MA-AODV: Mobility Aware Routing Protocols for Mobile Ad hoc Networks

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***Abstract*— A Mobile Ad hoc Network (MANET) is a collection of mobile nodes that communicate and collaborate with each other without reliance on any pre-existing infrastructure. In MANETs, wireless links are subject to frequent breakages due to nodes high mobility. While several routing protocols such AODV and DSR have been designed for MANETs, many of operate efficiently under low network mobility conditions and do not adapt well with high mobility conditions. Therefore, considering mobility is a demanding task that should be performed efficiently and accurately. In this paper, we propose novel mobility-aware routing protocols based on the well known Ad hoc On Demand Distance Vector (AODV) routing protocol called: MA-AODV (Mobility Aware-Ad hoc On Demand Distance Vector) in an attempt to improve the handling of high mobility in ad hoc networks. MA-AODV protocols perform periodic quantification of nodes mobility for the sake of establishing more stable paths between source/destination pairs, hence, avoiding the frequent link breakages associated with using unstable paths that contain high mobile nodes. Simulations are done using GloMoSim 2.03 simulator. According to the results, our proposed protocols prove their superiority over the original AODV protocol in terms of the reduced overhead and the increased packet delivery ratio.**

Keywords: Ad hoc networks; on demand routing; mobility; mobility quantification.

I. Introduction

A Mobile Ad hoc Network (MANET) is regarded to be a collection of mobile nodes that perform cooperation and communication with each other without relying on any pre-existing infrastructures or centralized access points [1[2]]. The nodes constituting MANETs are responsible to act not only as hosts, but also as routers to compensate for the lack of the centralized base stations that coordinate communications. MANETs can be applied in many situations, particularly whenever there is a need for establishing a network for a limited period of time and where a wired infrastructure maybe nonexistent or very difficult to be deployed. These applications include battlefields, search and rescue missions, industrial and academic purposes, where participants can share information dynamically through their mobile devices. Compared with the other types of networks, MANETs have the following exclusive characteristics: bandwidth and transmission rate limitations, energy constraints and dynamic topology.

In MANETs, there are no restrictions on nodes mobility, i.e., nodes are free to move at any time, towards any direction and at any speed; therefore, nodes may join or leave the network at any time [3]. Mobility is a crucial factor in MANETs and it plays an important role in determining the overall performance of the network this is because the high mobility of nodes can cause frequent changes in network topology, leading to less reliable routes and frequent link breakages, hence, increasing the re-initiation of the route discovery process, resulting in more control packets overhead due to the extra use of Route Request Packets (RREQ), Route Reply Packets (RREP), and Route Error Packets (RERR) [9], and increasing the average end-to-end delay.

To alleviate such problems, nodes mobility should be taken into consideration when designing any routing protocol for MANETs. In this paper, we propose mobility-aware routing protocols that periodically quantify nodes mobility based on neighboring knowledge and exploit the calculated mobility value to determine the best reliable route between source and destination during route discovery process.

The remainder of this paper is organized as follows: Section 2 overviews the state of the art works in mobility aware protocols. Our methodology is explained in details in Section 3, including a detailed discussion of the proposed approach. In Section 4, the simulation environment and the experimental results are illustrated. Finally, Sections 5 and 6 conclude the paper and provide our future directions, respectively.

II. Related Work

Mobility is one of the key characteristics of MANETs that introduce some limitations if not considered well. In [2], a mobility-based method was proposed for improving the performance of the Ad hoc On-demand Distance Vector routing (AODV). Mobility metric was defined and used in

978-0-7695-3775-7/09 $26.00 © 2009 IEEE
DOI 10.1109/ICSNC.2009.80

both route discovery and route maintenance. In route discovery, the standard AODV hop-count metric is dropped and replaced with a combination of two mobility parameters: average and mean of the *calculated mobility* along the path between any source node and destination. Consequently, more stable routes were obtained. In route maintenance, the local repair mechanism was extended in order to avoid the RERR packets by allowing the node that detects a broken link to choose an alternative route based also on the mobility metric. This affects the overall overhead of re-initiating the route discovery process and also reduces the use of REER packets.

In [5], AODV Hello packets were used to enhance mobility awareness in AODV. 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 which is not moving frequently. This process of selecting the best neighbor is done at each intermediate node. As a result, a path with the maximum number of low mobile nodes is established between source and destination.

An adaptive AODV algorithm is proposed in [6]. In their work, Tan et al. calculate mobility during the initiating of Hello messages by determining the differences between neighboring tables at different times. Based on that value, when mobility is high, the rate at which neighbors change is also high, so the suitable reaction is reducing the HELLO_INTERVAL. But for low mobility, the time interval of Hello messages should be increased so as to reduce network congestion and bandwidth consumption, since the neighbors are less likely to change.

Adaptively controlling the broadcast of Hello Messages will result in reducing the number of unnecessary hello packets; hence network control traffic is reduced. This will result in a number of chain effects, including less contention for bandwidth between different type of packets (Data Packets, RREQ, RREP and RERR Packets). The reduction in network overhead will also lead to lower packet loss, higher throughput and better overall utilization of network resources.

III. METHODOLOGY

In this section, we provide a detailed discussion of our proposed approaches and the routing mechanism they follow.

A. *Our Approach*

In our work, we propose **M**obility- **A**ware **A**d hoc **O**n-demand **D**istance **V**ector (MA-AODV) protocols that are capable to periodically compute mobility with its degrees (low or high), and then make useful routing decisions accordingly. The first protocol is **P**er **H**op **M**obility **A**ware AODV (PH-MA-AODV) and the second is the **Agg**regate Mobility Aware AODV (Agg-AODV). Our MA-AODV protocols offer major contributions and improve the performance of the original AODV protocol.

i. PH-MA-AODV Protocol

In the traditional AODV, the source node initiates a route discovery process for the sake of finding the intended destination node. The same RREQ packet may pass through several paths (routes) to find its way towards the destination. Upon receiving the RREQ, the destination node replies back choosing the first route it gets, and consequently, other routes with possibly better metrics and Quality of Service (QoS) are dropped.

Our contribution makes the traditional AODV conscious to the mobility when choosing the best route. In other words, in our PH-MA-AODV, each node computes its own mobility periodically. Then, while initiating the Route Discovery process, each node decides to whether participate in the discovery process and thus relay the RREQ further or not. Therefore, the overall selected route is stable and more reliable. Figure 1 illustrates the process of Route Discovery in PH-MA-AODV protocol.

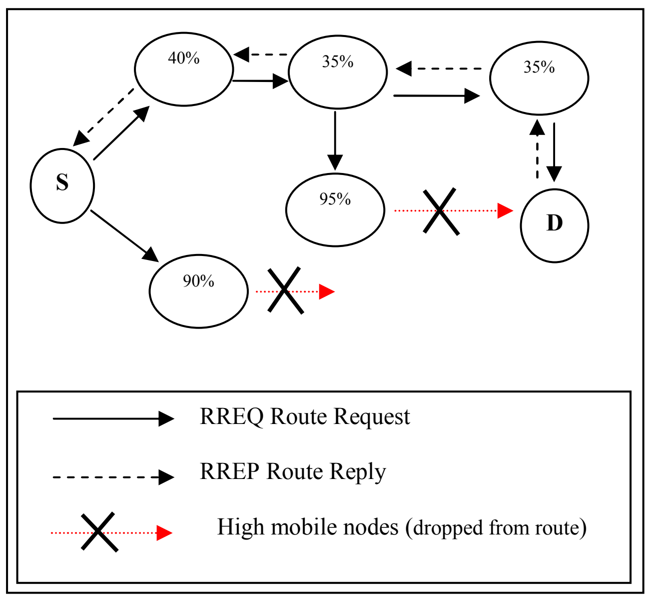

Figure 1: RREQ in PH-MA-AODV

ii. Agg-AODV Protocol

The mechanism of PH-MA-AODV is partially applied in this approach in the sense that periodically, each node computes its own mobility. However, unlike PH-MA-AODV, where the routing decision is made by the individual node as to whether participates in the route discovery process (based on that node's mobility), in Agg-AODV, upon receiving the RREQ packet, if the recipient node is not the intended destination, it adds its own mobility to the RREQ packet and forwards it further towards the destination. The destination node is responsible to store the aggregated value of mobility along the path from itself to the source, and to compare this value with future aggregated values that are obtained from other available paths towards the same source. If there are more than one active path between the source and the destination, the destination chooses the path whose aggregated mobility value is the least among all paths.

It is worthy to note that upon receiving the RREQ packet for the first time through a specific path, the destination has no other choice but to select this path (regardless to its aggregated mobility value) to send RREP back to the source as in Figure 2-a. However, the decision to whether continue using this path depends on the aggregated mobility of the subsequent paths as in Figure 2-b and 2-c, where the initially used path is replaced by another stable one with less aggregated mobility value.

B. *Our Contribution*

In this paper, we introduce Mobility Aware Ad hoc On-demand Distance Vector (MA-AODV) routing protocols for mobile ad hoc networks. MA-AODV protocols are mobility-aware, decentralized routing protocols that outperform the original AODV protocol and other mobility-aware routing protocols [5] in a number of ways. First, the nodes perform mobility quantification in a distributed manner based on the locally available information about neighborhood nodes and without the reliance on any global knowledge or localization schemes such as the signal-strength based localization. Secondly, MA-AODV protocols select the best candidate hop (as in PH-MA-AODV) and the best candidate path (as in Agg-AODV), such that the selected candidate are with low mobility. This mechanism guarantees establishing more stable and reliable routes and thus increasing the overall routing performance. In particular, our mobility-aware approaches achieve major enhancements in terms of reducing the overall packet overhead (since the number of relayed RREQ packets by intermediate nodes is reduced). Moreover, since each node chooses only stable routes, this guarantees that the number of broken links is lessened, and thus, reducing the process of reinitiating route discovery and reducing the number of dropped packets, as consequent, the packet delivery ratio is increased.

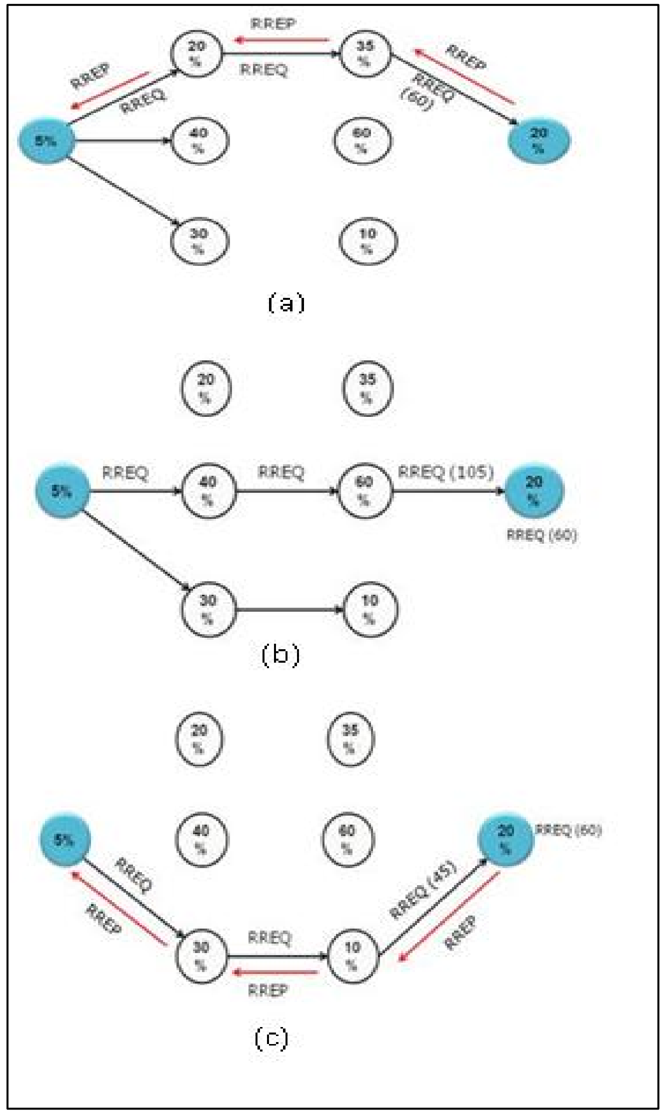

Figure 2: Agg-AODV

IV. PERFORMANCE EVALUATION

In order to evaluate the performance of our MA-AODV protocols, we simulate the proposed mechanisms using GloMoSim 2.03 simulator [7]. The simulation environment and parameters are clarified in the subsequent sections.

A. Simulation Environment

The network field considered for simulations is 1000 m × 1000 m. Radio propagation range for each node was 250 meters and channel capacity of 2 Mbps is chosen, and there is a bidirectional link between each pair of adjacent nodes. The time for simulation is 300s. The mobility of nodes is represented by the choice of a uniform speed between v_{min}=0 and v_{max}=50 m/s. the Mobility model used through simulation is the Random way point.

B. Simulation Parameters

The performance of our proposed protocols has been numerically evaluated by the estimation of the following parameters [4]:

- ***Packet Delivery Ratio***: the packet delivery ratio is a ratio of the correctly delivered data packets.
- ***Routing Overhead Ratio***: the routing overhead ratio is a ratio of the network control packets overhead and correctly delivered data packets.
- ***Average Link Reliability***: Suppose there are *n* single hop links between source *s* and destination *d*. Then the whole link is said to be reliable if each single link functions properly [8]. In our work, we choose the number of broken links as a parameter that characterizes the link reliability.

C. Simulation Results

According to the curves of Figure 3, we can see that the execution of PH-MA-AODV protocol with mobility constraints ensures better packet delivery ratio (PDF) for the different degrees of node mobility (ranging from high mobility with small pause times to low mobility with large pause times). It is obvious that the effectiveness of our approaches especially the Agg-AODV with high nodes mobility with (0 < Pause Time < 50) is proofed.

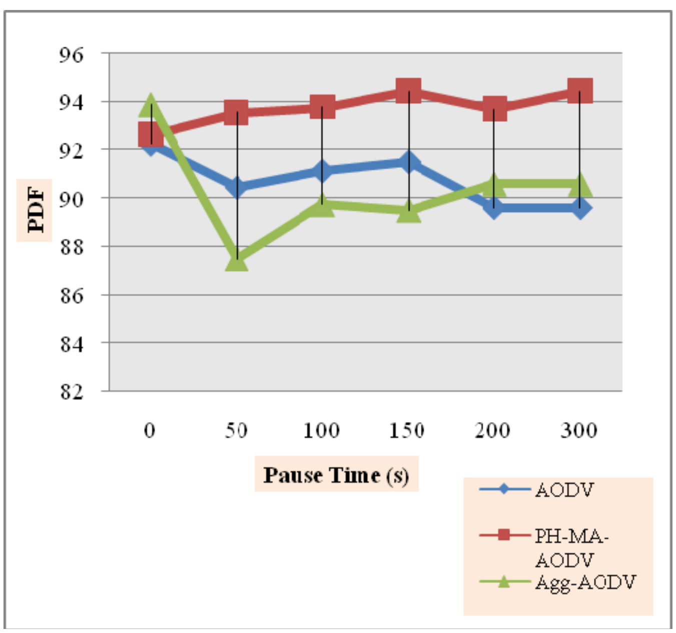

Figure 3: Average PDR vs. Pause Time

Figure 4 shows clearly the superiority of PH-MA-AODV approach over the original AODV protocol in terms of packet overhead reduction.

This is due to the fact that this protocol imposes routing only among those routes that are stable and have low mobility, so the number of packets rebroadcasted (relayed) by intermediate nodes is reduced.

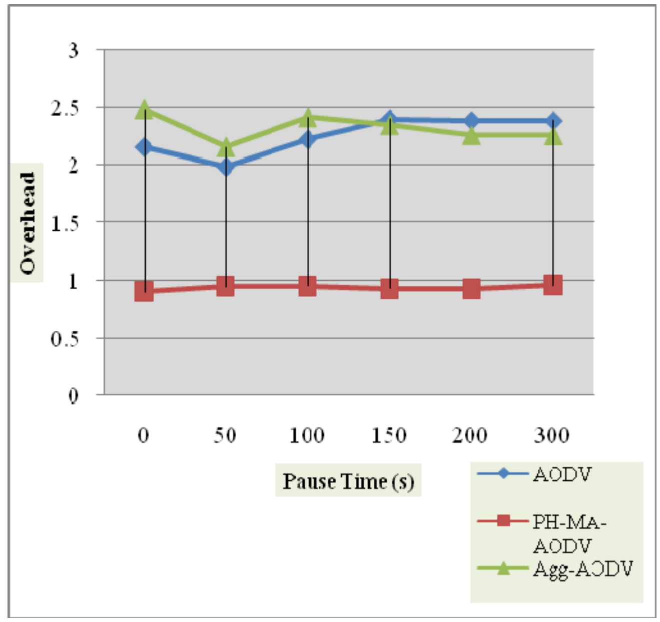

Figure 4: Average Packet Overhead vs. Pause time

According to the results of Figure 5, it is shown that the link reliability achieved by both PH-MA-AODV and Agg-AODV protocols is better than that of AODV protocols. The reason behind this is that the Mobility awareness of our protocols reduces the number of broken links by routing through the guaranteed stable links. The major enhancement in terms of link reliability appears evident with high mobility situations (where the pause time is 0), and this is a strong requirement that is achieved by our protocol.

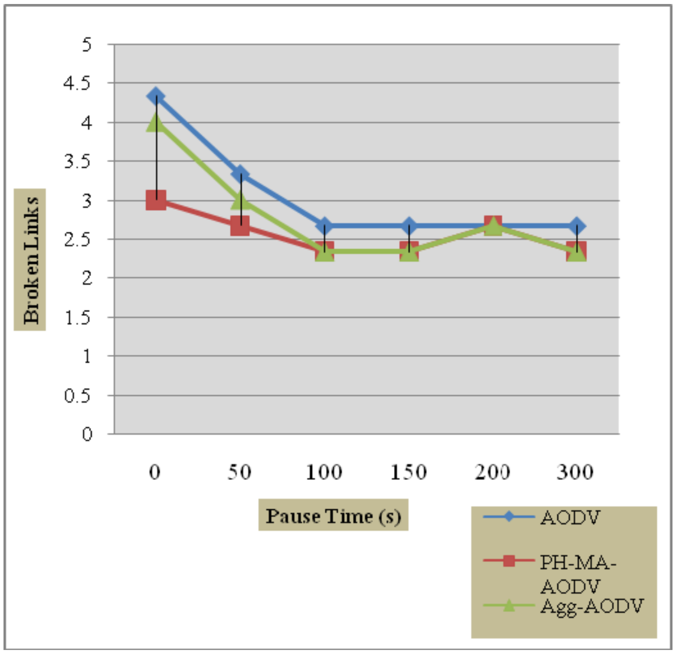

Figure 5: Average Link Reliability vs. Pause time

V. CONCLUSION

In this paper, we proposed mobility aware approaches that achieve significant improvements which touch in particular the three principal metrics: the Average Packets Overhead, the Average Delivery Ratio and the Average Link Reliability. The proposed approaches consider the degree of node's mobility in order to assist in making a proper routing decision. The decision is either made by the destination to send a reply back through the stable route, as the case of Agg-AODV, or by the intermediate nodes through the route discovery process, as in PH-MA-AODV. Taking the mobility metric into consideration introduces clear enhancements that are evident in terms of decreased control packets overhead and the increased delivery ratio.

VI. FUTURE WORK

There are still several research points that can be investigated further in the future in order to extend our proposed approaches. The MA-AODV approaches can be enhanced further by embedding their idea in the Route Maintenance process. That is, when a node detects its mobility as high, it should inform its neighbors by its critical status. Accordingly, the informed node updates its routing table entries based on neighbor's mobility, and then the node performs a local repair operation by choosing low mobility node as its next hop mobility. In addition, Our PH-MA-AODV protocol should be adaptive more, such that the mobility threshold should change based on the network density and node mobility.

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