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Reduction of Overheads with Dynamic Caching in Fixed AODV based MANETs

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***Abstract*—**In this paper we show that adjusting ART in accordance with static network scenario can substantially improve the performance of AODV by reducing control overheads. We explain the relationship of control overheads with network size and request patterns of the users. Through simulation we show that making ART proportionate to network static time reduces the amount of control overheads independent of network size and user request patterns**.**

***Keywords*—**AODV, ART, MANET, Route Cache, TTL.

I. Introduction

BY definition, "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 has afforded a new dimension in wireless networking; the technology gives its users a freedom to move anywhere while remaining in communication since it has become independent of communication infrastructure. Freedom from existing infrastructure has made MANETs more flexible, affordable and easily deployable in all terrains. MANETs are increasingly gaining popularity in all type of communication / networking environments including military and rescue operations, particularly disaster relief operations in areas void of communication infrastructure [2].

MANETs have been an area of great interest for research community and since past decade, a number of protocols have been designed for its implementation. The dynamic topology, limited bandwidth, power-constrained operation and limited computing capability of mobile hosts make the design of routing protocols more challenging compared to the conventional IP based routing protocols [3, 4]. Generally, MANET protocols are divided into two major categories; *Proactive* and *Reactive protocols*. In proactive approach the idea is to keep track of the routes from a source to all destinations in the network. This approach requires periodic exchange of routing information among the nodes, consequently these protocols show minimal delay when the route is required [5]. Reactive protocols 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 [6]. Lately, *Hybrid protocols*, another category has been included, which is the combination of the two protocols [2].

In this paper we have shown the effect of network population and different network usage patterns on control overheads that consume a considerable amount of network bandwidth. We have purposed a dynamic route caching based solution to reduce the overheads in static scenarios.

The rest of the paper is organized as follows, section 2 reviews the working of AODV and its salient features and section 3 analyzes AODV networks in static scenario and study of effects on control overheads due to network size and simulation of such scenarios in , the proposed solution and future work required.

II. Ad Hoc On-Demand Distance Vector (AODV) Routing

The AODV routing algorithm is a reactive routing protocol designed for MANETs. The protocol is designed for MANETs with population of tens to thousand of mobile nodes [10]. AODV combines the features of Destination Sequenced Distance Vector (DSDV) and Dynamic Source Routing (DSR) protocols. The route discovery and maintenance process is similar to that in DSR whereas the idea of using sequence numbers for route refreshness and periodic *Hello* messages (for checking neighbor nodes) is borrowed from DSDV protocol [5]. AODV can handle low, moderate and relatively high mobility rates, as well as variety of data traffic [10]. A number of studies indicate that the performance of AODV in terms of route latency, throughput and bandwidth utilization 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) [10]. In AODV routing, when a source has data to transmit to a new destination, it broadcasts a RREQ for that destination to

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its neighbors. If the receiving node is the destination or has a current route to the destination, it generates a RREP.A node on receiving the RREQ checks if it has not already received the same request from another node, also the node itself is not the destination and it does not have current route to the destination then it will rebroadcast the RREQ and at same time route to the source is created [11]. The RREP is unicasted 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 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]. Each node maintains a monotonically increasing sequence number for itself. Sequence number serves as a time stamp and allows a node to compare how fresh the routing information on other nodes is. A higher sequence number signifies a fresher route [13].

A. Route Maintenance Process

AODV also aims to maintain the established routes because this not only achieves stability in the network but also reduces the excessive overhead required in discovering new route. 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 the movement of one or more intermediate nodes [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). The ART is a static parameter that defines how long a route is kept in the routing table after the last transmission of a packet on the route [3, 17]. If a route is not used for this period of time the node removes the route from its routing table. ART is set to 3000 milliseconds [4, 10].

In AODV routing, movements of nodes affect only the routes passing through the specific moving 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 [18]. AODV uses an active neighbor node list for each routing entry to keep track of the neighbors that are using the entry to route data packets. These nodes are notified with RERR packets when the link to the next hop is broken. 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].

B. Bandwidth Constraints

As mentioned earlier, MANETs are characterized by limited bandwidth. Beside actual / intended data a considerable bandwidth is utilized by the control overheads. The bandwidth situation further aggravates 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 initial control traffic is further increased by the additional overheads used for detection and repair of frequent route breakages due to mobility of nodes. It is desired to keep the routes as long as possible so that not only the network sustains its stability, but also the overhead cost (signaling, computation, etc) associated with route discovery and maintenance is reduced [16]. In AODV, common control overheads include *Hello Messages* for detecting link breakage with neighbors and RREQ / RREP messages for route discovery. The main contribution to control traffic overhead is due to RREQ and RREP messages [19].

C. 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. This is particularly important in real time communication like audio and video transmissions. 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 packet gets a valid cached route, the chances for successful delivery of subsequent packets is almost guaranteed [20]. AODV allows two types of route caching one at the source node (that initiated the route request) this is called source route caching. Secondly, at intermediate node (that has a cached route to the destination and reply to the source with the cached route) called intermediate route caching [21].

Despite the advantage of reducing the route latency, prolonged caching may render the route obsolete due to frequent movement of the destination or intermediate node(s) in MANETs. When an invalid route cache is used, extra traffic overheads and routing delays are incurred to discover the broken links. 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 delays and traffic overheads 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 delays and traffic overheads 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.

III. Fixed AODV Based MANETs

MANETs because of their ease of deployment and cost effectiveness are increasingly gaining popularity as fixed networking solutions like small office home office (SOHO) solutions. In [22] we have discussed such static scenarios with intermittent request patterns and studied the overhead generated with in the network of 10 nodes, Fig. 1.

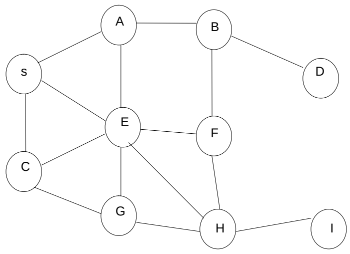

Fig. 1 Network Topology (Replicated from [22])

By calculating the number of RREQs and RREPs packets we have found that 6.084 KBits of control traffic is generated as node S seek node D for transferring intended data. We also studied the effect of user request pattern on control traffic overheads and found out that 120 KBits of control overheads are generated in 1 hour of internet browsing (Node D connected to the Internet, considering average download time of a web page is 30 seconds and a user takes 2-3 minutes to browse that page). The worst case scenario is considered once all refresh their route cache after every 3 seconds than the traffic generated will be increased 20 times (approximately)

A. Effect of Network Population on Overhead Traffic

The control overheads in AODV are mainly due to the broadcast and rebroadcast of route requests. Even if all the nodes may not be actively participating in a particular link even then all of them generate considerable control traffic in the process of route discovery. To study the effect of node population on the behaviour of the control traffic in a static network a simulation was carried out using NS-2. Initially a regular shaped network of 10 nodes was simulated and then it was expanded to 20 and 30 nodes, as show in Fig 2.

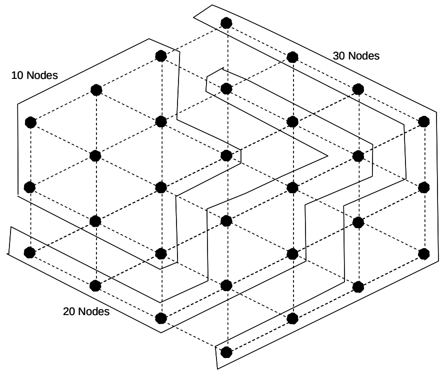

Fig. 2 Arrangement of nodes in simulated network

In each network arrangement, 5 intercommunicating nodes and 50% (of total population) intercommunicating nodes were randomly selected. Random CBR traffic (for 3 minutes) is used during each test simulation. The request intervals and ART is kept constant. Fig. 3a shows that even if we keep the number of communicating nodes constant, the overhead traffic increases in multiples when network size is increased. Fig. 3b shows that when 50% of the network nodes are communicating the overhead traffic increases many folds by just doubling or tripling the network size.

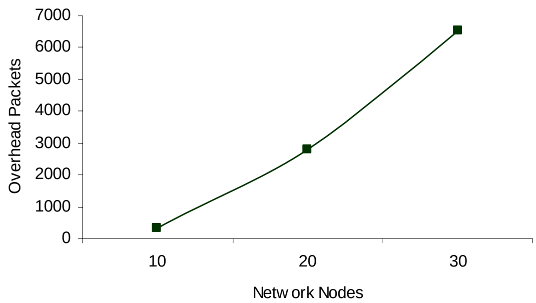

Fig. 3a Overhead traffic generated by 5 intercommunicating nodes in 10, 20 and 30 node network

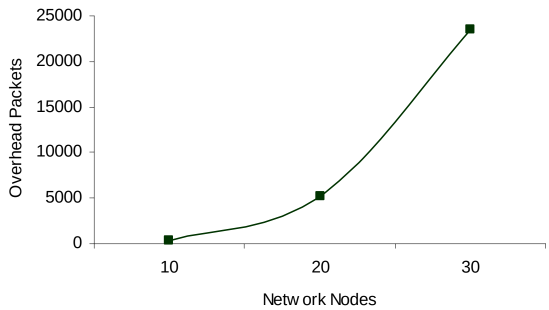

Fig. 3b Overhead traffic generated by 50% intercommunicating nodes in 10, 20 and 30 nodes network

B. Effect of Request Intervals / ART on Control Traffic

Request Interval, is the length of time between two consecutive requests made by the same node (user) for establishing the same link. To study the effect of request intervals on generation of control traffic we carried out simulation with varying request intervals (i.e. 2, 3, 6, 12, 24, 48, 90 and 180 Seconds). Network parameters are kept same as described above. Here, generation of overhead packets with each request interval was recorded against three ARTs (3, 12 and 48 seconds). Figs. 4 and 5 show the effect on the overhead control traffic by altering the request intervals for a specific ART. Fig. 4a, b and c indicate the comparison once 5 nodes (randomly selected) are intercommunicating in three simulated networks and graph 5a, b and c shows the same comparison once 50% nodes in each scenario is intercommunicating.

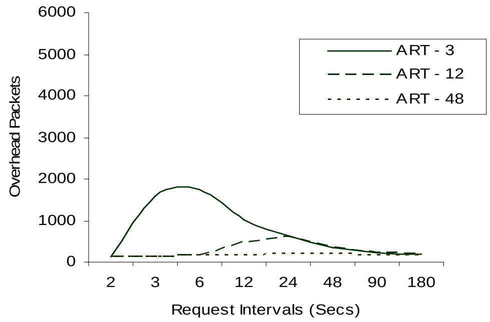

Fig. 4a Overhead traffic for 5/10 nodes intercommunicating with varying Request Intervals for ART 3, 12 and 48 seconds

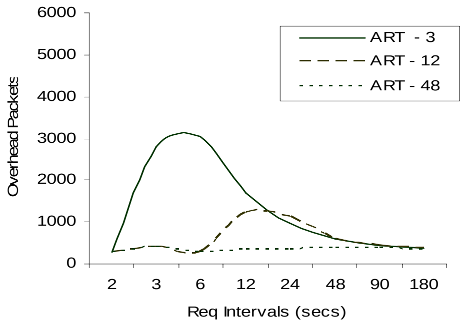

Fig. 4b Overhead traffic for 5/20 nodes intercommunicating with varying Request Intervals for ART 3, 12 and 48 seconds

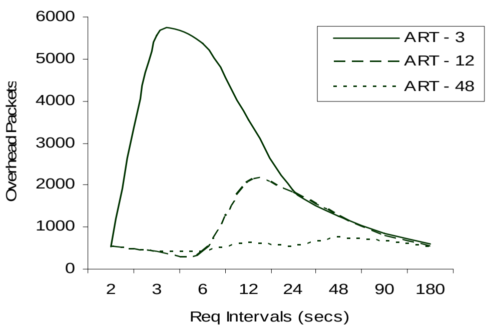

Fig. 4c Overhead traffic for 5/30 nodes intercommunicating with varying request intervals for ART 3, 12 and 48 seconds

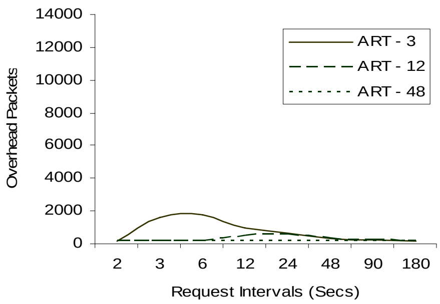

Fig. 5a Overhead traffic for 5/10 nodes intercommunicating with varying request intervals for ART 3, 12 and 48 seconds

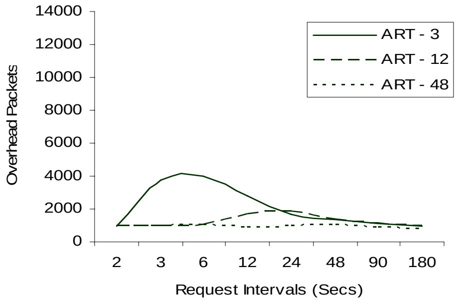

Fig. 5b Overhead traffic for 10/20 nodes intercommunicating with varying request intervals for ART 3, 12 and 48 seconds

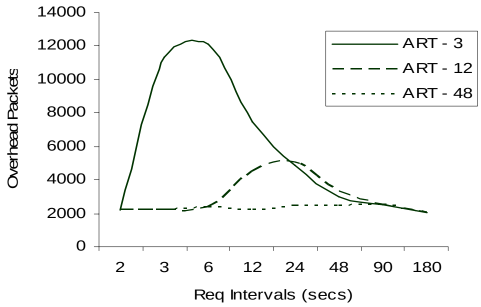

Fig. 5c Overhead traffic for 15/30 nodes intercommunicating with varying request intervals for ART 3, 12 and 48 seconds

The increase in the control traffic in the first half of graphs is due to increase in the number of route discovery requests by source nodes inspite of decrease in total number of requests by user due to increased interval. The downward trend in the second half of graphs is due to the reduced numbers of request (as the request intervals are increased in fixed simulation time). In all six scenarios the least amount of overhead is observed when ART is 48 seconds regardless of the request intervals.

Further, Figs. 4 and 5 show that same number of intercommunicating nodes produce more overhead traffic once the population of the network is increased (as in the previous simulation case) and once the nodes in AODV network are static for prolong period a larger value of ART will decrease the number of overheads irrespective of varying request intervals.

C. Results

The simulation reveals following facts:

1) AODV produce considerable amount of control overheads for route discovery.
2) Overheads increase with increase in the network size, even if the number of communicating nodes is kept constant.
3) For a fixed percentage of communication nodes overhead increase many folds as network size is increased linearly.
4) Usage pattern defined by request interval effects overhead
5) Large values of ART produce less overhead as compare to small value of ART regardless of request intervals.

IV. Enhancement of AODV

By looking at the above results / findings one may conclude that by increasing the ART value the volume of overheads will be reduced. But the problem with large ART scheme will be the storage of stale routes in the routing table at both the source and intermediate nodes, this prolong caching will result in even larger overhead. The scheme along with route discovery overheads will also generates overheads for link breakage and repair etc once bumped into a stale route. In static environment (or otherwise) a route will be deleted form table if it remained inactive for period longer than its defined ART. In this contrary situation optimal performance can be achieved by keeping ART as close as possible to the duration for which the network is static. This required amendment/adjustment in the ART value can be done by getting input from the node (user), once the node enters an existing ad hoc network. A suitable interface may be designed that enquires the static duration form user and pass/store the information to the neighbouring / intermediate node in the network along with other routing information. Such enhancement will ensure against the frequent deleting and rediscovering a route due to prolong idleness or indifferent user request patterns [22].

A. Analysis of the Solution

To analyze the purposed solution and the effectiveness of our suggested enhancement in AODV to reduce the overhead traffic, we again carried out simulation in NS-2 of two networks; one having 20 nodes with 5 nodes intercommunicating and other having 30 nodes with 15 nodes intercommunicating (as already described above). Results (Fig. 6a and b) confirm the purposed solution i.e. the volume of overheads for all request intervals is minimum at ART = 180 (which is the considered static time of nodes)

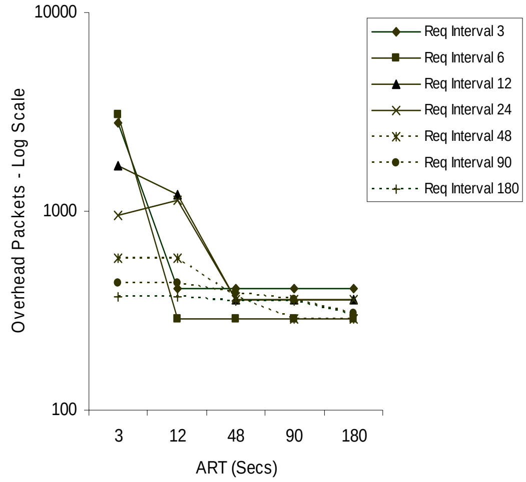

Fig 6a Overhead traffic in 3 minutes by increasing ART for different Request Intervals (5 nodes intercommunicating in 20 node network)

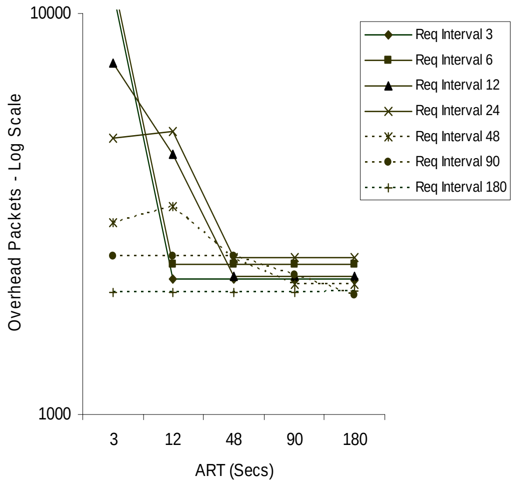

Fig. 6b Overhead traffic in 3 minutes by increasing ART for different Request Intervals (15 nodes intercommunicating in 30 node network)

V. Conclusion

A user defined interface to adjust the ART in AODV will have profound effects on the overall efficiency of the protocol. Apart form improving the bandwidth utilization of the protocol in static environment the enhancement will curtail the routing delays due to route discovery. It will also improve the computational efficiency of nodes by saving it from processing routes during the defined fixed period.

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