NEW ADAPTIVE ROUTING PROTOCOL FOR MANET

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ABSTRACT

Mobile ad-hoc networks (MANET) rely on wireless connections between mobile nodes, which mean limited bandwidth & high rate of disconnections between nodes. 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 MANET routing protocol that decreases both of the routing message overhead and the average end to end delay by on average 27.9%, 13.7% respectively less than the well known AODV routing protocol. This led to increase the throughput by 23.87% more than AODV routing protocol.

Keywords: Ad-hoc, AODV, Local Repair, MANET, and on-demand routing.

1 INTRODUCTION

Ad-hoc networks [1] are the networks that don't have any fixed infrastructure. Ad-hoc networks are often mobile and that is why the term MANET (Mobile Ad-hoc Network) is used. There are many applications for ad-hoc networks like conferencing, emergency services, personal area networks, embedded computing, and sensor dust.

A MANET is a peer-to-peer network that allows direct communication between any two nodes, when adequate radio propagation conditions exist between these two nodes. If there is no direct link between the source and the destination nodes, multi-hop routing is used. In multi-hop routing, a packet is forwarded from one node to another, until it reaches the destination.

A routing protocol is in general necessary in ad-hoc networks; this routing protocol has to adapt quickly to the frequent changes in the ad-hoc network topology. Ad-hoc routing protocols are classified into three categories. The first category is Table-driven (Proactive) routing protocols such as DSDV [2], CGSR [3], GSR [4], FSR [5], and OLSR [6]. The second category is on-demand (Reactive) routing protocols such as AODV [7], DSR [8], ABR [9], SSA [10], and TORA [11]. The third category is Hybrid (Reactive and proactive) routing protocols such as ZRP [12] and ZHLS [13].

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 adaptive routing protocol for MANET called AODVLRT (AODV with Local Repair Trials). The AODVLRT modifies the local repair algorithm used in the route maintenance of the AODV routing protocol. The AODVLRT 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 local repair in AODV. Section 3 proposes AODVLRT. The simulation environment is shown in section 4. The simulation results are shown in section 5. The conclusions and future works are shown in section 6.

2 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 TTL_{MXR}. 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:

$$TTL = Max\ (0.5 \times N_H, TTL_{MNR}) + TTL_{LA} \qquad (1)$$

Where:

TTL_{MNR}: the last known hop count from the upstream node of the failure to the destination.

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

TTL_{LA}: 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.

3 AODV WITH LOCAL REPAIR TRIALS (AODVLRT)

The AODVLRT is a modification to local repair in AODV. Local repair in AODVLRT act like local repair in AODV (described in section 2), 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 AODVLRT done on one or more trials to find a repair to the route. In AODVLRT, 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 AODVLRT can reach.

4 SIMULATION ENVIRONMENT

Simulations were carried out with the GloMoSim library [14] which is widely used in the academic research. The GloMoSim library is a scalable simulator for wireless network and it is built using the parallel discrete-event simulation capability provided by PARSEC [15]. The numbers of nodes used in the simulations are 50, 100, and 300 [16][17], with rectangular room sizes 1500 × 600, 2100×800, and 3600×1400 m^2, respectively. The nodes placed randomly within the simulation area. The radio propagation range for each node is 250 meters and channel capacity is 2Mb/s. Each simulation is executed for 300 seconds of simulation time [18]. IEEE 802.11 MAC protocol was used in the experiments for the MAC layer.

The sources used for the simulations are CBR (constant bit rate) sources [16], [17] and [18]. Twenty data sessions with randomly selected sources and destinations are used in the simulations. Each source transmits data packets at 4 packets/sec rate with packet size 512 bytes until the simulation run ends [18].

The mobility model used is the random waypoint model [16][17][18]. In this model, a node selects a random destination within the terrain range and moves towards it at a speed between the pre-defined minimum and maximum speed. Once the node arrives at the destination, it stays for a pause time. After being stationary for the pause time, it randomly selects another destination and speed and then resumes movement. The minimum and the maximum speed for the simulations are 0m/s and 10 m/s [17][18], respectively. Simulation runs done on variance pause time values from 0 to 300 second.

Simulations have been done for 84 times, each one has been executed for 3 times to take their average to a total of 252 simulation runs. The simulations have been done on a PC Pentium 4 1.5 GHZ processor and 512 MB RAM. The simulation times taken are approximately 1.5 hours for each simulation run on 50 nodes scenario, 3.5 hours for each simulation run on 100 nodes scenario, and 10 hours for each simulation on 300 nodes scenario.

5 PERFORMANCE PARAMETERS

This section presents the performance parameters used to evaluate the proposed AODVLRT routing protocol against the original AODV routing protocol. The main performance parameters are Routing message overhead, average end to end delay, and throughput. Under each main performance parameters, there are secondary performance parameters which affect it or depend on it.

5.1 Routing Message Overhead

Routing message overhead is calculated as the total number of control packets transmitted. The increase in the routing message overhead reduces the performance of the ad-hoc network as it consumes portions from the bandwidth available to transfer data between the nodes.

5.2 Average End to End Delay

Average end to end delay is used to measure the latency. It is calculated as the total summation of the division of total end to end delay (D_T) by the number of packets delivered (N_{PD}) divided by the number of nodes (N_N) as in Eq. (2)

$$\Sigma \left(\frac{D_T}{N_{PD}}\right) \Big/ (N_N) \qquad (2)$$

Average end to end delay is affected by path length as when the path lengths get longer the average end to end delay gets larger. Average path length is used to measure path lengths and it is calculated as the total summation of the division of the number of hop counts (N_{HC}) by the number of data packets received (N_{PR}) divided by the number of nodes (N_N) as in Eq. (3)

$$\Sigma \left(\frac{N_{HC}}{N_{PR}}\right) \Big/ (N_N) \qquad (3)$$

Average end to end delay is affected by the broken links as the increase in the number of broken links gets the average end to end delay increased. Broken links is calculated as the number of broken links for all the nodes.

The increase in the number of local repair retrials attempts after the first local repair attempt increase the delay of repairing a route. The percentage of local repair retrials to local repair first trails attempts is calculated as the division of the summation of the number of local repair retrials attempts (N_{LRR}) by the summation of the number of local repair first trials attempts (N_{LRF}) as in Eq. (4)

$$\frac{\Sigma (N_{LRR})}{\Sigma (N_{LRF})} \qquad (4)$$

5.3 Throughput

Throughput is a very important parameter in evaluating the modifications performance. It is calculated as the number of bits received per second.

Throughput is affected by the number of packets dropped or left wait for a route which is calculated as the summation of the number of packets dropped or left wait for a route for all the nodes.

6 SIMULATION SCENARIOS

The following subsections present the three simulation scenarios that have been chosen to evaluate the proposed AODVLRT routing protocol. 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). The third scenario is 300 nodes scenario which will be presented in subsection (6.3).

6.1 50 Nodes Scenario

This section presents the 50 nodes network simulation scenario on a rectangular area 1500 * 600 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 2100*800 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.

6.3 300 Nodes Scenario

This section presents the simulation results and their analysis for the 300 nodes network simulation scenario on area 3600*1400 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 large size ad-hoc networks. This ad-hoc network size can present many ad-hoc network applications like military applications and sensor dust.

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). The 300 nodes scenario results will be presented in subsection (7.3).

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 1500 * 600 m^2.

7.1.1 Routing Message Overhead

The routing message overhead resulted from both AODV and AODVLRT routing protocols has been presented in Fig. (1). From Fig. (1), it could be noticed that AODVLRT 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 AODVLRT on reducing routing message overhead.

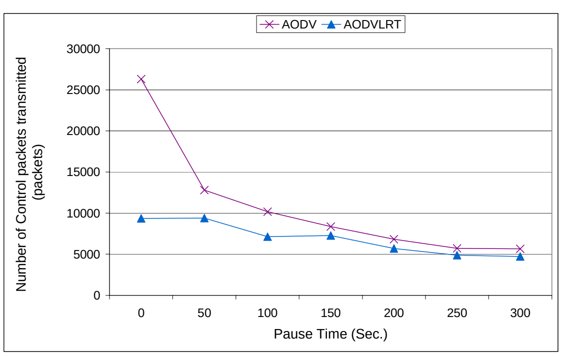

Figure 1: Routing message overhead vs. pause time for 50 nodes

7.1.2 Average End to End Delay

Fig. (2) demonstrates the average end to end delay of both the AODV and AODVLRT routing protocols. It is clear that AODVLRT 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 AODVLRT 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 AODVLRT.

The increase in the route length led to an increase in the end to end delay of transferring a packet between two nodes. AODVLRT 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 AODVLRT doesn’t have a salient effect on the path length if compared with the AODV routing protocol.

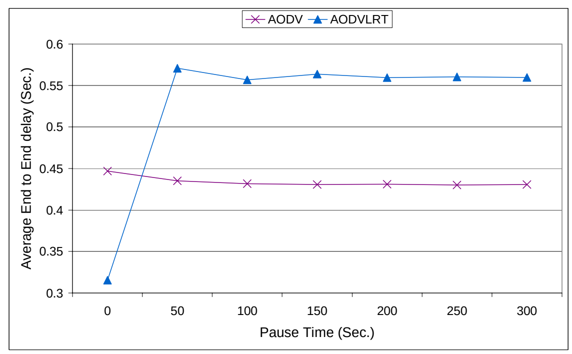

Figure 2: Average End to End delay vs. pause time for 50 nodes

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. AODVLRT 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. AODVLRT 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 AODVLRT do by on average 0.53 additional trials than the first trial.

7.1.3 Throughput

The throughput resulted from both AODV and AODVLRT has been presented in Fig. (3). It can be found that AODVLRT 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 AODVLRT doesn't appear in small sized networks.

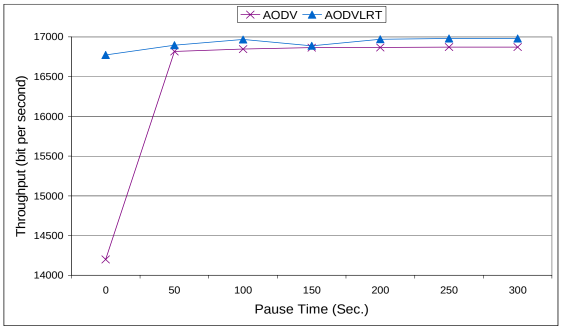

Figure 3: Throughput vs. pause time for 50 nodes

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. AODVLRT has number of packets dropped or left wait for a route higher than the AODV routing protocol by on average 13.7%.

7.2 100 Nodes Scenario Results

This section presents the simulation results and their analysis for the 100 nodes network simulation scenario on a rectangular area 2100*800 m^2.

7.2.1 Average End to End Delay

The routing message overhead resulted from both AODV and AODVLRT routing protocols has been presented in Fig. (4). From the figure, it could be noticed that the AODVLRT 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 AODVLRT 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).

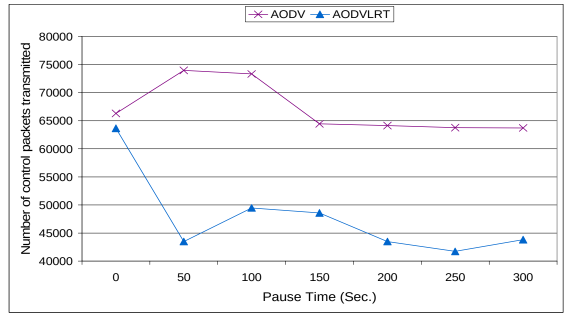

Figure 4: Routing message overhead vs. pause time for 100 nodes

7.2.2 Average End to End Delay

The average end to end delay resulted from both AODV and AODVLRT routing protocols has been presented in Fig. (5). AODVLRT 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.

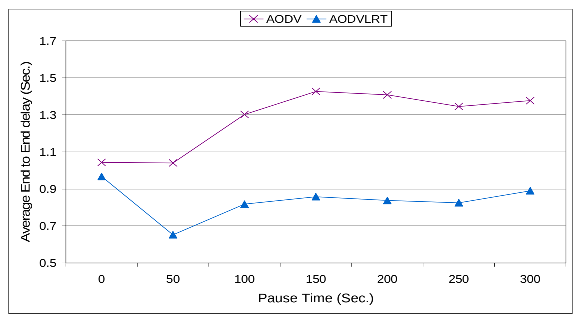

Figure 5: Average End to End delay vs. pause time for 100 nodes

AODVLRT 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.

AODVLRT 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 AODVLRT in reducing the number of broken links as it will be reflected on reducing the end to end delay of transferring data packets.

AODVLRT 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 AODVLRT do by on average 0.87 additional trials than the first trial.

7.2.3 Throughput

The throughput resulted from both AODV and AODVLRT routing protocols has been presented in Fig. (6). The result demonstrates that the AODVLRT routing protocol has higher throughput than the AODV routing protocol by on average 39%. This returns to that local repair in AODVLRT 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.

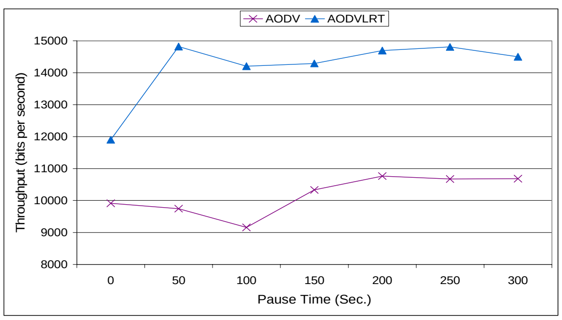

Figure 6: Throughput vs. pause time for 100 nodes

AODVLRT has lower number of packets dropped or left wait for a route than the AODV routing protocol by on average 13.6 %. This demonstrates the effect of AODVLRT in reducing the number of packets dropped or left wait for a route which will be reflected in increasing the throughput.

7.3 100 Nodes Scenario Results

This section presents the simulation results and their analysis for the 300 nodes network simulation scenario on area 3600*1400 m^2.

7.3.1 Routing Message Overhead

The routing message overhead resulted from both AODV and AODVLRT has been presented in Fig. (7). It can be noticed in Fig. (7) that the AODVLRT routing protocol has routing message overhead lower than the AODV routing protocol by on average 19%. This result illustrates that local repair trials in the AODVLRT routing protocol reduced the routing message overhead rather than the case of AODV routing protocol where local repair broadcasts RREQ packet once with TTL = LR_TTL_MAX, where LR_TTL_MAX as in Eq. (1).

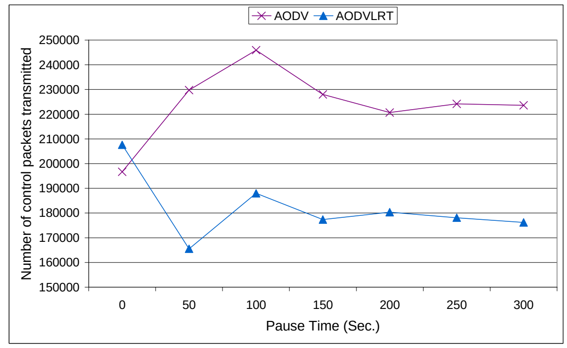

Figure 7: Routing message overhead vs. pause time for 300 nodes

7.3.2 Average End to End Delay

The average end to end delay resulted from both AODV and AODVLRT routing protocols has been presented in Fig. (8). From the figure, it can be demonstrated that the AODVLRT routing protocol has average end to end delay lower than the AODV routing protocol by on average 28%. 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.

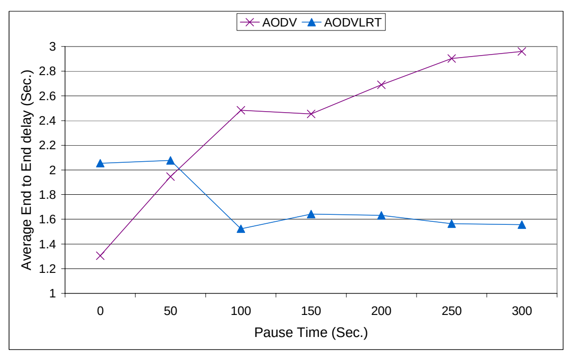

Figure 8: Average End to End delay vs. pause time for 300 nodes

AODVLRT has average route length lower than the AODV routing protocol by on average 4.8%. This result demonstrates that local trials in AODVLRT have a good impact on path length especially when the network size gets larger.

AODVLRT has higher number of broken links than the AODV routing protocol by on average 3.8%. This demonstrates the effect of local repair trials in increasing the number of broken links especially in large network size.

AODVLRT has percentage of local repair retrials attempts to local repair first attempts by on average equal to 120.6%. This percentage demonstrates that local repair in AODVLRT do by on average 1.2 additional trials than the first trial. This result illustrates that the percentage of local repair retrials attempts to local repair first attempts increases as the network size gets larger.

7.3.3 Throughput

The throughput resulted from both AODV and AODVLRT routing protocols has been presented in Fig. (9). In Fig. (9), it can be demonstrated that the AODVLRT routing protocol has throughput higher that the AODV routing protocol by on average 23.3%. This demonstrates the effect of local repair trials in reducing the routing overhead which by its turn resulted in increasing throughput.

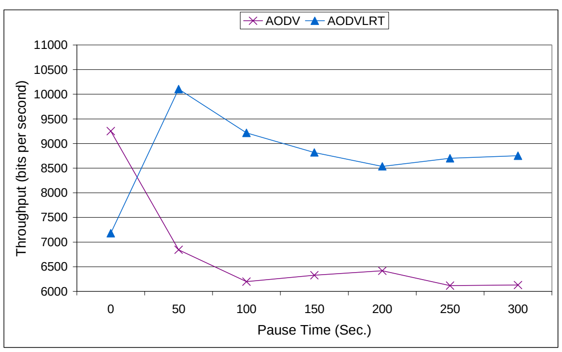

Figure 9: Throughput vs. pause time for 300 nodes

AODVLRT has number of packets dropped or left wait for a route lower than the AODV routing protocol by on average 28.1%.

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 AODVLRT 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, AODVLRT is suitable for the applications that need low routing message overhead which means by its turn more free bandwidth for data bytes transfer as AODVLRT routing message overhead reduced by on average 36% less than AODV routing message overhead. On the other side, AODVLRT 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 AODVLRT 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, AODVLRT is suitable for applications that need low routing message overhead, where AODVLRT has routing message overhead lower than the AODV routing protocol by on average 29%. AODVLRT is suitable for the applications that need low average end to end delay, where AODVLRT has average end to end delay lower than the AODV routing protocol by on average 35%. AODVLRT is suitable for applications that needs high throughput, where AODVLRT has throughput higher than the AODV routing protocol by on average 39%. It can be concluded that AODVLRT 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, AODVLRT is suitable for applications that need low routing message overhead, where AODVLRT has routing message overhead lower than the AODV routing message overhead by on average 19%. AODVLRT is suitable for applications that need low average end to end delay, where AODVLRT has average end to end delay lower than the AODV routing protocol by on average 28%. AODVLRT is suitable for the applications that need high throughput, where AODVLRT has throughput higher than the AODV routing protocol by on average 30%. It can be concluded that AODVLRT gives higher performance than the AODV routing protocol, so it is suitable for most of the applications within the range of 300 nodes.

Finally, it could be concluded that for the different ad-hoc network sizes ranging from 50 up to 300 nodes, the AODVLRT routing protocol enhance the network performance than the AODV routing protocol. Where, AODVLRT 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, AODVLRT increases the throughput by on average 24% than the AODV routing protocol. But it should be mentioned that the AODVLRT is not recommended for ad-hoc networks less than or equal to 50 nodes in which the AODVLRT 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 AODVLRT routing protocol can be studied by having large ad-hoc network sizes in comparison with the AODV routing protocol. Also the effect of the AODVLRT routing protocol in energy consumption could be studied in comparison with AODV routing protocol. Finally, the AODVLRT 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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