A Routing Protocol Based on Mobility Prediction for Mobile Ad Hoc Networks

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***Abstract*—In Mobile Ad hoc Networks (MANETs), where nodes have limited transmitting power, the transmission is typically multi-hop. The network topology changes frequently due to the unpredictable movement of mobile nodes because each node is free to move arbitrarily with different speeds. Thus, when one node enters in the transmission range of another node a link between those two nodes is established, and an existent link is broken when either node is out of the transmission range of the other. We refer as link duration, the time interval during in which the link still established.**

This paper presents a novel mobility metric for mobile ad hoc networks, called link duration (LD) that measures the stability of an active link. This mobility metric is introduced to represent relative mobility between nodes in multi-hop distance.

***Index Terms*—Mobile Ad hoc networks, on demand distance vector routing, mobility, velocity, Transmission range, Link expiration time, Link duration prediction.**

I. INTRODUCTION

A mobile ad-hoc network (MANET) [1-4] is a self-configuring network of routers connected by wireless links. Due to the limited transmission range, if two mobile nodes are not within direct wireless transmission range of each other, the communication between them must pass through one or more other nodes. So, these kinds of networks are multi-hop networks where each node acts both as router and as host, which contributes to and maintains connectivity of the network. Each mobile node moves randomly with the capability of changing its links to other nodes frequently.

Different ad hoc routing schemes have been proposed for MANETs [2-6]. Those routing protocols must adapt to frequently changing network topologies caused by nodes mobility, as well as other network characteristics. Since nodes can move at any time, wireless links are prone to be broken.

Any link breakage along an established routing path will lead to a path failure. A shortest path may fail sooner than other path connecting a given source and destination pair. Frequent routing discovery is costly and inefficient. Moreover, shortest path routing cannot support many Quality of Service (QoS) connection requests when path duration is a requirement. For example, a video stream may need to be transferred from a source node to a destination node without any interruption for 100 seconds in a multimedia application. Instead of shortest paths, more durable paths or paths with duration guarantees are preferred to be used for packet routing in such applications.

Mobility management in Ad Hoc network has been a topic of significant researches in recent years. Since frequent topology changes may break existing paths, thus decreases the routing performances. In this work, we aim to minimize the effect of mobility. We present a mobility estimation method to enhance AODV routing protocol by selecting the route that can decrease the variation of link quality. The rest of this paper is organized as follows; in the section 2, we briefly survey some related work. In section 3, we present some basis of mobility estimation. Section 4 gives a formulation of the problem. In Section 5, we describe in detail our proposition. In Section 6, we evaluate the performance of the proposed approach via simulation. Finally, we conclude and give future direction in Section 7.

II. RELATED WORK

Traditionally, the AODV algorithm [5] is a widely implemented and well known routing algorithm for MANETs. However, AODV 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 to discover new routes.

Several mobility prediction algorithms have been proposed in the literature for improving reactive routing protocols.
An improved mobility aware AODV was presented in [17]. In AODV, Hello packets were used to enhance mobility awareness. When receiving a Hello packet with the Global Positioning System (GPS) coordinates of the source node, a lightweight mobility aware agent on each node of the network compares these coordinates with previous ones and then can determine information about the mobility of the originator node. Now, when a node receives a RREQ packet and has to send a RREP (it is either the destination, or it has an active route to the desired destination), it will use the mobility awareness to choose the best neighbor that is not frequently moving.

In [5], the authors established a relational model of route and link duration. This duration is determined by the relative speed between the two nodes and the distance during which the link is connected. In [18], Path duration models have been used to predict link and route duration and consequentialy

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used to design availability based routing protocol.

III. MOBILITY ESTIMATION

Since mobile nodes may follow different mobility patterns in the network field, that may affect nodes connectivity, and thus, the routing protocol performance. Mobility prediction may positively affect the quality of the network services since it allows selecting the stable path. In this section we present the most important mobility prediction schemes for MANETs. Two specific mobility prediction schemes are presented in the literature- (1) Mobility Prediction using a linear model [6] and (2) Mobility Prediction using Linear Autoregressive Models [7]. In this paper, we restrict our analysis to the linear prediction model, since for linear prediction model, a simple algorithm is used. This algorithm estimates the position of a node at any future time instant assuming that its speed and direction of movement stay constant. This kind of prediction model is based on the Link Expiration Time (LET) as given in [6]. Lets note by (x_i,y_i) and (x_j, y_j) the location of node ***i*** and node ***j*** at time ***t***. Let ***Vi*** and ***Vj*** be their speeds respectively, and θ_i is the direction of node ***i*** and θ_j be the directions of the node ***j***. If nodes are assumed to have the same transmission range ***r***, then the Link Expiration Time, D_t, of the link between the two nodes, as defined in [6], is given by

$$D_t = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \qquad (1)$$

Where

$$a = v_i \cos\theta_i - v_j \cos\theta_j,$$
$$b = x_i - x_j,$$
$$c = v_i \sin\theta_i - v_j \sin\theta_j, and$$
$$d = y_j - y_j$$

IV. PROBLEM DEFINITION

We model the MANET using a graph ***G(V, E)*** with mobile node set ***V*** and wireless link set ***E***. We assume that every mobile node is aware of its location that can be obtained from GPS or some other location techniques. We also assume that all network mobile nodes have an identical fixed transmission range ***R*** > 0. Thus, there is an undirected link ***e*** between node ***u*** and ***v*** in ***G*** if and only if the Euclidean distance between nodes ***u*** and ***v*** is no more than ***R***. There is an edge weighting function, ***C(e)***, which assigns a cost value for each link ***e*** in ***G***. We define similarly, the duration of a wireless link ***e*** with end nodes ***u*** and ***v*** that we denoted by ***D(e).*** This duration is the time period during which node ***u*** and node ***v*** are within the transmission range of each other. We note that it is clear that a wireless link is considered to be broken if the Euclidean distance between its two end nodes becomes greater than R.

Let $e_1, e_2, \ldots, e_p$ be the links of a path ***P***. We can define then the duration of path ***P*** as ***D(P)*** = **min** $_{1\leq j\leq p} D(e j)$, where $D(e j)$ is the duration of link e_j.

V. LINK DURATION PREDICTION

In this section, we introduce our mobility prediction method utilizing the location and mobility information provided by Global Positioning System (GPS) [15], or based on analyzing the characteristics of received signal [9]. In our initial approach, we assume a two-ray ground propagation model [16], where the received signal strength solely depends on its distance to the transmitter.

A. Link Duration between Two Nodes

We assume that nodes N_i and N_j move at velocities $\overrightarrow{V_i}$ and $\overrightarrow{V_j}$ **respectively**. If node N_i is considered as the reference, then node N_j moves at relative velocity of $\overrightarrow{V_{ij}} = \overrightarrow{V_j} - \overrightarrow{V_i}$ and the relative speed is: $V_{ij} = |\overrightarrow{V_{ij}}|$.

The link duration between N_i and N_j is the length of the longest time interval during which the two nodes are within the transmission range of each other. The two nodes cannot communicate directly to each other if the N_j move out of range of the N_i

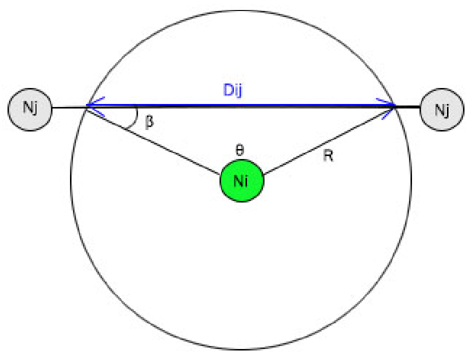

Fig.1. Link between Ni and Nj is established when node Nj enters in the transmission range of the node Ni

Since N_i and N_j can only communicate part of the time, the distance traversed by N_j with relative velocity V_{ij} during which the link is activated is referred to as the active distance between N_i and N_j, denoted by D_{ij}.

$$D_{ij} = 2R\cos\beta \qquad (2)$$

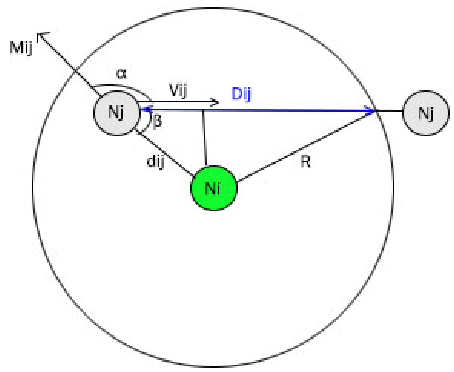

Fig. 2. node Nj is within range of Ni

In fig. 2., α is the angle formed by the relative velocity V_{ij} and the relative position vector $\overrightarrow{M_{ij}}$ and $d_{ij} = |\overrightarrow{M_{ij}}|$ **is** the distance between N_i and N_j.
The active distance traversed by node N_i is:

$$D_{ij} = d\cos(\pi - \alpha) + \sqrt{R^2 - d^2 \sin^2(\pi - \alpha)} \qquad (2)$$

The link duration T_{ij} between N_i and N_j can be expressed by

$$Tij = \frac{Dij}{Vij} \qquad (3)$$

B. Path duration

The path duration is an important design parameter that determines the performance of a mobile ad hoc network.
Let $N_1, N_2, \ldots, N_p$ be the path P. with **p** nodes, the path duration is the length of the longest time interval during which each of the p-1 links among the nodes exists. Thus, the duration of the path is limited by the duration of the links along the whole path. In fact, the path lifetime is defined by the minimum link duration along the path. So, the path duration is:

$$PD = \min_{1 \le i = j-1 \le p} T_{ij} \qquad (4)$$

C. Application of Mobility Prediction

In this section, we describe the AODV [5] routing protocol that utilize the mobility prediction mechanism as explained in previous section, that is called as MPAODV.
Whenever, a source node requires communicating with another node for which it does not have a route, it initiates the route discovery phase by broadcasting a Route Request (RREQ) packet to all its neighbors. The RREQ contains the following fields.

TABLE I
ROUTE REQUEST (*RREQ*) MESSAGE FORMAT

Type	Reserved	Hop Count
RREQ ID		
Destination IP Address		
Destination Sequence Number		
source IP Address		
LD		

The LD field is initialized to zero and is updated by intermediate nodes involved in route discovery, as follows. Upon receiving the RREQ, an intermediate node first checks whether it has received this RREQ before, then it drops this RREQ. Otherwise, it updates the hop count entry by the cost field with Equation (1). The intermediate node then creates a new entry in its routing table to record the previous hop and rebroadcasts the RREQ.

After the destination node receives the RREQ, it chooses the path whose LD value in RREQ is the least among all paths. The evaluation of the parameter will be made by the destination node at each received RREQ message, and the selected route is that the LD value is the smallest possible. If there are multiple routes with the same LD the route with the smallest hop count is selected. In other words, let ***pc*** be the chosen path and ***pa*** the set of all possible paths.

Then the chosen path fulfills:

$$LD(p_c) = \max_{p_j \in p^a} \min LD(p_j) \qquad (6)$$

$$if\ LD(p_c) = \underset{p_u \in p^a}{LD(p_u)}\ \text{Then}\ P_c = p_j | \min_{p_j \in \{p_u, p_c\}} hopcount(p_j)$$

Upon receiving the RREP, an intermediate node records the previous hop and relays the packet to the next hop.
As AODV do, if a node detects a link break during route maintenance phase, it sends a Route Error (RERR) packet to the source node. Upon receiving the RERR, the source node initiates a new round of route discovery.

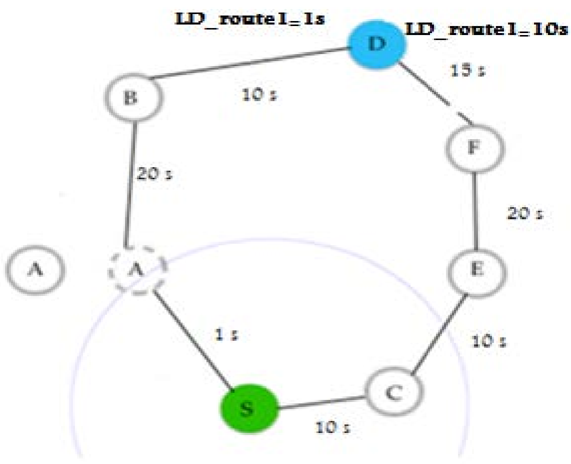

Fig. 3. Link breaks for the mobility of node A

In Fig. 3, we present an example in which we apply our approach. We note that AODV protocol selects the first path (LD_route1=1s) and discards the rest. But, MPAODV selects the path with (LD_route2=10s) which is more stable than the other selected routes which allows the reliability of the routes.

VI. SIMULATION ENVIRONMENT

To evaluate the performance of the proposed MPAODV protocol, it was tested on NS2 and the simulation result was compared with basic AODV protocol.

A. Simulation parameters

In our simulations, nodes were initially placed randomly within a fixed size 1500mx1500m square area. We used IEEE 802.11 MAC protocol for nodes layer 2. Transport layer protocol is UDP, a 30 Constant Bit Rate (CBR) data flows each node generating 4 packets/second with a packet size of 512 bytes are generated. Table II shows the simulation parameters used in this evaluation.

TABLE II
SIMULATION PARAMETERS

Simulator	ns-2.31
Network area	1500 m x 1500 m
Number of nodes	15, 25, 30, 35, 40, 45, 50
Mobility model	Random Waypoint
MAC Layer Protocol	IEEE 802.11
speed	10 m/s
Traffic type	CBR (UDP)
Data payload	512 bytes/packet
Packet rate	2 packets/sec

B. *Performance Metrics*

The performance of each routing protocol is compared using the following performance metrics:

- Packet Delivery Ratio (PDR) as a metric to select the best route, transmission rate or power.

PDR is the ratio of the number of packets received by the destination to the number of packets sent by the source.

- Normalized routing load is the ratio of the number of control packets propagated by every node in the network and the number of data packets received by the destination nodes.
- Average end-to-end delay (AEE) *is* the ratio between the sum of the delays of each packet received and number of packets received.

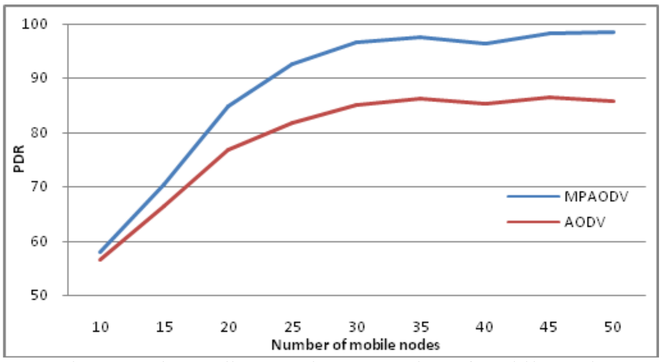

Fig. 4. Packet Delivery ratio Vs Number of Mobile Node

We have analyzed the performance of the proposed algorithm by varying the number of mobile nodes in the network. Fig. 4 shows a comparison between both the routing protocols AODV and MPAODV on the basis of PDR using a different number of mobile nodes, PDR is higher than AODV. By increasing number of nodes brings apparent difference between the two protocols because there are several possible paths in MPAODV that are ignored by AODV.

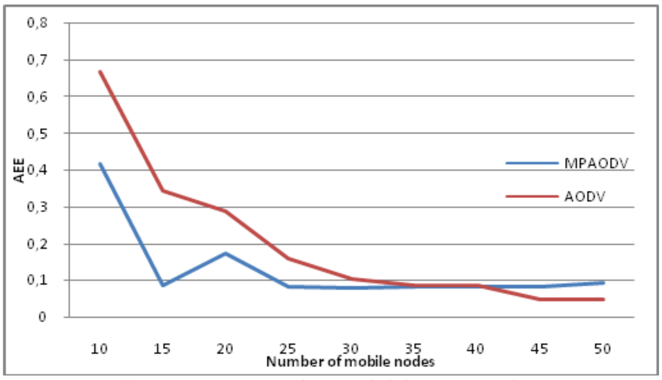

Fig. 5. Average End to End delay comparison

Fig. 5 shows that average end to end delay time is almost same in two protocols for higher network size. But for network with 15, 25 and 30 nodes, the AEE of MPAODV is less as compared to AODV.

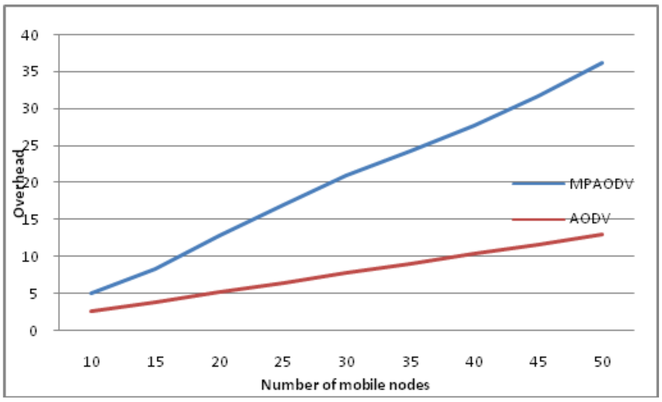

Fig. 6. Overhead comparison

Fig. 6 shows a comparison between both the routing protocols AODV and MPAODV on the basis of overhead using a different number of mobile nodes. As depicted in the figure, AODV generates less routing overhead than MPAODV.

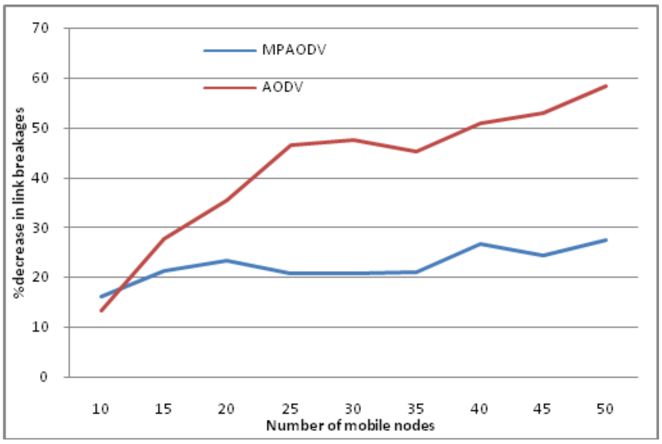

Fig. 7. Link breakage vs. number of nodes as compared to AODV and MPAODV

Fig. 7 shows the decrease in link breakages as a function of number of mobile nodes for the maximum speed of 10 m/s. As the number of mobile nodes increases the link breakages decreases because there are more possible routes, from which one with the stable path with longer lifetime can be selected. The improvement increases as the number of mobile nodes increases because MPAODV takes node mobility into account but AODV does not.

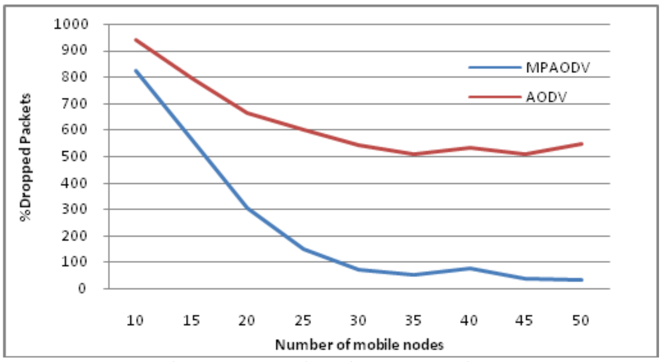

Fig. 8. Dropped packets comparison

Fig. 8. gives a comparison between both the routing protocols AODV and MPAODV on the basis of dropped packets using different number of nodes. The number of packets dropped for MPAODV is less than AODV. Packets dropped is mainly due to the end of TTL (Time To Live), AODV generate more RREQ packet after each link break than MPAODV.

We have also analyzed the performance of the proposed algorithm by varying the nodes speed in the network with 20 nodes.

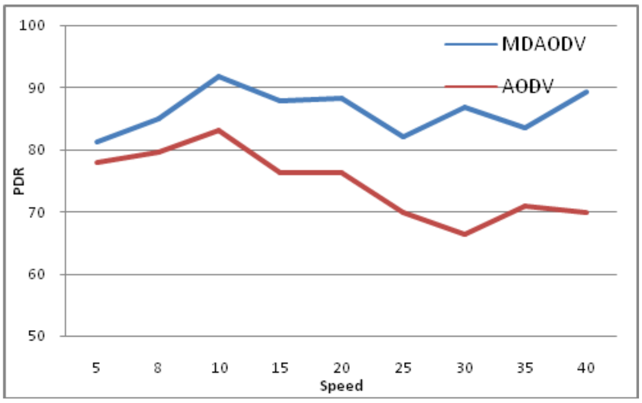

Fig. 9. Packet Delivery ratio Vs Speed (m/s)

Fig. 9. shows a comparison between both the routing protocols AODV and MPAODV on the basis of the PDR, using a different nodes speed, PDR is higher than AODV. By increasing the speed of nodes brings apparent difference between the two protocols because there are several possible paths in MPAODV that are ignored by AODV. As the node speed increases the link lifetime decreases and then the links are broken frequently in AODV which alter the PDR.

MPAODV chooses stable routes that minimizes the disruption caused by mobility since a different route with a greater expiration time is used prior to a given route gets disconnected.

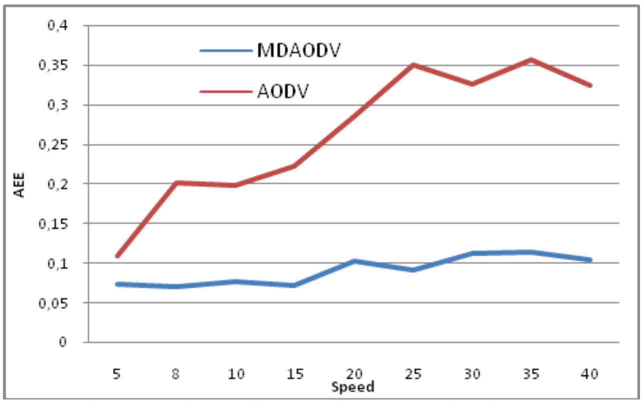

Fig. 10. Packet Delivery ratio Vs Speed (m/s)

Fig. 10. gives a comparison between both the routing protocols AODV and MPAODV on the basis of average end-to-end delay using different nodes speed. As we can see in the figure, AODV has higher average end-to-end delay, because the AODV selected paths that are the shorter ones are prone to failure.

VII. Conclusion

In this paper we presented an on-demand routing protocol called MPAODV which it takes advantages of a novel mobility estimation algorithm.

In this work we examined the use of mobility prediction to anticipate topology changes and perform rerouting prior to route breaks. Through the simulation on NS2, it is confirmed that the MPAODV could reduce the number of broken links and the dropped packets significantly. Yet, MPAODV giveshigher data packet delivery rate than AODV. As future, we intend to investigate the autoregressive model to estimate nodes mobility.

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