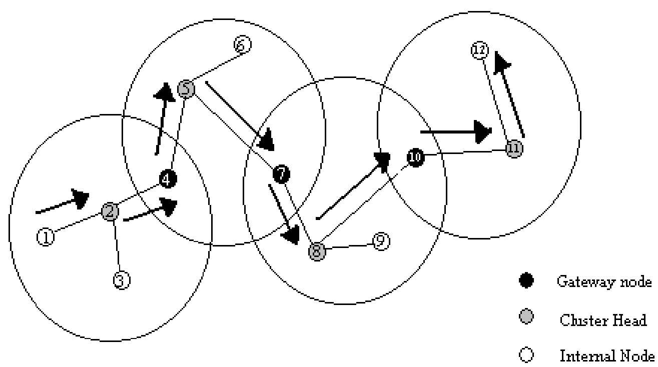

Figure 1: Shows a hierarchical division of a network under Cluster Gateway Switch Routing [11]

In contrast, the hierarchical networks classify nodes on a priority bases. The entire network is divided in to sectors, similar to circles in a mobile network. In each of the divided sectors of the networks one node is giving higher responsibility and functionalities to maintain the routing tables of that particular sector. Hierarchal protocols address the important problem of scalability [8]. These sectors or clusters can be three dimensional in practice. The Cluster Gateway Switch Routing (CGSR) [11] protocol is a good example of this class of routing protocols. Figure 2 shows an illustration of protocol where the network is divided into a large number of sectors each with a priority node.

On the downside side when the traffic increases these high priority nodes, also known as cluster-heads, become bottlenecks. Most data transfer and routing tables are controlled by these cluster-heads. This also leads to cluster-heads burning off power faster when compared to other regular nodes.

Another advantage of hierarchical protocols is that in case of a route failure the entire route doesn't need to be recalculated. Only the part of the route in the sector where the route has been broken needs to be recalculated. But, in case of flat networks if a route fails then the entire route has to be recalculated from the source to the destination which is not only time consuming but adds put a huge load on the network. Therefore, hierarchical networks not only address the problem of scalability, but also that of route failure.

There are many other hierarchical routing protocols such as the Hierarchical State Routing (HSR) [10], Zone-based Hierarchical Link State Routing Protocol (ZHLS) [8, 9], Fisheye State Routing (FSR) [9] to name a few.

III.PROPOSED PROTOCOL

Binding refers to keeping the network together, issuing routing updates, keeping track of nodes entering and exiting the network etc. As the size of the MANET increases, the control traffic also increases. When nodes are tasked with both binding the network as well as data transfer, bottlenecks are created within the network leading not only to battery drain out but slow network performance. Hence it is critically important to disassociate both of these functionalities to prevent node failures due to bottle necks and low power conditions as seen in hierarchical models. We also have to solve the problem of scalability. This can be done by dividing the MANET into clusters with a cluster-head which tasked with binding responsibilities.

Clustering within MANETs is essential as it discourages large routing tables. Each sector can only have a limited number of mobile nodes that the cluster-head can support. If the number is exceeded another cluster can be created with a cluster-head. This also limits the control traffic within the sector. For more details on cluster-head election mechanisms please refer [11]. The cluster-head of each sector is connected with the cluster-head of its immediate neighboring clusters through a gateway node (see Figure 1). The scope of other nodes within the cluster other than the cluster-head and the gateway nodes is limited to the cluster itself.

Cluster-heads do not participate in data transfer as their primary responsibility is to bind the cluster and keep the routing tables updated. This also saves the cluster-head from power drain and avoids the creation of bottlenecks with the route path which would occur due to handling of two tasks. However, the cluster-head can participate only under special conditions such as when it is either source or destination or no other node is active within the cluster. Also when, the participating node within the route becomes inactive in between the data transfer.

In case of a data transmission from one end of the MANET to the other end spanning many clusters, a route is established from the source to the destination. The cluster-head of each cluster nominates active nodes from within cluster to form a part of the route. The choice of the participating nodes is based on the information about the node with the cluster-head. Since MANETs and therefore clusters are groups of non-homogeneous mobile devices, the cluster-heads can choose mobile units depending on what data rates the active nodes are capable of supporting.

IV. ROUTING

Routes can be of two types; first spanning just one cluster, and the second, spanning multiple clusters. In the case of routes spanning multiple clusters, the entire route is divided into segments. This active route is hierarchically managed using two routing protocols; one at the inter-segment level and the other at the intra-segment level.

The entire route from the source to the destination has nodes involving multiple clusters is divided into segments. A segment is a part of a route that forms a part of a definite cluster. It is the route between two gateway nodes or the route between the gateway node and the source node or the destination node. In other words, a route is a connection of one or more segments and segment has a segment-head. The routing information needed to maintain the route is provided to the segment-head node by the cluster-head of that cluster. The entire route is reduced to a one dimensional connection of segments spanning many clusters from the source to the destination. As shown in Figure 2 cluster-head nodes do not form a part of the routing path. The dark nodes shown in the Figure 2 are cluster gateway nodes that interface two neighboring clusters. Also note that there are no Cluster-head nodes participating in the route.

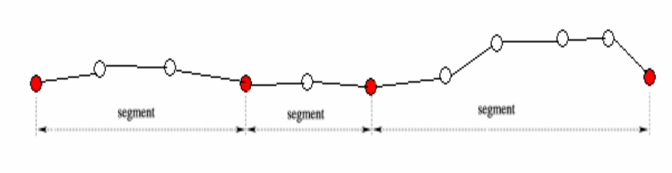

Figure 2: Route segmentation.

Hierarchically, managing routes can be advantageous when it comes to packet overhead and minimizing the end-to-end delay. In flat routing protocols, whenever a participating node drops out or becomes inactive the entire route needs to be established. As the size of the MANET increases routes become longer and break more often. This causes immense wastage of resources and time. Where as in the case of the proposed solution, whenever a node failure occurs for any reason it can be locally repaired without having to discard the complete route path. This saves a lot of time and greatly reduces the unnecessary network overhead. Hence two protocols are amalgamated in this hierarchy by implementing CGRP at the intra-segment level is and DSR at the inter-segment.

Cluster-head Gateway Switch Routing (CGSR) Protocol is a hierarchical protocol based upon the DSDV Routing algorithm [5]. The algorithm works in a very simple manner. The source transmits the data to the cluster-head of its cluster which in turn transmits it to the gateway of the destination cluster. The destination cluster-head transmits it to the destination node. There are numerous optimized cluster-head election mechanisms [11]. On receiving a packet, a node finds the nearest cluster-head along the route to the destination according to the cluster member table and the routing table. Then the node consults its routing table to find the next hop in order to reach the cluster-head selected in step one and transmits the packet to that node. This causes the cluster-head node to become a bottleneck in the network and rapidly lose power.

The Dynamic Source Routing (DSR) Protocol is a source routed reactive protocol. The DSR protocol is a learning protocol it generates routes based on the reply to the route packet request. The node updates its entry when it learns about a new node. Each node implementing the DSR maintains a cache of addresses. When the node learns about a new node it stores its address in the cache. The important feature of the DSR route is that it gives the address of each node through which it should traverse to reach the final destination. The packet header in the case of DSR is usually large.

By hierarchically combining CGSR and DSR we can exploit the advantages of both the protocols. The scalability greatly increased in spite of the limitation of DSR because DSR is used on an inter-segment level, hence the maximum route that can be supported is one spanning 200 clusters and not just 200 nodes. Also the overhead is very low as CGSR is used on intra-segment level which leads to the computation of the shortest route within the cluster. For reducing the load on the cluster-head node mapping of each node with respect to the cluster node is not done. The cluster periodically broadcast routing information for nodes with respect to the nearest gateway node. Since there are always more than one gateway node the load is also uniformly distributed within the cluster.

V. PROTOCOL IMPLEMENTATION

If a data needs to be transferred from one end of the MANET to the other, the source sends a request to its respective cluster-head of that cluster. The cluster-head then forwards the request to cluster-heads of the neighboring nodes. The cluster-heads of clusters that which to participate in the data transfer reply back with node addresses of nodes that are active and willing to participate in the route.

Propagation of the route establishment request is between the cluster-heads only, which decide on the basis of the instantaneous information able to them. By limiting the propagation of the route request to the cluster-heads only the traffic is greatly reduced, because as seen in other protocol the request keeps on propagating due to retransmission from nodes throughout the network until the TTL of the request has expired causing considerable traffic.

Before the source transmits data, it must setup proper headers to be used by the respective protocols. Firstly, depending upon the routing information received for its cluster-head, the source node attaches the routing information of participation inter-cluster gateway nodes from the source to the destination. This header is utilized by the inter-segment DSR protocol. Next the source adds intra-segment routing information for the packet to reach the first gateway node.

By adding headers in this fashion two purposes are served. First CGRS gets the route to the nearest gateway. Second the DSR protocol gets the next hop to inter-segment gateway node. The inter-segment header gets reduced with each hop where as the intra segment header is renewed at each gateway node. A new inter-segment header is appended while entering a new cluster. Inter-segment routing (DSR) occurs at the gateway nodes while the inter-segment routing occurs at both gateway nodes and cluster nodes until the data packet reaches the destination.

If both the source and the destination are within the same cluster, the entire route is just one segment hence only CGSR is implemented. If a route spanning multiple clusters is established, such that there is only one participating node from each cluster, then only DSR will be implemented.

VI. SIMULATION & RESULTS

We have simulated the proposed protocol with varying number of nodes using a stochastic model with Gaussian distribution to generate network failure conditions, such as node failures, route failure etc. The simulation was implemented in C++. We examined simulation one to test the scalability of the protocol and the next to test the network overhead generated by the protocol. These are the two main objectives we designed the algorithm to meet; scalability and network overhead.

Figure 3 provides comparison among the HSR, DSR and CGSR protocols for the number of control packets generated for marinating the network. As shown in the figure 4, it is difficult to maintain the network with a non-clustered architecture. DSR generates a lot of control packets to bind the network. This proves the fact that flat architectures can handle large amount of nodes.

But CGSR and HSR are far better that DSR due to the fact that they are hierarchical protocols. HSR is the same as CGSR when it comes to network maintenance, as shown in Figure 4.

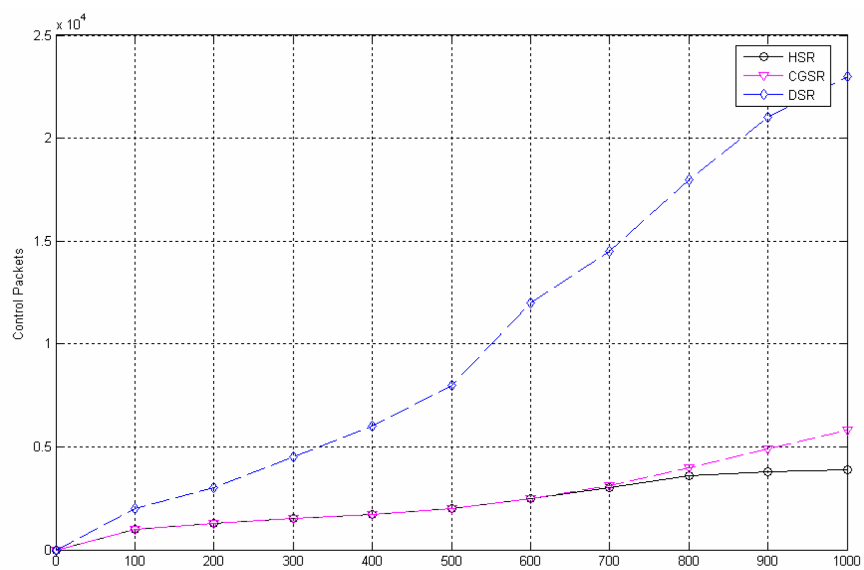

Figure 3: No of MANET Nodes Vs Control Packets

Figure 4 shows the percentage of packets delivered by each protocol. HSR is the best of the three protocols. As the number of nodes increases the DSR protocol fails very badly. DSR being a flat protocol, with the increase in the number of nodes the routing becomes extremely difficult due to nodes failing randomly.

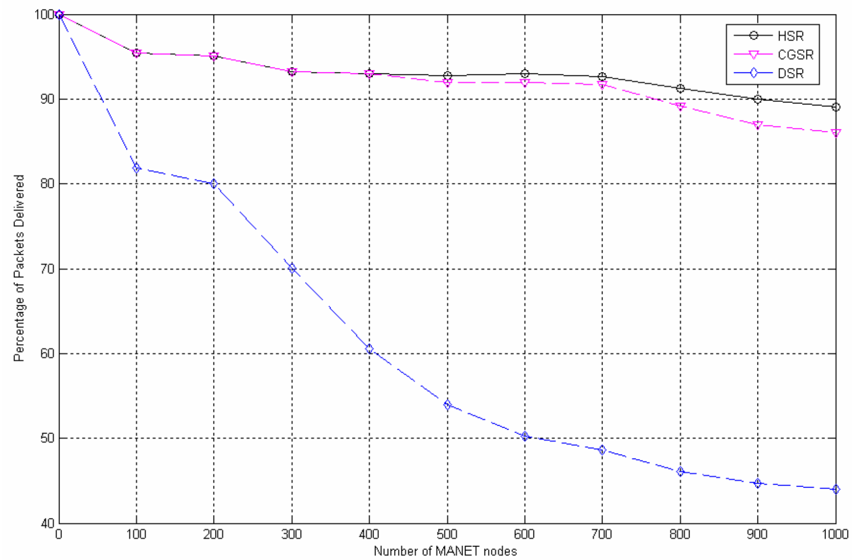

Figure 4: No of MANET Nodes Vs Percentage of packets delivered

CGSR and HSR protocols perform equally well when the numbers of nodes are small; there is no considerable difference in performance. The only difference in HSR is that routing tables are not with respect to the cluster-head but with respect to the nearest gateway node. With the increase in the number of nodes routing becomes relatively easier with HSR protocol than CGSR.

VII. CONCLUSION

In this paper we have introduced a new hierarchically segmented protocol for routing data within MANETs. The new protocol is based on CGSR and DSR protocols for segmented routing over gateway nodes. When compared to other protocols, the new routing algorithm is highly scalable due to its clustered hierarchical architecture, provides excellent scalability, and generates less network overhead and low end-to-end delays.

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Biography

Sarosh Patel received the B.E. degree in Electrical and Electronics Engineering with Distinction from the Faculty of Engineering Osmania University, India in 2002, and M.S. degrees in Electrical Engineering and Technology Management from the School of Engineering, University of Bridgeport (UB), in 2006. He is currently pursuing Ph.D. in Computer Engineering at U.B. He currently works as a Research Assistant at the Interdisciplinary RISC (Robotics and Intelligent Systems Control) Lab. He had been nominated for inclusion in 2005 & 2006 edition of Who’s Who Among Students in American Universities and has been elected to the Phi Kappa Phi honor society

Dr. Elleithy received the B.Sc. degree in computer science and automatic control from Alexandria University in 1983, the MS Degree in computer networks from the same university in 1986, and the MS and Ph.D. degrees in computer science from The Center for Advanced Computer Studies at the University of Louisiana at Lafayette in 1988 and 1990, respectively. From 1983 to 1986, he was with the Computer Science Department, Alexandria University, Egypt, as a lecturer. From September 1990 to May 1995 he worked as an assistant professor at the Department of Computer Engineering, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia. From May 1995 to December 2000, he has worked as an Associate Professor in the same department. In January 2000, Dr. Elleithy has joined the Department of Computer Science and Engineering in University of Bridgeport as an associate professor. In May 2003 Dr. Elleithy was promoted to full professor. In March 2006, Professor Elleithy was appointed Associate Dean for Graduate Programs in the School of Engineering at the University of Bridgeport. Dr. Elleithy published more than 100 papers in international journals and conferences. He has research interests are in the areas of computer networks, network security, mobile communications, and formal approaches for design and verification.