Dynamically Adjusting the Request Zone in GeoAODV Protocol

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Abstract

Geographical AODV (GeoAODV) Rotate is a variation of a regular GeoAODV scheme that aims to reduce the control message overhead introduced by ad-hoc on-demand distance vector (AODV) routing protocol. GeoAODV reduces the route discovery overhead by searching only a portion of the network that is likely to contain the desired node. The search area is computed based on the nodes' location coordinates obtained via the Global Positioning System (GPS). GeoAODV Rotate improves the performance of regular GeoAODV by dynamically adjusting the search area during the route discovery process. The paper also discusses the results of a comprehensive simulation study, conducted using OPNET Modeler version 16.0 software package, which compares the performance of GeoAODV Rotate against the AODV, regular GeoAODV, and two variations of Location-Aided Routing (LAR) protocol.

I. Introduction

Ad-hoc on-demand distance vector (AODV) routing protocol is a reactive routing protocol for mobile ad-hoc networks (MANET) [1-3]. When an upper layer protocol needs to transmit data, AODV finds a route to the destination if such route exists using a flooding technique. The AODV route discovery process starts at the source node which broadcasts a route request (RREQ) packet to its immediate neighbors, i.e., the nodes located one hop away from the source. The neighboring nodes retransmit RREQ packet and the process continues until the destination or a node that has a path to the destination is reached. At this point, a route reply packet (RREP) is generated and unicast back to the source node. Arrival of the RREP at the source completes route discovery phase of AODV protocol, at which point the data can be transmitted to destination.

Even though such an approach to finding a route to destination is simple and easy to implement, it may result in unnecessary control traffic overhead. AODV attempts to reduce the control traffic load by employing the expanding ring search technique. This approach relies on a value of the time-to-live (TTL) field in the IP header of an RREQ packet to limit how far the packet can travel in the network. Initially, the TTL field value is set to 1 in the outgoing IP datagram which carries RREQ. If the route discovery with the current TTL value fails to find a route to destination then the TTL field value is incremented and the route discovery process repeats using a larger value. The process continues until a route to destination is found or until the entire network has been searched unsuccessfully [1-3].

Geographical AODV (GeoAODV) [4, 5] further improves the route discovery phase of AODV by only searching the area that is likely to contain a path to destination. Such search area, called request zone, is computed based on the Global Position System (GPS) coordinates of the source and destination nodes. Only the nodes within the request zone re-broadcast the RREQ packets. The nodes outside the request zone simply discard the RREQ packets. Such an approach significantly reduces the control packet overhead associated with the route discovery phase of AODV protocol.

The idea of GeoAODV is based on Location-Aided Routing (LAR) protocol [6, 7]. However, unlike LAR, GeoAODV does not assume that the nodes know the location and the traveling velocity of all the other nodes in the network. GeoAODV assumes that the nodes only know their own location precisely, while the GPS coordinates of the other nodes in the network are dynamically distributed during the route discovery phase. If the source node does not know the location of the destination node then GeoAODV's route discovery is performed the same way as in AODV. However, when the destination's coordinates are known then, the route discovery is limited to the cone shaped request zone shown in Figure 1.

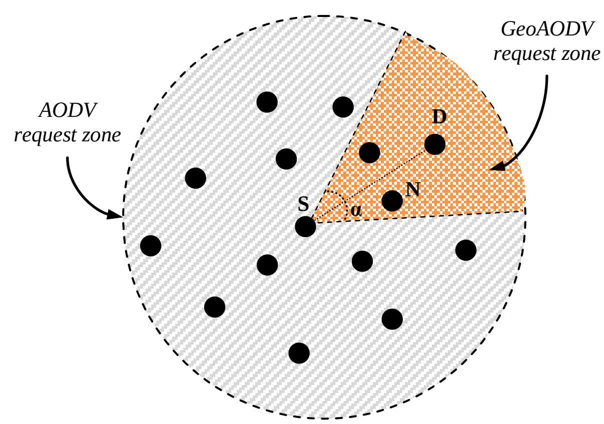

Figure 1. Example of Geographical AODV

This paper introduces the GeoAODV Rotate protocol and examines its performance in comparison to AODV, regular GeoAODV, and two variations of LAR protocol through simulation. GeoAODV Rotate is a variation on GeoAODV that dynamically adjusts the search area during the route discovery process, which effectively eliminates from the search area the nodes that are less likely to be part of the path to the destination. The network simulation software package OPNET Modeler version 16.0 [14] was used to conduct an experimental study.

The remainder of the paper is organized as follows. In Section II we give an overview of LAR and GeoAODV protocols. In Section III we briefly discuss encountered implementation issues of LAR and GeoAODV protocols. Section IV provides description of our simulation study set-up, followed by Section V which gives an analysis of collected results. The paper concludes in Section VI.

II. Overview of LAR and GeoAODV Protocols

A. Location-Aided Routing

There have been numerous studies in the literature of routing protocols that utilize location information [6-13]. In this study we examine and compare the performance of the LAR protocols introduced in [6, 7]. In particular we examine two LAR variations referred to as LAR zone and LAR distance. LAR zone scheme assumes that the destination's physical location at certain time t_0 and average traveling speed v are known to all the nodes in the network. This information allows the source node to approximate the area where the destination will be located at time t_1. This area is called the *expected zone* and is defined as a circle centered in the destination's location at time t_0 with radius r computed according to equation (1):

$$r = v \times (t_1 - t_0) \quad (1)$$

LAR zone scheme defines the request zone as a rectangular area with the following properties: (1) the request zone completely encompasses the expected area, (2) the sides of the rectangle are parallel to x and y coordinate axis, and (3) the sides of the rectangle are tangent to the circle that defines the expected zone. The request zone is defined as the smallest rectangle that contains the source node and the expected zone and satisfies the above conditions. LAR zone scheme performs the route discovery the same way as AODV except that only the nodes within the request zone re-broadcast the RREQ messages, while the RREQ messages that arrive at the nodes located outside the request zone are discarded. Figure 2 illustrates the expected and request zones for two cases of the LAR zone scheme: (a) source node S is located outside destination D's expected zone and (b) source node S is located inside destination D's expected zone.

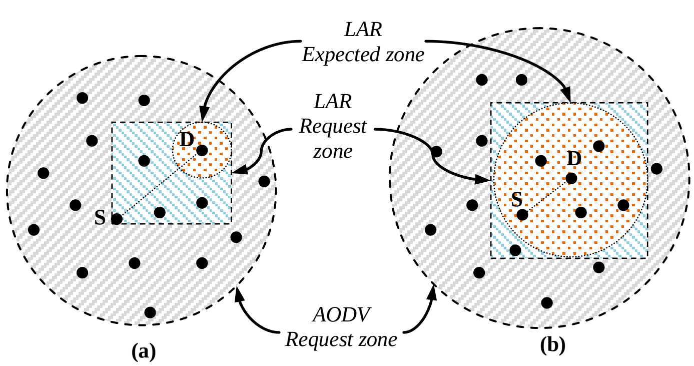

Figure 2. LAR Zone: Expected and Request Zones

The second LAR scheme is called LAR distance and it does not employ the concept of expected and request zones. Instead, LAR distance scheme relies on the distance between an intermediate node and destination to determine if an RREQ message will be rebroadcast or not. When an RREQ packet arrives at the intermediate node, let us call it $\mathbf{N_1}$, the LAR distance scheme compares the distance between node $\mathbf{N_1}$ and destination **D** and the distance between the node which forwarded this RREQ message to $\mathbf{N_1}$, let us call such node $\mathbf{N_0}$, and the destination **D**. If distance between $\mathbf{N_1}$ and **D** is not larger than the distance between $\mathbf{N_0}$ and **D** then the RREQ message is re-broadcast, otherwise the RREQ message is discarded. Specifically, the RREQ message is forwarded only if inequality (2) hold true:

$$\alpha \times Dist\,(N_0\, D) + \beta \leq Dist\,(N_1\, D) \quad (2)$$

In inequality (2) α and β are configuration parameters, while *Dist(AB)* is the distance between nodes A and B. Figure 3 illustrates operation of LAR distance scheme. When an RREQ message broadcasted by node $\mathbf{N_0}$ arrives at node $\mathbf{N_1}$ it is being rebroadcast again since distance $\mathbf{N_0D}$ is longer than distance $\mathbf{N_1D}$. However, node $\mathbf{N_2}$ will not rebroadcast an RREQ message that it receives from $\mathbf{N_0}$ because distance $\mathbf{N_0D}$ is shorter than distance $\mathbf{N_2D}$.

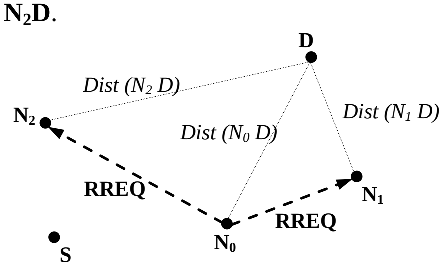

Figure 3. Example of LAR distance scheme

B. Geographical AODV

GeoAODV defines its request zone as a cone-shaped area of the network controlled via a flooding angle: a wider flooding angle corresponds to a larger request zone area. Whenever the value of the flooding angle is equal to 360 degrees the request zone area is equivalent to the whole network and GeoAODV operates the same way as AODV. The cone-shaped request zone is defined as an area where the source node is the apex of the cone, while the flooding angle is evenly divided by a line that connects the source and destination nodes. As shown in Figure 1, **α** is the flooding angle that defines the request zone for the route discovery process initiated from node **S**.

Let us call an intermediate node as node **N**, a source node as node **S**, and a destination node as node **D**. In GeoAODV each RREQ packet carries the last known GPS coordinates of **S** and **D** nodes. When an RREQ arrives at **N**, it computes an angle **θ** formed between nodes **D**, **S**, and **N**.

$$\theta = \cos^{-1} ((SD \bullet SN) / (|SD|\times|SN|)) \quad (3)$$

If **θ** is less than half of flooding angle **α**, then node **N** is located within the request zone and should rebroadcast the route request. Otherwise, node **N** discards RREQ. If source does not have coordinates of a destination node then GeoAODV sets the value of the flooding angle to 360 degrees and operates the same way as regular AODV.

In GeoAODV, the node coordinates are distributed in the network via control messages. Each control message carries the location coordinates of the originator node. The RREQ messages also carry last know coordinates of the destination node. Each node in the network maintains a location table which stores coordinates, IP address, and freshness (i.e., a sequence number) of the nodes in the network. Individual nodes update their location tables using the information carried in control messages. Stale location information is periodically purged by the nodes.

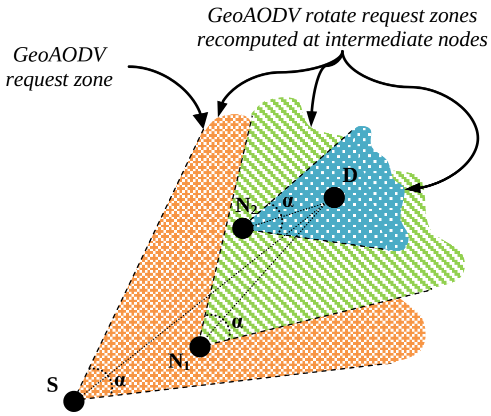

Figure 4. Example of Geographical AODV Rotate

GeoAODV Rotate operates similarly to GeoAODV, except that it computes the request zone based on the location of the previous hop, instead of the source node. This modification re-orients the cone-shape search area towards the destination node, excluding nodes that are less likely to be part of the path to destination. Figure 4 illustrates such a situation: node $\mathbf{N_1}$ computes the request zone based on the location information for **S** and **D**, while node $\mathbf{N_2}$, which receives an RREQ message from $\mathbf{N_1}$, uses coordinates of nodes $\mathbf{N_1}$ and **D** to determine if it belongs to a new, dynamically adjusted request zone. Note that such modification does not require changing the information carried in the RREQ messages since the location information of the neighboring nodes is distributed in the network via standard AODV HELLO messages, which are periodically exchanged by the nodes one hop away from one another. Thus, in Figure 4, node $\mathbf{N_2}$ has the location information about node $\mathbf{N_1}$ before an RREQ from $\mathbf{N_1}$ arrives.

III. Implementation of LAR and GeoAODV protocols in OPNET Modeler 16.0

We modified the standard AODV process model in OPNET Modeler 16.0 [14] to implement both LAR schemes and both variations of GeoAODV protocols. We implemented the sharing of location information in GeoAODV protocols by modifying the structure of OPNET's RREQ and RREP packets to additionally carry the coordinates of the originator and possibly destination nodes. AODV HELLO messages use the structure of the RREP messages and thus, also carry location information. Specifically, we modified the following process models and external C code and header files: *manet_mgr.pr.c, aodv_rte.pr.c, aodv_pk_support.exc.c, aodv_request_table.ex.c, aodv_ptypes.h, aodv_pkt_suport.h, aodv.h, manet_mgr.pr.m,* and few others. We also created several external C code and header files to store the code pertaining to GeoAODV implementation. A more detailed description of our OPNET Modeler implementation of GeoAODV protocol can be found in [4].

LAR assumes that the nodes in the network have access to location information and traveling speed of all other nodes in the network. To model such behavior we used data definition sub-package (*oms_data_def*) as follows. Upon initialization, each node records its coordinates and traveling speed in the network-wide database. During simulation, individual nodes periodically update this database with new values of their coordinates and traveling speed. To add an entry into a network-wide database we used *oms_data_def_entry_insert()* function call. LAR enabled nodes retrieve location and traveling speed of desired nodes from the network-wide database, as needed, using *oms_data_def_entry_access()* function call.

While implementing LAR protocols we discovered a few special cases in the definition of the request zone, which were not described in LAR protocol [6, 7]. Let us denote (X_s, Y_s) to be the coordinates of the source node, (X_d, Y_d) to be the coordinates of the destination node, and R to be the radius of the expected zone. Recall that the request zone is defined as a rectangle that encompasses the expected zone and has its sides tangent to the expected zone circle and parallel to x and y coordinate axis. We noticed that, if the source node is located in any shaded areas shown in Figure 5 then the definition of LAR request zone will not include a portion of the expected zone. We can define the locations of the source node which will violate the definition of request zone as follows:

- *Area 1:* X_s in $(X_d – R, X_d + R)$ and $Y_s > Y_d + R$
- *Area 2:* $X_s > X_d + R$ and Ys in $(Y_d – R, Y_d + R)$
- *Area 3:* X_s in $(X_d – R, X_d + R)$ and $Y_s < Y_d – R$
- *Area 4:* $X_s < X_d – R$ and Ys in $(Y_d – R, Y_d + R)$

We resolved this issue by changing the definition of the corners in the request zone, as follows:

- Lower-left corner: $[Min(X_d – R, X_s), Min(Y_d – R, Y_s)]$
- Upper-right corner: $[Max(X_d + R, X_s, Max(Y_d + R,Y_s)]$

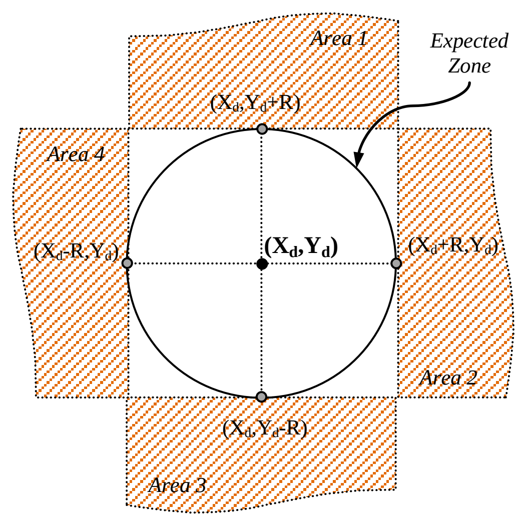

Figure 5. Special Cases for the definition of the request zone in LAR zone sheme

We also observed that LAR distance scheme in certain situations may fail to find a route to destination even if it exists. Specifically, if a path to destination contains sections which require traveling in the direction away from destination then LAR distance may fail to find such a route. The authors in [6] acknowledged this issue and tried to address it by introducing configuration parameters α and β shown in inequality (2). However, LAR distance does not provide any mechanism for identifying and dealing with the situations when the protocol fails to find the path to destination while the path exists, which is a major disadvantage. Furthermore, the optimal values of α and β very much depend on the network topology and in highly dynamic environments such as MANET, where nodes are often moving, identifying proper values of α and β could be quite challenging. LAR distance protocol does not address this issue either. That is why in our simulation study we set configuration parameters α to 1 and β to 0.

IV. Simulation Set-up

We compared the performance of AODV, LAR, and GeoAODV protocols using OPNET Modeler version 16.0 [14]. The network topology used in the simulation consisted of 50 nodes randomly placed within a 1500 meters x 1500 meters area. We examined scenarios with the following number of communicating nodes: 2, 5, 10, 20, and 30. The communicating nodes and their destinations were selected randomly. The communicating nodes in each scenario started their data transmissions at time 100 seconds. The nodes in the network were moving according to the Random Waypoint model with the pause time computed using exponential distribution with the mean outcome of 10 seconds. We considered four sets of scenarios with different node velocities. Specifically, we conducted simulation studies were the nodes were stationary (traveling speed was set to 0 meters per second), as well as were the nodes traveled at 5 meters per second speed, 10 meters per seconds speed, and random speed computed using uniform distribution with the outcome in the range [0, 20] meters per second. Wireless LAN configuration parameters of each node were set to default OPNET Modeler configuration values. Summary of simulation set-up is provided in Table I. The duration of each experiment was set to 300 seconds. We executed each scenario six times and averaged the results. Each simulation scenario was executed with a different seed value. We executed 600 simulation runs total, which took over 72 hours to complete.

TABLE I. SUMMARY OF NODE CONFIGURATION

Configuration Parameter	Value
Channel Data Rate	*11 Mbps*
Transmit Power	*0.0005 Watts*
Packet Reception Power Threshold	*-95 dBm*
Start of data transmission	*normal (100, 5) seconds*
End of data transmission	*End of simulation*
Duration of Simulation	*300 seconds*
Packet inter-arrival time	*exponential (1) second*
Packet size	*exponential (1024) bytes*
Mobility model	*Random Waypoint*
Pause Time	*exponential(10)*
Destination	*Random*

In our study, we configured GeoAODV protocols to have the initial flooding angle value set to 90 degrees. The flooding angle value is incremented by 90 degrees after each unsuccessful route discovery attempt, until GeoAODV reverts to regular AODV.

V. Analysis of Results

The simulation results collected in our study suggested that GeoAODV Rotate consistently outperforms AODV, LAR distance, and regular GeoAODV. In most cases performance of GeoADOV Rotate was close to that of LAR zone, even though LAR Zone assumes that node coordinates and traveling speed are available in the network while GeoAODV makes no such assumptions and distributes location information through the AODV control messages.

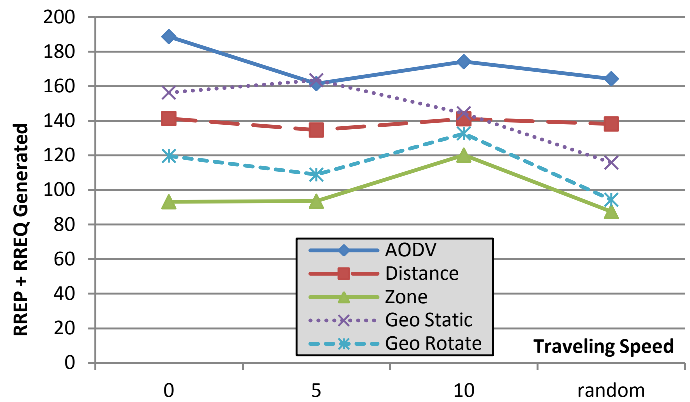

Figure 6. The number of control packets generated in scenarios with 2 communicating nodes

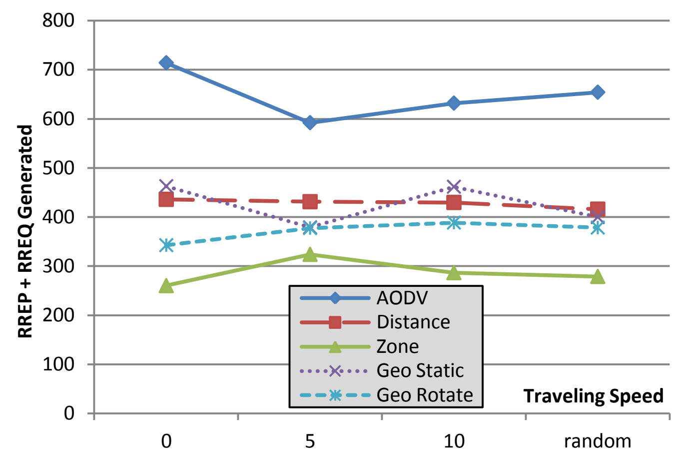

Figure 7. The number of control packets generated in scenarios with 5 communicating nodes

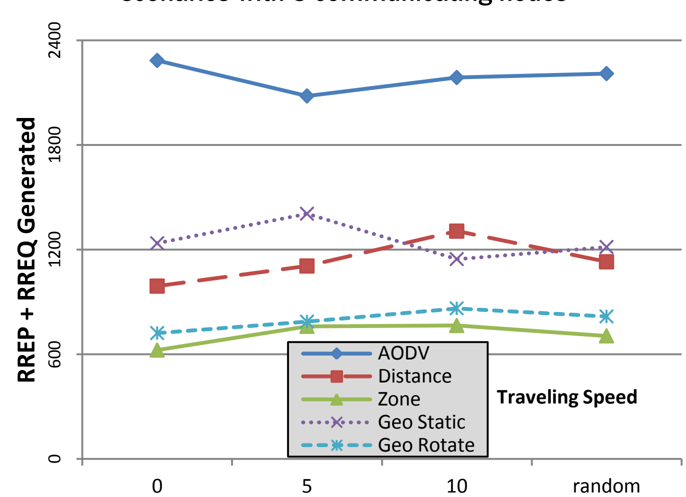

Figure 8. The number of control packets generated in scenarios with 10 communicating nodes

Figures 6 – 10 illustrate the total number of control packets (RREQ and RREP) generated by each protocol. Please note that in the figures we refer to LAR zone as Zone, to LAR distance as

Distance, to regular GeoAODV as Geo Static, and to GeoAODV Rotate as Geo Rotate.

As expected, the protocols that employ location information typically reduce the amount of control traffic overhead as compared to regular AODV. The only exception in our study was scenario with 30 communicating nodes, results for which are shown in Figure 10. In this scenario most of the protocols performed similarly, except for LAR Zone protocol which generated significantly fewer control messages than all the other protocols. This could be attributed to the high number of traffic flows traversing the network, which leads to more intermediate nodes having the path to destination. As a result, a route to destination could be found very quickly, just few hops away from the source and the route discovery process cannot take full advantage of the location information. Nevertheless, the GeoAODV Rotate is still consistently the second best option, outperforming AODV, LAR distance, and regular GeoAODV protocols in all of our simulation scenarios.

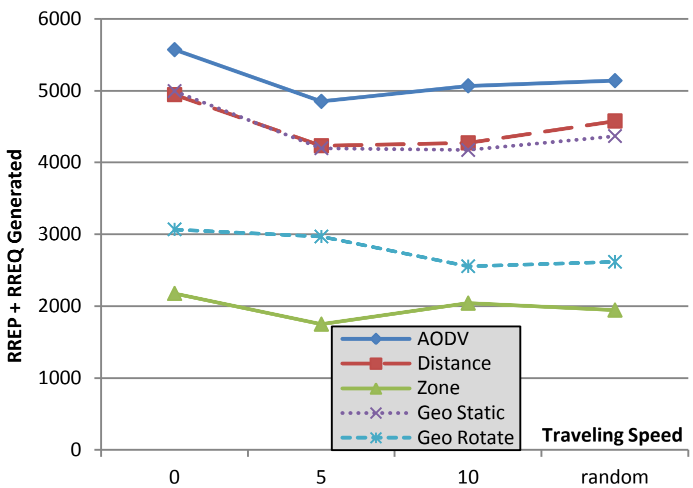

Figure 9. The number of control packets generated in scenarios with 20 communicating nodes

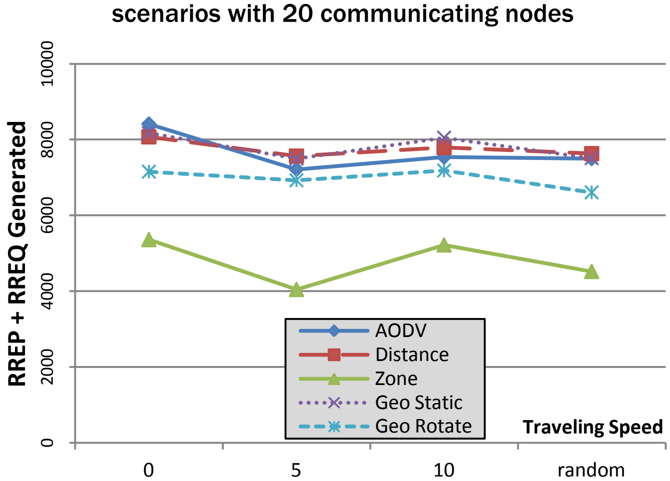

Figure 10. The number of control packets generated in scenarios with 30 communicating nodes

For all the other simulation scenarios the performance of GeoAODV Rotate was slightly worse but still fairly close to that of LAR Zone protocol. When we examined the results closer we realized that this difference in performance could be attributed to the fact that LAR Zone has direct access to the location information of all the nodes in the network, while GeoAODV first has to converge to a state where the node locations are distributed in the network. Otherwise, if the source node does not have any information about destination's location then GeoAODV, both variations, conduct the route discovery process the same way as regular AODV.

Simulation results suggest that even though GeoAODV Rotate performs slightly worse than LAR Zone, it has a potential to become a preferred mechanism for route discovery in MANET, because it does not require the location coordinates and traveling speed of individual nodes to be readily available to everyone in the network. Unlike, LAR Zone, GeoAODV Rotate uses its own, built-in mechanism to distribute coordinate information during the route discovery process, which could be preferable in certain environments where location information cannot be easily distributed among MANET nodes. On the other hand, LAR Zone is clearly superior in the environments where location and traveling speed of any node in the network is easily obtainable by any other node.

VI. Conclusions

This paper presents the GeoAODV Rotate, a new variation of GeoAODV protocol, and compares its performance against AODV, LAR Zone, LAR Distance, and GeoAODV. GeoAODV Rotate improves performance of regular GeoAODV and results in a smaller control packet overhead. The results of the simulation study indicate that GeoAODV Rotate outperforms AODV, LAR Distance, and GeoAODV protocols, and in many case its performance is comparable to that of LAR Zone. We currently investigating performance of GeoAODV Rotate in different environmental settings and developing mechanisms to more accurately increment the value of flooding angle after failures to find a route to destination. In our future studies we also plan to re-run the simulation study with a larger number of repetition (each with a different seed value), further analyze the collected results, examine the performance of the GeoAODV Rotate during the pre- and post-convergence periods, study how fast GeoAODV Rotate converges to a stable state, how accurate are the node locations stored in the intermediate nodes when GeoAODV Rotate is used for route discovery as well as how the accuracy of node locations influences the performance of GeoAODV Rotate.

References

[1] C. Perkins, E. Belding-Royer, S. Das. (July 2003). *Ad hoc On-Demand Distance Vector (AODV) Routing*. IETF RFC 3561. Last time accessed on 2012-01-26.

[2] E. M. Royer and C. E. Perkins. "An Implementation Study of the AODV Routing Protocol," Proc. of the IEEE Wireless Communications and Networking Conference, Chicago, IL, September 2000.

[3] C. E. Perkins and E. M. Royer. "Ad hoc On-Demand Distance Vector Routing," Proc. of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, Feb. 1999, pp. 90-100.

[4] V. Hnatyshin, and H. Asenov, "Design and Implementation of an OPNET model for simulating GeoAODV MANET routing protocol", Proc. of the OPNETWORK 2010 International Conference, Session: Wireless Ad Hoc and Wireless Personal Area Networks, Washington DC, August 2010.

[5] H. Asenov, and V. Hnatyshin, "GPS-Enhanced AODV routing," in Proceedings of the 2009 International Conference on Wireless Networks (ICWN'09), Las Vegas, Nevada, USA (July 13-16, 2009)

[6] Y. Ko and N. H. Vaidya, “Location-aided routing (LAR) in mobile ad hoc networks,” Wireless Networks, 6(4), July 2000, pp. 307-321.

[7] Y. Ko and N. H. Vaidya, “Flooding-based geocasting protocols for mobile ad hoc networks,” Mobile Networks and Applications, 7(6), Dec. 2002, pp. 471-480.

[8] A. Husain, B. Kumar, A. Doegar, “A Study of Location-Aided Routing (LAR) Protocol for Vehicular Ad Hoc Networks in Highway Scenario,” International Journal of Engineering and Information Technology, 2(2), 2010, pp 118-124.

[9] K.M.E. Defrawy and G. Tsudik, "ALARM: Anonymous Location-Aided Routing in Suspicious MANETs," Proc. of the IEEE International Conference on Network Protocols, 2007, pp.304-313.

[10] D. Deb, S. B. Roy, N. Chaki, “LACBER: A new Location-Aided routing protocol for GPS scarce MANET,” International Journal of Wireless & Mobile Networks (IJWMN), 1(1), August 2009.

[11] F. De Rango, A. Iera, A. Molinaro, S. Marano, “A modified location-aided routing protocol for the reduction of control overhead in ad-hoc wireless networks, ” Proc. of the 10th International Conference on Telecommunications, 2003, pp. 1033 – 1037.

[12] Y. Xue, B. Li, “A Location-aided Power-aware Routing Protocol in Mobile Ad Hoc Networks,” Proc. of the IEEE Global Telecommunications Conference, San Antonio, TX, November 2001, pp. 2837 – 2841.

[13] Y. Wang, L. Dong, T. Liang, X. Yang, X., D. Zhang, “Cluster based location-aided routing protocol for large scale mobile ad hoc networks,” IEICE Transactions, 2009, E92-D(5), pp. 1103–1124.

[14] OPNET Modeler ver. 16.0. OPNET Technologies, Inc®, www.opnet.com last visited 6/12/12.