Path Reliability of Multi Path Routing in MANET

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Abstract: ***Mobile Ad-hoc networks are more likely to link failures as it is not supported by a static infrastructure. The path for data transfer can be selected on the basis of many metrics like least hop counts, bandwidth quality of the path, residual life time of path etc. Most of routing protocols address selection of paths based on least hops counts of path. This paper estimates the reliability of the paths (multipath) quantitatively wherein the route selection is done on the basis of residual lifetime of the routes. Reliability of the path is computed using the residual life time of each link of the path. The residual life of a link is computed on the basis of current relative velocity and radial distance between two nodes.***

Keywords: MANET, Multipath routing, Residual life time, Reliability estimation.

1. Introduction

Situations like natural disasters, vehicle transportation and military wars are some application area of Mobile Ad-hoc network. In this network each mobile node works as router as well as sender/receiver of data. This requires an efficient routing strategy to ensure reliable and secure communication.

Various routing protocols have been proposed for MANET. They are mainly of two types; table-driven and On-demand routing protocols. The Destination-Sequenced Distance Vector (DSDV) [2] routing is a table driven routing protocol, which maintains large routing table which is updated in accordance with the frequent changes in the topology. It is very costly in term of battery life and control message overhead. The Dynamic Source Routing (DSR) [2] and Ad-hoc On-Demand Distance Vector (AODV) routing [2], are On-demand protocols. In these protocols, the first route request (RREQ) received by the destination is accepted without an estimation of the residual life time of links of the route. This route may contain weak links and cause frequent route failures. DSR, does not take into account mobility parameters during route discovery, resulting in paths which break often in highly mobile scenarios, causing excessive broadcasting and flooding the entire network for new routes to be discovered. This paper considers multipath for data transmission, each path is selected on the basis of high residual life time among all found that at the time, so it minimizes the frequent route discovery overhead. And as the data packets (transmission) are allocated to all path (multipath) selected parallel rather than sending data through one path and keeping remaining path in standalone mode, so the congestion and bandwidth of the selected paths can also be taken care of.

2. Related Works

The Signal Strength Adaptive (SSA) protocol [2] uses the stability of individual link qualitatively on the basis of link-layer beacons sent periodically. Route-Lifetime Assessment Based Routing protocol (RABR)[5] incorporates the residual-route-life time prediction on the basis of affinity appraisal, depending upon the current location of nodes, but does not consider direction of movement; whether two nodes are coming toward or going away.

A beaconless node-velocity-based stable path on-demand routing protocol (NVSP) [9] considers the current node velocity information in the RREQs. The maximum velocity of an intermediate node on the path is named bottleneck velocity of the path. The destination chooses the path with the least bottleneck velocity and sends Reply (RREP) packet on the path. The lifetime of NVSP routes is 25-35% and 55-75% more than that of the routes chosen Dynamic Source Routing (DSR) protocol in networks of low and high density respectively. It (NVSP) considers only current velocity of the node but not current location so determining residual life of the link is not exactly captured.

Another method of estimating the distance and the relative velocity of mobile nodes is the use of GPS receivers. But in many situations, using GPS is not appropriate to use e.g. indoor environments and it is not suitable for small devices due to its high power consumption. Although the use of GPS is common in mobile nodes, [8] introduces a scheme to estimate the LET (link-expiration time) without the need of GPS (in case the GPS is not able to effectively estimate the velocity of nodes or is simply not available).

The Doppler shift subjected to signals is used to calculate the relative velocity of nodes. This scheme considers movement of nodes is pseudo linear (i.e. With what speed they are moving towards or away from each other). To find relative mobility Doppler shift of frequency is used in [4], given by

$$f_r = f_e \left[\frac{v}{v + v_{sr}} \right]$$

Where, f_r is the received frequency, f_e is the emitted frequency, v is the speed of the signal in the medium and v_{sr} is the radial component of source to receiver velocity.

$$v_{sr} = v_e \left[\frac{f_e - f_r}{f_r} \right]$$

But in the scenario where many obstacles are present and because of interference of many reflected signals, strength of signal and frequency may change unexpectedly so computed distance, velocity and hence expiration time may be much deviated from exact figure. For the mobility model it is assumed that mobile nodes are pseudo-linear, and highly mobile in nature. A good example of this kind of system is an aeronautical ad hoc network. A simplified free space propagation model and a power attenuation model is given in [3]. Say signal strength and frequency level is specified for each mobile mode to transmit signal. Signal strength is attenuated with distance; the common power attenuation model for the decay is given by.

$$A_r = \frac{P_t}{d_\alpha}......................................(1)$$

$$where,......A_r, P_t, d_\alpha$$

are received amplitude at distance d, transmitted signal strength, and distance d respectively, α is power loss factor, typically given a range between 2 to 6. This model may not be suitable, if location contains lots of obstacle.

3. Model Description

This paper incorporates two main concepts;

1. Finding maximum number of disjoint paths using a simple algorithm explained in Split Multipath Routing (SMR) [1]. Providing multiple routes helps minimizing route discovery (overhead) process and control message overhead.
2. Computing residual life time of each path at destination using some additional information (starting transmission time of the forwarding packet, and current velocity of the node) incorporated by each node (procedure given in next subsection) along with its ID in Route Request (RREQ) packet.

The minimum residual life time of a link is considered as minimum residual life time of that path. Only those few path are replied back which are having considerable (maximal residual life of the path among all received paths) residual life time. In another word, the paths having residual life time greater than few RTT (round trip time) are replied back. A rough frame format of RREQ packet is shown in Figure (1) below.

SID	DID	SNO	NIDi	L_i	Ti	Vi

Figure 1: Structure of RREQ Packet

SID: Source Id (4 Bytes)
DID: Destination Id (4 Bytes)
SNO: Sequence number of the packet (4 Bytes).
NIDi: Node Id for i^{th} intermediate node (4 Bytes for each intermediate node)
Li: Residual lifetime for i^{th} link (4 Bytes for each intermediate link)
Ti: Current starting time of data transmission at i^{th} node (4 Bytes).
Vi: Velocity of i^{th} node at time Ti (4 Bytes).

The last two fields (Ti, Vi) are replaced by each next node after computing the Li. Path reliability is estimated using empirical method [7] (nonparametric method). Nonparametric method of Reliability estimation is done when probability distribution of random movement of mobile node are not known. There are many models [5] (e.g. *Random Waypoint* model, Random Walk Model, *Gauss-Markov* model) captures the mobility distribution and hence the route stability is predicted, but this approach involves more computational overhead than the proposed one in this paper.

3.1 Route Discovery

Route discovery is done as discussed in Split Multipath Routing (SMR) [1]. This is an on-demand routing protocol that builds multiple routes using request/reply cycles. It broadcasts the ROUTE REQUEST (RREQ) message to the entire network. Intermediate nodes forward the duplicate packets that traversed through a different incoming link, having lesser hop counts than the link from which the previous RREQ is received. Only the packets of same IDs and more hop count than received before are dropped.

One additional thing here is, starting time of transmission of a data packet from each node, and node's (its current) velocity information is also appended to RREQ packet, the next node extract these information, computes the residual link life time and append this information to forwarding packet and also replace the previous transmission time (starting) and velocity with its own.

3.2 Link Residual Life Time Estimation

To compute residual life time of a link first we have to find out distance between nodes and its relative velocity.

Consider a link A-B, after receiving a RREQ destined to some other node, node A will append three data field in RREQ; 1. starting time of transmission of packet, 2. Its own velocity, and 3. ID. Neighbor node B will receive this packet, and some computation will be done like this.

i. Extract time field, compare it with current time.
 Let extracted time is t_s, current time is t_r, transmission time is t_t (packet size/bandwidth) .
 Then (propagation time) $t= (t_r - t_s - 2t_t)$
 Distance between nodes, d=t.c……………...(1)
 c is signal speed in the medium.

ii. Extract the velocity field from the packet
 Compute relative velocity (with respect to A)

$$\overline{\Delta v} = \overline{v_B} - \overline{v_A}.................(2)$$

 So, Residual life time the link is

$$T= (R-d)/ \overline{\Delta v} ………………………(3)$$

Where R is range of signal coverage of a node.

iii. Append T (link residual life time), ID and modify starting time of rebroadcasting packet, and velocity with its own and rebroadcast it.

3.3 Route Reply

Originating Source_ID (4 Bytes)	Dest_ID (4 Bytes)	Seq_No Of the RREQ (4 Bytes)	Seq of IDs & T of each nodes on the path

Figure 2: The Route Reply (RREP) Packet Structure

After receiving a RREQ, destination node finds the minimum residual life time of the link corresponding to the RREQ and do the same for each RREQ till a specified time, then selects the paths with maximum of minimum link residual life time of all received RREQ and sends Route Reply (RREP) packet corresponding to that selected paths.

The route Reply (RREP) packet structure is shown in Figure2.

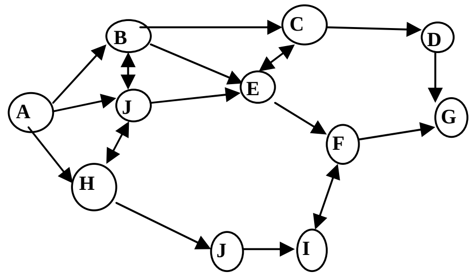

Figure 3: Optimal multipath between source (node A) and destination (node G).

The last field in Figure: 2, is of variable length (multiple of 8 bytes) depending upon number of intermediate nodes on the path, T is minimum residual life time of the link corresponding to the path.

From Figure (3), 3 disjoint paths are replied back, given by A-B-C-D-G, A-B-E-F-G, A-J-E-F-G

The double arrow link shows discarding of packet rebroadcasting, and absence of link between two nods shows not reachable link.

4. Reliability Estimation

Let residual time of j^{th} link of i^{th} path (having n links) is t_j. Then failure (mean) time of the path is given by.

$$t_i = \frac{\sum_{i=1}^{n} t_j}{n}$$

MTTF (mean time to failure) of each path is estimated using non parametric model [7] and this metric is sent with RREP to source node. Source node computes the overall reliability of paths, explained below.

Let $t_1, t_2, \ldots t_m$ are m ordered failure time of m paths, where $t_i \le t_{i+1}$. A possible estimate of the reliability function R(t), is simply the fraction of paths surviving at time t. or $R(t_i)=1-i/(m+1)$. Further, source node may use the information for data packets allocation and in route status maintenance.

5. Conclusion

This paper estimates the reliability of the paths (multipath) quantitatively wherein the route selection is done on the basis of residual lifetime of the routes. The residual life of a link is computed on the basis of current relative velocity and radial distance between two nodes. Further data packet allocation procedure can be incorporated in it and simulation of the mentioned strategy can be done to compare the performance with respect to other existing MANET routing protocols.

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