ADAPTIVE AODV ROUTING PROTOCOL FOR MOBILE ADHOC NETWORKS

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ABSTRACT

Enhancing route request broadcasting efficiency in protocols constitutes a substantial part of research in Mobile Adhoc NETwork (MANET) routing. We suggest a novel approach to constrain route request broadcast based on mobility of nodes. This technique is best suited for networks where the movement of the nodes is with different random velocities in different random directions. This protocol adapts itself automatically to two mobility conditions i.e. moderate and high speed. Intuition behind this technique is that the nodes moving with higher mobility rates will have better recent routes compared to slow moving nodes which may not be aware of the drastic changes happening in the network .In this approach we select the neighbourhood nodes for broadcasting route requests based on their mobility rate and recent involvement in routing so that blind flooding of the route request in the network can be avoided.

Our contributions include: (i) Two new enhancement technique to reduce route request broadcast for reactive ad hoc routing protocols; (ii) Implementation of Enhanced Ad-hoc On-demand Distance Vector routing 1 (EAODV1) for moderate speed of node movement;(iii) Implementation of Enhanced Ad-hoc On-demand Distance Vector routing 2 (EAODV2) for high speed of node movement; (iv) Implementation of Adaptive AODV (AAODV) which automatically switches over between EAODV1 and EAODV2 based on the mobility of the nodes. (v) An extensive simulation study of EAODV1, EAODV2 and AAODV using Glomosim showing significant improvement in overhead, packet delivery ratio and the end-to-end delay

KEYWORDS

Network Protocols, MANET, reactive routing, AODV, flooding, mobility.

1. INTRODUCTION

MANETs [3][11][12] are self-creating, self-organizing, self-administrating and do not require deployment of any kind of fixed infrastructure. They offer special benefits and versatility for wide range of applications in military (e.g., battlefields, sensor networks etc.), commercial (e.g., distributed mobile computing, disaster discovery systems, etc.), and educational environments (e.g., conferences, conventions, etc.), where fixed infrastructure is not easily acquired. With the absence of pre-established infrastructure (e.g., no router, no access point, etc.), two nodes communicate with one another in a peer-to-peer fashion. Two nodes communicate directly if they are within the transmission range of each other. Otherwise, the nodes communicate via a multihop route. To find such a multi-hop route, MANETs commonly employ on demand routing algorithms that use flooding or broadcast messages. Many ad hoc routing protocols [14] [20] [21], multicast schemes [18], or service discovery programs depend on massive flooding. In flooding, a node transmits a message to all of its neighbours. The neighbours in turn relay the information to their neighbours and so on until the message has been propagated to the entire network. In this paper, we will refer to such flooding as blind flooding. As one can easily see, the performance of blind flooding is closely related to the average number of neighbours (neighbour degree) in the Carrier Sense Multiple Access/Collision Avoidance network. As the neighbour degree gets higher, blind flooding suffers from the increase of (1) redundant and superfluous packets, (2) probability of collision, and (3) congestion of wireless medium [1]. Performance of blind flooding is severely impaired especially in large and dense networks [2][30]. When topology or neighbourhood information is available, only subsets of neighbours are required to participate in flooding to guarantee the complete flooding. We call such flooding as efficient flooding. The characteristics of MANETs (e.g. node mobility, the limited bandwidth and resource), however, make the periodic collection of topology information difficult and costly (in terms of overhead). For that reason many on-demand ad hoc routing schemes and service discovery protocols simply use blind flooding [14] [18]. In contrast with on-demand routing methods, the proactive ad hoc routing schemes by virtue of periodic route table exchange, can gather topological information without much extra overhead. Thus, the leading MANET proactive ad hoc routing schemes use route aggregation methods to forward routing packets through only a subset of the neighbours [21].

In Ad-hoc On-demand Distance Vector routing (AODV) [20] which is a reactive routing algorithm, every intermediate node decides where the routed packet should be forwarded next. AODV uses periodic neighbour detection packets in its routing mechanism. At each node, AODV maintains a routing table. The routing table entry for a destination contains three essential fields: a next hop node, a sequence number and a hop count. All packets destined to the destination are sent to the next hop node. The sequence number acts as a form of time-stamping, and is a measure of the freshness of a route. The hop count represents the current distance to the destination node. On the contrary, Dynamic Source Routing (DSR) uses the source routing in which each packet contains the complete route to the destination in its own header and each node maintains multiple routes in its cache. In case of less stressed situation (i.e. smaller number of nodes and lower load and/or mobility), DSR outperforms AODV in delay and throughput but when mobility and traffic increase, AODV outperforms DSR [5]. However, DSR consistently experiences less routing overhead than AODV.

In this paper, we focus on on-demand reactive routing protocol AODV and propose two methods for efficient flooding. The first method EAODV1 selects a neighbour node for forwarding the route request based on its recent usage and mobility. This was seen to be working efficiently when the speed of movement of the nodes were moderate, but as the speed of movement of the nodes increased to a high value the performance of EAODV1 was seen to deteriorate So for high mobility we have proposed EAODV2 which uses alternate phases of flooding of route requests and selection of nodes for relaying route based on mobility and recent usage. We have tried to reduce flooding in a dynamic network where the nodes move in random directions with random mobilities. We have also made the AODV adapt itself automatically to use EAODV1 or EAODV2 based on the mobility of the nodes. This technique does not create too much of extra overhead for routing and provides better performance compared to other existing techniques for reducing flooding like caching[31] [32] [22],clustering [10] [16] [19],node caching [32], single copy routing[23] etc.

The remainder of the article is organized as follows: In section 2 we discuss the various methods available for achieving efficient flooding. Section 3 gives an explanation about the algorithm AODV-NC and the algorithms we have proposed for achieving efficient flooding. Section 4 discusses the simulation parameters and results. The main conclusions from this paper are summarized in section 5.

2. RELATED WORK

Several papers [1] [6] [7] [8] have addressed the limitations of blind flooding and have proposed solutions to provide efficient flooding. However, because of the problem of finding a subset of dominant forwarding nodes in MANETs, all the work about efficient flooding has been directed to the development of efficient heuristics that select a sub-optimal dominant set with low forwarding overhead.

In [1] [6], the authors propose several heuristics to reduce rebroadcasts. More specifically, upon receiving a flood packet, a node decides whether to relay it or not based on one of the following heuristics: (1) rebroadcast with given probability; (2) rebroadcast if the number of received duplicate packets is less than a threshold; (3) distance-based scheme where the relative distance between hosts determines the rebroadcast decision; (4) location-based scheme where the decision is based on pre-acquired neighbour location information; (5) cluster-based scheme where only pre computed cluster heads and gateways rebroadcast.

Another approach to efficient flooding is to exploit topological information [6] [7] [8] [24]. In the absence of pre-existing infrastructure, all the above schemes use a periodic hello message exchange method to collect topological information. The authors of [8] suggest two schemes called self-pruning and dominant pruning. Self pruning is similar to the neighbour-coverage scheme in [6]. With self-pruning scheme, each forwarding node piggybacks the list of its neighbours on outgoing packet. A node rebroadcasts (becomes a forwarding node) only when it has neighbours that are not covered by its forwarding nodes. While the self-pruning heuristic utilizes information of directly connected neighbours only, the dominant-pruning heuristic extends the propagation of neighbour information two-hop away. The dominant pruning scheme is actually similar to Multipoint Relay scheme (MPR) [7].

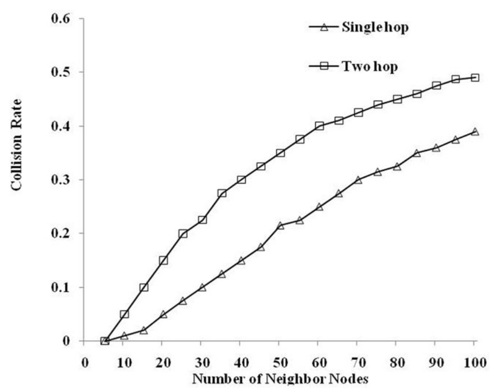

Fig. 1 The collision rate of broadcast.

In Multipoint Relay scheme, a node periodically exchanges the list of adjacent nodes with its neighbours so that each node can collect the information of two-hop away neighbours. Each node, based on the gathered information, selects the minimal subset of forwarding neighbours, which cover all nodes within two-hops. Each sender piggybacks its chosen Multipoint Relay forwarding Nodes (MPRNs) on the outgoing broadcast packet.

Along the similar lines, several other schemes have proposed the selection of a dominant set based on topology [25] [26]. All of these schemes, however, again depend on periodic hello messages to collect topological information.

The extra hello messages, however, consume resources and drop the network throughput in MANETs [27]. The extra traffic brings about congestion and collision as geographic density increases [1]. Fig 1 [16] depicts the collision probability of hello messages in a single hop and a two hop network as the number of neighbour's increases. This result clearly shows that the neighbour degree causes the broadcast collision probability to increase (note: the collision probability is more than 0.1 with more than 15 neighbours). Moreover, the hidden terminal condition aggravates collisions in the two hop network. Note that Fig 1 assumes no data traffic and only hello messages.

With user-data packets, the collision probability of hello messages will dramatically increase. Thus, it will be hard to collect complete neighbour topology information using hello messages. As a consequence, the aforementioned schemes (e.g., neighbour coverage, MPR, etc.) are not scalable to offered load and number of neighbours.

A novel approach to constrain route request broadcast based on node caching was proposed in [32]. This approach assumes that the nodes involved in recent data packet forwarding have more reliable information about its neighbours and have better locations (e.g., on the intersection of several data routes) than other MANET nodes. The nodes which are recently involved in data packet forwarding are cached, and only they are used to forward route requests.

Lastly, we consider clustering. Clustering can be described as grouping of nodes. A representative of each group (cluster) is dynamically elected to the role of cluster head based on some criterion (e.g., lowest ID). Nodes within one hop of a cluster head become associated to its cluster. A node belonging to two or more clusters at the same time is called a gateway. Other members are called ordinary nodes. Various distributed computation techniques can be used to dynamically create clusters. In an active clustering lowest ID technique [15] each node attempts to become cluster head by broadcasting its ID to neighbours. It will give up only if it hears from a lower ID neighbour. Based on the above definition, any two nodes in a cluster are at most 2 hops away [9]. With the clustering scheme, the dominant forwarding nodes are the cluster heads and the gateways.

Clustering in ad hoc networks has been extensively studied for hierarchical routing schemes [9] [5], and for approaches like the master election algorithms [4], power control [17] [26], reliable broadcast [28], efficient broadcast [29] and efficient flooding [16][19]. Some clustering schemes are based on the complete knowledge of neighbours. However, the complete knowledge of neighbour information in ad hoc networks is hard to collect and introduces substantial control overhead caused by periodic exchange of hello messages. Passive clustering [16] [19] is an "on demand" protocol, it constructs and maintains the cluster architecture only when there are on-going data packets that piggyback "cluster related information". Each node collects neighbour information through promiscuous packet receptions. Passive clustering, therefore, eliminates setup latency and major control overhead of clustering protocols.

Passive clustering has two innovative mechanisms for the cluster formation: First Declaration Wins rule and Gateway Selection Heuristic. With the First Declaration Wins rule, a node that first claims to be a cluster head "rules" the rest of nodes in its clustered area (radio coverage). There is no waiting period (to make sure all the neighbours have been checked) unlike for all the weight-driven clustering mechanism [5]. Also, the Gateway Selection Heuristic provides a procedure to elect the minimal number of gateways (including distributed gateways) required to maintain the connectivity in a distributed manner.

Passive clustering scheme [16][19] requires neither the deployment of GPS like systems nor explicit periodic control messages to identify the subset of forwarding neighbours. This scheme makes the following contributions compared with previous efficient flooding schemes (such as multipoint relay, neighbour coverage, etc): (1) It does not need any periodic messages. Instead, it exploits existing data packets by attaching few more extra fields. (2) It is very resource-efficient regardless of the degree of neighbour nodes or the size of network. This scheme provides scalability and practicality for choosing the minimal number of forwarding nodes in the presence of dynamic topology changes; (3) It does not introduce any start-up latency; (4) It saves energy if there is no traffic; (5) It easily adapts to topology and available resource changes.

In this paper we propose a method for efficient flooding when the nodes are moving in random direction with random velocity by selecting a few of the neighbouring nodes for forwarding the route requests based on their mobility and recent usage of the nodes for forwarding the data. This technique does not group the nodes in the network into clusters. We have used the mobility of the nodes as the criteria for selecting the nodes to forward the Route requests so that unnecessary flooding can be avoided. We have tested the implementations on AODV Routing protocol.

3. PROPOSED TECHNIQUE

Node caching AODV (AODV-NC) technique [32] caches the nodes which have recently forwarded the data packets and uses only these selected neighbours for forwarding the Route request packets. Route request uses a fixed threshold parameter H. The first route request is sent with the small threshold H. When a node N receives the route request, it compares the current time T with the time T(N) when the last data packet through N has been forwarded. If T - H > T (N), then N does not belong to the current node cache and, therefore, N will not propagate the route request. Otherwise, if T - H ≤ T (N), then N is in the node cache and the route request is propagated as usual. Of course, the node cache cannot guarantee existence of paths between all source-destination pairs, therefore, if the route request with the small threshold H fails to find a route to destination, then a standard route request (which is not constrained by cache) is generated at the source.

In the default settings of AODV, if the route to the destination is broken, obsolete or unestablished, the route request originated from the source is propagated through the entire MANET. If the route reply is not received by the source in a certain period of time, then the route request is periodically repeated. If all these Route Requests happened to be unsuccessful, several more requests with increasing time gaps are sent. In AODV-NC, modifications are restricted solely to the Route Request and its initiation.

3.1. Route Request in AODV-NC (H)

1) If a requested route is not available, then send an H restricted route request with the threshold H, i.e., for each route request recipient N
   - If the destination is the known neighbour of N, then N forwards the route request to the destination.
   - If no more than H seconds are gone from the last time a data packet has been forwarded by N, then N rebroadcasts the route request to all its neighbours.
2) Repeat H-restricted route request 2 times if route reply is not received during time of 0.3 sec after route request is sent.
3) If no route reply is received, then send unconstrained (standard AODV) route request with the standard repetition pattern.

Best initial values for H are suggested to be between 0.1sec and 1 sec. So we have chosen it to be 0.5sec in our simulation.

3.2. Route Request in EAODV1

We have modified AODV_NC (H) algorithm as listed below by adding the mobility factor to the existing criterion to select the neighbourhood node for efficient flooding.

1) The mobility of all the one hop neighbours are learnt and compared with the mobility of the current node.
2) Only if the mobility of the neighbouring node is greater than the mobility of the current node the Route Request is sent to the neighbouring node. A threshold M_{th1} is set in all the nodes. If M is the mobility of the current node, M_n is the mobility of neighbour node then Route Request is sent to the neighbouring node only if $(M_n - M) > M_{th1}$. We limit the number of Route requests by using the mobility criterion and prevent the route request being flooded to the entire network.

So our algorithm selects a node for efficient flooding of route requests only if the node was recently used and also meets the mobility criterion mentioned above. We have named the AODV after incorporating this modification as EAODV1 (Enhanced AODV1).

3.3. Route Request in EAODV2

We have modified AODV_NC (H) algorithm as listed below by adding a few extra factors to the existing criterion to select the neighbourhood node for efficient flooding.

1) In the first phase the Route requests are flooded to the entire network during which the mobility of all the one hop neighbours are learnt and compared with the mobility of the current node.
2) In the second phase only if the mobility of the neighbouring node is greater than the mobility of the current node the Route Request is sent to the neighbouring node. A threshold M_{th2} (Note: M_{th2} will be less than Mth1) is set in all the nodes. If M is the mobility of the current node, M_n is the mobility of neighbour node then Route Request is sent to the neighbouring node only if $(M_n - M) > M_{th2}$. We limit the number of Route requests by using the mobility criterion and prevent the route request being flooded to the entire network.
3) Route requests are transmitted by alternating between first phase and second phase. This is required as the mobilties of the nodes are high which results in quick changes in the topology of the network.

We have named the AODV after incorporating this modification as EAODV2 (Enhanced AODV2).

EAODV1 shows good performance for moderate speed of node movement in random direction with random speed and deteriorates in its performance for high speed of node movement. EAODV2 shows good performance for high speed of node movement in random direction with random speed and deteriorates in its performance for moderate speed of node movement. So we have implemented the AODV protocol such that it selects EAODV1 or EAODV2 automatically based on the speed of movement of the nodes in the network; we have named this AODV as Adaptive AODV. This enables us to use AODV efficiently under different speeds of movement of the nodes in the network.

4. SIMULATION RESULTS

The simulations were performed using Glomosim [13]. The mobility scenarios were randomly generated using modified Random Waypoint Model. We used Distributed Coordination Function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol.

In our simulation, 20 to 60 nodes were allowed to move in a 1000x1000 meter rectangular region for 900 seconds simulation time. Initial locations of the nodes were obtained using a uniform distribution. We have assumed that each node moves independently with a random speed in a random direction later. With the Random Waypoint Mobility model, a node randomly selects a destination from the physical terrain and moves in the direction of the destination with a uniform speed chosen between the minimal and maximal speed. After it reaches its destination, the node stays there for a pause time and then moves again. In our simulation, we have modified the random waypoint mobility model so that the node moves in random direction with random mobility and then stays there for the selected pause time till next random movement. This modification was done so that the movement matches to that of the real world scenario. The pause time was varied from 0 to 40 seconds. The simulated traffic was Constant Bit Rate (CBR).

We have analyzed the performance of the proposed algorithms by varying the number of nodes in the network keeping the pause time of the nodes constant. This scenario helps us in knowing whether the algorithm supports scalability of the network as well as dynamic traffic conditions in the network. Fig 2 shows that the overhead generated by EAODV1 and EAODV2 is less compared to AODV and AODV-NC; Fig 3 shows that the packet delivery ratio of EODV1 and EAODV2 is higher than AODV and AODV-NC and Fig 4 shows that end to end delay time is less for EODV1 and EAODV2 compared to AODV and AODV-NC. All these three graphs show that the performance of AODV is effectively enhanced by EAODV1 and EAODV2; it also shows that EAODV1 shows better performance than EAODV2 for pause time of 20s. So we can say that for moderate speed of movement of nodes in the network EADOV1 performs better than EAODV2. EAODV2 produces extra overhead due to alternate phases of blind flooding .Blind flooding is not necessary when the nodes are moving at a moderate speed as the topology of the network does not change very rapidly. So at moderate speed of movement of the nodes EAODV1 outperforms EAODV2.

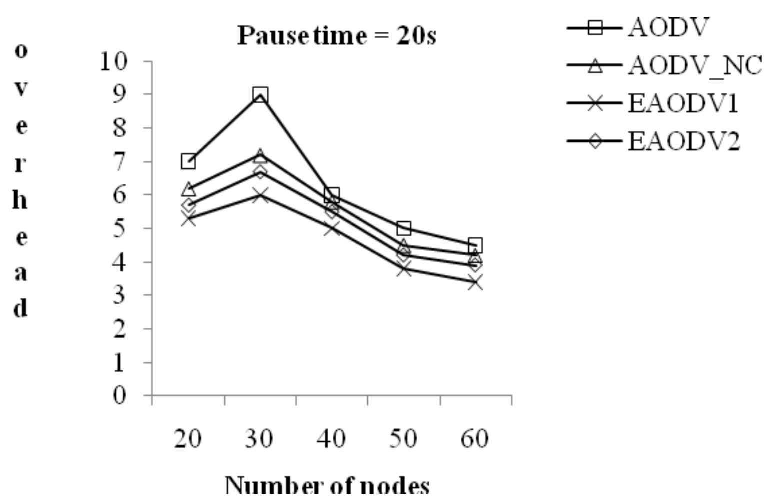

Fig. 2 Number of nodes v/s overhead.

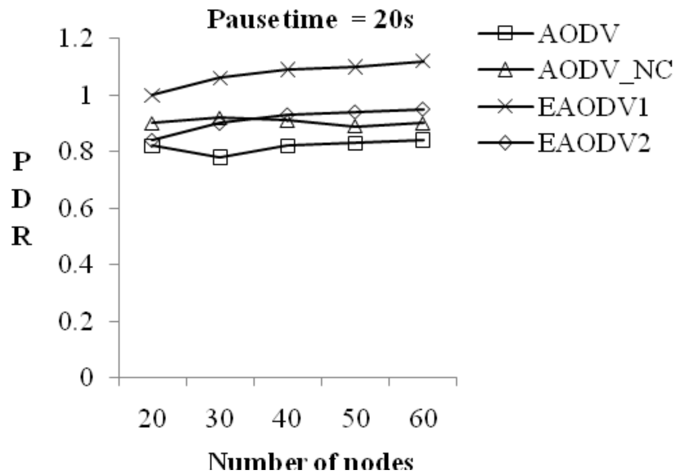

Fig. 3 Number of nodes v/s packet delivery ratio (PDR).

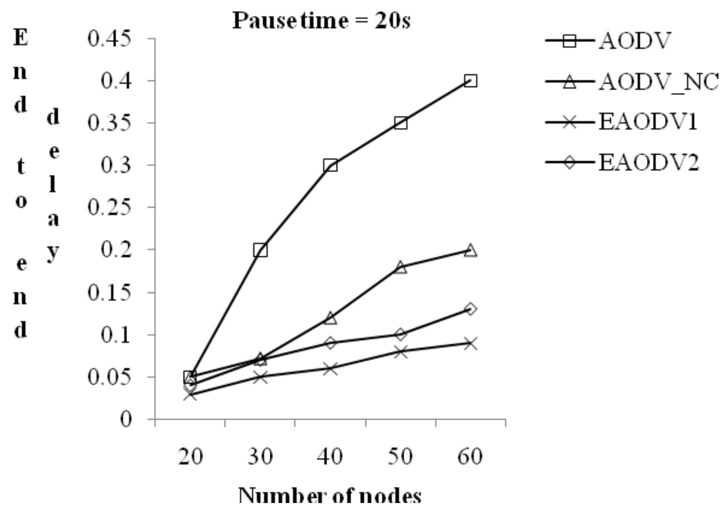

Fig. 4 Number of nodes v/s end to end delay.

We have also tried to analyze the behaviour of the protocol when the number of nodes in the network is kept constant and the time periods for which they remain static are varied. This scenario helps us in analyzing the performance of the protocol when the number of users is fixed, traffic is fixed and they move in the simulation terrain with different mobilities.

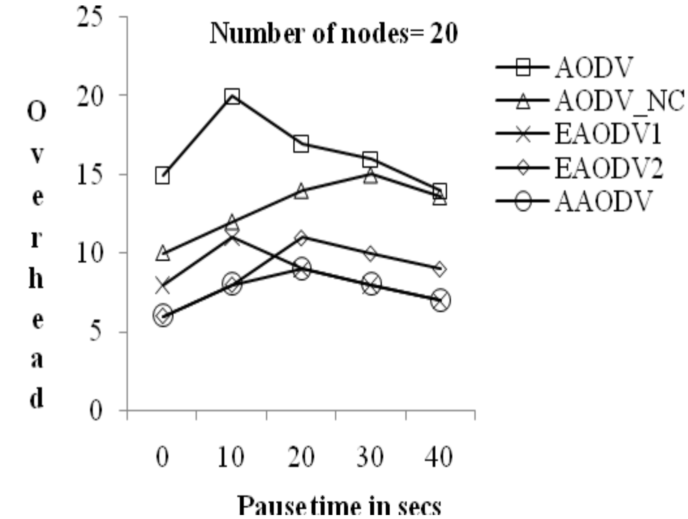

Fig. 5 Pause time v/s overhead.

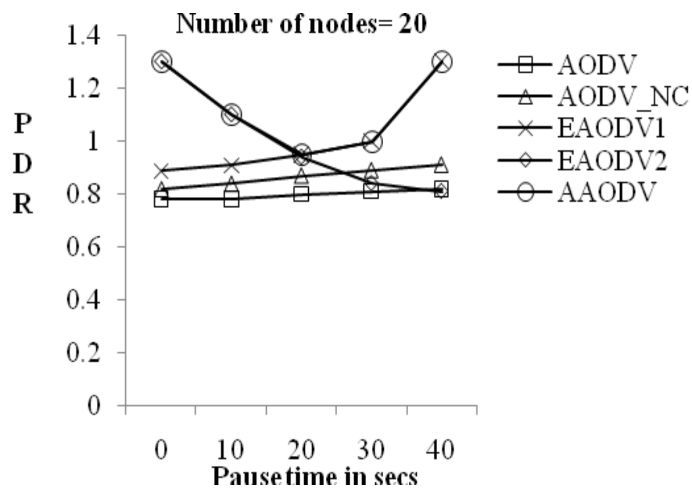

Fig.6 Pause time v/s Packet delivery ratio.

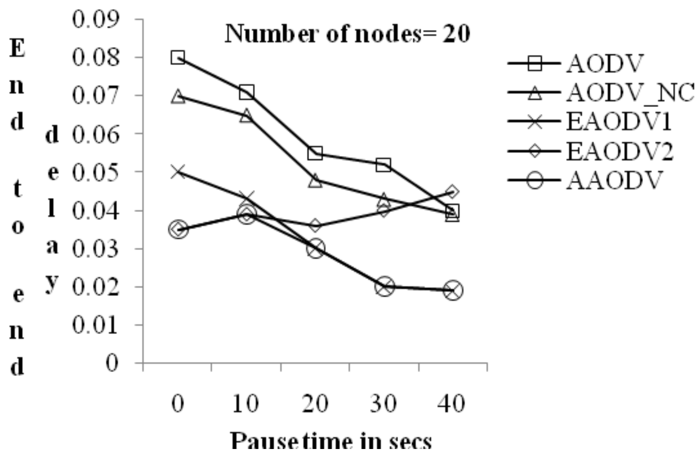

Fig. 7 Pause time v/s end to end delay.

We have analyzed the network keeping the number of users fixed at 20.Fig 5, 6 and 7 shows the for lower pause times i.e. when the nodes are moving with high speed (i.e. pause time of 0 to 10 sec) the performance of EAODV2 is better than EAODV1 with respect to all factors like overhead, PDR and end to end delay. But as the speed of the nodes decreases (i. e. Pause time of 20 to 40 sec) EAODV1 outperforms EAODV2. This shows that the EODV1 shows good performance at moderate speed of node movement and EAODV2 shows good performance at high speed of node movement. We have analyzed the performance of AODV by switching between EAODV1 and EAODV2 based on the speed of movement of the nodes. This modified AODV which can select between EAODV1 and EAODV2 is called as Adaptive AODV in our paper. From the graphs for AAODV in Fig 5,6,7 we can see that, irrespective of the speed of movement of the nodes, AAODV shows better performance than AODV and AODV_NC.

3. CONCLUSIONS

For carrying out this work we have investigated the problem of flooding based on topological information. To collect neighbourhood topology the network incurs a heavy overhead penalty- it is very costly to collect accurate topology information with node mobility and dynamically changing resources. The aforementioned topology based schemes, in consequence, are limiting in scalability and performance. Flooding scheme based on passive clustering removes such limitations but has some overhead and delay in transmission; it is also complex for implementation.

Our implementations have shown that EAODV1, EAODV2 and AAODV are very simple techniques and require substantially less knowledge of the network. Depending on the nature of movement of the nodes we can select EAODV1, EAODV2 or AAODV. Results have shown that EAODV1 is best suited for networks where movement of the nodes is moderate, EAODV2 is best suited for networks where the movement of the nodes is fast and AAODV is best suited for networks where the movement of the nodes is at varying speeds at different point of time. Results of AAODV has shown that, it is suitable for highly scalable and dynamic networks as it has drastically reduced the amount of overhead, improved PDR and reduced end to end delay in the popular reactive routing protocol AODV in different mobility scenarios. This algorithm can also be implemented and tested on the other reactive routing protocol like Dynamic Source Routing protocol (DSR), On-Demand Multicast Routing Protocol (ODMRP) etc.

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