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Local Repair with Handoff Approach for on Demand Routing Protocols in Ad Hoc Networks

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ABSTRACT

An Ad-Hoc network is a collection of autonomous arbitrarily located wireless nodes, with no fixed infrastructure. A Mobile Ad Hoc Network (MANET) consists of a set of mobile hosts. Two nodes can communicate directly with each other if they are within each others range otherwise, intermediate nodes have to relay messages for them. Nodes of an ad hoc network rely on one another in forwarding a packet to its destination, due to the limited transmission range of each mobile host. An ad hoc network uses no centralized administration In order to facilitate communication within the network; a routing protocol is used to discover routes between nodes. One of the major challenges in designing a routing protocol for ad hoc networks stems from the fact that, a node needs to know the reachability information to its neighbors for determining a path for a packet along with the fact that the network topology can change quite often in an ad hoc network. Furthermore, as the number of network nodes can be large, finding route to the destinations also requires large and frequent exchange of routing control information among the nodes. Thus, the amount of update traffic can be quite high, and it is even higher when high mobility nodes are present. Also, as the degree of mobility increases, such networks suffer more link errors

The Ad hoc On Demand Distance Vector (AODV) protocol, blends elements of the DSR and DSDV protocols, using the DSR reactive route discovery and maintenance models, in combination with the sequence number and periodic update features of the DSDV protocol. AODV is reactive routing protocol proposed by Perkins. It builds route only when needed and provides loop free routes due to the use of sequence number. On link failure AODV leads to increased delay and routing overheads while route repair procedures are carried out.

In this paper a Local Repair with Handoff Approach has been implemented, where after route errors, route rebuilding is done by some intermediate node rather than the source node. The decision for route rebuilding is done on the basis of distance of node where link break occurs from the destination node. After route rebuilding, handoff approach is used for further improvement.

Keywords: Mobile Ad hoc Networks, Handoff, Local Repair, AODV, Route Errors, On Demand Routing.

1. INTRODUCTION

A Wireless network is a cooperative engagement of a collection of wireless mobile nodes. Like traditional wired networks, wireless networks comprise of routers and hosts. In a wireless network, the routers are responsible for forwarding packets in the network and hosts may be sources or sinks of data flows. The fundamental difference between wired and wireless networks is the way that the network components communicate [1, 2, 17].

Mobile Ad hoc networking provides connectivity between mobile nodes, which have no supporting connections to the fixed networking infrastructure. In a mobile ad-hoc network, every node in the network carries its own router with it, and all nodes cooperate in traffic forwarding. The simplest Ad Hoc network can be envisaged as a wireless radio network between a collection of vehicles, ships, aircraft, or even people on foot, operating in a geographical area with no networking infrastructure.

1.1. Routing [3,4]

Routing in a MANET is fundamentally different from traditional routing. The traditional routing protocols like link state and distance vector protocols need to periodically broadcast information in order to keep the routing tables updated. This leads to a lot of overhead of bandwidth, exhaustion of battery and allows limited size networks thus restricting scalability. Routing in MANET depends on many factors including topology, selection of routers, and initiation of request and specific underlying characteristic that could serve as a heuristic in finding the path quickly and efficiently. The low resource availability in these networks demands efficient utilization and hence the motivation for optimal routing in ad hoc networks. Also, the highly dynamic nature of these networks imposes severe restrictions on routing protocols specifically designed for them, thus motivating the study of protocols which aim at achieving routing stability. For ad hoc networks it is better to use on-demand routing protocols such as dynamic source routing (DSR) and ad hoc on-demand distance vector routing (AODVR) to discover routes as needed so as to avoid periodical broadcasts of available routes hence reducing overhead[5].

Classification of Routing protocols can be done in many ways, but most of these can be done depending upon routing strategy and network structure [3,4]. Broadly the routing protocols can be classified as Flat, Hierarchical and Geographical.

1.2. Routing Metrics

Performance of various protocols depends upon the routing metrics [6]. The main routing metrics on the basis of which the performance can be determined are:

- *End-to-end Delay:* The time it takes for a data packet to traverse from the source node to the destination node. End-to-end delay evaluates the ability of the protocol to use the network resources efficiently.
- *Routing Message Overhead:* The number of routing packets transmitted. Evaluates the efficiency and scalability of the routing protocol.
- *End-to-end Data Throughput:* This value represents the ratio of the total number of data packets that reach their destination, to the total number of data packets sent by the source.

It is calculated according to this formula:

Throughput = Packets Received / Packets Sent.

The network throughput is directly influenced by packet loss, which may be caused by general network faults like link breaks or uncooperative behavior.

Link Error due to broken links usually happen in mobile Ad hoc networks and they are also inevitable. To minimize the link errors we can repair the routes with the proposed scheme "Local Repair with Handoff Approach". Localizing route request flooding with handoff approach aims to reduce control overheads as well as to optimize the throughput in a transport layer protocol such as TCP. Although AODV is an adaptable routing protocol [7,8,15] in high mobility environment, it may incur too much communication overhead when error due to link failure occurs. In such scenario RERR and RREQ packets will be triggered very frequently by intermediate nodes involved in route discovery.

The current implementation [9] often incorporates a version of local repair mechanism in AODV. However, the protocol has room for improvement by reduction in communication overhead. The goal of this paper is to reduce communication overhead as well as to optimize communication throughput. The remainder of this paper is organized as follows. Section 2 describes AODV protocol. Section 3 describes the related work. Section 4 focuses on the proposed work including results. Section 5 focuses on future work. In section 6 conclusions are included.

2. AD HOC ON-DEMAND DISTANCE VECTOR PROTOCOL (AODV)

AODV routing protocol [9,10,12] builds on DSDV algorithm [11]. The Ad Hoc On-Demand Distance Vector Routing Protocol is a reactive routing protocol introduced in 1997. AODV is designed for networks with tens to thousands of mobile nodes. One feature of AODV is the use of a destination sequence number for each routing table entry. The sequence number is created by the destination node. The sequence number included in a route request or route reply is sent to requesting nodes. Sequence numbers are very important because they ensure loop free routes and are simple to implement. Sequence numbers are used by other nodes to determine the freshness of routing information. If a node has the choice between two routes to a destination, a node is required to select the one with the greatest sequence number. AODV deals with routing table. Every node has a routing table. When a node knows a route to the destination, it sends a route reply to the source node. Its entries are:

1. Destination IP Address;
2. Prefix Size;
3. Destination Sequence Number;
4. Next Hop IP Address;
5. Lifetime (expiration or deletion time of the route);
6. Hop Count (number of hops to reach the destination);
7. Network Interface;
8. Other state and routing flags (e.g., valid, invalid).

2.1. AODV Control Messages [9,12]

Three message types are defined by AODV

RREQ**:** When a route is not available for the desired destination, a *route request* packet is flooded throughout the network.

RREP**:** If a node either is, or has a valid route to, the destination, it unicasts a *route reply* message back to the source.

RERR**:** When a path breaks, the nodes on both sides of the links issue a *route error* to inform their end nodes of the link break.

2.2. AODV Operation [9,12]

When a source node desires to send a message to some destination node and does not already have a valid route to that destination, it initiates a *path discovery* process to locate the destination. It broadcasts a route request (RREQ) packet to its neighbors, which then forward the request to their neighbors, and so on, until either the destination or an intermediate node with a "fresh enough" route to the destination is located.

During the process of forwarding the RREQ, intermediate nodes record in their routing tables the address of the neighbor from which the first copy of the broadcast packet is received, thereby establishing a reverse path. If additional copies of the same RREQ are later received, these packets are discarded.

Once the RREQ reaches the destination or an intermediate node with a fresh enough route, the destination/intermediate node responds by unicasting a route reply (RREP) packet back to the neighbor from which it first received the RREQ. As the RREP is routed back along the reverse path, nodes along this path set up forward route entries in their route tables which point to the node from which the RREP came. These forward route entries indicate the active forward route. Associated with each route entry is a route timer which will cause the deletion of the entry if it is not used within the specified time(lifetime of the route). Because the RREP is forwarded along the path established by the RREQ, AODV only supports the use of symmetric links. Routes are maintained as follows. If a source node moves, it is able to reinitiate the route discovery protocol to find a new route to the destination. If a node along the route moves, its upstream neighbor notices the move and propagates a *link failure notification* message (an RREP with infinite metric) to each of its active upstream neighbors to inform them of the removal of that part of the route [12].

These nodes in turn propagate the *link failure notification* to their upstream neighbors, and so on until the source node is reached. The source node may then choose to reinitiate route discovery for that destination if a route is still desired. An additional aspect of the protocol is the use of *hello* messages. These are periodic local broadcasts by a node to inform each mobile node of the other nodes in its neighborhood. Hello messages can be used to maintain the local connectivity of a node. However, the use of hello messages is not required. Nodes listen for retransmission of data packets to ensure that the next hop is still within reach. If such a retransmission is not heard, the node may use any one of a number of techniques, including the reception of hello messages, to determine whether the next hop is within communication range. The hello messages may list the other nodes from which a mobile has heard, thereby yielding greater knowledge of network connectivity.

3. LOCAL REPAIR TECHNIQUES

Local Repair Procedure is used in AODV whenever a link breaks. RREQ packets are broadcasted whenever a link failure occurs in the active path. Here, a few local repair procedures along with their advantages and disadvantages have been explained.

3.1. Local Repair Procedure [13]

A local repair procedure is initiated in AODV whenever nodes suffer link errors. Existing approach [6] tries to reduce the cost (RREQ packets) in AODV-LR (Local Repair) by decreasing breadth or depth. Decreasing the breadth means to limit TTL=m in RREQ packets to localize the repair RREQs Decreasing the depth means to limit the number of times a node is allowed to forward the repair route request.

In this local repair paper the author defines a Repair Quota [RQ] which is initialized to K initially (let us assume that each node carry out the route repair K times in some period T)

Advantages of this approach are good cost effective result and high bonus gain.

3.2. Router Handoff Approach [14]

This is a preemptive approach, in which weakening link is detected before the complete failure of link occurs. The algorithm tries to find suitable nodes in the vicinity which can participate in routing around the affected link. The decision to handoff is made on the basis of perceived signal strength of its neighbors with whom it forms part of an active route.

Each node maintains:

1. *NPL (Neighbors Power List):* This list contain the last received signal strength for packets originating from each neighbors. Table is updated whenever a packet is received and happens at least once every hello interval.
2. *PDT (Power Difference Table):* This table consists of the rate at which power is changing between each pair of neighbor node.

Decision that a weakening of link occurs is made on the basis of PDT entry. Node that detects a weakening link from one of its neighbors will broadcast a Handoff packet with TTL = 1 to its neighbors. On receiving Handoff packet, each node will determine if any of its neighbors has links with more signal power than the current links. This approach leads to increase in space complexity but at the same time reduces routing overheads and delays due to route breakage.

3.3. Query Localization Approach [16]

This approach is based on the notion of spatial locality "a mobile node cannot move too far too soon." i.e. when a link error occurs then with in a specified duration that node cannot move far away. Thus on the basis of prior routing histories we can cache a small region in the network with high probability of finding destination node.

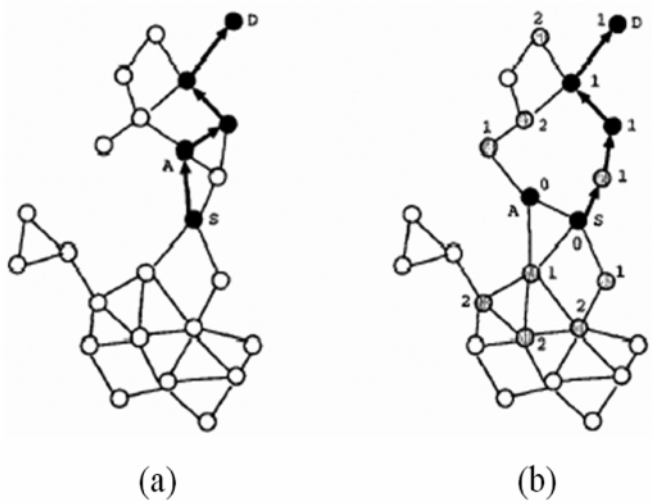

Fig.1: (a) Before Route Change (b) After Route Change

Following terminologies are used in this proposal:

P = Sequence of node that query packet has traversed so far.

P_{old} = Includes all the nodes on the last valid route between specific source destination pair.

K = Threshold value

C = Integer counter, incremented each time a node not in the set P_{old} is encountered by the query packet. The query is no longer propagated if the counter C exceeds threshold value K.

Fig. 1 shows the Illustration of the path locality principle with $K = 1$.

$P = \{S, A\}$

$P_{old} = \{S,A,B,C,D\}$

$K = 1$

Let Node A is the mobile node. Value of counter C is shown at each node in fig-1(b). Query is not propagated if the counter exceeds the threshold value which is set to 1.This protocol has advantages as well as disadvantages. Advantages of this protocol are reduction in routing overheads. It indirectly contributes to lower end to end delays for data packets because of reduced network congestion. Disadvantages are: the optimal value of K is dependent on the mobility pattern, which may be time varying. Too small value of K may result in the failure of route discovery while too large value of K leads to increased routing overhead by enlarging request zone. Secondly the protocol result in increased space complexity also there may be possibility that the discovered route is not the shortest route as there is no guarantee that shortest route will be contained entirely within the request zone which results in increased end to end delay.

4. PROPOSED LOCAL REPAIR WITH HANDOFF APPROACH

Limitation on the AODV motivates us to suggest and implement "Local Repair with Handoff Approach". The following limitations exist in the algorithm discussed on the previous section:

1. With the growing network size, longer routes must be established and maintained which increases the probability of packets drop and hence it may leads to increased average end-to-end delay which may degrade overall network performance.
2. With the increase in source node, congestion increases which leads to decrease in Network Throughput.
3. Routing overhead also increases with the increase in network size and number of source nodes.

Above limitation is mainly because of Route Errors i.e. broken of link after node movement and hence a strategy is required which increase overall network performance with minimizing end to end delay and routing overheads.

The proposed protocol tries to overcome above explained limitation. Protocol is based on the distance of a destination node from the node where the link break occurs.

Fields to be taken into account are:

- Hop_Count (RREP Packet)
- Last Hop _Count
- Next _Hop

New variables have been defined as follows:

- Reach _Hop _ Count: Hops travel from source node to the node where link break occurs.

Err_Hop_Count: Hops travel from the node where link break occurs to the destination node :

Err_Hop_cnt = Hop_cnt – Reach_hop_cnt

4.1. Proposed Algorithm

The following sequence of steps shows the detailed description of the proposed algorithm.

1. Every node detects the danger of link break on the basis of PDT entry [14].
2. No link break goto step 4
3. On link break call local repair ( )
4. Route rebuilding will be done by source node itself [12].
5. End

Local repair ()

1. If Err_Hop_Count <= INT(1/3 * Hop Count)
2. Then intermediate node which detect the link failure will take the responsibility of route rebuilding and call Router Handoff ().
3. Else Route rebuilding will be done by source node itself [12]
4. End.

Router Handoff () [14]

1. Maintain NPL, PDT and define HThresh [14].
2. For every predecessor node P, and next hop N, Handoff node H is to be found on the basis of PDT entry.
3. The node prepare a handoff packet with the address of node itself, addresses of P, H, destination node D and routing table entry containing Hop Count, sequence number and route life time.
4. This handoff packet is broadcast with TTL = 1.
5. When P receives a handoff packet, it changes its next hop for destination D from sending node to H.
6. H on receiving the handoff packet, checks if it already has a better route to D and if not creates a route with details from handoff packet.
7. End

5. SIMULATION RESULTS

Many simulating tools are available which can be used for MANET simulation. Few of the simulators are NS2, QualNet and GloMoSim. GloMoSim has been used as our simulating tool because GloMoSim's documentation is very good and it is easy to get support.. Also, the newly-developed features can be downloaded by communicating with the MANET special interest group. Most importantly, source code of AODV protocol [18, 19, 20, 21] is already implemented under the GloMoSim package. Thus, having this code implemented under Glomosim, it was not required rewrite the protocol.

Each generator produces 1000 data packets of 512 bytes each at the rate of 4 packets per second. All of these parameters were set in the Glomosim's application configuration file. Random Way Point Model (RWP) is chosen for movements of the node. In RWP a node chooses a random destination anywhere in the network field. The node moves towards that destination with a velocity chosen randomly from [0, V_{max}]. After reaching the destination, the node stops for a duration defined by the "pause time" parameter. This procedure is repeated until the simulation ends. V_{max} is taken as 20 m/s.

Table1
General Simulation Parameters

Parameter	*Value*
Simulation-Time	900s
Terrain-Dimensions	1500 * 300 M2
Number-Of-Nodes	50
Node-Placement	Random
Mobility Pattern	Random-Waypoint Model
Mobility-Wp-Pause	0 S
Mobility-Wp-Min-Speed	0.0 M/Sec
Mobility-Wp-Max-Speed	20.0 M/Sec
Application	Constant Bit Rate (CBR)
Number Of Generated Packets	1000 Packets Per CBR
Size Of Packets	512 Bytes
Mac-Protocol	802.11
Routing-Protocol	AODV

We ran simulations for Pause time 0,100,200, 300,400,500,600,700,800 and 900 sec. 0 sec pause time was considered as highly mobile environment whereas 900 sec was considered as static environment. Number of nodes is taken to be 50 and number of source nodes as 10, 20 and 30 (maximum is 60% of total nodes). Also simulation is carried out for 50,100,200,300 nodes with pause time as 200 sec and number of source node as 20 for calculating overall network performance.

Experiment 1: *Routing Overhead Performance Evaluation:* In this experiment Routing Protocol AODV and AODVNEW was simulated by varying Pause Time from 0 sec (highly mobile) to 900 sec (no mobile i.e. static condition) to measure overhead and then the results are compared.

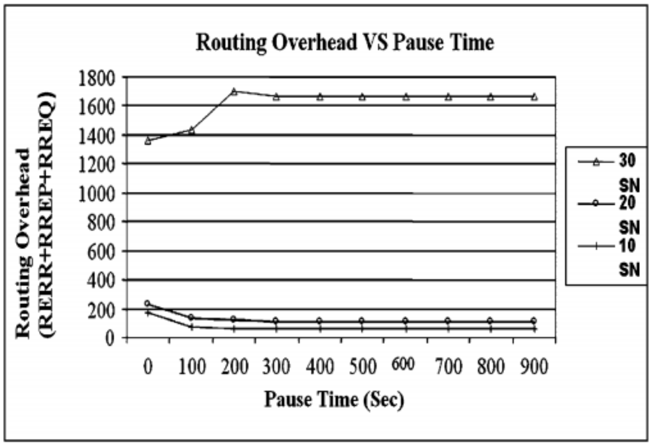

Fig. 2: Routing Overhead (RERR+ RREQ+RREP) for AODV

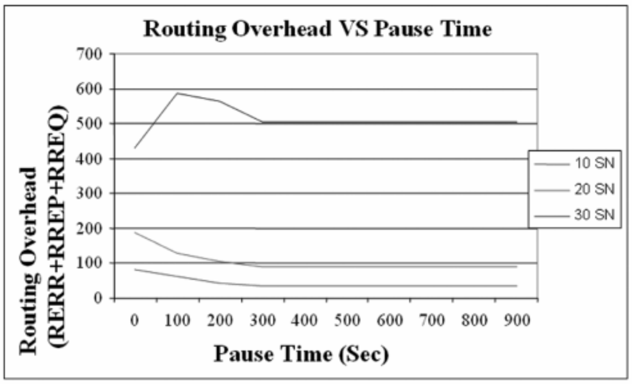

Fig. 3: Routing Overhead (RERR+ RREQ+RREP) for AODVNEW

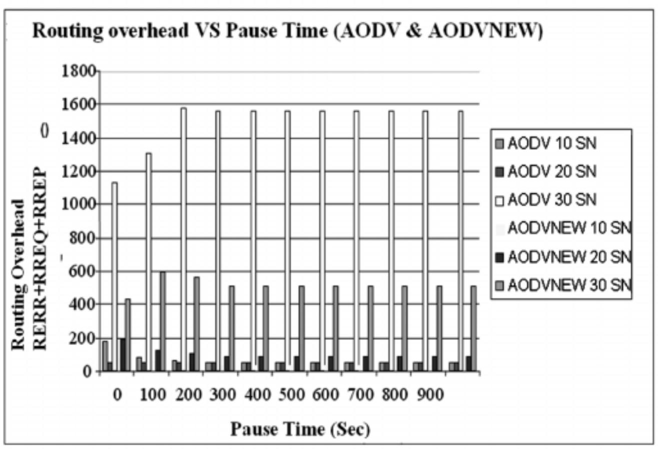

Fig. 4: Routing Overhead (RERR+ RREQ+RREP) for AODV and AODVNEW

Analysis: Overhead gives an insight of the network bandwidth consumed by routing packets with respect to connection request. Fairly stable overhead is desirable property when considering the performance as it would indicate that overhead remains linear with varying parameters. From Fig 2 and Fig 3 it is observed that the overhead is almost linear with varying pause time.

From Fig. 2 it can be seen that with the increase in mobility (Pause Time) routing overhead first increases and then become almost constant it means that static nature of the network doesn't affect the routing overhead metrics. For 10 and 20 source node results are almost similar for AODV it means if the number of source nodes are below 50% of total nodes in the network then affects on the routing overhead was not much. But, as the source nodes increase above 50% (results for 30 nodes as source nodes which are 60% of the total nodes) routing overhead almost increases 7 times. This is due to the fact that as the source nodes increase the requests for routes also increase thereby increasing route replies.

From Fig 3, nature of the graph for AODVNEW is almost same as that of original AODV as in Fig 2, but increase in routing overhead is less with increase in number of source node, also the highest value for total routing packets is around 1600 in case of AODV whereas 600 in case of AODVNEW. The new proposed protocol AODVNEW enables the local repair of routes thus drastically reducing the number of overhead packets as can be verified from Fig 4.

Experiment 2: *Average end-to-end Delay Performance Evaluation:* In this experiment original AODV and AODVNEW is simulated by varying Pause Time from 0 sec (highly mobile) to 900 sec (static network) and average end-to-end Delay of Data Packets are measured and compared.

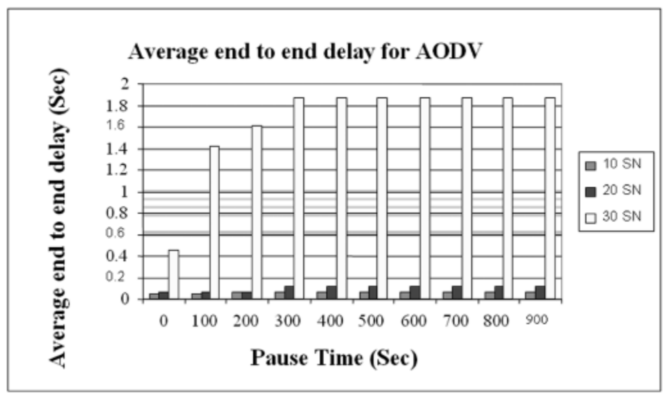

Fig. 5: Average End-to-End Delay AODV

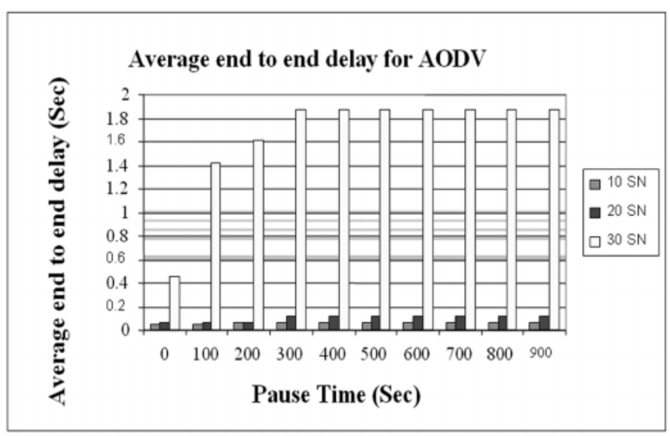

Fig. 6: Average End-to-End Delay AODVNEW

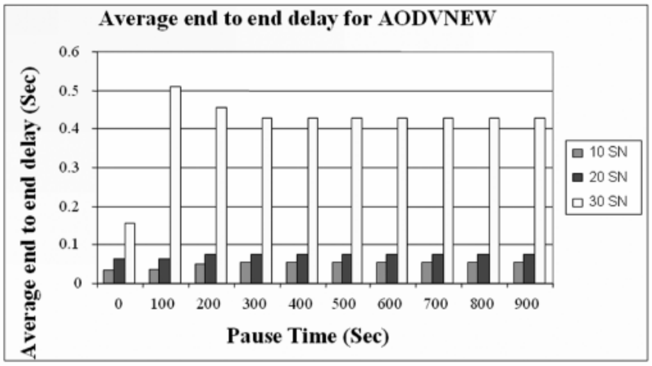

Fig. 7: Average End-to-End Delay AODV and AODVNEW

Analysis: As the network traffic increases, probability of packets drops gets increased and thus leads to increased end-to-end-Delay. Fig 5 and Fig 6 show that for 10 and 20 source node(less than 50% of total nodes) delay is very less but as the source node increased to 30 (above 50%) delay increased almost four times to that of 10 and 20 source nodes.

With low mobility delay is more this is because of the fact that AODV doesn't support any kind of load balancing, which would distribute the traffic more evenly within the network. With relatively large number of source node (60%) under static condition (large pause time) the lack of load balancing accumulates data packets to use the same routes, which causes high level of network congestion. With higher mobility (low pause time) routes get automatically more evenly distributed and the effect of congestion gets decreased. On the other hand, higher mobility leads to increased delay as more link failures happen and route discoveries have to be reinitiated and completed before data delivery continues. Proposed protocol AODVNEW reduces the time taken by route rediscovery procedures in original AODV and hence must results in lower end-to-end delay. As shown in Fig. 7 AODVNEW results in lower end-to-end delay as compared to original AODV.

Experiment 3: *Throughput Performance Evaluation:*

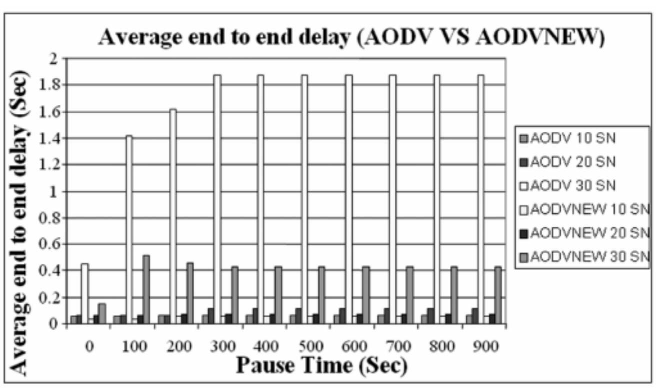

Fig. 8: Throughput (bps) AODV and AODVNEW

In this experiment, the network throughput is being measured for the original AODV and AODVNEW. Number of nodes is varied from 50,100,200 and 300. The pause time and number of source nodes were kept constant as 200secs and 20 respectively.

Analysis: *Network* Throughput of AODVNEW is more as compared to that of original AODV as shown in Fig 8. This is attributed to the fact lesser overhead packets are in the network for AODVNEW as seen from *Experiment-1*. The available bandwidth is used for data packets thus increasing the throughput. Thus, the protocol AODVNEW increases the overall network performance.

6. CONCLUSION

The improved technology and the day to day development of more powerful communication devices have increased the interest in ad hoc networks to higher levels than ever before. It has become the widely studied subject among communication researchers. However many problems concerning routing still remain unsolved and need to be addressed. Therefore, a lot research in area of efficient routing protocols for these special networks in last few years is taking place.

AODV is one of the most widely used protocols for routing in Ad hoc networks and are very efficient. However, the efficiency of protocol is limited due to the fact that flooding of control packets is needed to discover new routes during the failure of link.

An algorithm " Local Repair Strategy With Handoff Approach " has been proposed an implemented with the objective to keep the routing overhead and end-to-end delay low while optimizing overall throughput.

From the simulation results it has been observed that the maximum value for routing overhead with 30 source node in case of AODV is 1600 packets whereas in case of AODVNEW the value is 550 packets. A reduction of about 65% overhead has been observed. Similar result has also been observed for end-to-end delay which is 1.87sec for AODV and for 0.51 sec AODVNEW. Thus, AODVNEW leads to reduced routing overhead and end-to-end delay and shows better performance. Network throughput in case of AODVNEW is much higher than that of AODV.

Hence, various simulation results helps us in showing that protocol presented in this research work improve the network performance. The Local Repair has been implemented and the remaining algorithm is in process of implementation. As future works, we will try to implement and simulate the complete algorithm. Also the given algorithm can be implemented with multicast AODV by incorporating load balancing as new feature which is not current feature of AODV protocol.

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