

Performance Analysis of Grid Based AODV Routing Algorithm for AD Hoc Wireless Networks

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Abstract

In many traditional On Demand routing algorithms in Ad hoc wireless networks, a simple flooding mechanism is used to broadcast route request (RREQ) packets when there is a need to establish a route from a source node to a destination node. The broadcast of RREQ may lead to high channel contention, high packet collisions, and thus high delay to establish the routes, especially with high density networks. Ad hoc on Demand Distance Vector Routing Protocol (AODV) is one among the most effective Reactive Routing Protocols in MANETs which use simple flooding mechanism to broadcast the RREQ. It is also used in Wireless Sensor Networks (WSN) and in Vehicular Ad hoc Networks (VANET). This paper proposes a new modified AODV routing protocol EGBB-AODV where the RREQ mechanism is using a grid based broadcast (EGBB) which reduces considerably the number of rebroadcast of RREQ packets, and hence improves the performance of the routing protocol. We developed a simulation model based on NS2 simulator to measure the performance of EGBB-AODV and compare the results to the original AODV and a position-aware improved counter-based algorithm (PCB-AODV). The simulation experiments that EGBB-AODV outperforms AODV and PCB-AODV in terms of end-to-end delay, delivery ratio and power consumption, under different traffic load, and network density conditions.

Keywords

Mobile Ad-Hoc Networks, AODV Routing Algorithm, Position-Based Routing, Grid-Based Routing, NS2

1. Introduction

A Mobile Ad Hoc Network (MANET) is a collection of wireless nodes communicating with each other in the

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In [1], the routing protocols for Ad hoc networks are classified depending upon whether route is updated continuously or on-demand. The proactive class: try to maintain consistent and up-to-date routing information from each node to every other node in the network; the reactive class: routes are requested on-demand only when they are needed; and the hybrid class: combines the advantage of both proactive and on-demand protocols. To maintain up-to-date routing table information, proactive protocols generate periodic control packets which lead to a high communication overhead and thus could not be suitable for use in ad hoc network scenarios where the network density is large and where the topology may change frequently. For such scenarios on-demand routing protocols are preferable.

Conventional on-demand routing protocols such as Dynamic Source Routing (DSR) [2], Ad Hoc on Demand Distance Vector (AODV) [3], Zone Routing Protocol (ZRP) [4], and Location Aided Routing (LAR) [5], try to establish a route between a source and a destination when it is needed by broadcasting using a simple flooding operation to disseminate a route request RREQ. In a simple flooding operation, an RREQ packet is transmitted to the nodes within its transmission range. All the nodes receiving the RREQ will rebroadcast the message if they see it for the first time. This rebroadcast strategy leads to high network contention and collision because many nodes will be involved in the rebroadcast operation. This problem is known as the broadcast storm.

Efforts have been taken for achieving efficient broadcasting in mobile ad hoc networks. Network broadcasting is the process in which one node sends a packet to all other nodes in the network. Broadcasting in MANETs constitutes one of the fundamental network operations which serve various network services including: routing, information dissemination and resources discovery. As an example, several unicast routing protocols such as DSR, AODV, ZRP, and LAR, as well multicast protocols employ broadcasting to detect and maintain routes in a dynamic environment. Because many network services have stringent end-to-end delay requirements, the design of low-latency and low overhead broadcasting schemes is essential to many practical applications.

Recently, in [6] we proposed an efficient Extended Grid Based Broadcast algorithm EGBB which solves the broadcast storm problem in MANET. EGBB sees the terrain as a logical 2D grid with $k \times k$ grid cells. The main idea of EGBB resides in its rebroadcast strategy where only a gateway node (one per grid cell) will rebroadcast the packet. A gateway node is set dynamically and it can be any node. A normal node S1 in a given cell can be seen (or upgraded) as a gateway node for a node R located in another cell if it has seen (received) any kind of traffic from the node S1. Later if R receives any traffic from a node S2 located in the same cell as S1 it will be upgraded to gateway node in that cell instead of S1. It has been shown in [6] that EGBB has outperformed up-to-date broadcasting algorithm in MANET.

Ad hoc on Demand Distance Vector Routing Protocol (AODV) is one among the most effective Reactive Routing Protocols in MANETs. It is also used as routing protocol in Wireless Sensor Networks (WSN) [7] and in Vehicular Ad hoc Networks (VANET) [8]. Vehicular Ad Hoc Network VANET is becoming more and more important, which can provide intelligent transportation application, comfort application and other services for people in vehicles.

In this paper, we propose a new variation of AODV routing algorithm named EGBB-AODV which conserves most of the ideas of AODV but we change the RREQ mechanism originally using simple flooding and replace it with EGBB broadcasting.

The remainder of the paper is organized as follows: Section 2 presents some related work; Section 3 presents an overview of the proposed EGBB-AODV algorithm; Section 4 presents simulation model and some performance results; and Section 5 concludes the paper.

2. Related Work

Many route discovery protocols, found in the literature [9]-[15] proposed efficient protocols to optimize the route discovery MANETs. The proposed schemes alleviate the impact of the broadcast storm problem by re-

fraining some nodes from re-broadcasting and favoring others depending on probability, their location, and their knowledge of how many times the message has been broadcasted. In [16], the authors developed a cross-layer approach focusing on the Signal-Strength based Medium Access Control protocol to orchestrate the channel access based in MANETs. Another cross-layer approach is presented in [17] where a multipath routing protocol for MANET based on On-Demand Distance Vector (AODV) routing protocol to reduce the end-to-end delays.

A broad category of routing and broadcasting algorithms is the class of position-based algorithms [18]-[22]. These algorithms make use of the nodes' geographical positions to make routing decisions. Nodes are able to obtain their own geographical positions via Global Positioning System (GPS). This approach has become practical by the rapid development of low cost hardware and software solutions for determining absolute or relative node positions in MANETs [23].

In this paper we proposed an improvement for AODV routing protocol called EGBB-AODV routing algorithm which replaces the original RREQ simple flooding mechanism by a most sophisticated broadcast EGBB for forwarding the route request packets RREQ. In the EGBB-AODV algorithm, it is assumed that each node knows only its position using a Global Positioning System (GPS). Nowadays, mobile computing devices and smart phones are all equipped with such GPS system. The geographical region of the MANET is viewed as a logical 2-dimensional (2D) grid of cells as shown in Figure 1. With the help of the EGBB broadcast procedure, the initiator of the RREQ message within a given cell broadcasts its message to nodes located in its neighborhood cells based on the node's transmission range. This first step consists of a local broadcast or one-hop broadcast. In the second step of the EGBB algorithm, only one node (gateway node) per grid cell rebroadcasts the RREQ message. In the flooding algorithm, all the nodes which receive the message will rebroadcast the RREQ it (broadcast storm problem). In EGBB-AODV, the problem of broadcasting RREQ to mobile MANET nodes is transformed into a problem of broadcasting to geographically fixed grid cells using only the gateway nodes as RREQ rebroadcast nodes. Typically, each node will have a dynamic list of eight gateway nodes (one gateway node for each cardinal direction). A RREQ packet is rebroadcasted from a gateway node in a grid cell to nodes in neighboring grid cells within the node's transmission range repeatedly until it reaches all nodes in the 2D grid.

3. EGBB-AODV Protocol

Node will have in what follows we give a brief description of the original routing algorithm AODV, and the two broadcast algorithms candidates for replacing the simple flooding of RREQ in the improved AODV: Extended Grid-Based Broadcast EGBB [6] and the Position-aware Counter-Based algorithm (PCB) [24].



Figure 1. Logical 2D view of the area.

3.1. Overview of AODV

AODV is an on-demand routing algorithm that determines a route only when a node wants to send a packet to a destination. The route discovery process is started whenever a source node wants to communicate with a destination node for which it has no routing information (routing table). The source node initiates a path discovery by broadcasting a route request (RREQ) packet to its immediate neighbors. Each neighbor either satisfies the RREQ by sending a route reply (RREP) back to the source if it knows the path to destination or rebroadcasts the RREO to its own neighbors if the RREO is seen for the first time. Each intermediate node that forwards the RREQ packet creates a reverse route pointing towards the source node. When the intended destination node or an intermediate node with a valid route to the destination receives the RREQ packet, it replies by sending a route reply (RREP) packet. The RREP packet is unicast towards the source node along the reverse path set-up by the forwarded RREQ packet. Each intermediate node that participates in forwarding the RREP packet creates a forward route (entry in the routing table) pointing towards the destination. Once the next hop becomes unreachable, the node upstream from the breaking point propagates a route error packet RERR to all active upstream neighbors. Those nodes subsequently relay that message to their active neighbors and so on. This process continues until all active source nodes are notified. Upon receiving notification of a broken link, source node can restart the discovery process if it still requires a route to the destination. RREP packets are also sent when an entry in a routing table expires (relatively old route).

3.2. Extended Grid Based Broadcast EGBB

EGBB is an efficient broadcast algorithm for MANET [6] which uses a logical 2D grid representation of the terrain as a $k \times k$ grid cell of side d (see Figure 1).

Each grid cell has eight adjacent of neighboring grid cells (share a side or a corner), except the cells at the boundaries. For a given grid cell, the eight neighboring grid cell are identified using the cardinal direction. NorthWest grid cell GW[0], North grid cell GW[1], NorthEast grid cell GW[2], East grid cell GW[3], South-East grid cell GW[4], South grid cell GW[5], SouthWest grid cell GW[6], and East grid cell GW[9]. Each node in EGBB maintain continuously its list of eight gateway nodes corresponding to potential rebroadcast nodes in each neighboring grid cell (GW[0..7]). The list of gateway nodes GW is updated when a node hear any kind of traffic from a neighboring node in a neighboring grid cell. It will compute the sender node direction i using the sender position extracted from the received packet and updates its list of gateways GW[i] = idr where idr is the ID of the sender extracted from the received packet. When a node broadcast the packet it will add to the packet the list of gateways GW. When a node receive a broadcast packet it checks if its ID is among the GW list in the received packet in this case it will rebroadcast the message. Otherwise it will just consume the packet. The broadcast packet in EGBB is relayed only by the gateway nodes. This rebroadcast strategy is reduces the number of rebroadcast in each hop eight rebroadcast nodes per hop independently from the network density.

3.3. Position-Aware Counter-Based Algorithm (PCB)

PCB algorithm integrates the merits of counter-based and position-based schemes. When a node rebroadcasts a packet, it adds its own position to the header of the packet. When receiving a duplicated packet, it gets the position of the sender and recalculates its Expected Additional Coverage (EAC). A node rebroadcasts a packet only when the EAC) is larger than a certain threshold. Within PCB, threshold values of expected additional coverage and counters vary adaptively according to network density. Threshold value for counters of nodes in sparse networks is set differently from that in dense networks

As described in [24], the first (EAC) threshold V1 is set to 40% of the transmission range and the second EAC threshold V2 is set to 60% of the transmission range. The counter threshold Cth is set to 3 as in PCB algorithm. PCB implements two different RAD periods: a long RAD period LRAD for node located with range greater than V1 and less than V2. A shorter RAD period SRAD for nodes located in the range greater than V2. The nodes located in the later range will rebroadcast before the node located in the former range because of their shorter RAD period. This will be in favor of nodes with higher EAC and thus ensure better performance.

PCB Algorithm [24]

```
-On hearing a broadcast packet m at any node X
- Get the position information of previous node from m
- For new packet m received at X, calculate EAC [24]
if EAC > V1
{
if m is a new packet
  {
  initiate C = 1
  if EAC > V2 Set and wait for RAD=SRAD (short RAD) to expire
  else Set and wait for RAD=LRAD (Long RAD) to expire
 }
} else drop m
- For every duplicate packet m received within RAD, calculate EAC
if EAC > V1 increment C, C=C+1;
- RAD expires
if C < Cth rebroadcast m
 else drop m
```

3.4. EGBB-AODV

We propose a new variation of AODV routing algorithm named EGBB-AODV which conserves most of the ideas of AODV but we changed the RREQ mechanism originally using simple flooding and replace it with EGBB broadcast algorithm. EGBB-AODV sees the terrain as a logical 2D $k \times k$ grid cell of side d (see Figure 1).

Whenever a RREQ packet is generated by EGBB-AODV it will be broadcast using EGBB to reduce the number of rebroadcast and improve the performance of the new modified protocol. Some beneficial features have been added in EGBB-AODV to deal with some control packets such as route reply RREP and route error RERR. When a RREP is generated at the destination node, the information about RREP packet are used to maintain the list of gateways in the receiving or intermediate node located in neighboring grid cells. We do similar gateway updating when a node receives RERR. EGBB-AODV relay on any kind of traffic generated the nodes, RREQ, RREP, RERR, data, to maintain an up-to-date list of gateway GW[0..7]. This gateway updates does not incur any extra-cost compared to the original AODV algorithm.

For comparisons purpose, we implemented a new version PCB-AODV which uses PCB as the broadcast algorithm to disseminate the RREQ.

4. Performance Analysis

In what follows, we study the performance for the three routing protocols the original AODV, EGBB-AODV and PCB-EODV using Ns2 simulator. The performance metrics we are interested to analyze are as follows:

- The average end-to-end delay, the average time spent to complete one routing operation.
- The average reachability ratio, the average percentage of nodes that received the messages.
- The power consumed by a node, total number of packet (data and control packet) transmitted by a node per second.

For all simulation scenarios, all nodes move according to the random waypoint mobility model where the velocity of nodes is chosen uniformly from 0 to 12 m/s and the pause time is set to zero. All nodes start to move at the beginning of the simulation and do not stop until the end of simulation. The source nodes of CRB traffic are chosen randomly over the network allowing simultaneous CBR traffic operations from different sources. Identical mobility scenarios and traffic patterns are used across simulation scenarios in order to achieve a fair comparison. The simulation time is set to 1000 s and the first 100 s are discarded in order to be sure that the network has reached the steady state. All simulation results are obtained with 95% confidence interval and relative error less than 5%. The simulation model does not take into account the effect of environment such as buildings, mountains, etc. [25]. **Table 1** gives a summary of the simulation system parameters. The radio propagation model used in this study is the NS2 default, which uses characteristic similar to a commercial radio interface,

Table 1. Simulation parameters.	
Area	$1000 \ m \times 1000 \ m$
Protocols	AODV, EGBB-AODV, PCB-AODV
Mobility model	Random waypoint
Numb. of nodes	100, 200, 300
Nodes speed	3, 12, 24 m/s
Avg. pause time	0
CBR/sec.	1, 6, 12, 24 Pkt/sec
Trans. range	300 meters
Link bandwidth	2 Mbps
Simulation trials	30 times
Simulation time	1000 Seconds

Lucent's WaveLAN card with a 2 Mbps bit rate [26]. The distributed coordination function (DCF) of the IEEE 802.11 protocol [27], [28] is utilized as MAC layer protocol while random waypoint model [29] is used as the mobility model.

4.1. Effect of the Traffic Load

In this set of simulation experiments we fix the number of nodes to 100 and the node mobility to an average of 12 m/s (high mobility). We vary the number of CBR traffic per second and study the average end-to-end delay time, the delivery ratio, and the average power consumption per node per second.

Figure 2 shows a considerable improvement on the end-to-end delay of EGBB-AODV compared to AODV and PCB-AODV, especially when the traffic increases. EGBB-AODV finds routes faster than AODV and PCB-AODV because it involves less rebroadcast of RREQ and thus less collisions. Collision may prevent RREQ to reach the destination. AODV implements a retrial procedure to send again the RREQ if any RREP is not received within a given time out. **Figure 3** shows that EGBB-AODV has better delivery ratio compared to the traditional AODV and PCB-AODV. It shows also that when the traffic is high (24 pkts/s) the delivery ratio of AODV drops to 60%, and PCB-AODV drops to 72% when the delivery ratio of EGBB-AODV is within 80%. **Figure 4** reveals that the good performance of EGBB-AODV over AODV and PCB-AODV in terms of saving the battery energy. It also shows that with the increase of the traffic the battery consumption is increased for the three algorithm.

4.2. Effect of the Network Density

In this set of simulation experiments we vary the number of nodes in the network for a fixed traffic of 12 CBR/s and for a fixed node speed of 12 m/s. We vary the number of nodes in the network and study the average end-to-end delay time, the delivery ratio, and the average power consumption per node per second.

Figures 5-7 show an important improvement on the end-to-end delay, delivery ratio and power consumption of EGBB-AODV compared to AODV and PCB-AODV, especially when the network density increases. **Figure 5** shows that when the network density increases the end-to-end delay of EGBB-AODV remains constant which not the case for AODV and PCB-AODV where both have linear increase. **Figure 6** shows that when the density is high (300 nodes) the delivery ratio of AODV is as very low as 30% and 50% for PCB-AODV but the delivery ratio of EGBB-AODV is still good within 90%. The improvement in the overall performance could be explained by the same reasons as in the previous experiment. Add to it the fact that when the number of node increases the number of rebroadcast of RREQ increases considerably in AODV but the number of rebroadcast in EGBB-AODV is constant (independent from the network density, 8 gateway nodes per hop). This fact is clearly shown in **Figure 7** where the power consumption per node is very low compared to the others. It is almost constant in EGBB-AODV but the power consumption of AODV seems to increase linearly with the number of nodes in the network.











Figure 4. Power versus traffic.



Figure 5. End-to-end delay versus density.







Figure 7. Power consumption versus density.

5. Conclusion

This paper proposed a new modified EGBB-AODV routing protocol for MANET. EGBB-AODV protocol uses a sophisticated broadcast algorithm for sending route request packet RREQ when the original AODV uses a simple flooding to send RREQ. Results obtained from an extensive simulation have revealed a considerably lower end-to-end delay, lower power consumption, and higher delivery ratio of the new protocol EGBB-AODV compared to the traditional AODV and PCB-AODV especially with dense networks. EGBB broadcast algorithm could be applied to enhance the performance of any on-demand routing protocol which uses simple flooding to broadcast the route requests. As a future work, we plan to optimize better the number of rebroadcast in EGBB-AODV to adapt to the traffic density and the nodes mobility to apply it for WSN with high density and low mobility and VANET.

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