Mobility Prediction algorithm to improve the Routing performance in MANET

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Summary
One of the major challenges in mobile ad hoc networks (MANETs) is link failure due to mobility. If the degree of mobility of any node in any route increases, the route lifetime decreases. That causes frequent link failures, and results more packet loss and low throughput. Packet loss requires packet retransmissions, which further overload the network and can cause additional latency and packet loss. The proposed algorithm estimates the number of packets that can traverse through the route before it breaks because of mobility. This algorithm increases network throughput and packet delivery ratio. The algorithm is implemented in dynamic source routing (DSR) protocol, and simulated in Jprowler simulator. The simulation results show that the packet delivery ratio of DSR with the algorithm can improve up to forty six percent over DSR in mobile ad hoc networks.

Keywords:
Route Life Time(RLT) , Link Life Time(LLT), MANET , DSR

1. Introduction

A mobile ad-hoc network (MANET) is a self-configuring infrastructure-less network of mobile devices connected by wireless links. Ad hoc is Latin and means "for this purpose". Mobile Ad Hoc Networks (MANETs) has become one of the most prevalent areas of research in the recent years because of the challenges it pose to the related protocols. MANET is the new emerging technology, which enables users to communicate without any physical infrastructure regardless of their geographical location, that's why it is sometimes referred to as an "infrastructure less" network.
One of the major challenges in mobile ad hoc networks is link failure due to mobility. Because nodes in a MANET act as routers for any ongoing packet communication and have limited transmission ranges, the communication links are broken, and packet losses occur. This problem is amplified when a route constitutes several such links. If any of those links fails, the route breaks, which initiates series of undesirable events and outcomes. If how long a link can be operational is predicted, the routing protocol can use this to its advantage. It is assumed that every link remains connected for a limited time, called link life time (LLT), and a route has a limited life, called route life time (RLT). The RLT depends on the LLTs of links, and can be taken as the lowest LLT in the route. When degree of mobility increases, LLTs and eventually RLTs decrease. That contributes to increase in packet losses and low throughputs in a MANET. Since mobility is inevitable in MANETs, an algorithm that utilizes mobility to decrease packet loss in the network is designed, and presented in this paper. The proposed algorithm estimates the route's RLT, and allows routing protocol to send number of packets that can traverse the route successfully during the RLT period. This provision is implemented and shown effective in improving the routing performance in MANETs.
The following section will provide summary of the related work in this topic. The proposed algorithm is discussed in Section 3. Section 4 provides Simulation model, simulation results and comparisons are provided in Section 5, and the paper is concluded with Section 6.

2. Related work

A model to compute an upper bound for the maximum network size in a MANET is proposed in [2]. According to the analysis presented in [2], a route would die due to mobility after a certain number of hops. Topology dynamics is investigated in [4] based on the smooth

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mobility model. The smooth model generates smooth and microscopic nodal movements, and maintains a uniform spatial node distribution. The model predicts link existence based on the present distance between a pair of nodes and their relative speeds. The analysis in [4] reveals that the expected link lifetime decreases exponentially with increasing mobility. Results presented in [4] were not tested in any protocol. A mobility assessment on-demand (MAOD) routing protocol is proposed to select a stable route in order to enhance system throughput and performance [1]. MAOD is an on-demand routing protocol similar to dynamic source routing (DSR) protocol [5]. The difference between MAOD and DSR is in the path selection method. As MAOD takes the mobility of the hosts into consideration, it selects a more stable route than DSR. In MAOD, an error count parameter is used to measure mobility of a host. However, the error count method has problems in judging the mobility of the nodes because it does not indicate which node is mobile, the node itself or the nodes around it. Even if a node is static, it needs to increase its error count when its neighbors are mobile. A new measure of mobility in which each node estimates at regular time intervals its relative mobility with respect to its neighbors is proposed in [6]. A multicast scheme, on-demand multicast routing protocol (ODMRP) [7], has been recently proposed for MANETs. ODMRP is a reactive (on-demand) protocol that delivers packets to a destination in a mesh topology using scoped flooding of data. ODMRP proposes a method to predict the link expiration time, which is based on a more realistic propagation model, and uses received signal strength indication (RSSI). But, instantaneous RSSI values may not be reliable for fading channels since its fluctuations vary significantly in short time and distances.

3. Proposed Algorithm

3.1. Integration of Mobility scheme

The duration of connectivity between two nodes is unlimited for static ad hoc networks whereas it changes with mobility in MANETs. Link failures are inevitable if the nodes are mobile, and get more severe when the mobility of nodes increases. Link failures increase packet loss considerably. In order to reduce packet loss due to link failures, mobility needs to be integrated in routing protocols. This integration needs to be independent of routing protocols to have an effective solution. However, on-demand routing protocol (i.e. DSR) is considered as the candidate to apply the developed mobility scheme. The scheme is based on an efficient use of the duration of connectivity of two neighboring nodes in a route. This duration is called link life time (LLT).

3.1.1 Calculation of Link Life Time

A method to calculate LLT [3] is proposed and briefly presented here . Figure 1 shows two mobile nodes A and B with their radio ranges, *r*. The current locations of A and B are $A(x_{a1},y_{a1})$ and $B(x_{b1},y_{b1})$, respectively. A and B are moving with velocities v_a and v_b, and angles θ_a and θ_b, respectively. Their future locations are $A(x_{a2},ya_2)$ and $B(x_{b2},y_{b2})$ after some time duration, *t*. We are assuming that nodes A and B are not changing directions within this time duration, *t*.

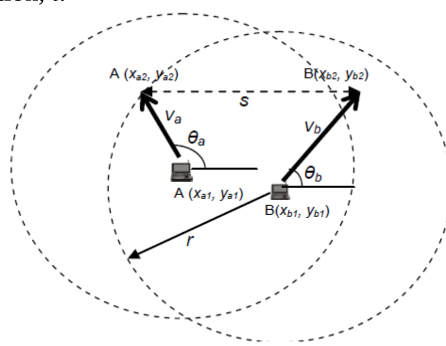

Figure 1. A scenario for calculating LLT

If all the information related to their current locations, such as v_a, θ_a, v_b, θ_b, x_{a1}, y_{a1}, *xb1* and *yb1* are known, their future locations can be calculated using the provided information from known values by the following two functions.

$A(x_{a2},y_{a2})=f(t,v_a,\theta_a,x_{a1},y_{a1})$. (1)

$B(x_{b2},y_{b2})=f(t,v_b,\theta_b,x_{b1},y_{b1})$. (2)

If the distance between A and B after time *t* is *s* then

$s^2=(x_{a2}-x_{b2})^2+(y_{a2}-y_{b2})^2$. (3)

A and B will be able to communicate with each other as long as they will remain within their transmission range, *r*. So, t = LLT if $s \le r$. After solving (3) with $s \le r$ and considering t = LLT, we get

$$LLT = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

where $a = v_i \cos\theta_i - v_j \cos\theta_j$, $b = x_i - x_j$, (4)
$c = v_i \sin\theta_i - v_j \sin\theta_j$ and $d = y_i - y_j$.

3.1.2 Mobility Algorithm

The algorithm has been designed to treat mobility related problems in wireless networks. The size of a wireless network is significantly affected by the mobility of nodes [8]. As mobility increases, LLT between nodes decreases. This causes the routes to break quickly, and packet losses due to route breakages. The proposed algorithm solves the mobility related routing problems and comprises the following 4 steps.

Step 1: Source estimates a minimum threshold link life time:

In any on-demand routing protocol like DSR, routes that are used for sending data packets are discovered based on some requirements (i.e., routing metrics). In the proposed mobility scheme, the source uses a minimum threshold link life time (TLLT) to discover more stable links and routes. The source estimates TLLT based on the nature of mobility (i.e. urban area or highway). Unlike highway, random mobility scenario prevails in urban area. Statistically more than twenty percent of the routes in a random mobility scenario die out within few seconds. Routes in a highway mobility scenario are more stable compared to routes in a random mobility scenario. Thus TLLT can be set higher for highways compared to a random mobility scenario. TLLT in a random mobility scenario can be set higher for low speeds compared to high speeds.

Step 2: Using TLLT in route discovery process to detect unstable routes:

In case of any on-demand routing protocol, whenever the source has a packet to send, it searches a route in the route cache. If there is no route available in the cache, the node sends a route discovery packet to a desired destination. In the proposed scheme, the source sends TLLT in the route discovery packet. Each node along the path toward the destination calculates its own LLT with the previous node, and compares the calculated LLT with the TLLT in the packet. If the calculated LLT is greater than the TLLT of the packet, this node becomes a part of the route. Otherwise, it is not included in the route.
Figure 2 illustrates a simple scenario where the source sends a route discovery packet with TLLT = 3 seconds. MN 2 and MN 4 agree to be part of the route comparing their LLTs. But, MN 6 refrains becoming part of the route since its LLT is lower than the TLLT. The described provision prevents discovering routes that have less stable links.

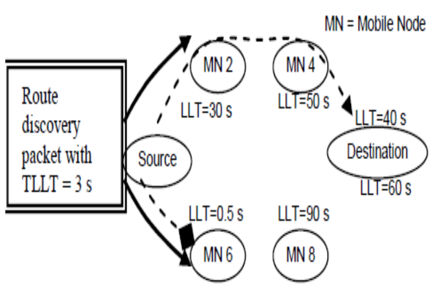

Figure 2 . Discarding unstable routes.

Step 3: Determination of route life time:

How long a route exists is an important criterion for the proposed algorithm. We call this duration “route life time (RLT)”, and it is defined as the duration of the liveliness of any route. All the nodes in any route have their own LLTs, and the node with the lowest LLT has higher probability of breaking the route. So, the lowest LLT in any route is the RLT. The scenario given in Figure 2 illustrates that, and MN 2’s LLT (i.e. 30 seconds) is taken as the RLT. According to our algorithm, the source sends the route discovery packet with a large number in its RLT field (e.g., RLT = 99999 seconds.). If any node is a part of the route, it compares its LLT with the RLT in the route discovery packet. If the LLT is less than the RLT, it replaces the RLT field in the discovery packet with its own LLT. Otherwise, it forwards the route discovery packet without changing the RLT field. After getting the route reply packet, the source calculates the net RLT, RLT_{net}, which is the difference between RLT of the packet and the time it took the route reply packet to arrive to the source, t_{route}. Then, RLT_{net} is given by

$$RLT_{net}=RLT-t_{route}. \quad (5)$$

The source stores the RLT_{net}, and the t_{route} in the route cache. t_{route} is considered average latency between source and destination, which will used to calculate how many packets successfully transferred from source to destination.

Step 4: Algorithm for reducing packet loss due to mobility using RLT:

The route discovery process with mobility assisted routing is explained in Step 3. Whenever there is a packet to send, the source finds a route from the route cache, and sends an estimated number of packets that the respective route is able to deliver before breaking. Latency between source and destination, $t_{oute,}$ is important as well. That is needed to estimate the number of packets that can be sent by the source to the destination. Let us assume N_{est} be the estimated number of packets to be sent through that route, and given by

$$N_{est}= RLT_{net}/ t_{route} \quad (6)$$

The selected route remains alive during RLT_{net}, and within this RLT_{net}, the source will be able to send approximately N_{est} number of packets. If the source sends more than N_{est} packets, the additional packets have higher probability of getting lost due to the broken route. After finding N_{est}, the packets are sent in order. If there are more packets to be sent, the source finds an alternative route from the route cache, and repeats the process for this route by calculating its Nest. If there is no route available in the route cache, the source starts the route discovery process.

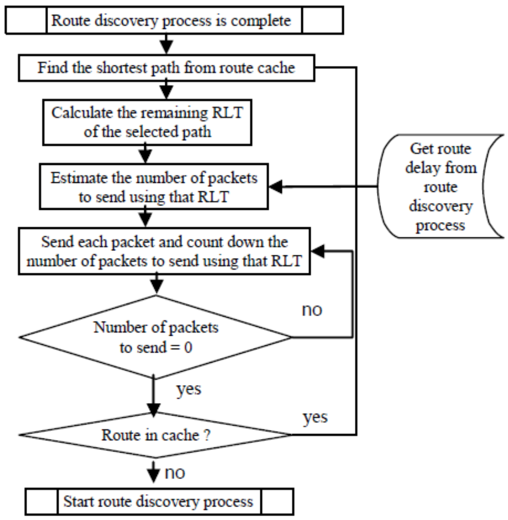

Figure 3. Flowchart of algorithm

4. System Model and Implementation

Jprowler simulator is used for simulation, which is programmed in Java. We can create network of any number of nodes with variable transmission range. Mobile ad hoc networks with 10 to 50 nodes are considered for testing the proposed algorithm. Each node in this network is placed randomly with known current location. It's assumed that all nodes are moving with the same velocity. Velocity can be varied. Source is producing data packets of size 512 bytes. Packet losses occur in two ways (i.e. due to link failures and due to collisions), and the emphasis here is given to reduce packet losses due to link failures.

We have used DSR as a routing layer protocol, and DSR is combined with the proposed algorithm. We have considered four modifications in the route discovery phase of DSR protocol. First, whenever a node receives a route discovery packet, it calculates LLT with its previous node. Second, each route discovery packet contains a TLLT value assigned by the source. Any node that receives a route discovery packet compares its calculated LLT with the TLLT in the packet, and drops the packet if the LLT is less than the TLLT. Third, the RLT of the discovered route is estimated with the minimum of the LLT values of the nodes along the route. Forth, the destination calculates latency of each route, and sends this to the source through route reply packet. In data transmission phase, the source finds the shortest route according to the principle of DSR. Then, the source estimates the approximate number of packets to be sent using the RLT and latency of the corresponding route. That provision reduces packet loss due to link failures. We call this implementation "DSR with LLT".

5. Simulation Results

The number of nodes and the range for each node within which they can contact other nodes should be specified in the "Nodes" and "Range" text fields in the simulator as shown in Figure 4. The button "CREATE AND SHOW NETWORK" is clicked to create the network. Source and destination nodes should be specified and the button "Find Route" is clicked. All the possible routes are found and five optimum paths along with their RLT and t_{route} are displayed. Node 1 is considered as Source and node 15 as destination. Found routes are 51. Optimum 5 routes are [1,11,0,15] RLT=504.8ms, [1,11,17,15] RLT= 221.2ms, [1,11,32,15] RLT=354.8ms, [1,45,32,15] RLT=496.9ms and [1,3,11,0,15] RLT=386.8ms. First route with highest RLT value is selected as route as shown in Figure 5.

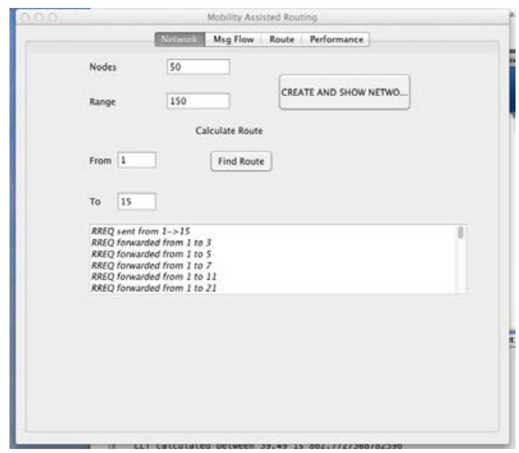

Figure 4. Simulator.

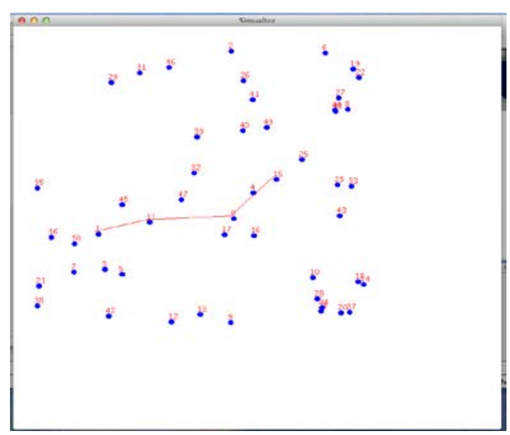

Figure 5. Path in network

Three metrics are considered in measuring and comparing the performance of the proposed algorithm with existing solutions. Those metrics are packet delivery ratio, average packet delay and average energy consumption. Packet delivery ratio is the ratio between the number of received packets by the destination and the total number of packets sent by the source at the end of each simulation. The total number of lost packets defines packet loss during the simulation. Packet delivery ratio depends on packet loss in the route. Average packet delay is defined as the span of time required by a packet to reach from source to destination. Average energy is energy consumed for transfer of packets from source to destination. As we are dealing with the effect of mobility in an ad hoc network, we have chosen speed (meter/second) of the mobile nodes as a variable while measuring the performance of the protocols. We have compared our implementation with original DSR for three performance parameters. Figures 6, 8 and10 provide results of the simulations for increasing number of nodes and Figures 7, 9 and 11 provide results of the simulations for the 10 node scenario with increase in the speed.

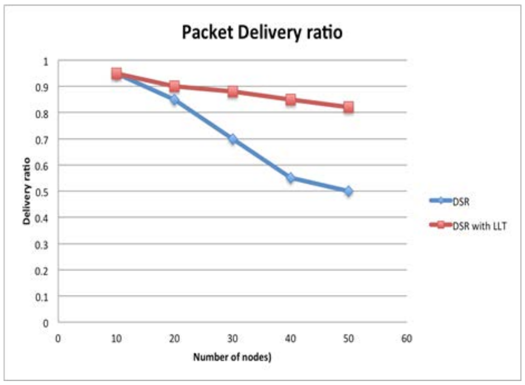

Figure 6. Packet Delivery ratio versus Number of nodes

The number of link failures is increasing with the increasing of number of nodes. So, packet delivery ratio is decreasing in both “DSR with LLT” and “DSR” as illustrated in Figure 6. As our algorithm is sending the number of packets that the route can handle, packet loss is reduced by about 90 percent, so packet delivery ratio is better compared to DSR.

As speed increases the nodes will move out of range frequently which leads to frequently link break so decreases the delivery ratio in DSR.

Figure 7 shows that a significant improvement in packet delivery ratio with “DSR with LLT”. DSR with LLT is sending the number of packets that the route can handle, packet loss is reduced by about 90 percent. Since packet loss is less the delivery ratio is high. In case of DSR there is huge packet loss so leads low delivery ratio. Packet delivery ratio is 46 percent more compared to DSR when the speed of the mobile nodes is about 25 meter/second. The red line in Figure 7 shows that the packet delivery ratio (using DSR with LLT) is decreasing with increasing mobile speeds. This is due to the assumption made during LLT calculation that nodes are not changing directions within the duration of LLT. This causes some links to expire before the calculated LLT. That is why some packets are lost, which decreases the packet delivery ratio.

Figure 7. Packet Delivery ratio versus Speed

Figure 8 shows graph of average end-to-end packet delay with increasing number of nodes and mobility is kept constant. Packet delay increases with increase in number of nodes for both protocols as number of hops gets increases in the paths so time required for packet to reach the destination increases. For both protocols the delay will be same as packets are transferred through same route.

We do not make any changes in the routing strategy. We are using the same routes as DSR does, but with a new algorithm to reduce packet loss. So, the average packet delay of both schemes (i.e. “DSR” and “DSR with LLT”) should be same. This is evident in Figure 9, which shows average packet delay of schemes (i.e. “DSR” and ”DSR with LLT”).

Figure 10 shows the Average energy consumption increases with increasing number of nodes as number of hops gets increases in the paths. As speed increases the nodes will move out of range frequently so there will be frequently link break which leads to loss of packets. Packet loss requires packet retransmissions and link break requires rerouting which further overload the network and can cause additional consumption of energy.

Figure 11 shows energy consumption is high in DSR compared to DSR with LLT. As “DSR with LLT” algorithm is sending the number of packets that the route can handle, packet loss is reduced. Since packet loss is less, less energy is wasted. In case of DSR, there is huge packet loss so lot of energy is wasted which leads to high-energy consumption.

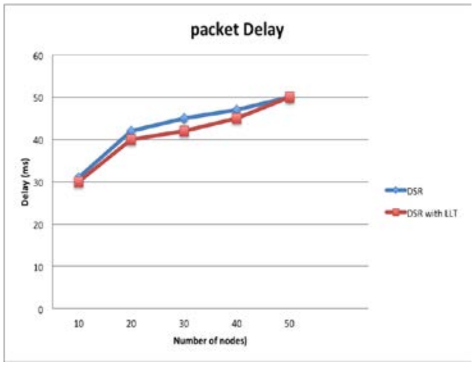

Figure 8. Packet Delay versus Number of nodes

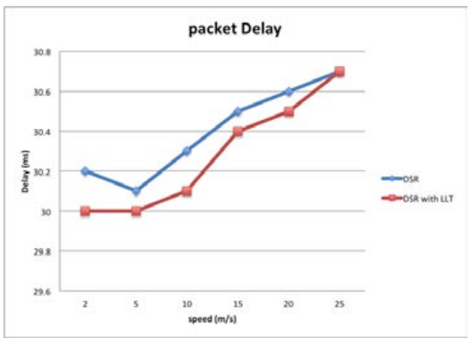

Figure 9. Packet Delay versus Speed

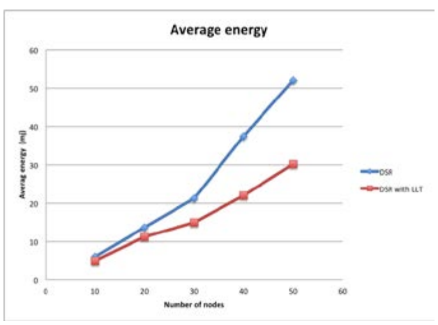

Figure 10. Average energy versus Number of nodes.

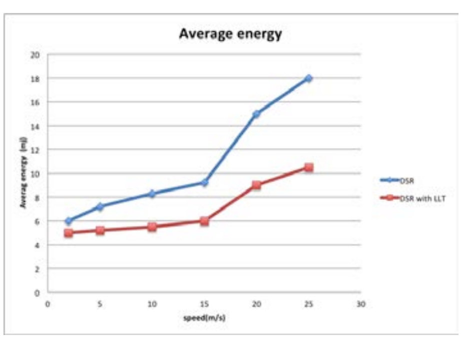

Figure 11. Average energy versus Speed

5. Conclusion and future work

A new approach to reduce packet loss due to inevitable link failures in MANET is presented. The proposed changes to the routing algorithm are implemented in DSR, but this approach is independent of the choice of any on-demand routing protocol. RLT is estimated using the route discovery mechanism. Using RLT and latency, the number of packets that can traverse a route is estimated, and only this number of packets is sent through that route. The simulation results show that packet loss decreases and packet delivery ratio increases significantly compared to the conventional DSR.

DSR performance degrades with increase in number of nodes so this algorithm can be implemented in AODV routing protocol to increase the performance of the routing in larger Mobile Ad hoc Networks. In the future, implementation can be extended to the scenario in which nodes display more heterogeneous behavior. Other performance matrices also such as Throughput, Routing overhead etc. can be included.

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