ALRP: Scalability Study of Ant based Local repair Routing Protocol for Mobile Adhoc Networks

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Abstract: - A mobile ad hoc network is a dynamic mobile wireless network that can be formed without the need for any pre-existing wired or wireless infrastructure. One of the main challenges in an ad hoc network is the design of robust routing algorithms that adapt to the frequent and randomly changing network topology. So there is a great need for a new routing protocol that have low routing message overhead to enhance the performance of MANET. The reduction of routing message overhead will decrease the wasted portions of bandwidth that used for exchange routing messages between nodes, and increase the bandwidth available for transferring data, which in turn increases the network throughput and decreases the latency. This paper proposes a new ant agent based Local repair routing protocol (ALRP) that decreases both of the routing message overhead and the average end to end delay by on average 28%, 14% respectively less than the well known AODV routing protocol. This led to increase the throughput by 24% more than AODV routing protocol.

Key-Words: - Ad-hoc, AODV, Local Repair, MANET, On demand ant based Multi agent routing and ALRP

1 Introduction

A mobile ad hoc network (MANET) is an autonomous network that consists of mobile nodes that communicate with each other over wireless links. This type of networks is suited for use in situations where a fixed infrastructure is not available, not trusted, too expensive or unreliable. A few examples include: a network of notebook computers or PDAs in a conference or campus setting, rescue operations, temporary headquarters, industry etc.. In the absence of a fixed infrastructure, nodes have to cooperate in order to provide the necessary network functionality. Routing is one of the primary functions each node has to perform in order to enable connections between nodes that are not directly within each others send range. The development of efficient routing protocols is a nontrivial and challenging task because of the specific characteristics of a MANET environment.

Several routing protocols have been proposed for these networks recently. These routing protocols can be classified into three main categories: proactive, reactive and hybrid. Proactive routing protocols maintain and update routes periodically or based on some defined events such as DSDV [2] and GSR [4]. Reactive protocols establish routes on demand such as AODV [7] and DSR [8]. The hybrid protocols use features of both reactive and proactive protocols such as ZPR [9] and DDR. AODV is a well known on-demand routing protocol where a source node initiates route discovery when it needs to communicate to a destination that doesn’t have a route to it. Once a route discovered between the two nodes, data transfer occurs through until the route broken due node movement or interference due the erroneous nature of wireless medium. Route maintenance initiated when a route failure happens between two nodes. The upstream node of the failure tries to find a repair to the route and this process called local repair. This paper proposes a new ant based local repair routing protocol for Mobile adhoc networks called ALRP (Ant based Local repair routing Protocol). The ALRP modifies the local repair algorithm used in the route maintenance of the AODV routing protocol. The ALRP mainly reduces the routing message overhead resulted from the original AODV local repair algorithm. This enhancement leads to higher throughput and lower latency than AODV. The rest of the paper is organized as follows. Section 2 describes background description of AODV and on demand ant based multi agents routing algorithm. Section 3 describes local repair in AODV. Section 4 proposes ALRP. The Performance environment is shown in section 5. The simulation and Result scenarios are shown in section 6 & 7. The conclusions and future works are shown in section 8.

2 Background description of AODV and on demand ant based multi agents routing Algorithm

2.1 AODV Routing Protocol

The specific challenges and possible applications of MANETs have made this a very popular research area, and a lot of routing algorithms have been proposed. People traditionally classify these algorithms as either proactive or reactive. In purely proactive protocols (e.g., DSDV) nodes try to maintain at all times routes to all other nodes. This means that they need to keep track of all topology changes, which can become difficult if there are a lot of nodes or if they are very mobile. Therefore, reactive protocols (e.g., AODV or DSR) are in general more scalable (see [3, 10, and 16]). In these protocols, nodes only gather routing information on demand only when they have data for a certain destination they construct a path, and only when the path becomes infeasible they search a new path. In this way they greatly reduce the routing overhead, but they can super from oscillations in performance since they are never prepared for disruptive events. Hybrid algorithms like ZRP have both a proactive and a reactive component, in order to try to combine the best of both worlds. Most of the algorithms are single path: at any time, they use only one path .The rest ant-based routing algorithms were ABC and Ant Net. Both algorithms follow a similar general strategy. Nodes send ant agents out at regular intervals to randomly chosen destinations.

The main aim of the ants is to sample the paths, assign a quality to them, and use this information to update the routing tables in the nodes they pass. These routing tables contain an entry for each destination and each neighbor, indicating the goodness of going over this neighbor on the way to the destination. This goodness value is called pheromone. This pheromone information is used for the routing of both ants and data packets. All packets are routed stochastically, choosing with a higher probability those links with higher pheromone values. If enough ants are sent to the different destinations, nodes keep up-to-date information about the best paths, and automatically adapt their data load spreading to this. Ant-based routing algorithms have a number of properties which are desirable in MANETs: they are highly adaptive to network changes, use active path sampling, are robust to agent failures, provide multi path routing, and take care of data load spreading. However, the fact that they crucially rely on repeated path sampling can cause significant overhead if not dealt with carefully. There have been a number of attempts to design ant-based routing algorithms for MANETs. Examples are ARA [5] and PERA [6]. However, these algorithms loose much of the proactive sampling and exploratory behavior of the original ant-based algorithms in their attempt to limit the overhead caused by the ants.

2.2 Ant Agents based routing protocol

Ant-based routing algorithm for MANETs has been previously explored by [14 and 15]. Ants in network routing applications are simple agents embodying intelligence and moving around in the network from one node to the other, updating the routing tables of the nodes that they visit with what they have learned in their traversal so far (fig. 1).

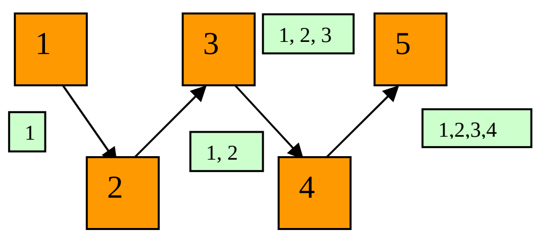


Fig 1. Figure shows an ant traversing the network and providing routing information to nodes.

Routing ants keep a history of the nodes previously visited by them. When an ant arrives at a node, it uses the information in its history to update the routing table at that node with the best routes that it has for the other nodes in the network. The higher the history size the larger the overhead, hence a careful decision on the history size of the ants has to be made. All the nodes in the network rely on the ants for providing them the routing information, as they themselves do not run any program (protocol) for finding routes. The ant-based routing algorithm implemented in this paper does not consider any kind of communication among the ants and each ant works independently. The population size of the ants is another important parameter, which affects the routing overhead. This paper implements ants that take the “no return rule” while selecting the next hop at a node. In the conventional ant algorithms the next hop is selected randomly. This is because, if the next hop selected is the same as the previous node (from where the ant came to the current node) then this route would not be optimal. Data packets sent on such routes would just be visiting a node and going back to the previous node in order to reach the destination. Every node frequent broadcasts HELLO messages to its neighbors so that every node can maintain a neighbor list, which is used for selecting the next hop by the ants.

3 Local repair in AODV

Local repair is a technique used to repair a broken route locally on the upstream node of the link failure if the destination is no farther than TTLMXR. To repair the link failure, the upstream node broadcasts RREQ packet after increasing the destination sequence number [7]. The TTL value used in RREQ packet is set to the following value:

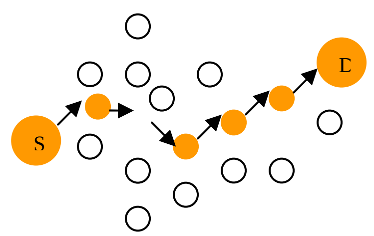
$$TTL = Max\ (0.5 \times NH,\ TTLMNR) + TTLLA \quad (1)$$

Where: TTLMNR: the last known hop count from the upstream node of the failure to the destination.

NH: the number of hops from the upstream node of the failure to the source of the currently undeliverable packet.

TTLLA: constant value

After the upstream node broadcasts the RREQ packet, it waits the discovery period to receive RREP packets in response to the RREQ packet. When the destination or an intermediate node that has a fresh route to the destination receives the RREQ packet, a RREP packet will be forwarded towards the upstream node. If discovery period finished and the upstream node didn't receive a RREP for that destination, it transmits a RERR message for that destination to the source. On the other hand, if the upstream node receives one or more RREP packets during the discovery period, it first compares the hop count of the new route with the value in the hop count field of the invalid route table entry for that destination. In the case of the hop count of the newly determined route to the destination is greater than the hop count of the previously known route, the upstream node transmits a RERR message for that destination towards the source, with 'N' bit set. Finally, the upstream node updates its route table entry for that destination.



Figs 2 a. Link breaks in active route

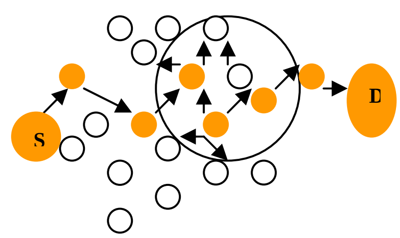


Fig 2 b. Broadcast RREQ with small TTL

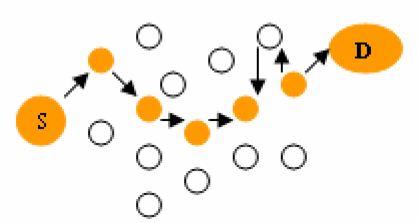


Fig 2 c. Propagation of RREP

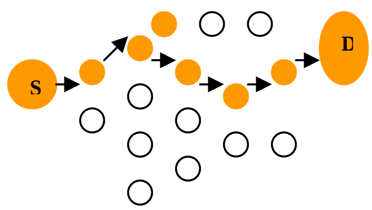


Fig 2 d. Repaired route

4 Ant based Local Repair routing Protocol for mobile adhoc networks (ALRP)

The ALRP is a modification to local repair in AODV. Local repair in ALRP act like local repair in AODV (described in section 3), the difference is that local repair in AODV done with just one trial to find a repair to the route by broadcasting RREQ packet with TTL come from Eq. (1) and on the other side local repair in ALRP done on one or more trials to find a repair to the route. In the ALRP specification, when a link break in an active route occur, the node upstream of the break creates a Route Error(RERR) message listing all the destinations which have become unreachable due to the break. It then sends this message to its upstream neighbors,if,instead of sending an error message to the source node, the upstream node attempts to repair the broken link itself, fewer data packets may be lost and the link can be repaired without the source node(and other upstream nodes) being disturbed. For short routes, local repair may not have any significant performance advantages. but for the large networks with increasingly longer routes(e.g.,10 or more hops) ,it is likely that link breaks will occur so frequently that it will be nearly impossible for the source node to keep up with all the necessary repairs. A node upstream of a link break that attempts to repair the route does so by broadcasting a RREQ with a TTL set to the last known distance to the destination, plus an increment value. this TTL value is used so that only the most recent whereabouts of the destination will be searched, which prevents flooding of entire network. the upstream node places the sequence number of the destination, incremented by one, into the RREQ.This prevents nodes further upstream on the route from replying to the RREQ,which would form a loop.Fig.2 illustrates an example of a local repair. If a route to the destination is not located on the first attempt, a RERR message is sent back to the source node, and route re-discovery continues as described in section 2.2.

Table 1

Summary of Room Sizes

No of Nodes	Room Size(m^2)	Average no of Neighbors
50	1000 X 1000	7.32
100	1500 X 1500	7.46
500	3500 X 3500	7.33
1000	5000 x 5000	7.69

In ALRP, when a route failure happens, the upstream node increments the destination sequence number by one and then it initiates its first local repair trial by broadcasting RREQ packet with

TTL = LR_TTL_START. LR_TTL_START

has been choose to be equal 2 to increase the chances in finding a repair from the first trial and in the same time the small value for TTL will reduce the routing message overhead. The upstream node that initiates the route repair waits during the discovery period to receive RREPs packet. If the upstream fails to receive any RREPs during the discovery period, it increments TTL by LR_TTL_INCREMENT (which equal 2) and it compares the resulted TTL with LR_TTL_THRESHOLD which equal to half LR_TTL_MAX (LR_TTL_MAX come from Eq. (1), where LR_TTL_THRESHOLD used to limit the number of local repair trials which will led to limit the delay of finding a repair to the route. If the upstream node finds TTL smaller or equal to LR_TTL_THRESHOLD, it will broadcast RREQ packet with the new value of TTL. If the upstream node fails to receive RREP packet again during the discovery period, it repeats the previously described process again until it receives RREP packet or TTL value exceeds LR_TTL_THRESHOLD then the upstream node make its final trial by broadcasting RREQ packet with TTL = LR_TTL_MAX and it is the worst case that ALRP can reach.

5 Performance Evaluations

We evaluate the performance of an ALRP using simulations and compare them with existing AODV.

5.1 Simulation Environment

The simulations used to evaluate the scalability ANT and its modifications were implemented within the

GloMoSim library[19].The GloMoSim library is a scalable simulation environment for wireless network systems using the parallel discrete-event simulation capability provided by PARSEC[19].the simulations model networks between 10 and 100 mobile hosts placed randomly within the simulation area. The simulation boundary and average connectivity for each simulated number of nodes are shown in Table 1. the room size for each simulation was chosen so as to keep the node density approximately constant in the different size networks. Instead of holding the room size constant and increasing the node population density, the node density was held constant in the simulations because it was desired to

Table 2

Parameter Values

	Parameter	Value
General	net_diameter node_traversal_time	35,70 40ms
Local Repair	Local_add_ttl	2

investigate the scalability of networks in terms of increasing the room size, as opposed to increasing the density. Increasing density caused congestive failures not closely related to routing protocol performance. All our simulation scenarios are derived from the base scenario used in [17 and 18], which is an important reference.

5.2 Channel and Radio Model

A free space propagation model [18] with a threshold cutoff was used in the experiments. In the free space model, the power of a signal attenuates as $1/d^2$, where d is the distance between radios. In the radio model, capture is assumed, whereby a radio has the ability to lock onto a sufficiently strong signal in the presence of interfering signals. If the capture ratio (the minimum ratio of an arriving packet's signal strength relative to those of other colliding packets) [18] is greater than the predefined threshold value, the arriving packet is received while other interfering packets are dropped.

5.3 Traffic Pattern

A traffic generator was developed to simulate constant bit rate sources. The size of data payload is 512 bytes. Twenty data sessions with randomly selected sources and destinations are simulated. Each source transmits data packets at a rate of four packets/sec. The number of data sessions was held constant to limit the number of variables in the experiment, and because of the time required to run the large simulations with more data sessions.

5.4 Mobility Pattern

The random waypoint model is utilized as the mobility model. In this model, a node selects a random destination within the terrain range and moves towards that destination at a speed between the pre-defined minimum and maximum speed. Once the node arrives at the destination, it stays at its current position for a pause time. After being stationary for the pause time, it randomly selects another destination and speed and then resumes movement. The minimum speed for the simulations is 0 m/s. The selected pause time is 30 seconds.

5.5 Parameter Values

Table 2 gives a summary of the chosen parameter values. The network diameter (`net diameter`) for the simulations represents the approximate diameter of the network, and is used for setting the TTL value of broadcast control packets. It is also a factor in the calculation of how long a node should wait to receive a RREP after sending another RREQ. If the RREQ is broadcast across the network, the reception of the RREP may take longer for large networks than for small. The setting of the `net diameter` variable to 35 for small networks (50, 100, 500, and 1,000 nodes) and 70 for the larger networks (5,000 and 10,000 nodes) provides an upper bound of the actual network diameter for these networks.

The node traversal time represents an estimation of the processing time of a packet at a given node. It is also used for estimating the period of time a source node should wait to receive a RREP after broadcasting a RREQ. Finally, the `local add ttl` parameter is used for local repair. It represents the value added to the previously known distance to the destination. This sum is used as the TTL of the RREQ for the local repair. Among the runs that were performed with varied parameter values for expanding ring search, query localization, and local repair, the values that yielded the best results are presented.

6 Simulation Scenarios

The following subsections present the two simulation scenarios that have been chosen to evaluate the proposed ALRP for Mobile Adhoc Networks. The first scenario is 50 nodes scenario which will be presented in subsection (6.1). The second scenario is 100 nodes scenario which will be presented in subsection (6.2).

6.1 50 Nodes Scenario

This section presents the 50 nodes network simulation scenario on a rectangular area 1000 X 1000 m^2. Rectangular area is used to force the nodes to create long routes and this help in studying the effect of the proposed modifications. This scenario represents small size ad-hoc networks. This network size can present many ad-hoc applications like conferencing, Emergency services where there is no infrastructure and search and rescue operations.

6.2 100 Nodes Scenario

This section presents the simulation results and their analysis for the 100 nodes network simulation scenario on a rectangular area 1500 X 1500 m^2. Rectangular area is used to force the nodes to create long routes and this help in studying the effect of the proposed modifications. This scenario represents medium size ad-hoc networks. This network size can present many ad-hoc network applications like conferencing and medical care operations.

7 Scenarios Results

The following subsections represent the results of the simulation scenarios. The 50 nodes scenario results will be presented in subsection (7.1). The 100 nodes scenario results will be presented in subsection (7.2).

7.1 50 Nodes Scenario Results

This section presents the simulation results and their analysis for the 50 nodes network simulation scenario on a rectangular area 1000 X 1000 m^2. 7.1.1 Routing Message Overhead. The routing message overhead resulted from both AODV and ALRP routing protocols has been presented in Fig.3. From Fig.3, it could be noticed that ALRP has lower routing message overhead by on average 36% less than the AODV routing message overhead. This result demonstrates the effect of local repair trials in ALRP on reducing routing message overhead.

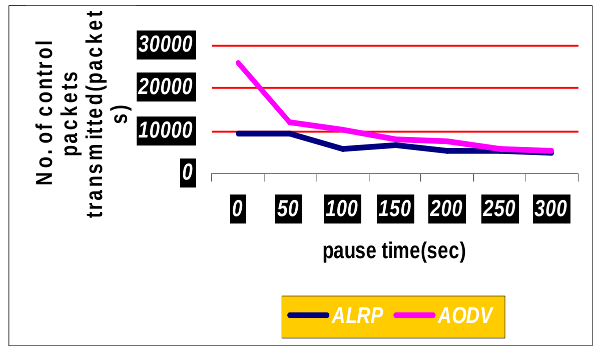


Fig. 3 Routing message overhead vs. pause time for 50 nodes

7.1.2 Average End to End Delay

Fig. 4 demonstrates the average end to end delay of both the AODV and ALRP routing protocols. It is clear that ALRP gives average end to end delay higher than the AODV by on average 30% when excluding the 0 pause time results and 21% with the 0 pause time results. The results demonstrates the high effect of local repair trials in ALRP on the delay of the small size networks which resulted from broadcasting RREQ with TTL as in Eq. (1). This means that the AODV routing protocol is suitable for small size networks from the end to end delay point of view than the proposed ALRP. The increase in the route length led to an increase in the end to end delay of transferring a packet between two nodes. ALRP has an increase in average path length than the AODV routing protocol by on average 0.4%. This small increase in the average path length demonstrates that ALRP doesn't have a salient effect on the path length if compared with the AODV routing protocol.

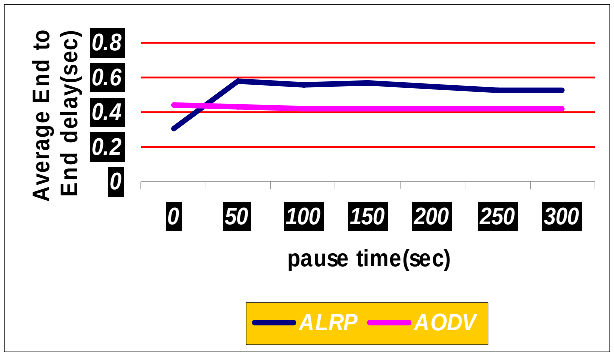


Fig. 4: Average End to End delay vs. pause time for 50 nodes

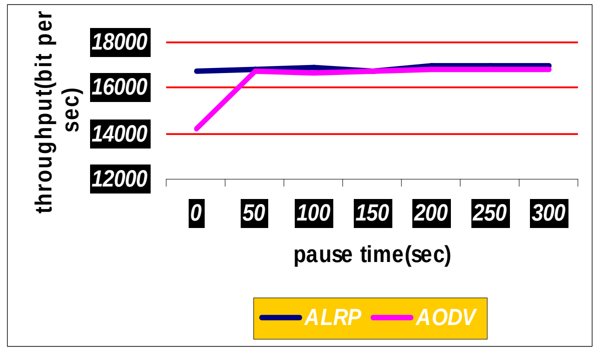


Fig.5: Throughput vs. pause time for 50 nodes

The increase in the number of broken links will led to increase the delay of transferring packets on a route until finding a repair to the route. The number of broken links affected by the route length as longer routes means the higher chances for broken links. In the same time, the number of broken links affected by mobility as higher mobility means higher number of broken links. ALRP has number of broken links lower than the AODV routing protocol by on average 22.5%. The increase in the number of local repair retrials attempts after the first local repair attempt led to increase the delay of repairing a route. AODV doesn't make any local repair retrials as it makes one local repair attempt only. ALRP has percentage of local repair retrials attempts to local repair first attempts by on average equal to 52.7%. This percentage demonstrates that local repair in ALRP do by on average 0.53 additional trials than the first trial.

7.1.3 Throughput

The throughput resulted from both AODV and ALRP has been presented in Fig.5. It can be found that ALRP has higher throughput than AODV routing protocol by on average 4.3% which is a small increase. This result demonstrates that the effect of the modifications in ALRP doesn’t appear in small sized networks.

The number of packets dropped or left wait for a route affect the throughput as the increase in the number of packets dropped or left wait for a route reduce the throughput. The number of packets dropped or left wait for a route affected by the success of local repair in repairing a failed route, where the number of packets dropped or left wait reduced as the percentage of success local repair attempts increased. ALRP has number of packets dropped or left wait for a route higher than the AODV routing protocol by on average 13.7%.

7.2.1 100 Nodes Scenario Results

This section presents the simulation results and their analysis for the 100 nodes network simulation scenario on a rectangular area 1500 X 1500 m^2. The routing message overhead resulted from both AODV and ALRP routing protocols has been presented in Fig. 6. From the figure, it could be noticed that the ALRP routing protocol has lower routing message overhead by on average 29 % less than the AODV routing protocol. This result demonstrates the effect of local repair trials in ALRP on reducing routing message overhead not like the case of local repair in the AODV routing protocol which broadcasts RREQ packet once with TTL as in Eq. (1).

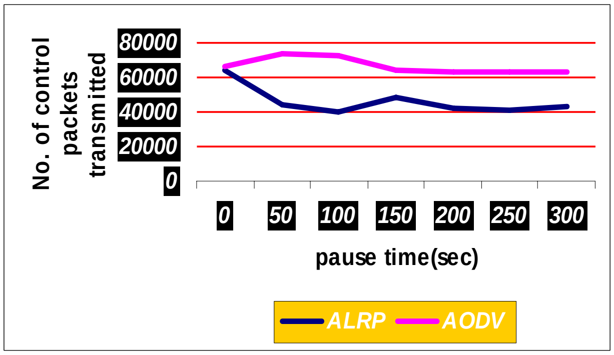


Fig.6: Routing message overhead vs. pause time for 100 nodes

7.2.2 Average End to End Delay

The average end to end delay resulted from both AODV and ALRP routing protocols has been presented in Fig. 7. ALRP has lower average end to end delay than the AODV routing protocol by on average 35%. This demonstrates the effect of local repair trials and especially as the network size grows up, where the trials of local repair reduce routing message overhead and by its turn free bandwidth channels and this led to transfer data packets faster.

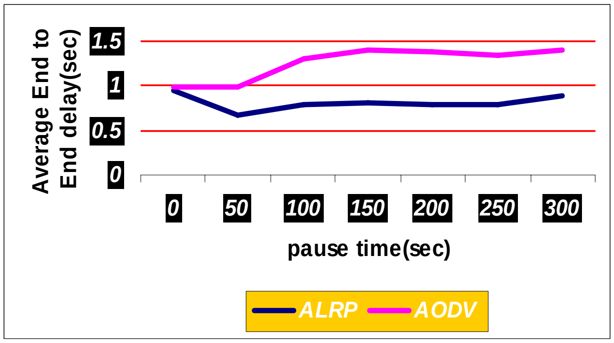


Fig.7: Average End to End delay vs. pause time for 100 nodes

ALRP has an increase in the average route length than the AODV routing protocol by on average 4.7%. This demonstrates the effect of local repair trials in increasing routes lengths, where local repair trials depend on the idea of getting the nearest route repair to the upstream node. On the other side, local repair in AODV broadcasts RREQ packet once with TTL come from Eq. (1). This means that the RREQ packet reach more nodes, which will led to not only reach the nearest route repair that reply to the upstream node but also far route repairs which may have smaller hop counts to the destination than the nearest route repair. ALRP has lower number of broken links than the AODV routing protocol by on average 16.9%. This demonstrates the effect of local repair trials in ALRP in reducing the number of broken links as it will be reflected on reducing the end to end delay of transferring data packets. ALRP has percentage of local repair retrials attempts to local repair first attempts by on average equal to 86.8%. This percentage demonstrates that local repair in ALRP do by on average 0.87 additional trials than the first trial.

7.2.3 Throughput

The throughput resulted from both AODV and ALRP routing protocols has been presented in Fig. 8. The result demonstrates that the ALRP routing protocol has higher throughput than the AODV routing protocol by on average 39%. This returns to that local repair in ALRP acts in trials by broadcasting first RREQ packet with

TLL = LR_TTL_START (equal to 2 in the experiment).

This reduces the routing overhead which by its turn resulted in increasing throughput. On the other side, local repair in AODV broadcasts RREQ packet once with TTL as in Eq. (1) which resulted in higher routing message overhead which led by its turn to reduce the throughput.

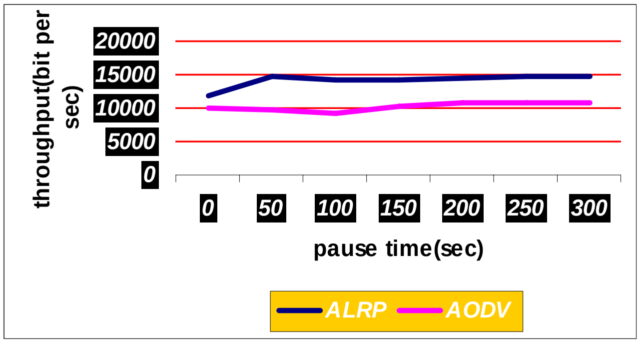


Fig.8: Throughput vs. pause time for 100 nodes

8 Conclusion and Future work

The following subsections represent conclusion and future work. The conclusion will be represented in subsection (8.1).The future work will be represented in subsection (8.2).

8.1 Conclusion

AODV is one of the most popular ad-hoc on demand routing protocols. In the AODV routing protocol, local repair operation done by broadcasting RREQ packet with TTL equal to Eq. (1). This process produces high routing message overhead which consumes high portions from the bandwidth of the connected nodes. Whereas the new adaptive ALRP routing protocol, local repair done on one or more trials with TLL in the first trial initialized to a small value equal to LR_TTL_START. This will reduce the routing message overhead resulted from local repair operation in the AODV routing protocol. First from the obtained results it could be concluded that in small ad-hoc networks, ALRP is suitable for the applications that need low routing message overhead which means by its turn more free bandwidth for data bytes transfer as ALRP routing message overhead reduced by on average 36% less than AODV routing message overhead. On the other side, ALRP is not suitable for the applications that need low average end to end delay. This is return to the increase of average end to end delay in ALRP by on average 21% more than the AODV routing protocol. Second from the obtained results it could be concluded that in medium ad-hoc networks, ALRP is suitable for applications that need low routing message overhead, where ALRP has routing message overhead lower than the AODV routing protocol by on average 29%. ALRP is suitable for the applications that need low average end to end delay, where ALRP has average end to end delay lower than the AODV routing protocol by on average 35%. ALRP is suitable for applications that needs high throughput, where ALRP has throughput higher than the AODV routing protocol by on average 39%. It can be concluded that ALRP gives higher performance than the AODV routing protocol, so it is suitable for most of the applications within the range of 100 nodes. Third from the obtained results it could be concluded that in large ad-hoc networks, ALRP is suitable for applications that need low routing message overhead, where ALRP has routing message overhead lower than the AODV routing message overhead by on average 19%. ALRP is suitable for applications that need low average end to end delay, where ALRP has average end to end delay lower than the AODV routing protocol by on average 28%. ALRP is suitable for the applications that need high throughput, where ALRP has throughput higher than the AODV routing protocol by on average 30%. It can be concluded that ALRP gives higher performance than the AODV routing protocol, so it is suitable for most of the applications within the range of 100 nodes. Finally, it could be concluded that for the different ad-hoc network sizes ranging from 50 up to 100nodes, the ALRP routing protocol enhance the network performance than the AODV routing protocol. Where, ALRP reduces both of the routing message overhead and average end to end delay by on average 28%, 14% respectively than the AODV routing protocol. Moreover, ALRP increases the throughput by on average 24% than the AODV routing protocol. But it should be mentioned that the ALRP is not recommended for ad-hoc networks less than or equal to 50 nodes in which the ALRP increases the average end to end delay by on average 21% over the AODV routing protocol.

8.2 Future Work

The scalability of the proposed ALRP routing protocol for Mobile Adhoc Networks can be studied by having large adhoc network sizes in comparison with the AODV routing protocol. Also the effect of the ALRP routing protocol in energy consumption could be studied in comparison with AODV routing protocol. Finally, the ALRP routing protocol can be studied on different types of application layer protocols like http, ftp, telnet, and real time audio/video transmissions.

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