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Reducing the Overhead Cost in Fixed & Low Mobility AODV Based MANETs

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Abstract. The primary goal of an ad hoc network routing protocol is to establish correct and efficient route between two nodes so that message may be delivered in time. It is observed that in high mobility network models AODV performs superior than other proactive and reactive protocols (DSDV and DSR). However for low mobility or static network models the routing efficiency of AODV is marginally better than others. The major reason for this decline in the performance is due to the shorter route cache in AODV protocol. Frequently discarding the valid routes and rediscovering them causes unnecessary delay in routing and increase control overheads. This paper analyzes the bandwidth utilization and routing delay once MANETs are subjected to prolong static environments and suggests a provision of dynamic route cache in AODV routing protocol.

Keywords: MANETs, AODV, ART, TTL, Route Cache

1 Introduction

“An ad hoc network is a collection of wireless mobile hosts forming a temporary network without aid of any centralized administration or standard support services regularly available on the wide-area network to which the host may normally be connected”[1]. MANET is increasingly gaining popularity in all types of communication and networking environments as the technology provides its user more flexible, affordable and easily deployable networking solutions. This includes military and rescue operations, particularly disaster relief operations in areas void of any communication infrastructure [2].

MANETs have been an area of interest for research community and since past decade numbers of protocol have come up to implement it. Beside the ever increasing utilities / advantages of infrastructure-free networking it also poses new challenges of efficient routing for its designers. These challenges include the dynamic topology, limited bandwidth, variable bit error rate, energy-constrained operation, limited physical security and variable capacity links. So far a number of protocols have been designed tackling these constraints [3, 4]. Generally, MANET protocols are divided into two major categories; Proactive and Reactive protocols. In proactive approach the source as well as intermediate nodes keep track of the routes to all destination nodes in the network. This tracking of routes is carried out with periodic exchange of routing information among the nodes. Proactive routing shows minimal delay when the route is required. This type of routing is important for time sensitive data [5]. Reactive protocols on the other hand use the concept of acquiring information about routing only when needed; a route is discovered on demand and maintained as long as desired by the source. The approach circumvents large overheads due to maintaining routes between all possible source and destination pairs. Major advantages of reactive approach address bandwidth constraint in MANET [6]. Lately, Hybrid protocols, another category has been included, which is the combination of the above two protocols [2].

AODV is a reactive routing protocol designed for MANETs. Its performance in high mobility networks is remarkable as compared to other protocols but in case of static and low mobility networks the protocol performs marginally better and at times worse than its counterparts [3, 13]. This paper studies the behavior of AODV routing protocol for fixed networks and those exhibiting low mobility with a view to highlight the reasons for this shortfall in the performance of AODV and in the end we propose suitable enhancement for making up this deficiency.

The rest of the paper is organized as follows, section 2 reviews the working of AODV and its salient features and section 3 gives the motivation for the paper analyzes the scenario of static and low mobility AODV networks, the proposed solution and future work required.

2 Overview of AODV

AODV routing algorithm is a reactive routing protocol designed for MANETs. and capable of handling networks with larger populations of tens to thousand of mobile nodes [10]. AODV combines the features of proactive and reactive protocol i.e. Destination Sequenced Distance Vector (DSDV) and Dynamic Source Routing (DSR) protocols. The route discovery and maintenance process in AODV is similar to that in DSR. However the periodic use of Hello messages for checking the neighbour nodes and using sequence numbers for route refresh ness is borrowed from DSDV protocol [5]. AODV can handle low, moderate and relatively high mobility rates, as well as variety of data traffic [10]. Ever since its inception number of studies have been carried out to analyze the performance and behaviour of AODV in terms of route latency, throughput and bandwidth utilization the results surpass DSR and DSDV [4, 8]. To discover, establish, recover and maintain a routing path AODV uses four types of control messages, these are Route Request (RREQ), Route Reply (RREP), Route Acknowledgment (RREP-ACK) and Route Error (RERR) messages [10].

2.1 Route Discovery Process

In AODV routing, when a source has data to transmit to a new destination, it broadcast a RREQ for that destination to its neighbors A node on receiving the RREQ checks if it has not received the same request before, it is not the destination and does not have a current route to the destination, it rebroadcasts the RREQ and at same time route to the source is created [11]. If the receiving node is the destination or has a current route to the destination, it generates a RREP. The RREP is unicast in a hop-by-hop fashion to the source. As the RREP propagates, each intermediate node creates a route to the destination. When the source receives the RREP, it records the route to the destination and begins sending data. If multiple RREPs are received by the source, the route with the shortest hop count is chosen.

In case a link break is detected, a RERR message is sent to the source of the data in a hop-by-hop fashion. As the RERR propagates towards the source, each intermediate node invalidates route to an unreachable destinations. When the source of the data receives the RERR, it invalidates the route and reinitiates route discovery. Sequence numbers in AODV play a key role in ensuring loop freedom and freshness of the route [13, 14].

2.2 Route Maintenance Process

Once the route is established, a route maintenance protocol is used to provide feedback about the links of the route and to allow the route to be modified in case of any disruption due to movement of one or more nodes along the route. Maintenance of the discovered/established route is necessary for two main advantages, first to achieve stability in the network and secondly to reduce the excessive overhead required in discovering new route [16]. Each time the route is used to forward a data packet, its expiry time is updated to be the current time plus ACTIVE_ROUTE_TIMEOUT (ART) and it is set to 3000 milliseconds [4, 10]. ART is a constant value that defines as to how long a new discovered route is to be kept in the routing table of a node after the last transmission of a packet on that route. ART is defined for both the source and intermediate nodes in the network [3, 17]. If a route is not used for this predefined period, a node (source or intermediate) cannot be sure whether the route is still valid or not and removes the route from its routing table, this is to ensure no unnecessary packet loss.

In AODV routing movements of nodes affect only the routes passing through the specific node and thus do not have global effects. If the source node moves while having an active session, and loses connectivity with the next hop of the route, it can rebroadcast an RREQ. When either the destination or some intermediate node moves, it initiates an RERR message and broadcasts it to its precursor nodes and marks the entry of the destination in the route table as invalid, by setting its distance to infinity [18]. An active neighbor node list is maintained to keep track of the neighbouring nodes that are using the entry to route data packets. In case link to the next hop is broken these neighbouring nodes are notified with RERR packets. Each such neighbor node, in turn forwards the RERR to its own list of active neighbors, thus invalidating all the routes using the broken link [15].

2.3 Route Caching

Route caching is carried out for two purposes; firstly, a cached route is readily available to the demanding node thus reducing the routing latency significantly. Secondly, route caching avoids route discovery process and in that way reduces the control traffic that is required in searching for a new route [21]. The caching mechanism in AODV allows only one cache entry per destination, therefore, once the initial data packets get a valid cached route, the chances for successful delivery of subsequent packets is almost guaranteed [20]. In AODV routing protocol, a newly discovered route is cached, so that it may be reused the next time when the same route is requested. AODV carries out route caching both at the source node and at intermediate node that has a cached route to the destination and reply to the source with the cached route [21].

Route caching on one hand reduces the route latency but at the same time prolonged caching may results into storing obsolete / invalid routes, which due to frequent movement of the destination or intermediate node(s) in MANETs. Extra traffic overhead and routing delay is incurred when an invalid route is used further it may result in loss of information packets. One approach to minimize the effect of invalid route cache is to purge the cache entry after some Time-to-Live (TTL) interval. If the TTL is set too small, valid routes are likely to be discarded, and large routing delay and traffic overhead may result due to the new route search. On the other hand, if the TTL is set too large, invalid route-caches are likely to be used, and additional routing delay and traffic overhead may result before the broken route is discovered [21]. Thus the efficiency of route caching lay between two contradictory conditions, how long the route has to be stored for subsequent use and how often to purge the same in order to avoid invalid routes. The aim in both cases is to avoid overheads and consequently save bandwidth and route latency

2.4 Motivation

MANETs are characterized by limited bandwidth. With the transfer of intended data considerable bandwidth is also utilized by the control overheads. This bandwidth situation is further aggravated in case of large population networks exhibiting high mobility. Both the proactive and reactive (On-demand) protocols generate a considerable amount of control overhead traffic for the route discovery and maintenance; this is further increased by the additional overheads used for detection and repair of frequent route breakages due to node mobility. Appropriate route caching not only achieve network stability, but the overhead cost (signaling, computation, etc) associated with route discovery and maintenance is reduced [16].

3 MANET Working Scenarios

3.1 MANETs in Static Scenarios.

In daily working it may be observed that most of the time mobile nodes (users) remain static in their offices or workplaces for prolong periods and there is no change in the topology of initially established network. Examples of such static networks are, a MANET established in an office building for exchanging mail between departments, a conference/presentation in progress or an internet user at home browsing internet or playing network games. In these examples one may observe the intermittent usage of network resources, clients after downloading data/information take considerably long for AODV to stale the existing route (ACTIVE_ROUTE_TIMEOUT set to 3 sec [10]) and consequently for every exchange of information a new route discovery is required.

To calculate the size of control messages in discovering a route between two nodes consider a MANET workgroup implemented by AODV protocol, consisting of 10 mobile nodes. The networking topology is shown in Fig. 1a. Fig. 1b and c indicate the number of RREQ and RREP packets exchanged in the network, while node S seeks the destination node D.

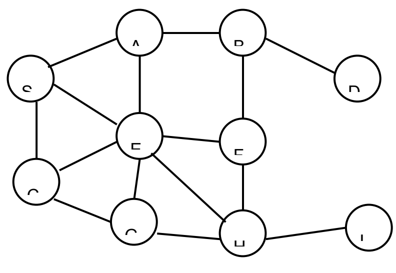

Fig. 1a. Workgroup MANET**.**

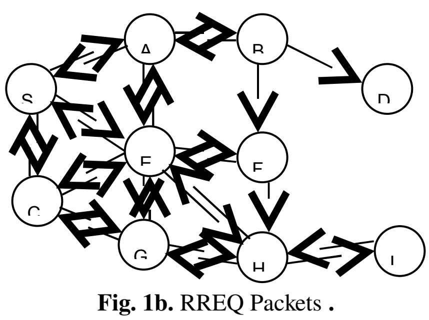

Fig. 1b. RREQ Packets **.**

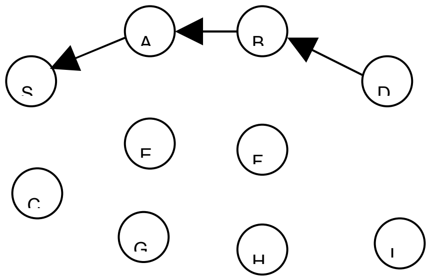

Fig. 1c. RREP Packets .

Table 1. AODV Packet Parameters [10]

RREQ	192 Bits
RREP	160 Bits
RERR	160 Bits

Table 2. Control Traffic for single route discovery

Node	RREQ	RREP	Size(Bits)
S	3	-	576
A	3	1	736
B	3	1	736
C	3	-	576
D	-	1	160
E	6	-	1152
F	3	-	576
G	3	-	576
H	4	-	768
I	1	-	192
Total	29	3	6048

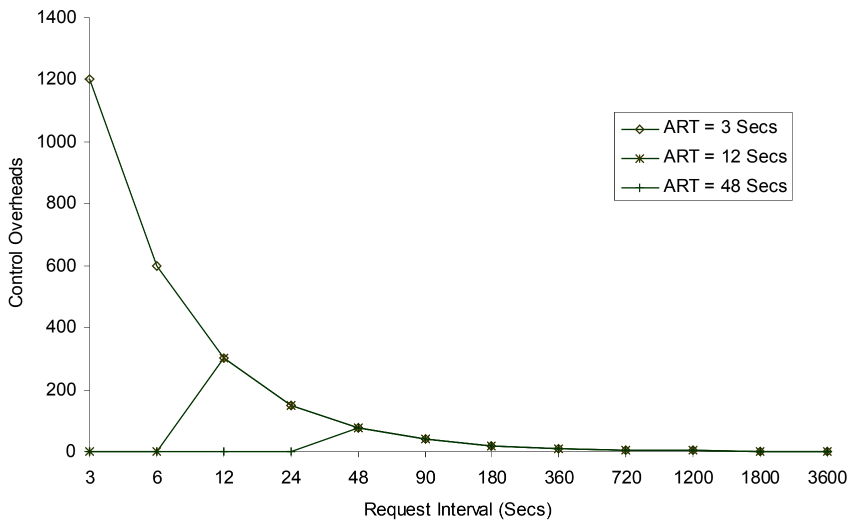

Fig. 2. Control Traffic in 1 hour.

The metric is the request interval which defines time of consecutive route requests for the same node/path. Calculations above show that 6.084Kbits of control traffic will be generated once node S tries to seek node D located at 3 hops away. Here the average distance in the given network is also 3 hops, therefore it may be assumed that any one node generates approximately same overheads for reaching any other node in the network. Fig. 2 indicates the amount of overhead traffic generated in one hour, once route cache time is kept as 3, 12 and 48 seconds.

Now considering the above network established in a Public Library where a user at node S is accessing internet and node D is a proxy server. Assuming average download time of a web page as 30 seconds and a user takes 2-3 minutes to browse the page. By keeping ART set to 3 seconds the overheads generated in one hour while browsing the internet will be 120.968 Kbits. With 10 nodes approximately 29 GBits control traffic will be generated per day and the figure will further increase drastically with the increase in number of nodes as the control traffic packets increase exponentially. Worst case scenario in above example will be, when all the nodes refresh their route after every 3 seconds then the traffic generated by each node per hour will be increased 20 times (2419.360 Kbits)

3.2 Linear Mobility Scenario

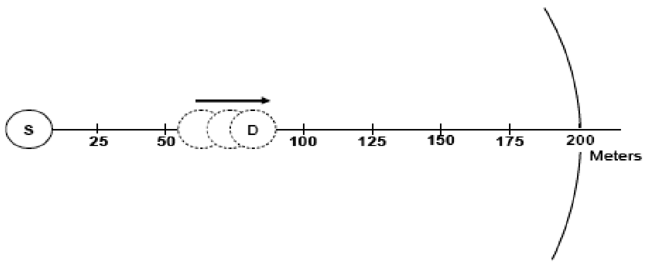

Fig. 3. Linear Mobility**.**

To understand the working of AODV a simple scenario is considered in Fig. 3; here two nodes are interacting with each other. Source S is considered stationary and destination node D initially at 25 meters from the source is moving linearly away from it. Speed and direction of movement of node D in this scenario is critical in deciding the optimal time for which the route has to be kept alive which consequently affect the control overheads. Initially in this experiment ART is kept as 3 seconds and speed is varied from 0.5 to 2 meter per second depicting a person walking to an average vehicle moving in a city.

Fig. 4(a-d) indicate the number of control overheads generated once request intervals are increased from 3 second (worst case scenario) to the maximum time of interaction i.e. two nodes are in communication range. For each speed exhibited by node D, ART is varied from its default value (3 seconds) to maximum value depending on the time taken by node D to be out of communication range. The sharp increase in the graphs indicates the out of range conditions of each scenario. A look on the graphs conclude that keeping the ART closer to the time interval before which two nodes run out of range gives the least number of control overheads.

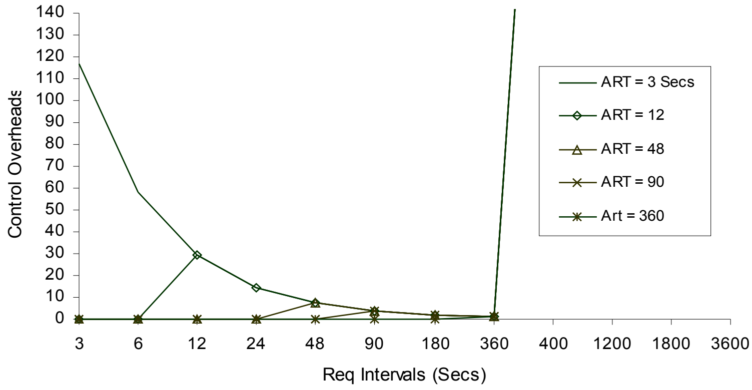

Fig. 4a. Speed of node D is 0.5 m/s.

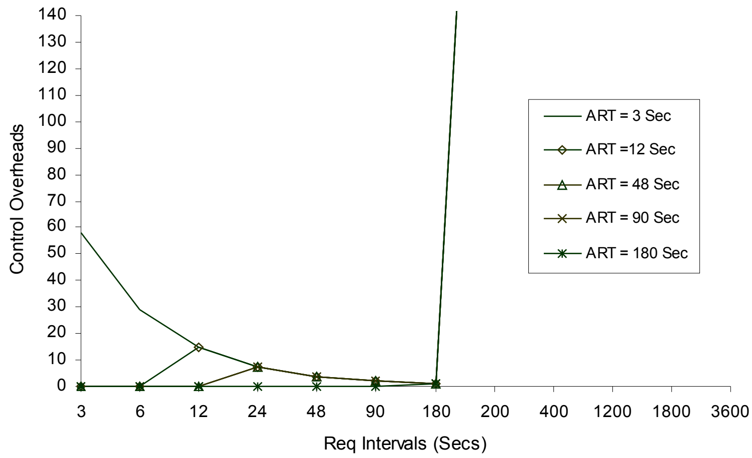

Fig.4b. Speed of node D is 1 m/s.

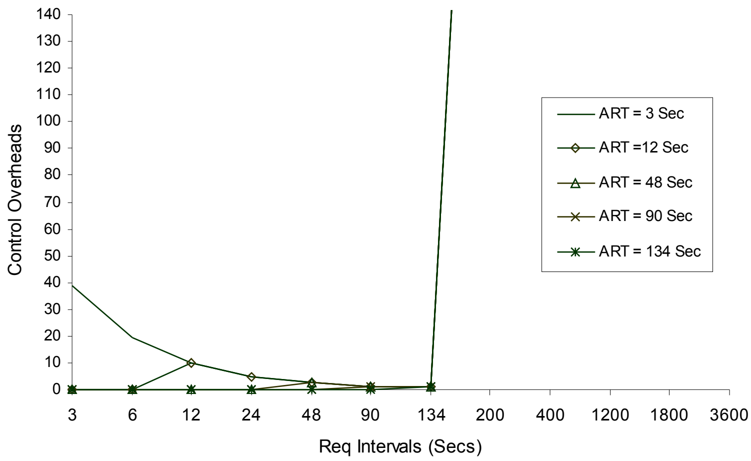

Fig.4c. Speed of node D is 1.5 m/s.

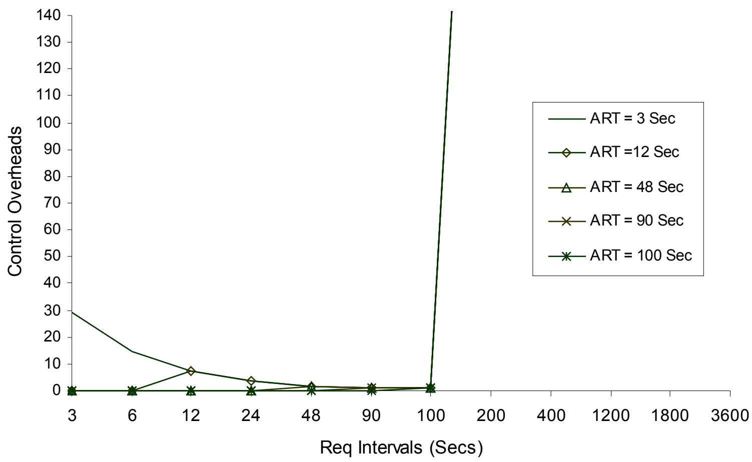

Fig.4d. Speed of node D is 2 m/s.

3.3 Enhancement of AODV

The performance of AODV for high mobility networks has been established through a number of simulated analysis and comparative studies with other reactive as well as proactive protocols [3] [6] [7] [11] [13]. However, performance of AODV in low mobility / Static environment networks is only marginally better than most reactive protocols, like DSR, especially in terms of control overheads [13]. After analyzing the overhead cost (section3 & 3.1), generated by AODV routing protocol while working in static / low mobility environment, it is imperative to enhance the existing AODV protocol with parameters that reduces the overheads in such conditions but without altering the protocol efficiency for high mobility networks.

In AODV, once a route is established it will be maintained as long as it is actively utilized by the source that demanded the route. It is the prolonged idleness of the route that stales its entry in the routing table and invokes route discovery process, which in turn generates large overheads. To improve upon the situation it is suggested that an interface may be designed in AODV protocol that takes inputs from the users about their mobility patterns. This information may be stored at each node (routing table) and basing on this information the ART value and route cache time for the node's route is calculated. In this, the source node will have a prior knowledge about existence of the destination and will not stale its route during that time period. In above example of browsing internet (section 3), if a user announces the time duration of his presence then the source and intermediate route cache is set accordingly, this will save time-and-again discarding and rediscovering the same route. The enhancement will not only save the bandwidth but also curtail the route delay in the specific environment. As each mobile device performs a dual role i.e. end user terminal and a network router, the suggested enhancement will have profound effect on user nodes as it will save node's resources form processing route for itself and for others (as intermediate node) during the fixed period.

The AODV scenarios modeled above are intentionally kept simple in order to highlight the issue of route caching at fixed and at low mobility. The additional information in these scenarios from the destination or intermediate nodes will certainly increase the processing time at the nodes. The effect of suggested enhancement on the protocol's efficiency especially in case of large population networks and nodes exhibiting complex mobility can be analyzed as future work.

4 Conclusion

Routing delay and bandwidth utilization by the control traffic are two major drawbacks once AODV network is subjected to static environments. By introducing user defined parameters for route caching and ART the cost of overheads in AODV can be reduced drastically which in turn will not only improve the bandwidth utilization factor and routing delay but also save the resources from unnecessary route processing. Such enhancement will make AODV a more versatile and adoptable routing protocol for MANETs.

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