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ZLERP: Zone and Link Expiry based Routing Protocol for MANETs

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ABSTRACT

Mobile Ad hoc Network (MANET) is a self organized network where network is set up on the fly. Some of the issues in MANETs are routing, security, power management, bandwidth management, mobility management, etc. Zone Routing Protocol (ZRP) provides a flexible solution for discovering and maintaining routes in MANETs. This paper addresses the problem of routing by considering link stability (link expiry time) and node mobility. Link instability and node mobility causes frequent topology changes that result in routing complexity. The proposed Zone and Link Expiry based Routing Protocol (ZLERP) for MANETs is an enhancement to existing ZRP that offers better routing services. An attempt is made to limit control overheads in the network by selecting the path with stable links between two nodes. Nodes measure link stability using the received signal strengths from neighboring nodes at periodic time intervals. The proposed routing protocol is simulated in several network scenarios to test its operation effectiveness. It is observed that modified ZRP performs better than existing ZRP.

Keywords - MANET, ZRP, Routing, Link expiry, ZLERP

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I. INTRODUCTION

Mobile Ad hoc Network (MANET) is an autonomous collection of mobile devices that communicate with each other over wireless links and cooperate in a distributed manner, in order to provide necessary network functionality in absence of a fixed infrastructure. Nodes are computing and communicating devices that include laptops and mobile phones. In a MANET, there are no centralized access points or base stations like cellular networks. Routes between two nodes may consist of several hops through other nodes in the network. Therefore, each mobile node takes part in discovery and maintenance of routes to other nodes. Some specific applications of MANET are military communications, virtual classrooms, emergency search and rescue operations, communication set-up in exhibitions, conferences, presentations, meetings, etc.

Link stability is an essential factor for formation of stable networks, which gives high reliability and better quality of service support. With network stability, data packets can be delivered more successfully, resulting in higher packet delivery ratio, lower end-to-end delay and improved network performance.

In a network with unstable links, link breakages tend to occur frequently. Due to breakage of existing routes, more control packets have to be propagated in the network for route maintenance. Thus there is greater contention for bandwidth, which leads to undesirable performance such as higher packet loss and higher latency. Therefore routing protocols should ensure that stable links are established during route formation itself without causing excessive control traffic overhead or computational burden with an aim of enhancing the overall system performance. Nodes in an ad-hoc network usually have limited power and processing capability. Therefore algorithm to compute the stability should not be too complex.

The Zone Routing Protocol (ZRP) was introduced in 1997 by Haas and Pearlman [8]. It is a hybrid routing protocol that combines the advantages of proactive and reactive routing. It takes the advantage of pro-active discovery within a node`s local neighborhood (Intra zone Routing Protocol

(IARP)), and uses a reactive protocol for communication between these neighborhoods (Inter zone Routing Protocol (IERP)). The Broadcast Resolution Protocol (BRP) is responsible for the forwarding of a route request.

II. RELATED WORKS

Proactive routing protocols attempt to keep an up-to-date topological map of the entire network. With this map, the route is known and immediately available when a packet needs to be sent. The approach is similar to the one used in wired IP networks. Example of proactive routing protocols are Destination-Sequenced Distance-Vector routing (DSDV) [1] protocol, Cluster head Gateway Switch Routing (CGSR), Optimized Link-State Routing Protocol (OLSR) [2], and Wireless Routing protocol (WRP) [3].

In contrast to proactive routing, reactive routing does not attempt to continuously determine the network connectivity. Instead, a route determination procedure is invoked on demand when a packet needs to be forwarded. The technique relies on queries that are flooded throughout the network [4]. Reactive route determination is used in the Temporally Ordered Routing Algorithm (TORA) [5], Dynamic Source Routing (DSR) [6] and Ad-hoc On-demand Distance Vector (AODV) [7] protocols.

Both proactive and reactive routing schemes have specific advantages and disadvantages that make them suitable for certain types of scenarios. Since proactive routing maintains information that is immediately available, the delay before sending a packet is minimal. On the contrary, reactive protocols must first determine the route, which may result in considerable delay if the information is not available in cache. Moreover, the reactive route search procedure may involve significant control traffic due to global flooding. Purely proactive schemes use a large portion of the bandwidth to keep routing information up-to-date. Because of fast node mobility, the route updates may be more frequent than the route requests, and most of the routing information is never used. Some of the scarce bandwidth is thus wasted [8].

Another type of routing scheme is Hybrid routing, which combines the best features of both proactive and reactive approaches. Examples of such kind of protocols are Zone Routing Protocol (ZRP) [9]-[10], Distributed Dynamic Routing algorithm (DDR).

Zone-Based Routing (ZBR) protocol, where the network area is divided into fixed none-overlapping square zones is proposed in [11]. There is a zone-head in each zone that acts as a router in the network and maintains information of its member nodes. A Path is a collection of ID numbers, which represent the specific zones the path traverses. A signal strength-based, on-demand routing protocol has been proposed, which uses the earliest established path to forward packets, then changes to the strongest signal strength path for long transmissions is explained in [12]. Extension of ZRP for application to multicast routing MZRP, is given in [13]. MZRP is a shared tree multicast routing protocol that proactively maintains the multicast tree membership for local routing zones at each node while establishing multicast trees on-demand. It is scalable to a large number of multicast senders and groups. IP tunnel mechanism is used to improve the data packet delivery ratio during transmission.

Dynamic Zone Topology Routing protocol (DZTR) for scalable routing in a MANET is proposed in [14]. DZTR breaks the network into a number of zones by using a GPS. The topology of each zone is maintained proactively and the route to the nodes in other zones is determined reactively. DZTR proposes a number of different strategies to reduce routing overhead in large networks and reduce the single point of failure during data forwarding. Fisheye Zone Routing Protocol (FZRP) was proposed in [15]. FZRP provides the advantage of a larger zone with only a little increase of the maintenance overhead. Two levels of routing zone are defined in FZRP: the basic zone and the extended zone. Different updating frequencies of changes of link connectivity are associated with the basic zone and extended zone. Performance of route query control mechanisms for the ZRP for ad hoc networks is proposed in [16].

Virtual Backbone Routing (VBR) is a scalable hybrid routing framework for ad hoc networks, which combines local proactive and global reactive routing components over a variable-sized zone hierarchy, is presented in [17]. The zone hierarchy is maintained through a novel distributed virtual backbone maintenance scheme, termed the Distributed Database Coverage Heuristic (DDCH). VBR limits the proactive link information exchange to the local routing zones only. Multicast routing protocol ZBMRP (Zone Based Multicast Routing Protocol) for MANETs is proposed in [18]. ZBMRP applies on-demand procedures to dynamically establish mesh based multicast routing zones along the path from the multicast source node to the multicast receivers. Control packet flooding is employed inside multicast zones, thus multicast overhead is vastly reduced, and good scalability can be achieved.

We observed from the literature that most of the earlier works focus on different routing strategies which efficiently find shortest route to the destination. However the main problem faced by routing protocols in very dynamic conditions is that, links may be broken soon after routes have been established. This leads to a high number of control packets and do not take into account of network overheads caused by routing; neither have they dealt with the problem of unstable messages and data packets that are propagating inside the network, which result in higher bandwidth contention and consequently reduced throughput. Hence we propose Zone and Link Expiry based Routing Protocol (ZLERP) for MANETs to reduce network overhead using link stability as a metric.

Remainder of the paper is structured as follows. Section III describes the proposed work. Section IV presents simulation procedure. Section V presents result analysis. Finally, conclusions are given in section VI.

III. ZONE AND LINK EXPIRY ROUTING PROTOCOLS FOR MANETS

In ZLERP, stability of link is determined on the basis of signal strength received at periodic time interval by node which is on the periphery of other node's zone. Signal strength depends on many factors such as distance between nodes, angles between nodes, obstacles, blocked regions, noise, interference etc. ZLERP considers two main factors, distance between nodes and blocked terrains.

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A. Network environment

We consider a MANET for ZLERP comprising of several nodes that are randomly distributed across a given geographical area as given in figure 1.

ZLERP divides its network in different zones. That's the node's local neighborhood. Each node may be within multiple overlapping zones, and each zone may be of a different size. The size of a zone is not determined by geographical measurement. It is given by a radius of length, where the number of hops is the perimeter of the zone. Each node has its own zone.

Before constructing a zone and determine border nodes, a node needs to know about its local neighbors. A node may use the Media Access Control (MAC) protocols to learn about its direct neighbors. It also may require a Neighbor Discovery Protocol (NDP). NDP relies on the transmission of hello messages by each node. When the node for example node A gets a response from a node C which has received the Hello - messages, the node A notice that it has a direct point-to-point connection with that node C. The NDP selects nodes on various criteria, e.g. signal strength, frequency/delay of beacons etc. Routing zone diameter is variable and this should be chosen based on the topology. By zoning, control message overhead is attempted to be lowered.

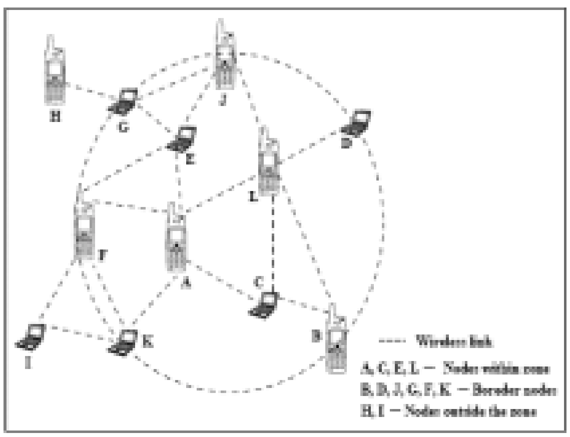

Fig. 1. Network environment

B. Estimation of Inter Signal Strength Difference (ISSD)

As nodes in the ad-hoc network are mobile, their signal strengths with respect to other nodes in the network change as distance between nodes change or as they move into blocked regions where signal strengths are poor. These frequently changing signal strengths are recorded at periodic time intervals in which a window of measurements is done. This can be done with the help of NDP in ZRP by introducing additional field "signal strength received" in neighbor table of each node.

First we mention some commonly used symbols in this section. N = total number of nodes, $D_{AB}(t)$ = distance between nodes A and B at time t, t_r = transmission range, Si(t) = signal strength of node at time t, R = zone radius, δ = threshold constant defined by the network administrator.

At time t, a link (A,B) exists if $D_{AB}(t) <= R$. $S_1, S_2, S_3, \ldots, S_n$ are different signal strengths received by node A from node B at periodic time intervals $t_1, t_2, t_3, \ldots, t_n$. $ISSD_{old}$ and $ISSD_{new}$ be the previous and the present values of ISSD.

ISSD is estimated as shown in the equation (1).

$$ISSD_{new} = (S1 + S2 + S3 + \ldots Sn)/n \qquad (1)$$

- If $ISSD_{new} > ISSD_{old} + \delta$, nodes are moving towards each other. It happens usually, when signal strengths are such that S1 > S2 > S3 >…Sn.
- If $ISSD_{new} < ISSD_{old} - \delta$, nodes are moving away from each other. It happens usually, when signal strengths are such that S1 < S2 < S3 < …..Sn.
- If ISSD $-\delta$ < ISSD < ISSD $+\delta$, nodes are moving around in a certain small area or they are stationary. Nodes are either stationary or they tend to move less frequently and even if they move, they move in proximity of each other.

C. Algorithm

Algorithm 1 presents pseudocode for ZLERP.

Algorithm 1: ZLERP

{Nomenclature: N = Number of nodes in the network, S = Source node, D = Destination node}

Begin

For i = 1 to N do

begin

1) NDP of node 'i' transmits "HELLO" beacons at regular intervals to discover its one hop neighbors;
2) A window of signal strengths received from neighboring nodes are recorded when node 'i' receives "HELLO-RESPONSE" beacons from neighbors;

end

For i = 1 to N do

begin

3) Node i compute ISSD of their peripheral nodes and update the database;

end

4) Application request arrives from node 'S' destined to node 'D';
5) If D is not present in the zone of S then forward route request query to peripheral nodes of S where ISSD is nearer to zero (based on some threshold, may be in the range +0.1 to 0.1 in normalized range); Let us say a node X is found, then set S = X;
6) Repeat the above step until `D' is found; During forwarding of route request query packet, visited nodes information is recorded in query packet; In case if a node does not find a peripheral node within the ISSD threshold range, such node sends a stable path error message to node who has initiated route request;
7) If `D' is found then a route reply packet (containing path information) is sent in the reverse path to a node who initiated route request;
8) Stop

End

D. Example scenario

For better picturization of the proposed algorithm consider the example as shown in the figure 2 (a).

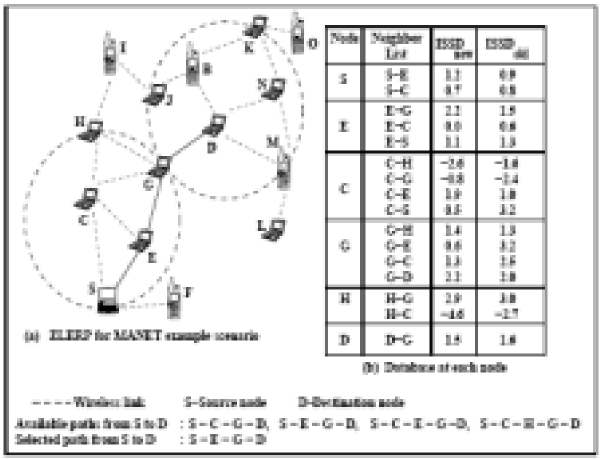

Fig. 2. Example scenario

At each node a data base is maintained consisting of neighbor list, ISSD, at different times, as shown in figure 2(b). In this example `S' is the source and `D' is the destination. In order to set up the path for routing from `S' to `D', first `S' sends it's neighbor list and ISSD value from the database. After comparing the present ISSD value with the previous ISSD node `S' selects path as S - E (because for link S - E, $ISSD_{new} > ISSD_{old}$. At node `E', path selected is E – G by comparing new ISSD value with the old ISSD. In this way, the neighbor list is taken and the link is established until the destination node `D' is found. For this example, the selected path is S - E - G - D.

IV. SIMULATION

Proposed model has been simulated in various network scenarios using "C" language. Simulation is carried out extensively for different network parameters by using number of iterations. In this section, we describe the simulation model, simulation procedure and performance parameters.

A. Simulation model

In order to achieve the uniform transmission power we assume that all the mobile nodes use omni-directional antennas. An ad-hoc network of N number of nodes is generated by randomly placing nodes within the area a X b square meters which is divided into grids. Numbers of moving nodes in a network at a particular time are fraction f of N. For mobility, "Random way point model" is considered. In this model, each node selects a random point in the simulation area as its destination, and a speed from an input range. The node then moves to its destination at its chosen speed. When the node reaches its destination, it rests for some amount of time. At the end of this period, it selects a new destination and speed and resumes movement. Nodes can move in the speed range X to Y meters/second. Each node starts from a random location and moves in any one of the eight directions: North, south, East, West, Northwest, and southwest. If a node tries to go out of the boundary its direction is reversed (Bouncing ball model). Each node keeps the information about its routing zone, i.e., list of its interior nodes and peripheral nodes.

In ZLERP, each node also keeps information about signal strengths ss received from its zone members at periodic time interval. Numbers of application requests appreq are generated by selecting source-destination pairs randomly for finding corresponding paths. Zone radius R is used for defining a zone. Every node has its routing zone, hence zones are overlapping. ISSD threshold ranges are th_1 and th_2. Channel model for signal propagation is based on Gilbert model [19] [20] where probability of channel being good varies from 0.5 to 0.9, channel being bad varies from 0.0 to 0.5, transition probability from good to bad varies between 0.1 to 0.9, and transition probability from bad to good varies from 0.5 to 0.9. The signal propagation model considered for simulation is based on "Friss free space equation" which considers only a single path of propagation.

B. Simulation procedure

Begin

- Generate ad hoc network with given number of nodes.
- Based on the value of zone radius find internal nodes and peripheral nodes of each node's zone.
- Generate application connection requests by randomly selecting source destination pairs.
- For every source destination pair selected, find out path using ZRP and ZLERP.
- Compute performance parameters of the system such as control overheads, reduction in control overheads, and connectivity.

End

C. Performance parameters

Performance parameters measured are as follows.

- ***Control Overheads:*** It is defined as the normalized value of the total number of route request (RREQ) and route reply (RREP) packets that are being propagated into the network for discovering a route.
- ***Connectivity:*** It is defined as the ratio of paths found for connection requests to number of connection requests arrived. It is expressed in terms of percentage.
- ***Reduction in control overheads:*** It is defined as the percentage reduction in control overheads in ZLERP compared to ZRP with varying number of mobile nodes.

To illustrate some results of the simulation following parameters are considered.
N = 40, R = 75, a = 250 meters, b = 200 meters, size of each grid = 50 square meters, f = 10 to 60% or 0.1 to 0.6, appreq = 5 to 30, ss = 0.0 to 1.0, th1 and th2 are considered for different cases, +0.2 to 0.2 and +0.1 to 0.1.

V. RESULT ANALYSIS

We observe from figure 3 that control overheads in both ZRP and ZLERP increase with the rise in number of application connection requests. It also shows a marked decrease in total number of control packets in ZLERP as compared to ZRP. This is expected, since the total number of RREQ packets (and hence RREP packets) that are being propagated into the network are greatly reduced as route

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request packets are not forwarded by a node to all its peripheral nodes because some nodes corresponds to unstable links. Thus for ISSD threshold range +0.2 to -0.2, control overheads are reduced by 13% to 16% as compared to ZRP.

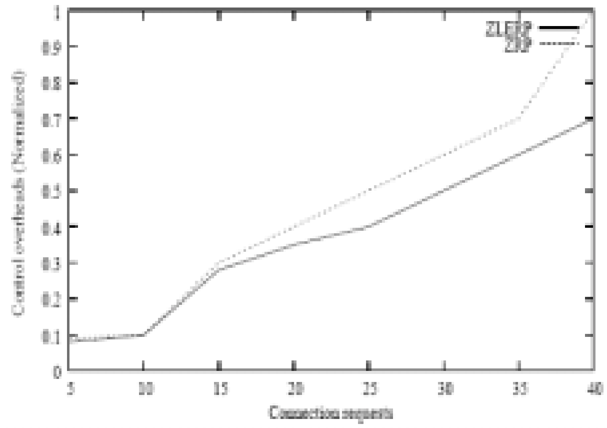

Fig. 3. Control overheads Vs. Connection requests (for N=40, R=75, f=20%, ISSD=0.2 to -0.2)

Since the routes via unstable links are not preferred, the scheme also reduces the number of link breakages and thus number of route error packets. It is also discovered that scheme also reduces number of "HELLO" packets being transmitted by nodes, because of restriction of propagation of control packets between unstable links. Also, with significant decrease in network overheads caused by control packets, there is less congestion in the network. Figure 4 shows, connectivity percentage in ZLERP is reduced by 2 to 3% as compared to ZRP. This is because ZLERP does not forward route request packets on unstable links. Due to this some application connection requests are rejected as they could not find next node constituting stable link to forward route request.

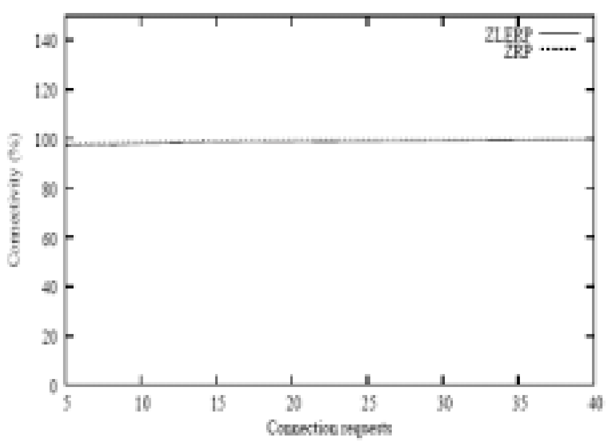

Fig. 4. Connectivity Vs. Connection requests (for N=40, R=75, f=20%, ISSD=0.2 to -0.2)

From figure 5, we observe that ZLERP works well even with increasing mobility of the network. With increasing mobility, connectivity of ZLERP decreases very slightly but overheads are reduced compared to ZRP. Thus in highly mobile networks, overheads in ZLERP are still reduced.

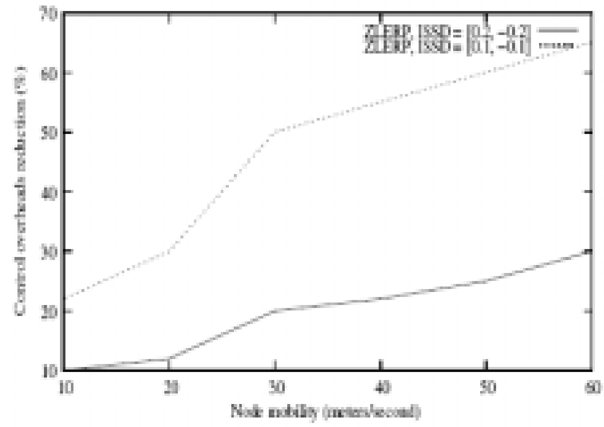

Fig. 5. Control overheads reduction in ZLERP Vs. Node mobility

VI. CONCLUSIONS

This paper presented a model for unicast, source initiated routing for mobile ad hoc networks using hybrid protocol which ensures link stability and limits the control overheads of the network to some extent. In this proposed method, pattern of node movements is studied using received signal strengths between neighboring nodes at periodic time intervals and link stability is determined.

It does not introduce any extra overheads into the network for getting necessary information which is required for discovering stable links, as it is done by NDP while finding neighbors. As links are stable, breakage will occur less frequently, hence less number of control packets are propagated in the network for route maintenance. However the limitation of the protocol is, path found may not be a shortest path because links contributing in a shortest path may not be stable links. We need to address the connectivity improvement with the proposed scheme.

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