Analysis of Energy Consumption Pattern for On Demand Adhoc Routing Protocols

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Summary

Energy Conservation is a critical issue in mobile ad hoc networks (MANETs) for node and network lifetime. MANET nodes have limited battery power, limited computational power and small amount of memory. Such nodes must conserve energy to prolong the network lifetime. Different energy aware routing protocols use traditional protocols like AODV and DSR as base protocols. The selection of base protocol assumes importance for any kind of energy related proposal based on them. In this paper, a critical analysis for AODV and DSR, widely used on demand routing protocol, has been done for different energy related parameters like network lifetime, death rate of nodes, average energy distribution etc. to aid in deciding the base protocol should be chosen in different network conditions. Extensive simulation has been done to benchmark the performance of AODV and DSR in different network scenarios.

Key words: *Routing, Active Routes, Local Repair*

1. Introduction

Mobile ad hoc networks (MANETs) [1] are Infrastructure-less multihop networks. All nodes in MANETs move and dynamically connect to form a network. Nodes of these networks function as routers which discover and maintain routes to other nodes in the network. Routing protocols in MANETs may generally be categorized as either proactive [2-3] or reactive [4-7]. Despite being designed for the same type of underlying network, the characteristics of each of these protocols are quite distinct.

Proactive routing protocols try to maintain consistent, up-to-date routing information one each node of the network. These protocols require each node to maintain one or more tables to store routing information, and update their routing information for any change in network topology to maintain a consistent network view. In reactive protocols discover routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from the source or until the route is no longer desired.

The limited energy capacity of the mobile devices making up the network draws our attention to the importance of power awareness in ad hoc network/protocol design. Bandwidth efficiency and end-to-end delays were initially the main concern of the developed protocols and the conducted simulation studies. Due to the limited energy capacity of the wireless devices and the importance of power awareness in ad hoc routing protocol design, a thorough energy-based performance study is essential to any bandwidth-based study.

In ad hoc networks, the nonexistence of a centralized authority complicates the problem of medium access control. The medium access regulation procedures have to be enforced in a distributed, and hence collaborative, fashion by mobile stations. Transmissions of packets from distinct mobile terminals are more prone to collide. This contention based access results in retransmissions and noticeable delays. Hence, the performance of the MAC scheme affects the performance of the routing protocol drastically and consequently on the energy consumption of the wireless network.

On-demand routing is composed of route discovery and route maintenance. In route discovery, a source uses flooding to acquire a route to its destination. This degrades system-wide energy conservation. The transit nodes, upon receiving a query, learn the path to the source and enter the route in their forwarding tables. The destination node responds using the path traversed by the query. Route maintenance is responsible for reacting to topological changes in the network, and its implementation differs from one algorithm to the other. On-demand protocols include ad hoc on demand distance vector routing (AODV), and dynamic source routing (DSR). In on-demand protocols, route discovery and maintenance may become inefficient under heavy network load since intermediate nodes will have a higher probability of moving due to the delay in packet transmissions attributed to MAC contention. Hence, routes will also have a higher probability of breaking as a result of mobility. This *wastes battery power*, and thus the lifetime of the wireless nodes decreases. The flooding of route request and route reply

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packets in on-demand routing protocols may result in considerable energy drains under realistic energy consumption model that takes idle time and promiscuous mode power into account. Every station that hears the route request broadcasts will consume an amount of energy proportional to the size of the broadcast packet. In addition, stations that hear a corrupted version of a broadcast packet will still consume some amount of energy. Besides, the simulation studies carried out for table-driven and on-demand routing protocols fall short of providing necessary power-based performance metrics, such as average node and network lifetime, average dissipated energy per protocol, standard deviation of the energy dissipated by each individual node, etc.

In a multi-hop ad hoc network, wireless stations must always be ready and willing to receive traffic from their neighbors. All the wireless nodes will consume power unnecessarily due to overhearing the transmissions of their neighbors. This wastes an extensive amount of the total consumed energy throughout the lifetime of the wireless station, on-demand routing protocols require that nodes remain powered on at all times so as to participate in on-the-fly route setup using route request broadcasts and route reply packets. Table-driven protocols also require constant operation in the active state in order to exchange periodic updates and participate in packet routing. Energy use is, thus, crucial in designing wireless ad hoc networks. As a result, designing energy-aware routing protocols has attracted a lot of attention for prolonged network operational time and much work has been carried out. The design objectives require selecting energy-efficient routes and minimizing the control messaging in acquiring the route information.

The rest of the paper is organized as follows. Section 2 defines the problem followed by description of DSR and AODV in section 3. In section 4, the simulation framework is given. Section 5 contains the results and discussion with conclusion in section 6.

2. Problem Definition

The MANET nodes have limited resources and move continually. The frequent change in the topology requires rediscovery of the route while the network is within a session, route refreshes with almost every route discovery request from other nodes. This computational and communication overhead consumes computational resources and quickly depletes the energy of node. As a result, the network life shortens considerably. Both transmission and reception communication cost is very high. A routing protocol must be energy efficient and must also be aware of the energy consumption patterns of the underlying base protocol. The benchmarking of the base protocols is, therefore, required under different network conditions like varying mobility and pause time. Moreover, the energy exhaustion pattern of various nodes and the degradation of connectivity and network lifetime must be known with these base protocols so that new energy efficient protocols could be designed.

3. Description of Base Protocols

3.1. Ad Hoc On-Demand Distance Vector Routing

The Ad Hoc On-Demand Distance Vector (AODV) routing protocol[i] builds on the DSDV algorithm and typically minimizes the number of required broadcasts by creating routes on a demand basis, as opposed to maintaining a complete list of routes as in the DSDV algorithm. The authors of AODV classify it as a *pure on-demand route acquisition* system, since nodes that are not on a selected path do not maintain routing information or participate in routing table exchanges.

When a source node desires to send a message to some destination node and does not already have a valid route to that destination, it initiates a *path discovery* process to locate the other node. It broadcasts a route request (RREQ) packet to its neighbors, which then forward the request to their neighbors, and so on, until either the destination or an intermediate node with a “fresh enough” route to the destination is located. Figure 3a illustrates the propagation of the broadcast RREQs across the network. AODV utilizes destination sequence numbers to ensure all routes are loop-free and contain the most recent route information. Each node maintains its own sequence number, as well as a broadcast ID. The broadcast ID is incremented for every RREQ the node initiates, and together with the node’s IP address, uniquely identifies an RREQ. Along with its own sequence number and the broadcast ID, the source node includes in the RREQ the most recent sequence number it has for the destination. Intermediate nodes can reply to the RREQ only if they have a route to the destination whose corresponding destination sequence number is greater than or equal to that contained in the RREQ.

During the process of forwarding the RREQ, intermediate nodes record in their route tables the address of the neighbor from which the first copy of the broadcast packet is received, thereby establishing a reverse path. If additional copies of the same RREQ are later received, these packets are discarded. Once the RREQ reaches the destination or an intermediate node with a fresh enough route, the destination/intermediate node responds by unicasting a route reply (RREP) packet back to the neighbor from which it first received the RREQ. As the RREP is routed back along the reverse path, nodes along this path set up forward route entries in their route tables which point to the node from which the RREP came.

These forward route entries indicate the active forward route. Associated with each route entry is a route timer which will cause the deletion of the entry if it is not used within the specified lifetime. Because the RREP is forwarded along the path established by the RREQ, AODV only supports the use of symmetric links.

Routes are maintained as follows. If a source node moves, it is able to reinitiate the route discovery protocol to find a new route to the destination. If a node along the route moves, its upstream neighbor notices the move and propagates a *link failure notification* message (an RREP with infinite metric) to each of its active upstream neighbors to inform them of the erasure of that part of the route. These nodes in turn propagate the *link failure notification* to their upstream neighbors, and so on until the source node is reached. The source node may then choose to reinitiate route discovery for that destination if a route is still desired.

An additional aspect of the protocol is the use of *hello* messages, periodic local broadcasts by a node to inform each mobile node of other nodes in its neighborhood. Hello messages can be used to maintain the local connectivity of a node. However, the use of hello messages is not required. Nodes listen for retransmission of data packets to ensure that the next hop is still within reach. If such a retransmission is not heard, the node may use any one of a number of techniques, including the reception of hello messages, to determine whether the next hop is within communication range. The hello messages may list the other nodes from which a mobile has heard, thereby yielding greater knowledge of network connectivity.

3.2. Dynamic Source Routing

The Dynamic Source Routing (DSR) protocol[ii] is an on-demand routing protocol that is based on the concept of source routing. Mobile nodes are required to maintain route caches that contain the source routes of which the mobile is aware. Entries in the route cache are continually updated as new routes are learned.

The protocol consists of two major phases: route discovery and route maintenance. When a mobile node has a packet to send to some destination, it first consults its route cache to determine whether it already has a route to the destination. If it has an unexpired route to the destination, it will use this route to send the packet. On the other hand, if the node does not have such a route, it initiates route discovery by broadcasting a *route request* packet. This route request contains the address of the destination, along with the source node's address and a unique identification number. Each node receiving the packet checks whether it knows of a route to the destination. If it does not, it adds its own address to the *route record* of the packet and then forwards the packet along its outgoing links. To limit the number of route requests propagated on the outgoing links of a node, a mobile only forwards the route request if the request has not yet been seen by the mobile and if the mobile's address does not already appear in the route record.

A *route reply* is generated when the route request reaches either the destination itself, or an intermediate node which contains in its route cache an unexpired route to the destination[iii]. By the time the packet reaches either the destination or such an intermediate node, it contains a route record yielding the sequence of hops taken. If the node generating the route reply is the destination, it places the route record contained in the route request into the route reply. If the responding node is an intermediate node, it will append its cached route to the route record and then generate the route reply. To return the route reply, the responding node must have a route to the initiator. If it has a route to the initiator in its route cache, it may use that route. Otherwise, if symmetric links are supported, the node may reverse the route in the route record. If symmetric links are not supported, the node may initiate its own route discovery and piggyback the route reply on the new route request.

Route maintenance is accomplished through the use of route error packets and acknowledgments. *Route error* packets are generated at a node when the data link layer encounters a fatal transmission problem. When a route error packet is received, the hop in error is removed from the node's route cache and all routes containing the hop are truncated at that point. In addition to route error messages, acknowledgments are used to verify the correct operation of the route links. Such acknowledgments include passive acknowledgments, where a mobile is able to hear the next hop forwarding the packet along the route.

4. Simulation Framework

The simulation results presented in this paper were obtained using the *ns-2* simulator (version *ns-2.29*) [8]. Simulations are run over a 1000m * 1000m square flat topology. The number of wireless mobile nodes was fixed to 50. The *random waypoint* model is used to model mobility. All random scenarios have been generated for a maximum speed of 16.67 m/s and a pause time of 0 seconds and 500 seconds.

Traffic sources are chosen as TCP-IP with a packet-size of 512 bytes and a window-size of 32. All traffic sessions are established at random times near the beginning of the simulation run and they remain active until the end of the simulation period. Simulations are run for 500 simulated seconds.

Ns-2 inbuilt 714 MHz Lucent WaveLAN Direct Sequence Spread Spectrum (DSSS) Model with various simulation parameter (as shown in Table I) used for generating energy patterns.

TABLE 1. Simulation Parameter for AODV and DSR

Frequency	914e+6
transmitted signal power	0.2818 W
power consumption for transmission	1.6 W
power consumption for reception	1.2 W
idle power consumption	0.0 W
capture threshold	10.0 db
carrier sense threshold	1.559e-11 W
receive power threshold	3.652e-10 W
system loss factor	1.0
Data Rate	2 Mbps
Transmission Range	250 mtr.
Area	1000*1000 m^2
Packet size	512 byte

Each of the 50 nodes has a 100 Joules of energy at the start of every simulation, while varying the number of traffic sources from 10, 22, 30, 38 and 45. The corresponding number for traffic connections were 20, 20, 33, 43 and 54.Identical mobility and traffic scenarios are used across the protocol variations.

5. Results and Discussion

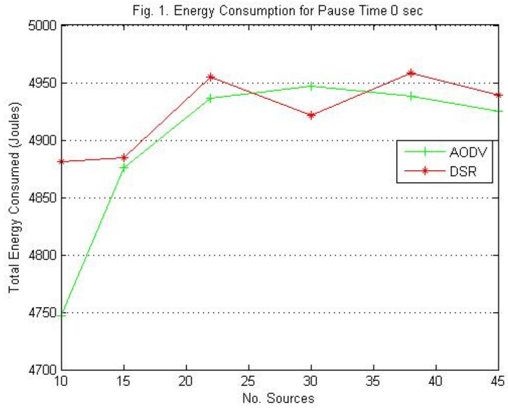
In this section a discussion on results over the energy efficiency of the two MANET routing protocols, namely AODV and DSR, is given for different performance metrics as follows.

5.1. Total Energy Consumption

Total energy consumption is the difference of the total energy supplied to the network and the residual energy with the network, in Joules. The initial energy supplied to the network in each scenario is 5000 Joules.

Scenario 1: Pause Time: 0 Sec, No. of Sources: 10 -45

Fig. 1 illustrates the behavior of AODV and DSR for 0 pause time (max. mobility) and varying no. of sources. It is observed in the Fig. 1 that AODV consumes an average of 28.269332 Joules of energy less than DSR for the pause time of zero seconds. Thus, for a network of continuously moving nodes with varying no. of sources the performance of AODV is better than DSR, except for 30 numbers of sources.



Scenario 2: Pause Time: 500 Sec; No. of Sources: 10 to 45

For a large pause time i.e 500 seconds, Fig. 2 illustrates that DSR consumes 55.709165 Joules more than AODV. This corresponds to a better performance of AODV with respect to DSR in a network of stationary nodes.

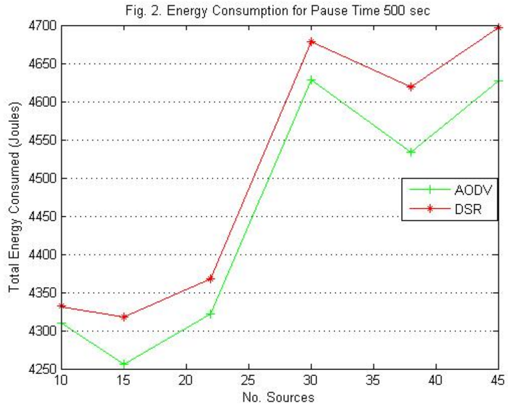


Fig. 1 & Fig. 2 depicts that AODV is a better protocol than DSR in terms of total energy consumption, irrespective of the mobility pattern of the nodes.

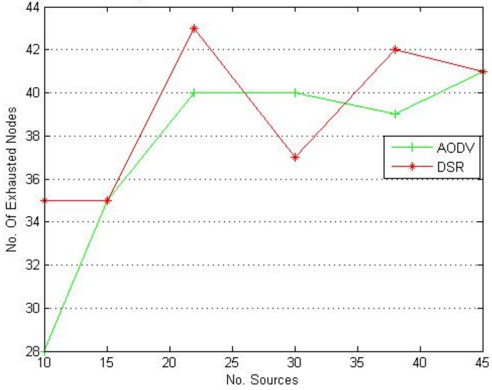
5.2. No. of Exhausted Nodes

This is the no. of nodes that die-out at the end of each simulation run, due to the consumption of all the 100 Joules of energy supplied to them at the start of the simulation.

Scenario 1: Pause Time: 0 Sec; No. of Sources: 10 to 45

It can be observed from Fig.3 that for o pause time and various no. of sources, on an average, only 74.33% of the total nodes died till the end of simulation run in case of AODV while 78% of deaths were reported in the case of DSR.

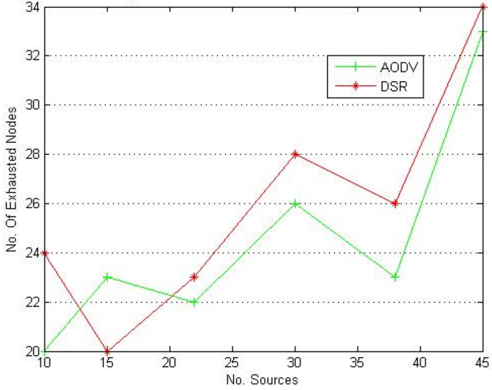
Fig. 3. Exhausted Nodes for Pause Time 0 sec



Scenario 2: Pause Time: 500 Sec; No. of Sources: 10 to 45

For a large value of pause time and for various traffic loads, fig. 4 shows, an average of 52.34% of total nodes gets exhausted when DSR is employed, against 49% deaths in AODV.

Fig. 4. Exhausted Nodes for Pause Time 500 sec



Hence, AODV outperforms DSR in terms of no. of exhausted nodes whatever be the mobility and traffic load conditions in a network of 50 nodes.

5.3. *Network Life-time*

This is the time in seconds from the start of the simulation till 50% of the total number of nodes, i.e. 25, gets exhausted. This is considered the network lifetime since after the death of 50% of the nodes, network has been considered impaired as most of the connections gets broken-up without any possibility of being repaired till the exhausted nodes again becomes active.

Scenario 1: Pause Time: 0 Sec; No. of Sources: 10 to 45

It can be seen from Fig. 5 that for 0 pause time and for varying no. of sources , DSR has a higher network life for heavy traffic conditions (no. of sources greater than 22), while for lesser traffic (no. of sources being < 22) AODV provides greater network life.

Scenario 2: Pause Time: 500 Sec; No. of Sources: 10 to 45

Fig. 6 clearly depicts greater network life for AODV than DSR, for a network with stationary nodes (i.e for a pause time of 500 seconds).
Hence, for moderate traffic conditions AODV is a better choice than DSR if increased network lifetime is the prime concern.

Fig. 5. Network Lifetime for Pause Time 0 sec

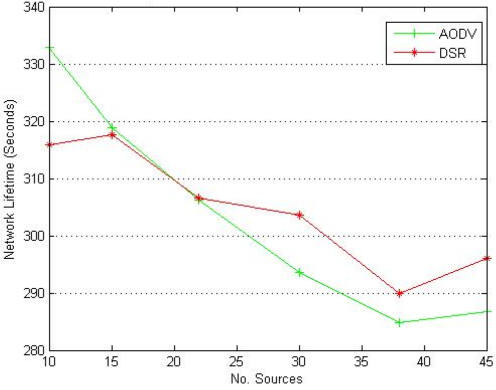
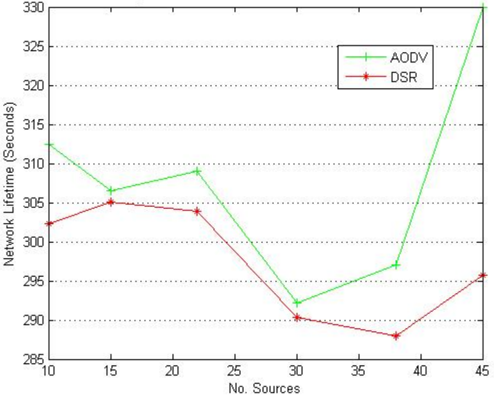


Fig. 6. Network Lifetime for Pause Time 500 sec



5.4. Average Energy Left per Alive Node

This efficiency metric considers two parameters – viz. the no. of exhausted nodes at the end of the simulation and the total energy consumed. It is calculated as the ratio of the total energy left with the network after each simulation run and the no. of nodes active till the end. Thus the greater the value of this metric the better is the protocol

Scenario 1: Pause Time: 0 Sec; No. of Sources: 10 to 45

A mixed behavior for the protocols can be seen in Fig. 7 for AODV and DSR.. A greater amount of energy left per alive node in case of DSR for moderate traffic load only, when the nodes are continuously moving. While for very low and very high traffic, performamce of AODV(in terms of average energy left) is better than DSR .

Fig. 7. Average Energy per Alive Node for Pause Time 0 sec

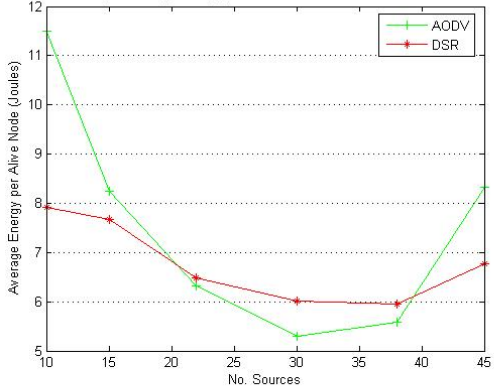
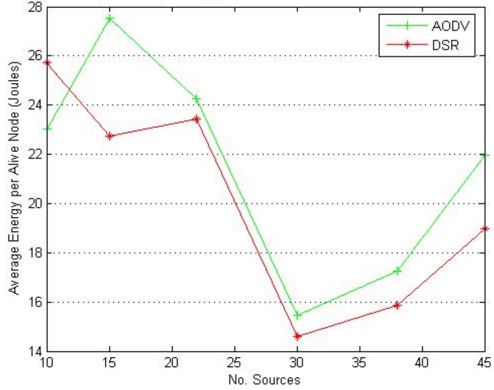


Fig. 8. Average Energy per Alive Node for Pause Time 500 sec



Scenario 2: Pause Time: 500 Sec; No. of Sources: 10 to 45

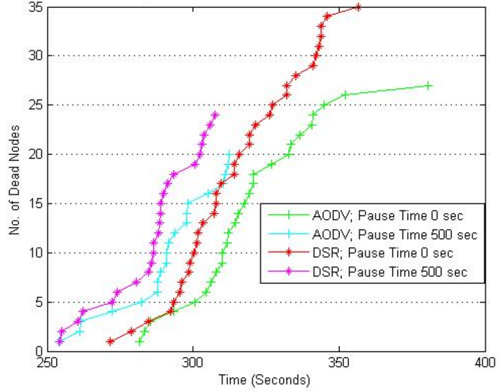
For a network of stationary nodes (for a pause time of 500 seconds), Fig. 8 shows that in AODV greater amount of energy is left per alive node as compare to DSR.

Hence, for a network of all traffic load conditions, AODV outperforms DSR in terms of distribution of energy consumption except in the start of the simulation with very low traffic (10 to 12 sources).

5.5. Node Termination Rate

This efficiency metric describes the time of successive deaths of the mobile nodes in the network. The greater is the slope of the graphs for the time of nodes' deaths the greater is the death rate and the worse is the protocol performance.

Fig. 9. Node Termination Rate for 10 Sources



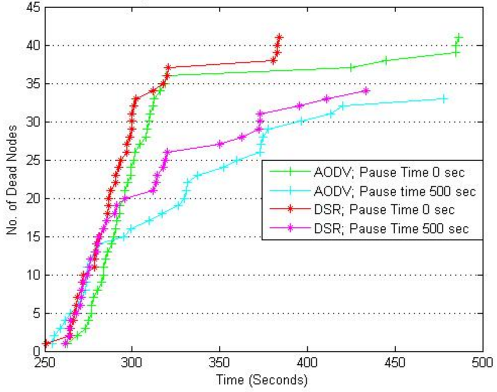
Scenario 1: Pause Time- 0 & 500 Sec; No. of Sources- 10

Termination rates of AODV and DSR is shown in Fig. 9. It can be observed that termination rates of DSR for pause times of 0 & 500 seconds is greater than that of AODV when the network consist of 10 sources (light traffic).

Scenario 2: Pause Time- 0 & 500 Sec; No. of Sources- 45

For large number of sources (45 sources). It is evident from Fig. 10 that termination rates of DSR for pause times of 0 & 500 seconds is greater than that of AODV when the network consist of 45 sources.Hence, the performance of AODV is better than DSR when the node termination rate is the criterion at higher speed and varying number of sources (traffic variation).

Fig. 10. Node Termination Rate for 45 Sources



6. Conclusion

. Energy is a critical issue in mobile adhoc networks and path selection with out energy efficiency may lead to premature depletion of the network or a node. In this paper, energy consumption based critical analysis of AODV and DSR, two highly rated on demand routing protocol, is done. Performance of both the protocols have been measured in terms of various energy related parameters such as total energy consumption, number of exhausted nodes, network lifetime and average energy left per node. Extensive simulation results show the energy consumption behavior of AODV and DSR for different network scenarios (for varying mobility, for varying pause time and for varying no. of sources). This paper paves the path for a better selection of base protocol for new energy related routing proposal in adhoc wireless networks.

References

[1] E. M. Royer and Chai Keong Toh, “A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks”, IEEE Personal Communications, Vol. 6, No. 2, April 1999, pp 46-55.

[2] C. Perkins and P. Bhagwat, “Highly Dynamic Destination Sequenced Distance Vector Routing (DSDV) for Mobile Computers,” Computer Communication Reviews, pp. 234-244, Oct. 1994.

[3] S. Murthy and J. J. Gracia-Luna-Aceves,”An Efficient Routing Protocol for Wireless Networks”, ACM Mobile Networks and Applications Journal, Special Issue on Routing in Mobile Communication Networks, pp. 183-197, Oct. 1996.

[4] D. Johnson, “The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)”, draft-ietf-manet-dsr-07.txt, Feb 21, 2002.

[5] Yong-Bae Ko and Nitin H. Vaidya,”Location Added Routing (LAR) in Mobile Ad Hoc Networks”, ACM/IEEE International Conference on Mobile Computing and Networking, pp. 66-75, Oct. 1998.

[6] V. D. Park and M. S. Corsion, “A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Network”, IEEE Sixteenth Annual Joint Conference of the IEEE Computer and Communication Societies, INFOCOM’97, pp 1405-1413, vol. 3 April 1997.

[7] R. Dube, C. D. Rais, K. Y. Wang, and S. K. Tripathi, “Signal Stability Based Adaptive Routing (SSR) for Ad Hoc Mobile Networks”, IEEE Personal Communications, pp. 36-45, Feb. 1997.

[8] Eitan Altman and Tania Jimenez (2003). , Lecture Notes on NS Simulator for Beginners, December 03, 2003.

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