Adaptive Zone Routing Technique for Wireless Ad hoc Network

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Abstract: Ad hoc networks are characterized by multi-hop wireless connectivity, frequently changing network topology and the need for efficient dynamic routing protocols. In this paper, we proposed a new technique to adjust the zone radius by concentrating the changes of network traffic in a particular direction, which we refer to as AZRP. We demonstrate that even though ZRP and AZRP share a similar hybrid routing behavior, the differences in the protocol mechanics can lead to significant performance differentials. We discuss the algorithm and report on the performance of AZRP scheme, and compare it to the ZRP routing protocol. Our results indicate clearly that AZRP outperforms ZRP by reducing significantly the number of route query messages. And thereby increases the efficiency of the network load.

Keywords—Ad hoc networks, wireless networks, mobile networks, routing protocols, performance evaluation.

1. Introduction

In an ad hoc network, mobile nodes communicate with each other using multi-hop wireless links. There is no stationary infrastructure such as base stations. Each node in the network also acts as a router, forwarding data packets for other nodes. A central challenge in the design of ad hoc networks is the development of dynamic routing protocols that can efficiently find routes between two communicating nodes. The routing protocol must be able to keep up with the high degree of node mobility that often changes the network topology drastically and unpredictably. Such networks have been studied in the past in relation to defense research, often under the name of packet radio networks (see, for example, [10]). Recently there has been a renewed interest in this field due to the common availability of low-cost laptops and palmtops with radio interfaces. Interest is also partly fueled by growing enthusiasm in running common network protocols in dynamic wireless environments without the requirement of specific infrastructures. A mobile ad hoc networking (MANET) working group [11] has also been formed within the Internet Engineering Task Force (IETF) to develop a routing framework for IP-based protocols in ad hoc networks.

In this paper, we propose an adaptive routing protocol, which we refer to as AZRP, based upon the zone routing protocol [1] (ZRP). Our scheme examines an adaptation of the reactive part of ZRP and the Adaptive Zone Radius Technique to adjust the zone radius by concentrating the changes of network traffic in a particular direction. Thus, our AZRP outperforms ZRP by reducing significantly the number of route query messages. And thereby increases the efficiency of the network load.

2. Previous and Related Work

Accordingly, several routing protocols have been proposed for ad hoc wireless network are classified as proactive or reactive depending whether they keep routes continuously updated or whether they react on demand. Proactive routing protocols constantly maintain routes to all nodes in the network. Reactive routing protocols only search for routes when they are requested. Proactive and reactive routing schemes are typically complimentary in their advantages and disadvantages. Proactive routing provides an immediate route, thus decreasing the waiting time for sending data. Yet, proactive schemes also require many control packets to maintain the most up-to-date information. Reactive routing algorithms, alternatively, do not constantly congest the network with control packets (depending on the locality of routes) to maintain routing information; on the other hand, reactive routing requires flooding to perform route queries. Another disadvantage of reactive routing schemes is that they require much more time to determine a best route than a proactive protocol. In the final analysis, however, neither proactive nor reactive protocols are adequate solutions to routing in an ad-hoc network-particularly one in which the nodes are very mobile in relation to their transmission range.

3. ZRP

In order to understand how the AZRP protocol works, we must first understand how the Zone Routing Protocol works. ZRP is a hybrid protocol. This protocol divides the network into non-overlapping routing zones and runs independent protocols that study within and between the zones. Intra-zone protocol (IARP) operates within a zone, and learns all the possible routes. So, all nodes within a zone knows about its zone topology very well. Protocol which will run in intra-zone is not defined, but can be any proactive protocol such as DSDV. Different zones may operate with different protocols. Inter-zone protocol (IERP)

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is reactive and a source node finds a destination node which is not located within the same zone, by sending RREQ messages to all border nodes. This continues until destination is found.

The notions of routing zone and zone radius are the most important terms in the ZRP protocol. Each node defines its zone as the set of all of the nodes whose minimum distance (number of hops) from itself is at most equal to the zone radius. More precisely, a node's routing zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as the zone radius.

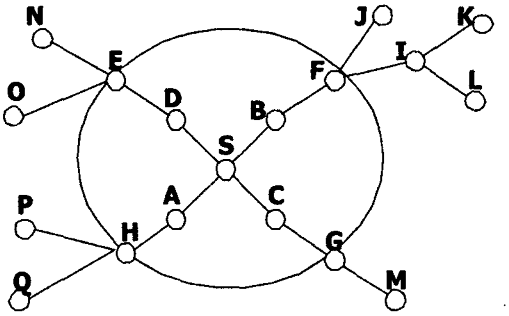

Figure 1: A Routing Zone of Radius 2 hops

In Figure 1 illustrates the routing zone concept with a routing zone of radius 2 hops. The particular routing zone belongs to node S which we refer to as the central node of routing zone. Node A though H are member of S's routing zone. Node J, However, is three hop away form node S. and is therefore outside of S's routing zone. An important subset of the routing zone nodes is the collection of nodes whose minimum distance to the central node is exactly equal to the zone radius. These modes are aptly named peripheral nodes. In our example, nodes G-K are peripheral nodes of node A. We typically illustrate a routing zone as a circle centered around the central node. However, one should keep in mind the zone is not a description of physical distance, but rather nodal connectivity (hops).

In Figure 2 illustrate is demonstrated the Route Discovery procedure. The source node S prepared to sent data to the destination D. S first check s whether D is within its routing zone. If so, S already knows the route to node D. Otherwise, S sends a query to all its peripheral nodes (E, F, G and H). Now, in turn, each own zone, forwards the query to its peripheral, F sends the query to I ,which is recognize D as being in its routing zone of I and responds to the query indication the forwarding path : S-F-L-D

The architecture of ZRP consists of four major parts on a per-node basis: MAC-level functions, IARP, IERP and BRP. The MAC-level performs a protocol called the Neighbor Discovery/Maintenance (NDM). NDM informs the IARP layer of neighbor nodes found or lost. The NDM component will notify the IARP layers of the new neighbors. A node uses IARP to maintain route information about nodes within its zone. Using the IARP routing table, all nodes maintain information about the nodes in their zones. Therefore, whenever a node wishes to route messages to a node within its zone, it simply gets the next-hop information to that destination from the IARP routing table. The IARP routing table is discussed in further detail in[2]. If a node wishes to route a packet to a, node outside its zone, it must first find the best route using IERP. The IERP layer maintains a routing table of routes to destinations outside of the node's zone. When a node wishes to send data to a node outside its zone, the IERP first checks to see if it has a route to that destination within the IERP routing table. If a route to that destination is not in the table, the IERP initiates a route query and passes control to the BRP layer. BRP uses a message-passing mechanism called bordercasting to transmit route queries and replies across the ad hoc network. Bordercasting gets its name from the fact that route control packets are passed between border nodes. Therefore, BRP traffic does not technically flood the network, since only nodes on the periphery of a zone transmit and receive packets. BRP prevents the looping of route queries and replies by maintaining two tables: the Detected Queries Table (DQT) and the Detected Replies Table (DRT). [2]

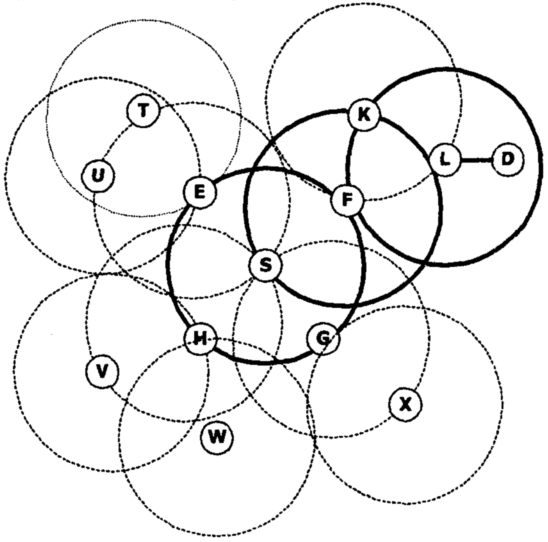

Figure 2: An Example IERP Operation (zone radius = 2 hops)

4. AZRP

In zone routing, each node has its own zone. Intrazone routing (e.g., DSDV and DBF) maintains communication path within the zone, while Interzone routing determines routes to the destination using flooding technique. In [2], techniques called "min-searching" and "traffic adaptive" have been proposed. The techniques allow individual nodes to identify changes in the network, and appropriately react to the changes in the network's configuration. The modifications are conducted by either increment or decrement the number of hops used by each node. Note that the number of hop for a particular node will be increased (or decreased) in all directions depending on the traffic between interzone and intrazone routing (see Figure 3).

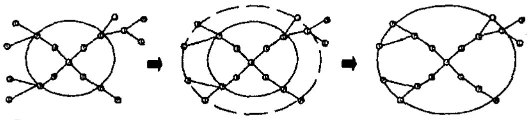

Figure 3. Changes of zone radius in all direction

This introduces changes in routing table for intrazone routing. Imagine that network traffic in a zone only occurs in a particular direction, changes in the zone radius for all directions can seriously increase the size of the routing table even though the traffic in other direction is not significant.

We proposed a new technique for adaptively resizing the zone radius by concentrating the changes of network traffic in a particular direction depending on the interzone traffic. By periodically monitor the interzone network traffic, the direction that generates high interzone traffic can be determined. Further, changing number of hops can also be implemented only for that particular direction. An example of this technique is demonstrated in figure 4.

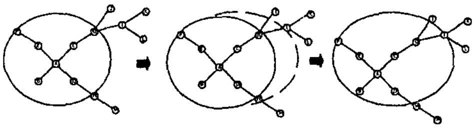

Figure 4. Changes of zone radius in a particular direction.

Changing in radius only in a particular direction, which has heavily loaded traffic, can significantly reduce the size of the routing table. Therefore, maintaining small routing table for individual zones is much simpler. Moreover, the amount of control traffic particularly used to update the routing table will also be decreased since the number of nodes after changing zone radius is relatively small comparing to ZRP technique [2].

Methodology

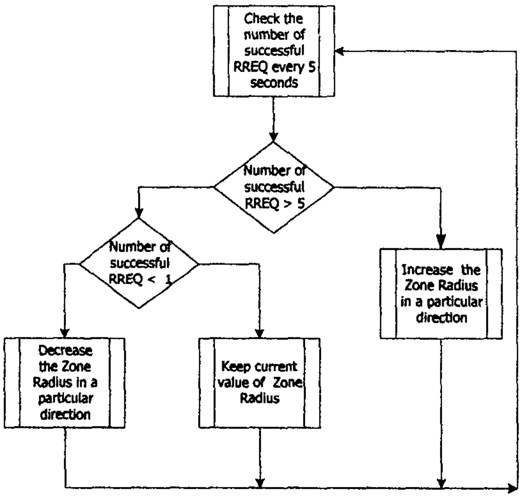

Figure 5. Decision Making for Adjust Zone Radius

In order to adaptively adjust the zone radius in a particular direction, there are two parameters that must be taken into account. The first parameter is the number of frequency RREQ collected by each peripheral node. The second is the period of time that is spent to collect the value RREQ. Every 5 seconds each node will adjust the zone radius by checking the number of successful RREQ. If the number of collected RREQ from any particular direction is greater than 5, then the node will increase the size of zone radius to next hop ($P_n=P_{n+1}$). In contrast, if the number of RREQ from the peripheral nodes is less than 1 then the node will reduce the size of zone to previous hop ($P_n=P_{n-1}$). The value of previous hop is maintained in a routing table. Note that every peripheral node will collect the successful RREQ and then forward it back to the source node in figure 5.

5. Simulation model

We use a detailed simulation model based on ns-2 [3] in our evaluation. In a recent work, the Monarch research group in CMU developed support for simulating multi-hop wireless networks complete with physical, data link and MAC layer models [3] on ns-2. The distributed coordination function (DCF) of IEEE 802.11 [4] for wireless LANs is used as the MAC layer. The 802.11 DCF uses Request-to-send (RTS) and Clear-to-send (CTS) control packets for "unicast" data transmission to a neighboring node. The RTS/CTS exchange precedes the data packet transmission and implements a form of virtual carrier sensing and channel reservation to reduce the impact of the well-known hidden terminal problem. Data packet transmission is followed by an ACK. "Broadcast" data packets and the RTS control packets are sent using physical carrier sensing. An unslotted CSMA technique with collision avoidance (CSMA/CA) is used to transmit these packets [5]. The radio model uses characteristics similar to a commercial radio interface, Lucent's WaveLAN [5]. WaveLAN is a shared-media radio with a nominal bit-rate of 2 Mb/sec and a nominal radio range of 250 meters.

The routing protocol model "sees" all data packets transmitted or forwarded, and "responds" by invoking routing activities as appropriate. The RREQ packets are treated as broadcast packets in the MAC. RREP, RERR and data packets are all unicast packets with a specified neighbor as the MAC destination. Both protocols detect link breakage using feedback from the MAC layer. No additional network layer mechanism such as hello messages is used. Both protocols maintain a send buffer of 64 packets. It buffers all data packets waiting for a route, e.g., packets for which route discovery has started, but no reply has arrived yet. To prevent buffering of packets indefinitely, packets are dropped if they wait in the send buffer for more than 30 sec. All packets (both data and routing) sent by the routing layer are queued at the interface queue until the MAC layer can transmit them. The interface queue is FIFO, with a maximum size of 64. Routing packets are given higher priority than data packets in the interface queue.

A. Traffic and mobility models

Traffic sources are CBR (continuous bit-rate). The source-destination pairs are spread randomly over the network. Only 512 byte data packets are used. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network.

The mobility model uses the random waypoint model in a rectangular field. 1500 m 300 m field with 50 nodes

Here, each node starts its journey from a random location to a random destination with a randomly chosen speed (uniformly distributed between 0–20 m/sec). Once the destination is reached, another random destination is targeted after a pause. We vary the pause time, which affects the relative speeds of the mobiles. Simulations are run for 900 simulated seconds for 50 nodes Each data point represents an average of at least five runs with identical traffic models, but different randomly generated mobility scenarios. For fairness, identical mobility and traffic scenarios are used across protocols.

6. Performance results

A. Performance metrics

Two key performance metrics are evaluated:

1 Packet delivery fraction---ratio of the data packets delivered to the destination to those generated by the CBR sources.

2 Average end-to-end delay of data packets --this includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times;

B. Varying mobility and number of sources

The first set of experiments uses differing number of sources with a moderate packet rate and changing pause times. For the 50 node experiments we used 10, 20, 30 and 40 traffic sources and a packet rate of 4 packets/sec. Note that the packet delivery fractions for ZRP and AZRP are very similar for both protocols for 10 and 20 sources (see Figure 7(a) and (b)). With 30 and 40 sources, however, AZRP outperforms ZRP (Figure 7(c) and (d)) except at very high pause times (low mobility). ZRP loses about 30–50% more packets than AZRP for lower pause times (higher mobility)

ZRP has a better delay than AZRP with 10 and 20 sources (see Figure 8). The differential for 10 sources is large, often more than factor of 4 for lower pause times. The differential reduces for higher pause time (low mobility). With 20 sources, the differential is much smaller. With larger number of sources AZRP has a lower delay than ZRP for all pause times (Figure 8(c) and (d)), the difference being large (about half) for lower pause times.

7. Conclusion

The result has shown that the AZRP outperforms ZRP by reducing significantly the number of route query messages. And thereby increases the efficiency of the network load. This technique can have a significant impact on cost of updating the routing table compared to ZRP. However, while our proposed method leads a promising performance, we also note that the method is only suitable for a particular situation. Nevertheless, this promising result has led to a number of interesting researches, especially the implementation of hybrid technique, which combine advantages of proactive and reactive routing techniques.

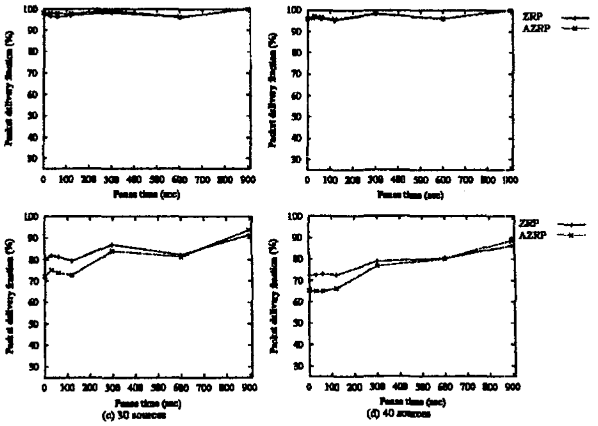

Figure 7. Packet delivery fractions for the 50 node model with various numbers of sources.

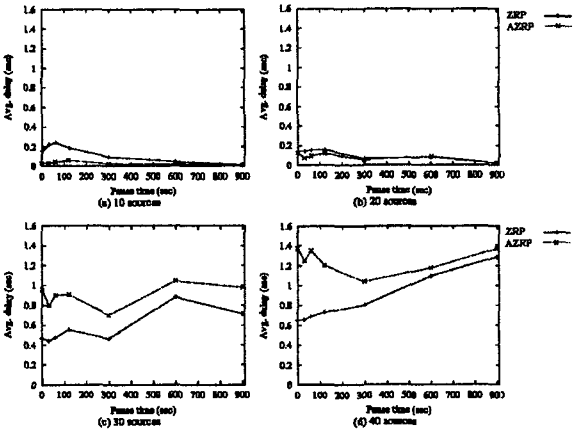

Figure 8. Average data packet delays for the 50 nodes model with various numbers of sources.

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