# Energy Aware QoS on-demand Routing Protocols for MANETs

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## ABSTRACT
Mobile nodes in an ad hoc wireless network have limited battery power. These nodes need to be energy conserved to maximize the battery life. Thus, development of energy efficient routing protocols is needed due to the limited battery power of all nodes. In this paper, we have considered two on-demand routing protocols- AODV & DSR for mobile ad hoc networks and evaluated the energy performance metrics in all the four modes (transmitting, receiving, idle & sleep) and the residual energy. We have also evaluated other performance metrics such as packet delivery fraction, throughput and end-to-end delay for both protocols. The simulation has been carried out using ns2. Finally, by the observations we conclude that DSR offers the best combination of energy consumption and throughput performance. AODV gives better packet delivery fraction and delay performance compared to DSR in a more stressful conditions i.e., more number of nodes.

## General Terms
Mobile ad hoc networks, AODV, DSR.

## Keywords
Energy consumption, throughput, packet delivery fraction, end-to-end delay.

## 1. INTRODUCTION
In mobile ad hoc networks [1], [3] all nodes are mobile and can be connected dynamically in an arbitrary manner. Nodes are free to move, independent of each other and the topology of such networks keep on changing dynamically which makes routing much difficult [2]. Therefore routing is one of the most concern areas in these networks. Normal routing protocols works well in fixed networks but does not show the same performance in mobile ad hoc networks. These networks require routing protocols which should be more dynamic so that they quickly respond to topological changes [2].

There has been a lot of work done on evaluating performances of various MANET routing protocols [4],[5] but there is very little work done on evaluating the metric–Energy consumption of nodes. In this paper we have evaluated performances of two on-demand routing protocols viz. AODV and DSR for various performances metrics including energy consumption- energy in idle state, sleep state (which occurs when the wireless interface of the mobile node is turned off), transmitting state & receiving state and remaining (residual) energy of nodes in a network. Our observations have shown that DSR performs better than AODV in terms of energy consumption and throughput. Further DSR performs better in terms of end-to-end delay and packet delivery ratio for smaller networks but as the size of the network increases AODV outperforms DSR.

The rest of the paper is organized as follows: Section 2 presents the related work focusing on the evaluation of routing protocols. Section 3 deals with the on-demand routing protocols- AODV and DSR. Section 4 gives the simulation setup. In section 5 we present our simulation results and observations. Finally, section 6 concludes the paper.

## 2. RELATED WORK
A variety of routing protocols have been proposed and implemented for MANETs in the recent past in order to enhance the bandwidth utilization, higher throughputs, lesser overheads per packet, minimum energy consumption and others[5],[22],[23].

Several performance evaluation of MANET routing protocols using performance evaluation of MANET routing protocols using CBR traffic have been done by considering various parameters such as mobility, network load and pause time. Biradar, S.R. et.al. [6] have analyzed AODV and DSR protocol using Group Mobility Model and CBR traffic sources. Biradar, S.R.et.al [6] investigated that DSR performs better in high mobility and average delay is better in case of AODV for increased number of groups. Also Rathy, R.K.et.al [7] investigated AODV & DSR routing protocols under Random Way Point Mobility Model with TCP and CBR traffic sources. They concluded that AODV outperforms DSR in high load and/or high mobility situations. The major requirements of a routing protocol was proposed by Zuraida Binti et.al[8]that includes minimum route acquisition delay, quick routing reconfiguration, loop-free routing, distributed routing approach, minimum control overhead and scalability.

The performance of various routing protocols AODV, DSR and OLSR was examined by considering the metrics- packet delivery ratio, control traffic overhead and route length using NS2 [9],[10]. The performance of routing protocols OLSR, AODV, DSR & TORA was evaluated using OPNET [11],[12]. Route discovery procedure and design of AODV protocol is discussed by C. Perkin,et.al.[13]. The design of R-AODV and comparative analysis of AODV and R-AODV using UDP traffic for constant bit rate applications considering scalability is discussed by E.Talipov,et.al.[14].

Several studies have dealt with measuring energy consumption in the wireless interfaces of mobile node [21],[22],[23] to determine the exact sources of energy consumption in the wireless interfaces. It was found that a mobile node's wireless interface consumes energy not only while communicating with other nodes, but also while in idle mode i.e., when the node is listening to the medium but not handling packets. In order to address the energy efficiency issues in the communications within ad hoc networks, it is important to understand the energy model which represents the power consumption behavior in the ad hoc network node wireless interfaces [23].

## 3. ON-DEMAND ROUTING PROTOCOLS

### 3.1 Ad hoc on-demand distance vector (AODV)

Ad hoc on demand distance vector (AODV) [13],[15],[16] routing protocol creates routes on-demand. The procedure of route establishment is as follows. Assume that node X wants to set up a connection with node Y. Node X initiates a path discovery process in an effort to establish a route to node Y by broadcasting a Route Request (RREQ) packet to its immediate neighbors. Each RREQ packet is identified through a combination of the transmitting node's IP address and a broadcast ID. The latter is used to identify different RREQ broadcasts by the same node and is incremented for each RREQ broadcast. Furthermore, each RREQ packet carries a sequence number which allows intermediate nodes to reply to route requests only with up-to-date route information. Upon reception of an RREQ packet by a node, the information is forwarded to the immediate neighbors of the node and the procedure continues until the RREQ is received either by node Y or by a node that has recently established a route to node Y. If subsequent copies of the same RREQ are received by a node, these are discarded.

When a node forwards a RREQ packet to its neighbors, it records in its routing table the address of the neighbor node where the first copy of the RREQ was received. This helps the nodes to establish a reverse path, which will be used to carry the response to the RREQ. AODV supports only the use of symmetric links. A timer starts running when the route is not used. If the timer exceeds the value of the 'lifetime', then the route entry is deleted. .Routes may change due to the movement of a node within the path of the route. In such a case, the upstream neighbor of this node generates a 'link failure notification message' which notifies about the deletion of the part of the route and forwards this to its upstream neighbor. The procedure continues until the source node is notified about the deletion of the route part caused by the movement of the node. Upon reception of the 'link failure notification message' the source node can initiate discovery of a route to the destination node.

### 3.2 Dynamic Source Routing (DSR)

Dynamic Source Routing (DSR) [17],[18] uses source routing rather than hop-by-hop routing. Thus, in DSR every packet to be routed carries in its header the ordered list of network nodes that constitute the route over which the packet is to be relayed. Thus, intermediate nodes do not need to maintain routing information as the contents of the packet itself are sufficient to route the packet. This fact eliminates the need for the periodic route advertisement and neighbor detection packets that are employed in other protocols. The overhead in DSR is large as each packet must contain the whole sequence of nodes comprising the route.

DSR comprise the processes of route discovery and route maintenance. A source node wishing to set up a connection to another node initiates the route discovery process by broadcasting a RREQ packet. This packet is received by neighboring nodes which in turn forward it to their own neighbors. A node forward a RREQ message only if it has not yet been seen by this node and if the nodes address is not part of route. The RREQ packet initiates a route reply packet (RREP) upon reception of the RREQ packet either by the destination node or by an intermediate node that knows a route to the destination. Upon arrival of the RREQ message either to the destination or to an intermediate node that knows a route to the destination, the packet contains the sequence of nodes that constitute the route. This information is piggybacked on to the RREP message and consequently made available at the source node. DSR supports both symmetric and asymmetric links. Thus, the RREP message can be either carried over the same path with original RREQ, or the destination node might initiate its own route discovery towards the source node and piggyback the RREP message in its RREQ.

In order to limit the overhead of these control messages, each node maintains a cache comprising routes that were either used by these nodes or overheard. As a result of route request by a certain node, all the possible routes that are learned are stored in the cache. Thus, a RREQ process may result in a number of routes being stored in the source node's cache.

Route maintenance is initiated by the source node upon detection of a change in network topology that prevents its packet from reaching the destination node. In such a case the source node can either attempt to use alternative routes to the destination node or reinitiate route discovery. Storing in the cache of alternative routes means that route discovery can be avoided when alternative routes for the broken one exist in the cache. Therefore route recovery in DSR can be faster than any other on-demand routing protocols. Since route maintenance is initiated only upon link failure, DSR does not make use of periodic transmissions of routing information, resulting in less control signaling overhead and less power consumption at the mobile nodes.

## 4. SIMULATION SETUP

We have used network simulator (NS-2.34) for the evaluation of our work. NS2 is a discrete event driven simulator [19],[20] developed at University of Berkeley and the Virtual Inter Network Test bed (VINT) project fall 1997[19],[20]. We have used Ubuntu 9.04 Linux environment. NS2 is suitable for designing new protocols, comparing different protocols and traffic evaluations. It is an object oriented simulation written in C++, with an OTCL interpreter as a frontend.

Our simulation setup is a network with randomly placed nodes within an area of 1000m *1000m for a simulation time of 100sec. The parameters used for carrying out simulation are summarized in the table1.We have used different number of sources with a moderate packet rate and bandwidth. Initially we started with 10 nodes in a network scenario, later we increased the size of nodes to 20, 30, 40 & 50. The goal of our simulation is to evaluate the performance differences of these two on-demand routing protocols in terms of performance metrics such as energy consumption, throughput, delay and packet delivery fraction using TCP as traffic source.

**Table1. Simulation parameters**

| Parameter | Value |
|---|---|
| Routing Protocols | AODV,DSR |
| MAC Layer | 802.11 |
| Terrain Size | 1000m*1000m |
| No. of Nodes | 10,20,30,40,50 |
| Packet Size | 512B |
| Initial Energy | 1000Joules |
| Idle Power Consumption | 1.0W |
| Rx Power Consumption | 1.0W |
| Tx Power Consumption | 1.0W |
| Transition Power Consumption | 0.2W |
| Simulation Time | 100s |
| Traffic Source | TCP |

### 4.1 Performance Metrics

MANET routing protocols can be evaluated by a number of quantitative metrics described by RFC 2501[24] as well as energy efficiency metrics which are needed to both devise and evaluate energy conservation schemes. We have used the following metrics for evaluating the performance of the two routing protocols (AODV & DSR).

#### *4.1.1 Average Energy*

It is the average energy consumption of all nodes in sending (transmitting), receiving, idle and sleep mode.

#### *4.1.2 Average Residual Energy*

It is the average remaining energy of all nodes in a network by the end of communication.

#### *4.1.3 Packet Delivery Fraction*

It is the ratio of the number of packets received by the destination to the number of data packets generated by the source.

#### *4.1.4 Average end-to-end delay*

It is defined as the average time taken by the data packets to propagate from source to destination across a MANET. This includes all possible delays caused by buffering during routing discovery latency, queuing at the interface queue, and retransmission delays at the MAC, propagation and transfer times.

#### *4.1.5 Throughput*

It is the rate of successfully transmitted data packets per second in the network during the simulation.

## 5. RESULTS

Here we present a comparative analysis of the performance metrics of both the on-demand routing protocols AODV and DSR using TCP traffic source for varying number of nodes 10, 20, 30, 40 & 50.

### 5.1 Simulation Results

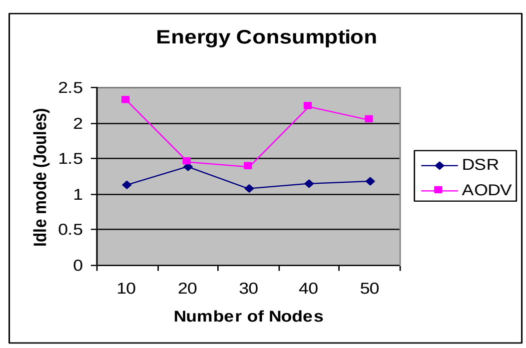


**Fig 1: Energy consumption in idle mode.**

Idle energy consumption is an obvious candidate for energy conservation efforts. From firure.1 it is clear that energy consumed by the nodes in idle mode is more for AODV than

DSR and constitutes almost one-third of the energy consumption.

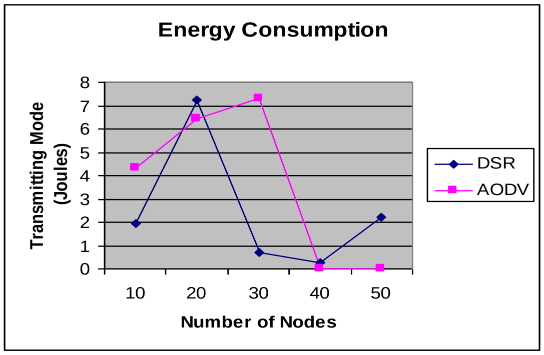


**Fig 2: Energy consumption in transmitting mode.**

Energy consumption in transmitting mode for DSR for a small network size of 10 is very less compared to that of AODV, but as the network size grows to 20, energy consumption also increases for both AODV and DSR as seen in figure 2. But as the size grows to 30, 40, 50, transmitting energy reduces for DSR. AODV outperforms DSR for a network size of 50. Due to large overhead with the increase in size of network, energy consumed by nodes with DSR is more than AODV. We conclude that DSR gives better performance for a small size network but as the number of nodes increases, AODV outperforms DSR.

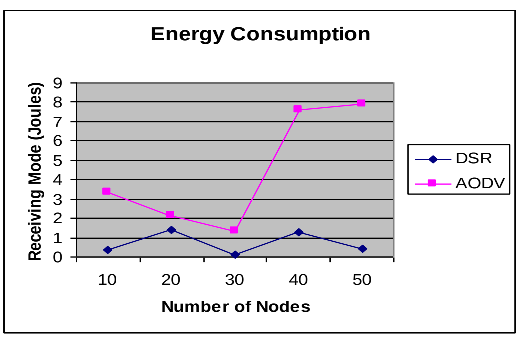


**Fig 3: Energy consumption in receiving mode.**

Energy consumption in receiving mode is the largest source of energy consumption of all modes. This is followed by energy consumption in transmitting mode. From figure 3 it is clear that energy consumed by DSR in receiving mode is less and is almost constant for variable network size. But for DSR, energy consumed increases as the size of network increases. Hence, we conclude that DSR performs better than AODV.

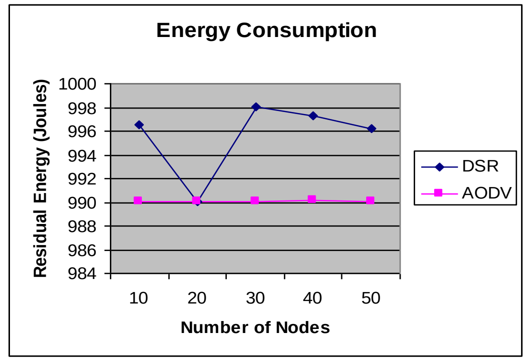


**Fig 4: Residual energy of nodes in the network.**

From figure 4, it is clear that the residual energy is almost constant in case of AODV routing protocol for different network size. In case of DSR, the residual energy of the nodes in a network is more by the end of simulation. Hence, DSR outperforms AODV.

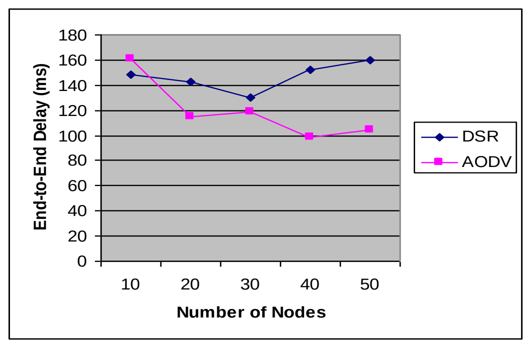


**Fig 5: End-to-end delay vs number of nodes.**

The packet end-to-end delay is the average time a packet takes to traverse the network. Initially the end-to-end delay of DSR was less compared to AODV with 10 nodes but with the increased network size the end-to-end delay for AODV decreases. Thus, it is clear from figure 5 that AODV has shorter end-to-end delay than DSR.

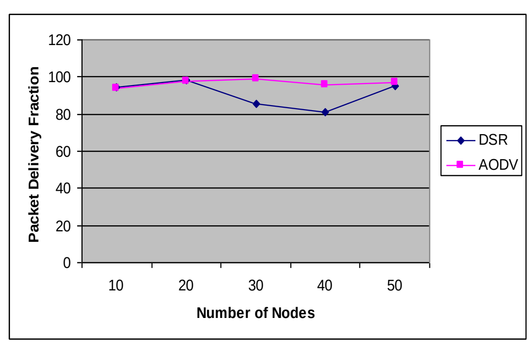


**Fig 6: Packet delivery fraction vs number of nodes.**

Packet delivery fraction for AODV and DSR are similar with 10 & 20 nodes. However, as the size of the network increases to 30, 40 & 50 nodes, AODV outperforms DSR.

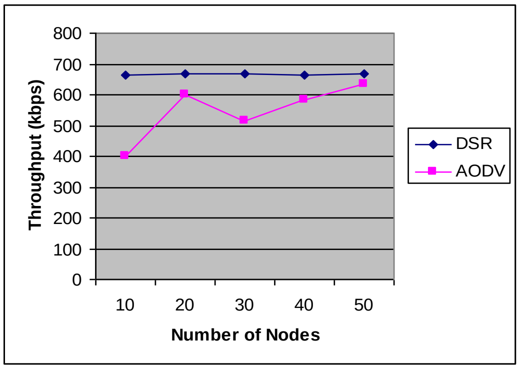


**Fig 7: Throughput vs number of nodes.**

Based on the simulation results, it is clear that the throughput value of AODV increases slowly with the network size. The throughput value of DSR remains constant even if the size of the network increases and is comparatively better than AODV. Hence, DSR shows better performance with respect to throughput among the two on-demand protocols.

## 5.2 Result Analysis

We have compared the performance of two on-demand routing protocols DSR and AODV for ad hoc networks using NS2 simulator. Though DSR and AODV share the on-demand behavior, their routing mechanisms are quite different. DSR uses source routing and route caches and does not depend on any periodic or timing-based activities. DSR maintain multiple routes per destination whereas AODV uses routing tables, one route per destination, destination sequence numbers and a mechanism to prevent loops and to determine freshness of routes.

In case of application oriented metrics such as delay and packet delivery ratio DSR outperforms AODV in less stressful situations i.e., smaller number of nodes. However, AODV outperforms DSR in more stressful situations i.e., more number of nodes. Throughput remains constant and is more for DSR than AODV. Hence, DSR outperforms AODV in case of throughput.

Due to the caching strategy used by DSR, DSR is more likely to find a route in the cache and hence resorts to route discovery less frequently than AODV. Aggressive caching, however, seems to help DSR at low loads and also keeps its routing load down resulting in more residual energy. Thus, nodes have more residual energy resulting in more network lifetime with DSR routing protocol. Also energy consumed by the nodes in idle mode and receiving mode is very less for DSR than AODV.

Hence, DSR outperforms in all the three cases of energy consumption- residual energy, idle mode and receiving mode. In transmitting mode DSR performs better only in less stressful situations i.e., smaller number of nodes but as the size of network increases, nodes requires almost same amount of energy with both DSR and AODV routing protocols and finally with 50 nodes, energy consumed by nodes in transmitting mode is more for DSR than for AODV.

It is also observed that energy consumed during receiving a packet is the largest source of energy consumption of all modes. This is followed by the energy consumption during receiving a packet. Despite the fact that while in idle mode the node does not actually handle data communication operations, it was found that the wireless interface consumes a considerable amount of energy nevertheless. This amount approaches the amount that is consumed in the received mode. Idle energy is the energy that is wasted and should be eliminated or reduced through energy-efficient schemes.

## 6. CONCLUSIONS

We have used a detailed simulation model to demonstrate the differing performance characteristics of the two protocols in terms of energy consumption in various states- idle, sleep, transmitting, receiving & residual energy, average end-to-end delay, throughput and packet delivery ratio over the two on-demand routing protocols DSR & AODV by varying the network size.

Considering metrics such as energy consumption-idle mode, receiving mode & residual energy and throughput we have observed that DSR outperforms AODV due to less routing overhead. The poor end-to-end delay and packet delivery ratio performances of DSR are mainly attributed to aggressive use of caching and lack of any mechanism to determine the freshness of routes when multiple choices are available. However, aggressive caching helps DSR to keep its routing load down resulting in less energy consumption.

Our simulation study has compared the behavior of the on-demand routing protocols DSR & AODV. Further we can extend our study by working on modifying the existing routing protocol to give better performance even in high stressful conditions i.e., reducing the energy consumed by nodes in a large network.

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