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ORIGINAL ARTICLE

Evaluation comparison of some ad hoc networks routing protocols

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Abstract Mobile ad hoc networks (MANETs) are characterized by multi-hop wireless connectivity, frequently changing network topology and the need for efficient dynamic routing protocols plays an important role. A variety of routing protocols targeted specifically at this environment have been developed and some performance simulations are made on numbers of routing protocols like Ad hoc On-Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR) and Location-Aided Routing (LAR). To the best of our knowledge, no published work is available in the literature, which compares as many criteria as we have done to evaluate the performance of the considered routing protocols. In this paper we perform extensive simulations using GloMoSim simulator considering 18 performance metrics. To determine the impact of network size on the performance of these protocols we considered two different scenarios, namely, 100 and 200 nodes, with rectangular area sizes 1500×1000 and 2000×1500 m^2, respectively.

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1. Introduction

With the advance in networking and communications technologies, portable wireless devices are found in our common activities. Most people carry and use laptop computers, cellular phones, and pagers that support nomadic computing of network users. A mobile ad hoc network (MANET), which is one form of wireless networks, is an autonomous system of mobile hosts connected by wireless links. There is no static infrastructure such as base stations. Each node in the network also acts as a router, forwarding data packets for other nodes [1,2].

In MANET, nodes move arbitrarily, therefore the network may experience rapidly and unpredictably topology changes.

Additionally, because nodes in MANET normally have limited transmission ranges, some nodes cannot communicate directly with each other. Hence, routing paths MANETs potentially contain multiple hops, and every node in mobile ad hoc networks has the respon to act as a router [3].

Many protocols have been proposed for MANETs, with the goal of achieving efficient routing [4–7]. These algorithms differ in the approach used for searching a new route and/or modifying a known route, when hosts move. The ad hoc routing protocols may be generally categorized as table-driven and source initiated on-demand driven. The simulation results reported in several papers show that normally on demand routing protocols have higher packet delivery ratio and need less routing messages than table-driven routing protocols [8,9]. Energy consumption in ad hoc networks is a very important factor. Because batteries carried by each mobile node have limited power supply, processing power is limited, which in turn limits services and applications that can be supported by each node. This becomes a bigger issue in mobile ad hoc networks because, as each node is acting as both an end system and a router at the same time, additional energy is required to forward packets from other nodes [10,11]. However, little is known about the actual performance of these protocols, and no attempt has previously been made to directly compare them in a realistic manner.

These ad hoc routing protocols can be divided into two categories: proactive driven routing protocols, consistent and up-to-date routing information to all nodes is maintained at each node. Reactive routing protocols, the routes are created as and when required, when a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destination [12].

At this time, the parallel discrete event-driven simulator, GloMoSim 2.03, contains the following routing protocols:

– Ad Hoc On Demand Distance Vector (AODV)
– Location Aided Routing (LAR)
– Wireless Routing Protocol (WRP)
– Dynamic Source Routing (DSR)
– Fisheye State Routing (FSR)
– Zone Routing Protocol (ZRP)

As a result, a comprehensive performance evaluation of ad hoc routing protocols is essential. This paper compares the performance of three ad hoc routing protocols namely, AODV, DSR and LAR routing protocols using the GloMoSim simulator version 2.03. We evaluated all available metrics supported by GloMoSim for these protocols and then performed a comparative performance evaluation. Since these protocols have different characteristics, the comparison of all performance differentials is not always possible. However, the following system parameters are utilized for comparative study on the protocols:

– Normalized routing overhead,
– throughput,
– data packets sent,
– data packets retransmitted,
– ACK packets received,
– signals arrived with power above RX sensitivity,
– signals transmitted,
– BCAST (pkts rcvd clearly),
– UCAST (pkts rcvd clearly),
– average end-to-end delay,
– collisions,
– data packets received,
– number of packet attempt to be sent to MAC,
– signals arrived with power above RX threshold,
– BCAST (pkts sent to channel),
– UCAST (pkts sent to channel),
– total of the TTL's of delivered packets.

The rest of the paper is organized as follows. Section 2 gives briefly a review of the related work. The simulation environment is presented in Section 3. Section 4 discusses the simulation results and performance analysis. Section 5 introduces the summarized results. Finally, the conclusions are given in Section 6.

2. Related work

2.1. Ad hoc On-Demand Distance Vector Routing (AODV)

AODV is a state-of-the-art routing protocol that adopts a purely reactive strategy: it sets up a route on-demand at the start of a communication session, and uses it till it breaks, after which a new route setup is initiated. AODV adopts a very different mechanism to maintain routing information. It uses traditional routing tables, one entry per destination [13–16]. Without source routing, AODV relies on routing table entries to propagate a route replay (RREP) back to the source and, subsequently, to route data packets to the destination. AODV uses sequence numbers maintained at each destination to determine the freshness of routing information and to prevent routing loops. All routing packets carry these sequence numbers. An important feature of AODV is the maintenance of timer-based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. These nodes are notified with route error (RERR) packets when the next-hop link breaks. Each predecessor node, in turn, forwards the RERR to its own set of predecessors, thus effectively erasing all routes using the broken link. Route error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link [17].

2.2. Dynamic Source Routing (DSR)

The key distinguishing feature of the reactive protocol DSR is the use of source routing. That is, the sender knows the complete hop-by-hop route to the destination. These routes are stored in a route cache; this is in contrast to AODV which uses traditional routing tables, one entry per destination. DSR can maintain multiple route cache entries for each destination. The data packets carry the source route in the packet header. When a node in the ad hoc network attempts to send a data packet to a destination for which it does not already know the route, it uses a route discovery process to dynamically determine such a route [18]. Route discovery works by flooding the network with route request (RREQ) packets. Each node receiving an RREQ rebroadcasts it, unless it is the destination or it has a route to the destination in its route cache. Such a node replies to the RREQ with a route reply (RREP) packet that is routed back to the original source. RREQ and RREP packets are also source routed. The RREQ builds up the path traversed across the network. The RREP routes itself back to the source by traversing this path backward. The route carried back by the RREP packet is cached at the source for future use. If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source if this route is still needed. DSR makes very aggressive use of source routing and route caching [19].

2.3. Location-Aided Routing (LAR)

LAR is reactive routing protocol like AODV and DSR. It attempts to reduce the routing overheads present in the traditional flooding algorithm by using location information. This protocol assumes that each node knows its location through a Global Positioning System (GPS). Two different LAR schemes were proposed in [20,21], the first scheme calculates a request zone which defines a boundary where the route request packets can travel to reach the required destination. The second method stores the coordinates of the destination in the route request packets. These packets can only travel in the direction as the relative distance to the destination becomes smaller as they travel from one hop to another. Both methods limit the control overhead transmitted through the network and hence conserve bandwidth. They will also determine the shortest path (in most cases) to the destination, since the route request packets travel away from the source and toward the destination. The disadvantage of this protocol is that each node is required to carry a GPS [22].

3. Simulation environment

To compare the performance of the three routing protocols described in section 2, simulation experiments were performed. The simulations were carried out with the GloMoSim library which is widely used in the academic research [23,24]. The number of nodes used in the simulation scenarios is 100 and 200 nodes, with rectangular area sizes 1500×1000 and 2000×1500 m^2, respectively. The nodes are placed randomly within the simulation area. The radio propagation range for each node is 376 m and channel capacity is 2 Mb/s. Each simulation is executed for 300 s of simulation time. IEEE 802.11 MAC protocol was used in the experiments for the MAC layer. The sources used for the simulations are constant bit rate (CBR) sources. Twenty data sessions with randomly selected sources and destinations are used in the simulations. Each source transmits data packets at 4 packets/s rate with packet size 512 bytes until the simulation run ends.

The mobility model used is the random waypoint model [25]. In this model, a node selects a random destination within the terrain range and moves toward 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 0 and 10 m/s, respectively. Simulation runs are done on variance pause time values from 0 to 300 s. The simulations have been done on a PC Pentium IV, 2 GHz processor and 3 GB RAM.

4. Simulation results and performance analysis

The following subsections present the two simulation scenarios that have been chosen and the performance analysis to evaluate the performance of AODV, DSR, and LAR routing protocols. The system parameters given in section 1 are used for the comparative study.

4.1. Normalized routing overhead

The normalized routing overhead resulted from the considered routing protocols have been presented in Figs. 1 and 2. It could be noticed that the DSR routing protocol has less routing overhead than the other protocols in the small network and then increases in the large one at the end of the simulation time. DSR has less overhead than AODV because instead of maintaining a route table for tracking routing information, DSR utilizes a route cache. The cache allows multiple route entries to be maintained per destination, thereby enabling

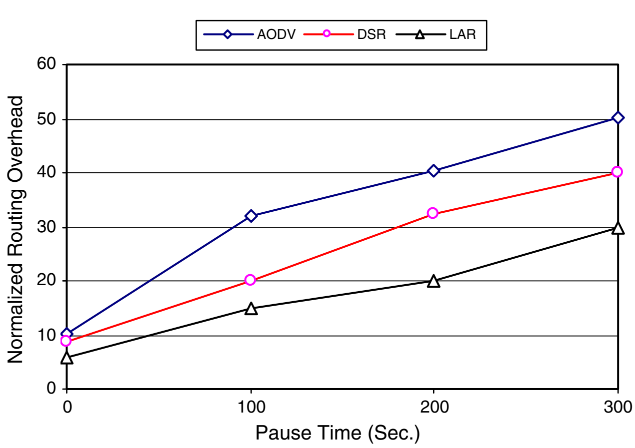

Figure 1 Normalized routing overhead vs. pause time for 100 nodes.

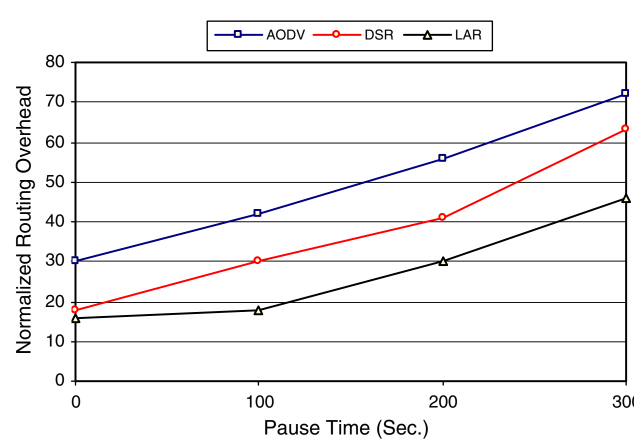

Figure 2 Normalized routing overhead vs. pause time for 200 nodes.

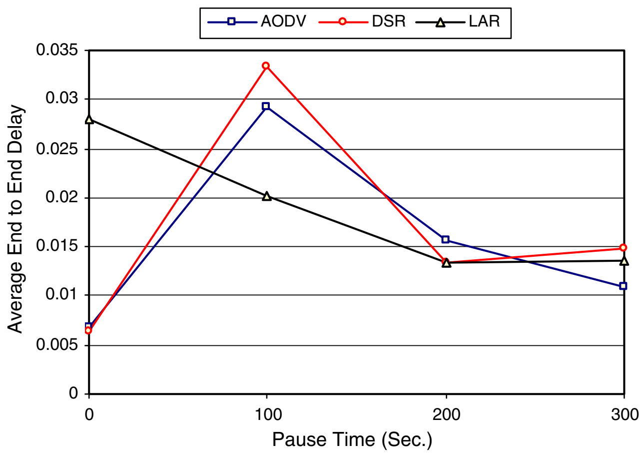

Figure 3 Average end to end delay vs. pause time for 100 nodes.

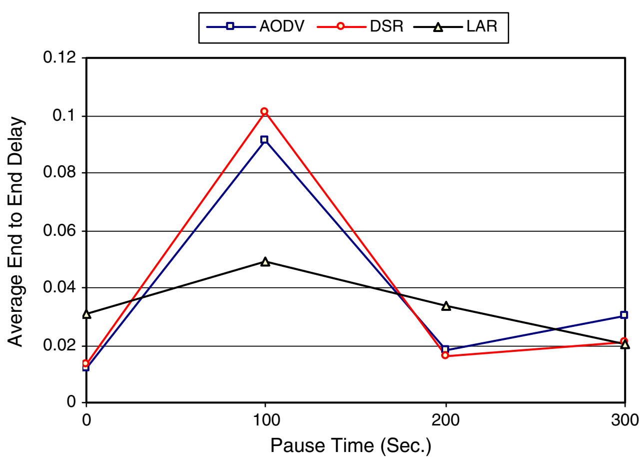

Figure 4 Average end to end delay vs. pause time for 200 nodes.

multipath routing. When one route to a destination breaks, the source can utilize alternate routes from the route cache, if they are available, to prevent another route discovery and able to react quickly to changes in the network. On the other side, LAR is utilizes location information of mobile nodes to decrease the routing overhead. LAR uses flooding like AODV and DSR to discover the route but flooding is restricted to a certain area called "request zone". It uses location information to flood a route request packet for destination in request zone instead of in the entire ad hoc network. Finally, AODV contains a number of the routing control messages such as RREQ, RREP, RRER and Hello, etc., and accordingly the routing overhead is increased.

4.2. Average end to end delay

Figs. 3 and 4, demonstrates the average end to end delay of the considered routing protocols. It is clear that DSR gives average end to end delay higher than the AODV and LAR routing protocols. DSR gives largest delay because the source node will obtain a suitable source route by searching its route cache of routes previously learned. If no route is found in its cache, it will initiate the route discovery to dynamically find a new route to distention which leads to the delay.

The average end to end delay for AODV is higher than LAR because, due to its single path nature and inefficient manner to handle route failure. LAR, on the other hand, shows low delays in all cases. This is because, instead of buffering data packets for a new route to be found, LAR forwards the data packets through alternative routes.

4.3. Throughput

The throughput resulted from the considered routing protocols have been presented in Figs. 5 and 6. As can been seen, LAR protocol shows higher throughput than AODV and DSR routing protocols since its routing overhead is less than the others. The number of packets dropped or left wait for a route affect the throughput.

4.4. Collisions

Figs. 7 and 8, depicts the collisions resulted from the considered protocols. As can been seen in these figures, DSR protocol has lower collisions compared with the AODV and LAR routing protocols. Because of the mobility of the nodes, links along paths are likely to break. Breaks in active routes must be quickly repaired so that data packets are not dropped. When a link break along an active path occurs, the node upstream of the break (i.e., closer to the source node) invalidates the routes to each of those destinations in its route table. It then creates a route error (RERR) message. In this message it lists all of the destinations that are now unreachable due to the loss of the link. After creating the RERR message, it sends this message to its upstream neighbors that were also utilizing the link. These nodes, in turn, invalidate the broken routes and send their own RERR messages to their upstream neighbors that were utilizing the link. The RERR message thus traverses the reverse path to the source node, once the source node receives the RERR, it can repair the route if the route is still needed. Also, the collisions resulted from the DSR routing protocol lower because instead of maintaining a route table for tracking routing information, DSR utilizes a route cache. The cache allows multiple route entries to be maintained per destination, thereby enabling multipath routing. When one route to a destination breaks, the source can utilize alternate routes

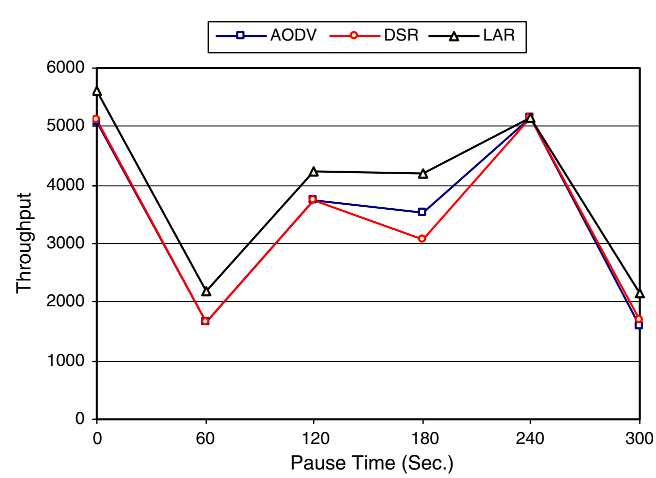

Figure 5 Throughput vs. pause time for 100 nodes.

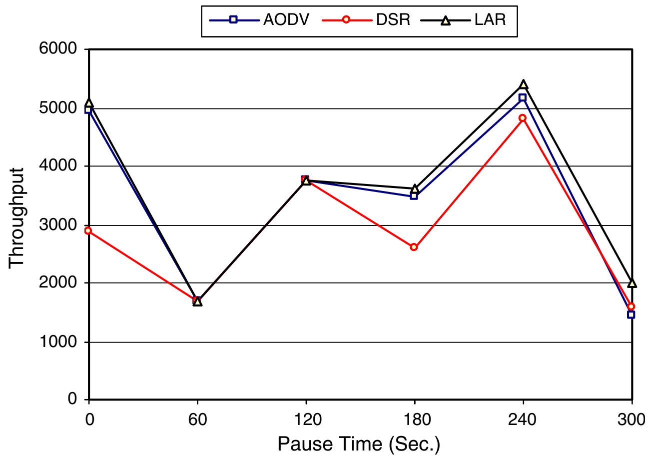

Figure 6 Throughput vs. pause time for 200 nodes.

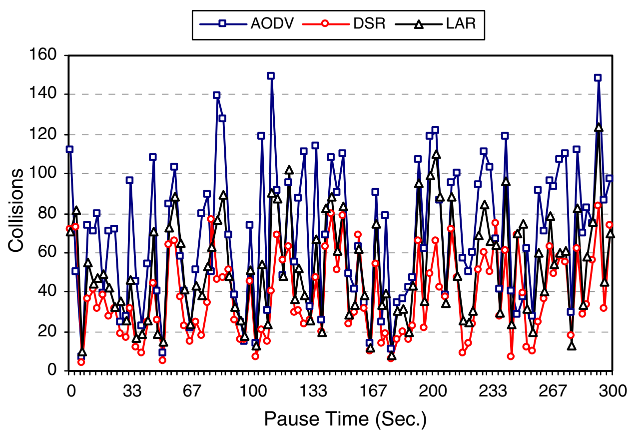

Figure 7 Collisions vs. pause time for 100 nodes.

from the route cache, if they are available, to prevent another route discovery.

Similarly, when a link break in a route occurs, the node upstream of the break can perform route salvaging, whereby it utilizes a different route from its route cache, if one is available, to repair the route. However, even when route salvaging is performed, a RERR message must still be sent to the source to inform it of the break. The collisions for the considered protocols increased when the number of nodes increased.

4.5. Data packets sent

As can been seen in Figs. 9 and 10, the LAR protocol performs better than the other two protocols. At the start of the simulation time the data packets sent by the routing protocols have the same value and decreased to the minimum value at pause time 100. During the range pause time between 100 and 200 the data packets sent using the considered protocols is increased. At pause time 200 the data packets sent is increased using AODV protocol with 100 nodes and decreased.

4.6. Data packets received

Figs. 11 and 12, demonstrate the data packets received for the considered protocols. It is clear from the figure that LAR protocol performs better than the other two protocols. At the start of the simulation time the data packets received by the protocols have the same value and increased until pause time 100. During the range pause time between 100 and 200 the data packets received using the considered protocols is decreased. Starting with pause time 200, LAR and DSR routing protocols performs better than the AODV protocol.

4.7. Data packets retransmitted

The data packets retransmitted using the considered protocols are shown in Figs. 13 and 14. It is clear that although AODV does not perform well at the beginning, later it does well near the end of simulation time. The DSR and LAR routing protocols increased and decreased according to the increase of pause time. Obviously from the figures the DSR protocol is better in the small network size otherwise the AODV protocol is better in the large network size.

The ratio between the number of packets sent by sources and the number of received packets at the destination. This performance evaluation parameter measures effectiveness, reliability and efficiency of a protocol called packet delivery ratio. Figs. 9–12, indicates the fraction of the originated application data packets each protocol was able to deliver, as a function of node mobility rate (pause time) and network load (number of nodes). For AODV, DSR and LAR packet delivery ratio is independent of offered traffic load. In case of LAR protocol

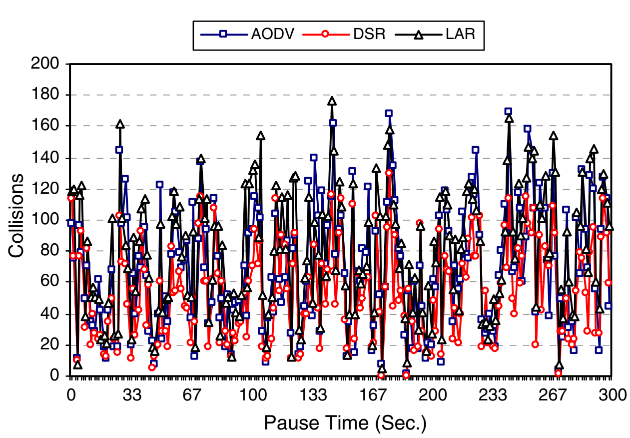

Figure 8 Collisions vs. pause time for 200 nodes.

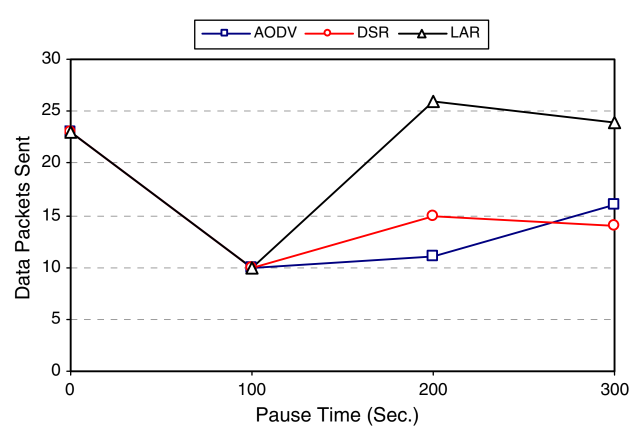

Figure 9 Data packets sent vs. pause time for 100 nodes.

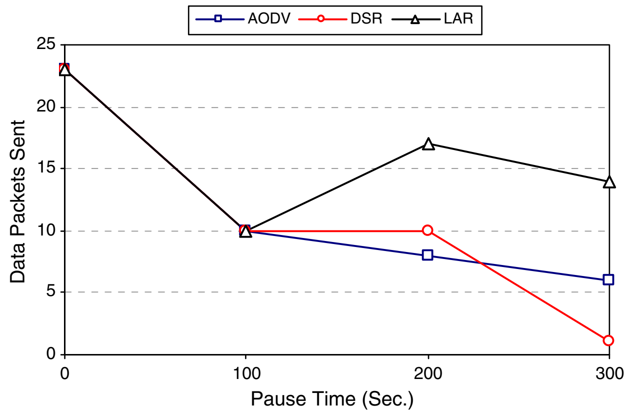

Figure 10 Data packets sent vs. pause time for 200 nodes.

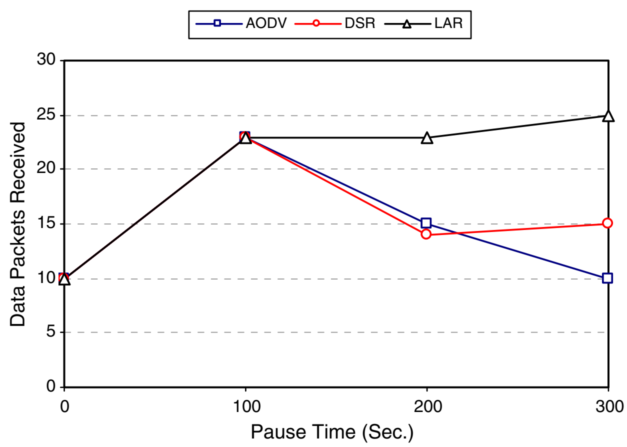

Figure 11 Data packets received vs. pause time for 100 nodes.

when numbers of nodes increases, initially throughput increases as number of routes are available compared to AODV and DSR protocols. Regretfully DSR was not up to the task and it performed poorly throughout all the simulation sequences because increasing the overhead resulted from carrying source routes in data packets which reduces the throughput.

4.8. Energy consumption

Figs. 15 and 16, present the energy consumption vs. pause time for the considered protocols. It is clear that AODV and DSR routing protocols show nearing performance as compared to LAR protocol. When the pause time increases the energy seems to be increased and decreased. The energy consumption of the LAR protocol is higher than both AODV and DSR protocols nearly for the small network size other wise the DSR protocol is higher than for the large network size. However, sending RREQ, RREP, controls packets and spreading traffic requires that some packets take long "detours", which will incur extra energy cost.

4.9. ACK packets received

Figs. 17 and 18, illustrates the ACK packets received using the considered protocols. They decreased at the beginning of the

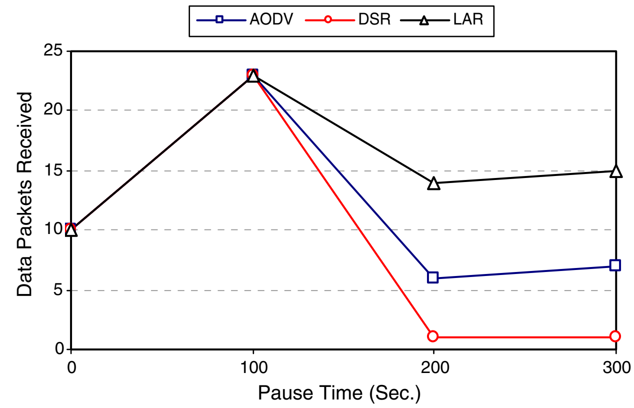

Figure 12 Data packets received vs. pause time for 200 nodes.

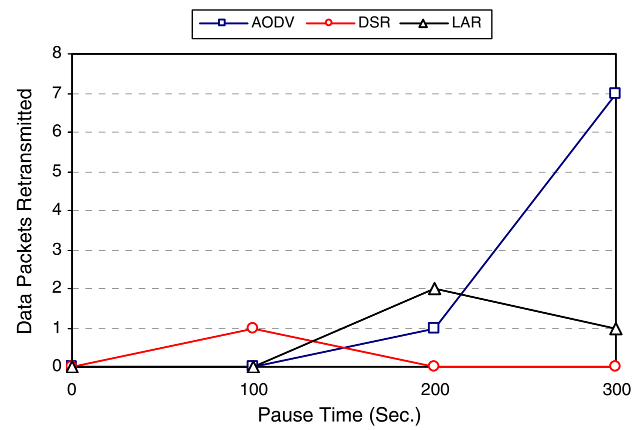

Figure 13 Data packets retransmitted vs. pause time for 100 nodes.

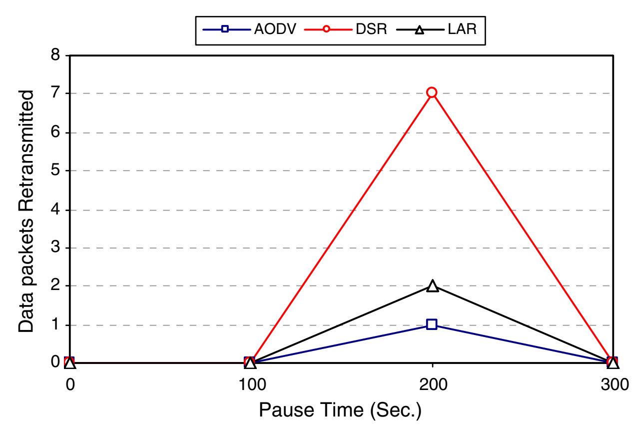

Figure 14 Data packets retransmitted vs. pause time for 200 nodes.

simulation. The ACK packets are increased using LAR and DSR routing protocols between pause time 100 and 200 compared to the AODV protocol. For the large network size and at the pause time 200, the ACK packets received using the LAR protocol is increased compared to the other two protocols. We note the ACK packets received for the DSR protocol

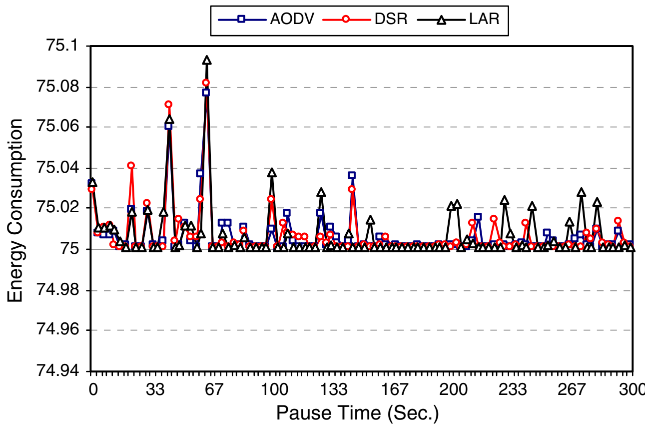

Figure 15 Energy consumption vs. pause time for 100 nodes.

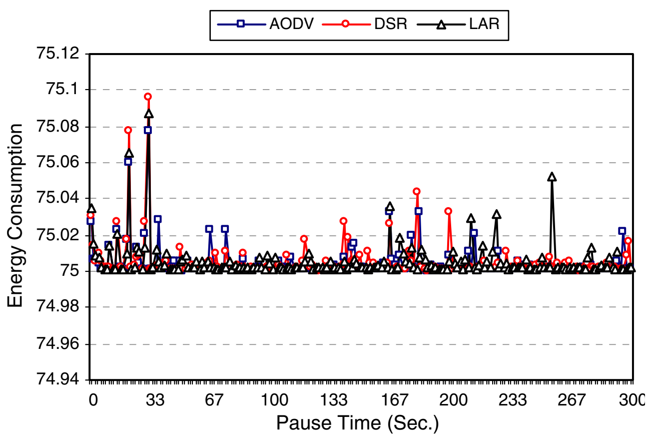

Figure 16 Energy consumption vs. pause time for 200 nodes.

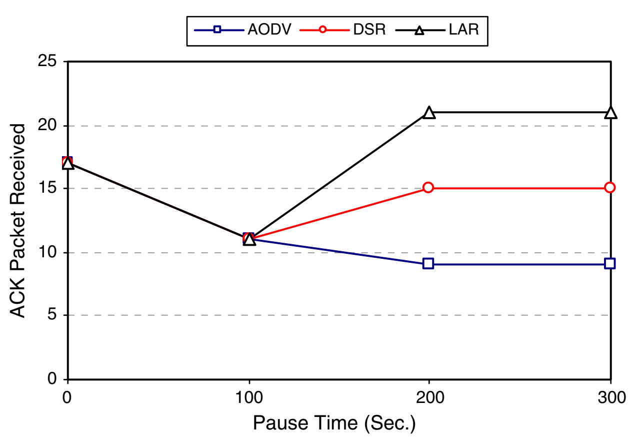

Figure 17 ACK packet received vs. pause time for 100 nodes.

is lower than the other two protocols because another optional feature is the RREP acknowledgment (RREP-ACK). When unidirectional links are suspected, the RREP-ACK can be utilized to ensure the next hop received the RREP. If an RREP-ACK is not received, blacklists can be utilized to indicate unidirectional links so that these links are not used in future route discoveries.

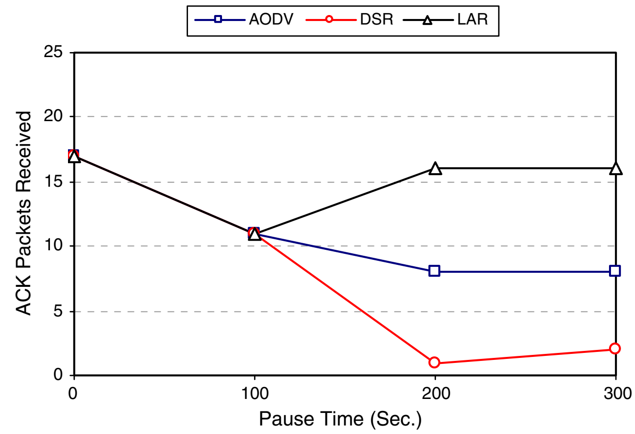

Figure 18 ACK packet received vs. pause time for 200 nodes.

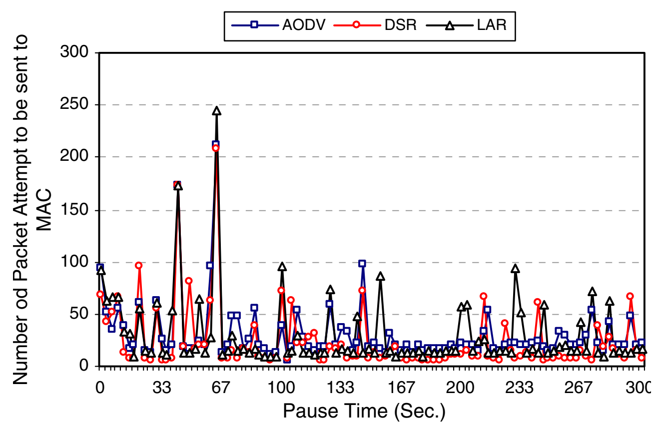

Figure 19 Number of packet attempt to be sent to MAC vs. pause time for 100 nodes.

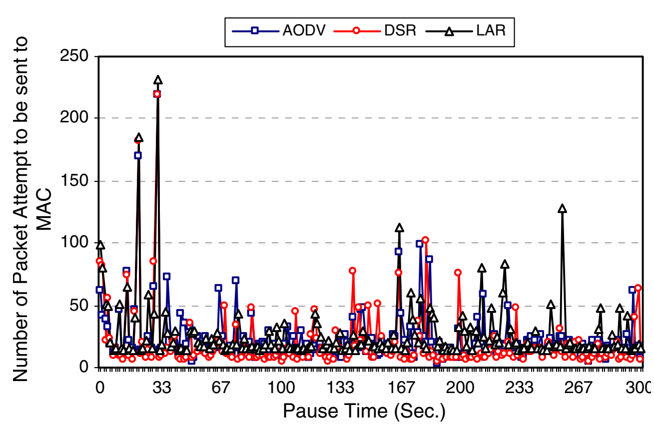

Figure 20 Number of packet attempt to be sent to MAC vs. pause time for 200 nodes.

4.10. Number of packet attempt to be sent to MAC

The number of packet attempt to be sent to MAC for the LAR protocol is higher than the other two protocols as shown in Figs. 19 and 20. However, DSR and LAR nodes have the option of promiscuous listening, whereby nodes can receive and process data and control packets that are not addressed, at

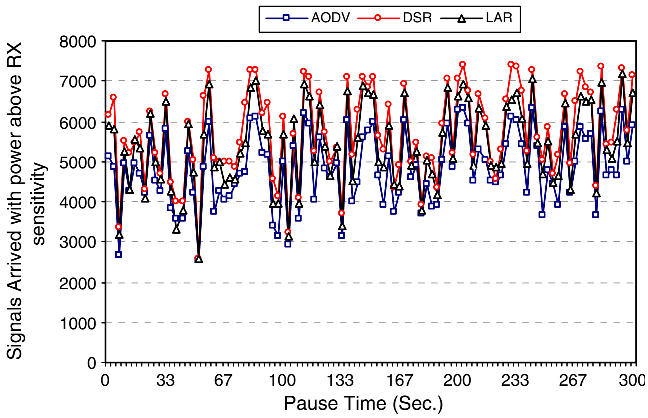

Figure 21 Signals arrived with power above RX sensitivity vs. pause time for 100 nodes.

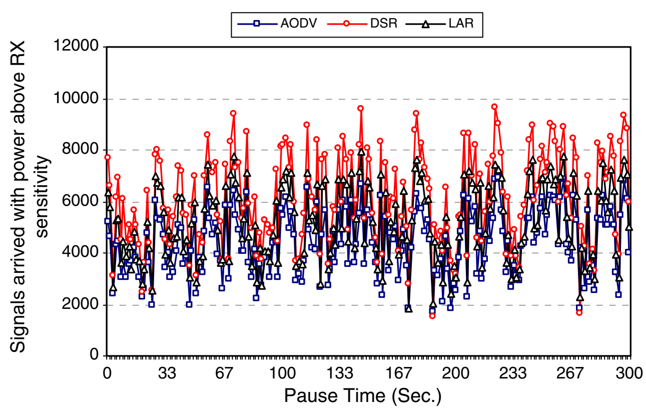

Figure 22 Signals arrived with power above RX sensitivity vs. pause time for 200 nodes.

the MAC layer, to themselves. Through promiscuous listening, nodes can utilize the source routes carried in both control messages and data packets to gratuitously learn routing information for other network destinations.

4.11. Signals

4.11.1. Signals arrived with power above RX sensitivity

The RX sensitivity of an electronic device, such as a communications system receiver, or detection device, such as a PIN diode, is the minimum magnitude of input signal required to produce a specified output signal having a specified Signal Noise Ratio (SNR). Because receive sensitivity indicates how faint an input signal can be to be successfully received by the receiver, the lower the power level, the better. Lower power for a given SNR means better sensitivity since the receiver's contribution is smaller [18].

Figs. 21 and 22, give the signals arrived with power above RX sensitivity. The performance of AODV is the better because its RX sensitivity is lower than the other two protocols.

4.11.2. Signals arrived with power above RX threshold

The RX threshold is defined as the minimum power required by the receiver to detect the received packet. If the Signal to Noise Ratio (SNR) is more than RX threshold, it receives

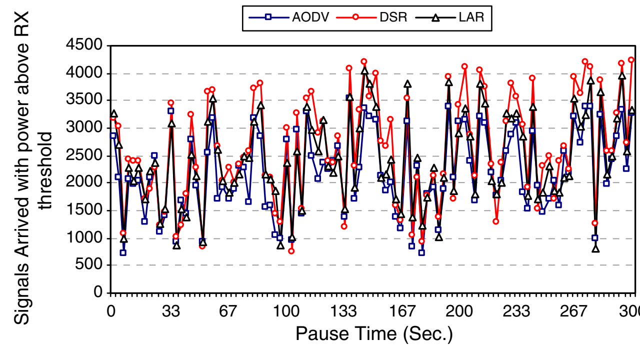

Figure 23 Signals arrived with power above RX threshold vs. pause time for 100 nodes.

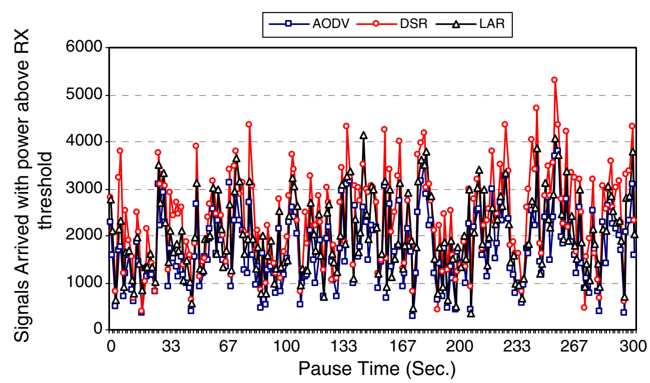

Figure 24 Signals arrived with power above RX threshold vs. pause time for 200 nodes.

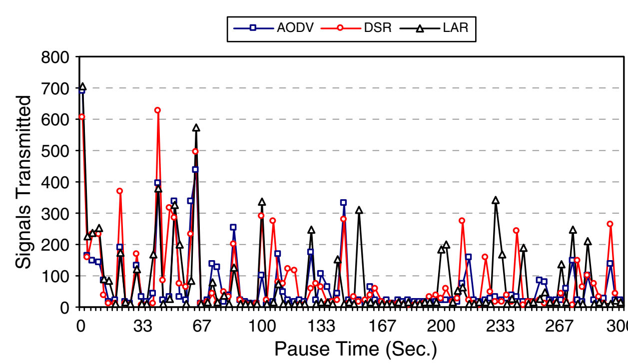

Figure 25 Signals transmitted vs. pause time for 100 nodes.

the signal without error, otherwise the packet is dropped [18]. Figs. 23 and 24 illustrate the signals arrived with power above RX threshold for the considered protocols. As can been seen in these figures, the performance of DSR protocol is better than the other protocols because its RX threshold is higher.

4.11.3. Signals transmitted

Signal transmitted along radio waves travel at the speed of light, in straight lines, and by more than one path. Local signals that you hear from nearby FM radio stations are usually traveling by space wave or "line of sight". These travels, as the name suggest, from antenna to antenna direct.

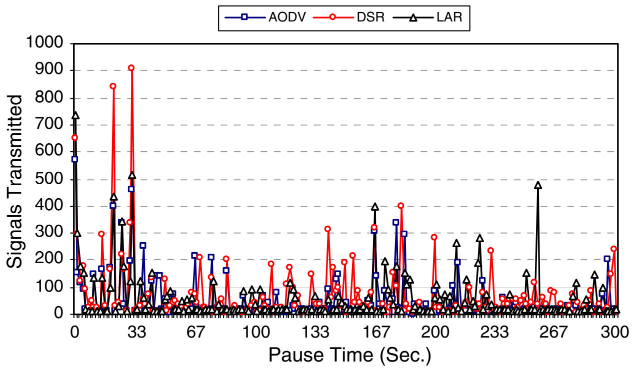

Figure 26 Signals transmitted vs. pause time for 200 nodes.

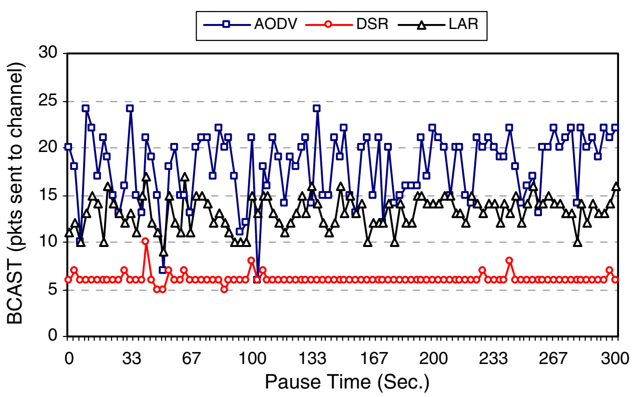

Figure 27 BCAST (pkts sent to channel) vs. pause time for 100 nodes.

Figs. 25 and 26, illustrate the signals transmitted using the considered protocols. The performance of DSR is the better because its signal transmitted is higher than the other two protocols.

4.12. BCAST and UCAST packets

4.12.1. BCAST (pkts sent to channel)

Figs. 27 and 28, show the BCAST (pkts sent to channel) using the considered protocols. It is clear that the AODV protocol performs better than the other two routing protocols.

4.12.2. BCAST (pkts rcvd clearly)

The BCAST (pkts rcvd clearly) using the considered routing protocols are shown in Figs. 29 and 30. It is clear from the figure AODV protocol performs better than the other two routing protocols.

Like most reactive routing protocols, when a source node has data packets to send to some destination, it must initiate a route discovery procedure to find a route. To start route discovery, the source node creates a route request (RREQ) packet (broadcast). Thus, the reverse route that was created as the RREQ was forwarded is utilized to route the route reply RREP back to the source node (unicast). When a link break along an active path occurs, the node upstream of the break invalidates the routes to each of those destinations in its route table. It then creates a route error (RERR) message. After creating the RERR message, it sends this message to its upstream

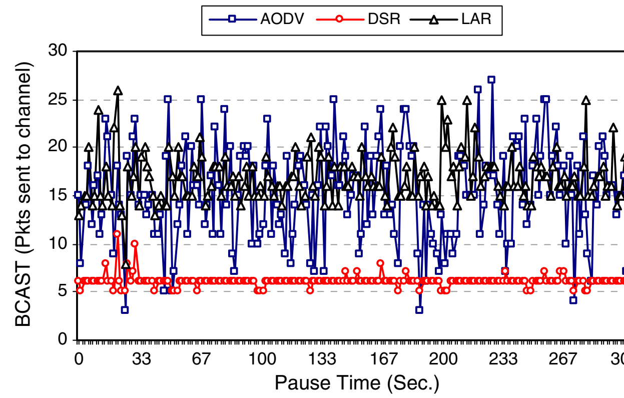

Figure 28 BCAST (pkts sent to channel) vs. pause time for 200 nodes.

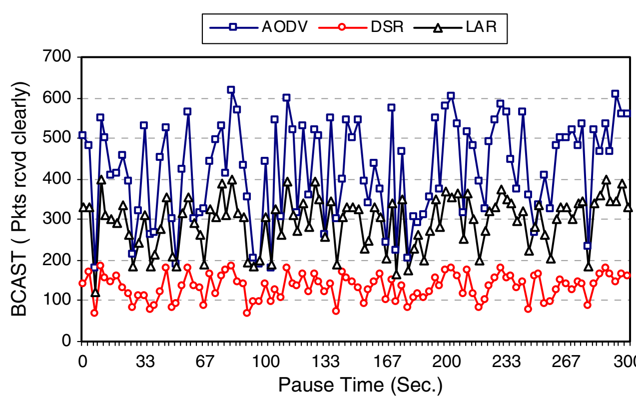

Figure 29 BCAST (pkts rcvd clearly) vs. pause time for 100 nodes.

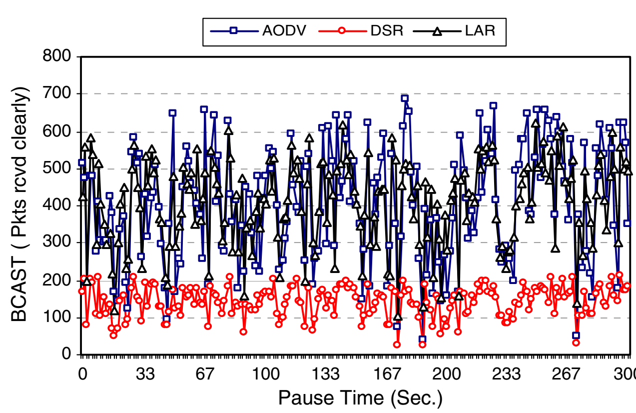

Figure 30 BCAST (pkts rcvd clearly) vs. pause time for 200 nodes.

neighbors that were also utilizing the link. These nodes, in turn, invalidate the broken routes and send their own RERR messages to their upstream neighbors that were utilizing the link. The RERR message thus traverses the reverse path to the source node. In addition, AODV allows the use of periodic Hello messages for monitoring connectivity to neighboring nodes. It's obvious from the behavior of the AODV protocol

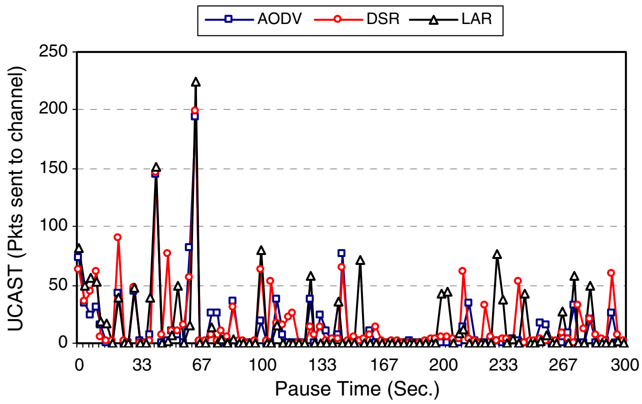

Figure 31 UCAST (pkts sent to channel) vs. pause time for 100 nodes.

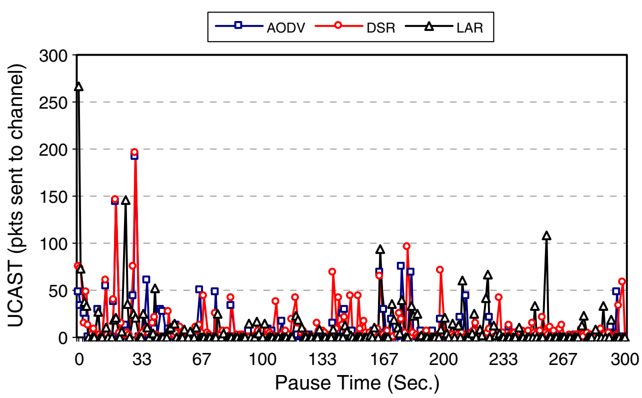

Figure 32 UCAST (pkts sent to channel) vs. pause time for 200 nodes.

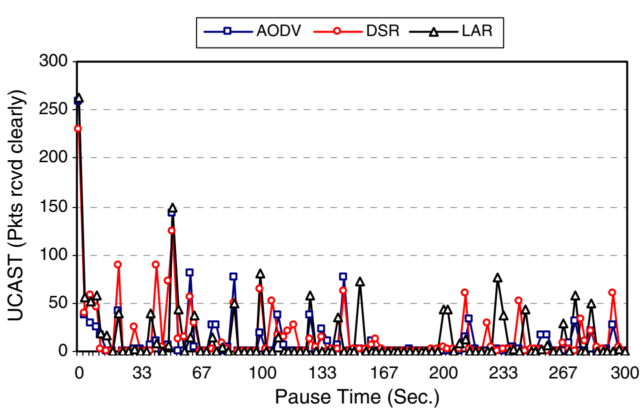

Figure 33 UCAST (pkts rcvd clearly) vs. pause time for 100 nodes.

it broadcasts and unicasts much messages more than the other two protocols as shown in Figs. 27–34.

4.12.3. UCAST (pkts sent to channel)

Figs. 31 and 32, illustrates the UCAST (pkts sent to channel) using the considered protocols. As can been seen in this figure LAR protocol performs better than the other two routing protocols.

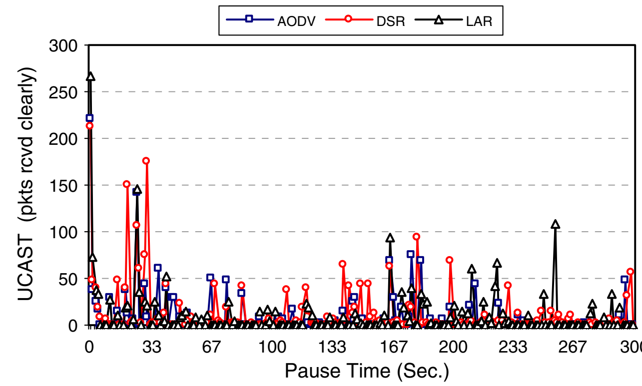

Figure 34 UCAST (pkts rcvd clearly) vs. pause time for 200 nodes.

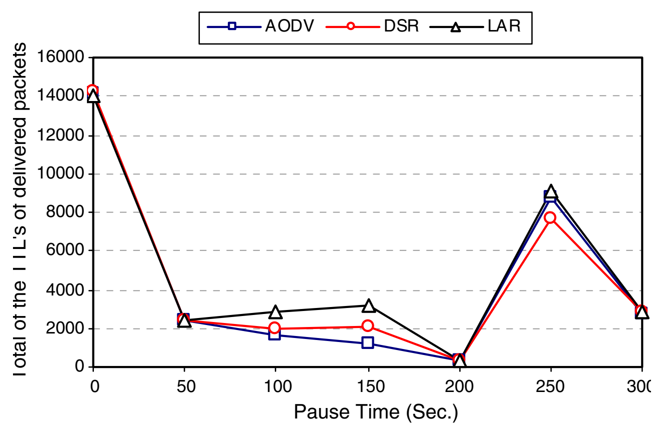

Figure 35 TTL's of delivered packets vs. pause time for 100 nodes.

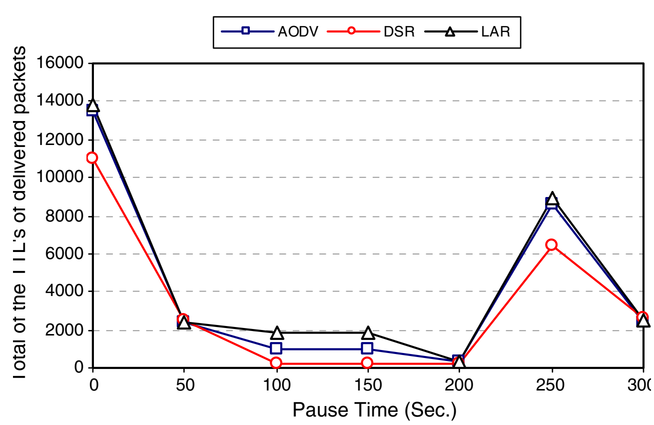

Figure 36 TTL's of delivered packets vs. pause time for 200 nodes.

4.12.4. UCAST (pkts rcvd clearly)

Figs. 33 and 34, illustrates the UCAST (pkts rcvd clearly) using the considered protocols. As can been seen in this figure LAR protocol performs better than the other two routing protocols.

Table 1 Summary of performance results.

Performance	100 nodes			200 nodes		
Matrices	AODV	DSR	LAR	AODV	DSR	LAR
Normalized routing overhead	H	M	L	H	M	L
Average end-to-end delay	M	H	L	M	H	L
Throughput	M	L	H	M	L	H
Collisions	L	M	H	M	H	L
Data packets sent	L	M	H	M	L	H
Data packets received	L	M	H	M	L	H
Packets retransmitted	H	L	M	L	H	M
Energy consumption	H	M	L	H	L	M
ACK packets rcvd	L	M	H	M	L	H
Packet attempt to be sent to MAC	M	L	H	L	M	H
Signals arrived with power above RX sensitivity	L	H	M	L	H	M
Signals arrived with power above RX threshold	L	H	M	L	H	M
Signals transmitted	L	H	M	L	H	M
BCAST (pkts sent) and BCAST (pkts rcvd)	H	L	M	H	L	M
UCAST (pkts sent) and UCAST (pkts rcvd)	L	M	H	L	M	H
TTL's of packets	M	L	H	M	L	H

4.13. Total of the TTL's of delivered packets

As can been seen in Figs. 35 and 36, the total of the TTL's of delivered packets using the considered protocols, we find out that the TTL's decrease as the pause time is increasing until the pause time reaches 200. Starting from the pause time 200 we can note that the TTL's is increasing to its maximum value at pause time 250 and then decreases. Other characteristics that distinguish LAR from other reactive routing protocols include the fact that LAR's route cache entries need not have lifetimes. Once if the source recently had a route to the destination, then the source calculates the expected zone and the request zone, and places the coordinates of the request zone boundary into the RREQ message.

5. Summarized results

Our goal was to compare the three routing protocols to each other, not to find the optimal performance possible in our scenarios, we observe that the mobility pattern does influence the performance of MANET routing protocols. This conclusion is consistent with the observation of previous studies. But unlike previous studies that compared different mobile ad hoc network routing protocols under variety of performance metrics, there is no clear winner among the protocols in our case, since different performance metrics and network size seems to give different performance rankings of the protocols.

Finally, Table 1 summarizes the performance evaluation of the considered routing protocols mentioned in this paper. It provides correspondingly, the protocol name, the network size, and the performance matrices, where, H, M and L mean High, Medium and Lower performance, respectively.

6. Conclusion

This paper evaluated the performance of AODV, DSR, and LAR routing protocols for MANET using GloMoSim simulator. Comparison was based on variety of performances metrics, namely normalized routing overhead, average end-to-end delay, throughput, collisions, data packets sent, data packets received, data packets retransmitted, energy consumption (in mWhr), ACK packets received, packet attempt to be sent to MAC, signals arrived with power above RX sensitivity, signals arrived with power above RX threshold, signals transmitted, BCAST (pkts sent to channel), BCAST (pkts rcvd clearly), UCAST (pkts sent to channel), UCAST (pkts rcvd clearly), and total of the TTL's of delivered packets. To determine the impact of network size on the performance of the considered protocols we considered two different scenarios, namely, 100 and 200 nodes, with rectangular area sizes 1500×1000 and 2000×1500 m^2, respectively.

In the *first scenario (100 nodes)*, LAR protocol showed good performance for normalized routing overhead, average end-to-end delay, throughput, data packets sent, data packets received, energy consumption (in mWhr), number of packet attempt to be sent to MAC, UCAST (pkts sent to channel), UCAST (pkts rcvd clearly), and total of the TTL's of delivered packets. However, AODV protocol showed better performance for collisions, ACK packets received, signals arrived with power above RX sensitivity, BCAST (pkts sent to channel) and BCAST (pkts rcvd clearly). Finally, DSR protocol showed good performance for packets retransmitted and signals arrived with power above RX threshold and signals transmitted.

In the *second scenario (200 nodes)*, LAR protocol showed good performance for normalized routing overhead, average end-to-end delay, throughput, collisions, data packets sent, data packets received, ACK packets received, packet attempt to be sent to MAC, UCAST (pkts sent to channel), UCAST (pkts rcvd clearly), and total of the TTL's of delivered packets. However, AODV protocol showed better performance for throughput, packets retransmitted, signals arrived with power above RX sensitivity, BCAST (pkts sent to channel) and BCAST (pkts rcvd clearly). Finally, DSR protocol showed good performance for signals arrived with power above RX threshold and signals transmitted.

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