EFFICIENT ENERGY MANAGEMENT FOR MOBILE AD HOC NETWORKS

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ABSTRACT

A Mobile Ad Hoc network (MANET) is a collection of digital data terminals that can communicate with one another without any fixed networking infrastructure. Since the nodes in a MANET are mobile, the routing and power management become critical issues. Wireless communication has the advantage of allowing untethered communication, which implies reliance on portable power sources such as batteries. However, due to the slow advancement in battery technology, battery power continues to be a constrained resource and so power management in wireless networks remains to be an important issue. Though many proactive and reactive routing protocols exist for MANETs the reactive Dynamic Source Routing (DSR) Protocol is considered to be an efficient protocol. But, when the network size is increased, it is observed that in DSR overhead and power consumption of the nodes in the network increase, which in turn drastically reduce the efficiency of the protocol. In order to overcome these effects, in this paper it is proposed to implement overhead reduction and efficient energy management for DSR in mobile Ad Hoc networks.

Key words: MANET, DSR, Energy Management, overhead reduction.

1. INTRODUCTION

An Ad Hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any established infrastructure or centralized administration [1]. The absence of any fixed infrastructure, such as access points, makes Ad-Hoc networks prominently different from other wireless LANs. In such an environment each node may act as a router, source and destination, and forwards packets to the next hop allowing them to reach the final destination through multiple hops.

With the proliferation of portable computing platforms and small wireless devices, Ad Hoc wireless networks have received more and more attention as a means for providing data communications among devices regardless of their physical locations. The main characteristic of Ad-Hoc networks is the absence of pre-planning. The topology of the network is discovered on the fly, after the network's deployment. Thus, such a network must exchange a number of messages which are used to "set-up" various parameters in the network. Example of such parameters is the very existence of other nodes in the network, their position, information about their neighbors, what they offer (e.g., local maps, files, printing facilities etc).

Various solutions for Overhead Reduction and Power Management in DSR protocol are found in the literature. Dynamic Source Routing protocol is a simple and efficient routing protocol designed specially for use in multi-hop wireless Ad Hoc networks of mobile nodes. DSR allows network to be completely self-organising and self-configuring, without the need for any existing infrastructure or administration [2].Energy management is an essential requirement for the efficient operation of the battery powered MANETs. Rong Zheng and Robin Kravats proposed an extensible on-demand power management framework for Ad Hoc networks in [3] that adapts to traffic loads.Sheetalkumar Doshi and Timothy X Brown[4] identified the necessary features of an on-demand minimum energy routing protocol and suggested mechanisms for their implementation. Jorge Nuevo[5] elucidates the simulating software used in this work. It presents an easy tutorial to use and simulate Ad Hoc networks in GloMoSim as well as the basic structure of the simulator. Several distributed power aware routing protocols in mobile ad hoc networks are discussed in [6]. Gill Zussman et al [7] introduced iterative algorithms for energy efficient routing in ad hoc networks. The problem is formulated as an anycast routing problem in which the objective is to maximize the time until the first battery drains out.Nicolaos B.Karayiannis et al present an approach which relies an entropy constrained routing algorithm for power conservation, which were developed by utilizing the information theoretic concept of the entropy to gradually reduce the uncertainty associated with route discovery through a deterministic annealing process [8]. Stephanie Lindsey and Cauligib S. present energy efficient one-to-all and all-to-all broadcast operations of ad hoc network in [9]. Although establishing correct and efficient routes is an important design issue in MANETs, a more challenging goal is to provide energy efficient routes. Authors of [10] give the idea of minimize the active communication energy required to transmit or receive packets or energy consumed by the idle nodes. Incorporating current estimates of battery levels into routing metrics has been shown in [11] to reduce the demand on nodes with little remaining energy and allow them to participate in the network longer.The Energy Saving Dynamic Source Routing (ESDSR) protocol is introduced in [12] to maximize the life span of a mobile ad hoc network. Pierpaolo Bergamo et al [13] proposed distributed power control as a means to improve the energy efficiency of routing algorithms in ad hoc networks. A table-driven protocol called BEST and an on demand routing protocol called DST were introduced in [15] which are compared to DSR. Samir R Das et al introduce several routing protocols including protocols specifically designed for Ad hoc networks in [16] and traditional protocols such as link state and distance vector used for dynamic networking. It is found that the new generation of on-demand routing protocols use much lower routing load while the traditional link state and distance vector protocols provide better packet delivery and delay performance.Three routing protocols for ad hoc networks namely DSR, DSDV and AODV are compared in [17]. Three different realistic scenarios are considered and it is found that the reactive protocols (AODV and DSR) perform significantly better than DSDV. AODV fared better than DSR at higher traffic loads while DSR performed better than AODV at moderate traffic load.

In this paper we propose an algorithm for modifying DSR to reduce overhead by reducing the number of route reply packets and the header size of DSR data packets. Besides this an algorithm for energy management is incorporated in the Modified DSR by transmitting the data packets with minimum required energy .The rest of the paper is organized as follows: Section 2 deals with the Modified DSR for overhead reduction. Section 3 describes the Efficient Energy Management algorithm. Section 4 presents the simulation results and conclusions are given in Section 5.

2. MODIFIED DSR

The propagation of Route Request and Route Reply packets in DSR are as shown in Figure.1 and Figure.2 respectively.

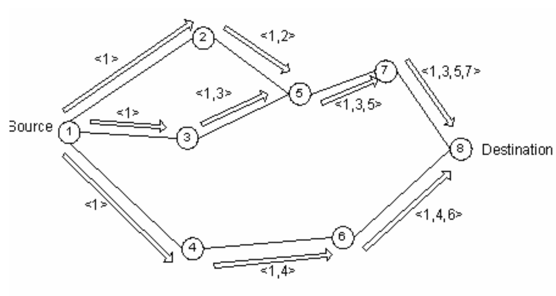

Figure.1 DSR Route Request

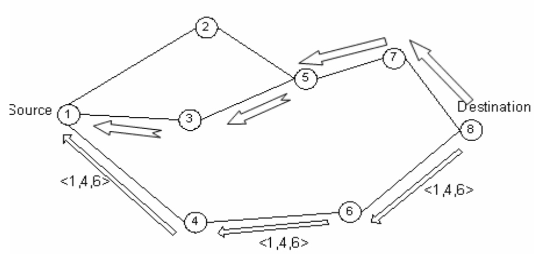

Figure. 2 DSR Route Reply

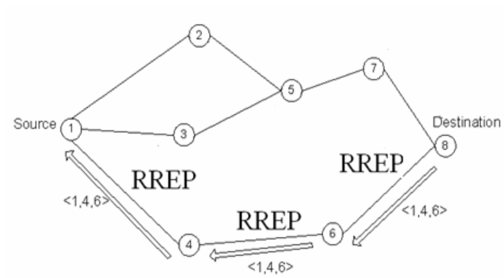

Figure.3 DSR (modified) Route Reply

The main drawback in DSR protocol is the large number of unwanted Route Replies, because a Route Reply is sent through all the available routes leading to unnecessary congestion and waste of energy (battery power). It is found through observations that it is sufficient if the destination node sends the Route Reply through one selected route rather than through all the routes. Hence it is proposed to limit the number of Route Replies to only one. This is sent via the route through which the destination received the first Route Request, because it is the most active route for the particular source-destination pair at the moment of sending the request. Moreover this is the route through which the data packets can be transmitted fastest. Hence the same is chosen as the route for the data transmission, which can reduce the propagation delay to a great extant. Furthermore it leads to the decrease in control packets generated in the network and the increase in packet delivery ratio. Thus these modifications make the data transmission optimum. Figure.3 shows the modified DSR for route reply mechanism.

Another drawback of the DSR protocol is the overhead, which occurs due to appending of the addresses of intermediate nodes present on the route from source to destination (this happens especially as the number of nodes in a particular network increases). The Data Packet Format of existing DSR protocol is shown below.

SNA	INA	INA	INA	DNA	DATA

Figure .4 Data Packet Format of existing DSR protocol

Here it is proposed to exclude the addresses of intermediate nodes from the header of the data packets in order to reduce the overhead in existing protocol. Thus the header of Data Packet contains only source and destination addresses as shown below.

SNA	DNA	DATA

Figure.5 Data Packet Format of modified DSR protocol

SNA- Source Node Address
INA- Intermediate Node Address
DNA- Destination Node Address

2.1 Implementation of Overhead Reduction

2.1.1 Algorithm for overhead reduction:

Step1: Source broadcasts Route Request packets which are heard by nodes within the coverage area

Step2: The neighboring nodes re-broadcast the route request
Step3: Destination sends Route Reply only to the first received Route Request

Step4: Source address, destination address and previous node addresses are stored during route reply.

Step5: The data packet contains only source & destination addresses in its header.

Step6: When the data packet travels from source to destination, through intermediate nodes, for re-broadcasting of data packet, the node verifies source and destination addresses in its cache. If it is present, the data packets are forwarded, otherwise it is rejected.

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Step7: After re-broadcasting the data packet, acknowledgement will be sent to the previous node

3. Efficient Energy Management in Modified DSR

In the Ad Hoc networks, each node is powered by a battery which has a limited energy supply [4]. Over the time, various nodes will deplete their energy supplies and drop out from network. Unless nodes are replaced or recharged, the network will eventually become partitioned. In a large network, relatively few nodes may be able to communicate directly with their intended destinations. Instead, most nodes must rely on other radios to forward their packets. Some radios may be especially critical for forwarding these packets because they provide the only path between certain pairs of radios. Associated with each radio that depletes its battery and stop operating, there may be a number of other radios that can no longer communicate. For this reason a number of researchers have focused on the design of communication protocols that preserve energy so as to network failures for as long as possible [12].

In existing DSR, each node uses constant power to forward the packet or to transmit the packet. According to the DSR draft [1] each node uses 280mw power. Irrespective of the distance between adjacent nodes, each node transmits with a constant power. In the proposed MDSR the transmit power is tuned according to the distance between transmitting node and receiving node [3].

3.1 Algorithm for implementing power management:

Step1: Once the route request process is over and the route is established, the Route Reply packet is broadcast by the destination

Step2: The immediately previous node in the selected path determines the distance between itself and the destination, by means of the time taken by the Route Reply packet to reach it.

Step3: All the nodes in the selected path follow the same procedure and the distance between the nodes is determined and stored in the cache.

Step4: The transmitted power is determined using the following formula,

$$\text{Transmitted Power} = (a \times d^4) + c \qquad (1)$$

Where'd' is the distance between two adjacent nodes 'a' and 'c' are arbitrary constants

$$a = Pr * k \qquad (2)$$

Pr=Minimum Received power=-91dbm
k =8 then find c
$a = 6.48 \times 10^{-11}$ and $c = 30 \times 10^{-3}$ W

Step5: Transmitted power is varied in accordance with the distance

4.SIMULATION RESULTS

Using GloMoSim (Global Mobile Simulator) the DSR was simulated. Then the proposed modifications are introduced and the modified protocol is simulated to verify the predicted changes in parameters of packet delivery ratio, end to end delay and number of control packets at different pause times, with respect to the number of nodes in the network.

The packet delivery ratio(PDR) is the ratio of the number of packets received by the destination to the number of packets transmitted by the source. PDR reduces as the pause time decreases from 900 seconds to 0 seconds. This is due to the mobility of the network and the probability of link failures increases as the pause time decreases. It is observed that the MDSR maintains a better Packet delivery Ratio than the existing DSR. This may be attributed to the reduction in the number of control packets which reduces the collisions between the transmitted data packets and control packets. It is also observed that the MDSR maintains a significantly high Packet Delivery Ratio than the existing DSR as the pause time decreases. This is a result of the fact that in the MDSR, unlike in existing DSR, the most active path is selected which is less probable to fail and in turn increases the Packet Delivery Ratio.

The number of control packets is the sum of all the Route Requests, Route Replies and Route Error packets. In existing DSR, the destination initiates Route Reply for all the Route Requests received, but in MDSR, destination initiates Route Reply only to the first received Route Request. Thus, it is seen that the MDSR maintains less number of control packets than the existing DSR. As the pause time decreases, the complexity of the network increases and the probability of link failures increases. Though the MDSR reduces the number of Route Replies, the source has to re-perform the route discovery process in case of link failures, unlike in existing DSR, where it chooses the next path in its route cache. Thus, as the mobility increases, the MDSR requires almost the same number of control packets as the existing DSR.

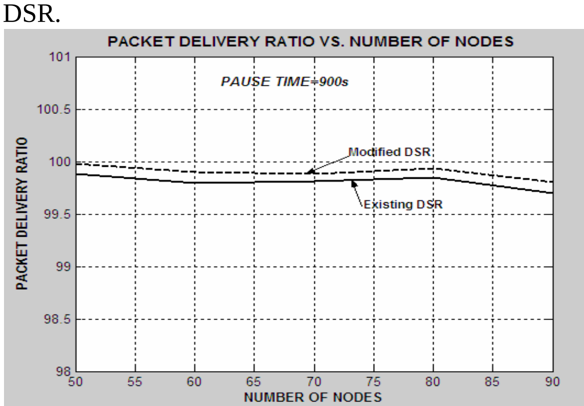

Figure.6 Packet Delivery ratio Vs. No. Of nodes for pause time of 900s

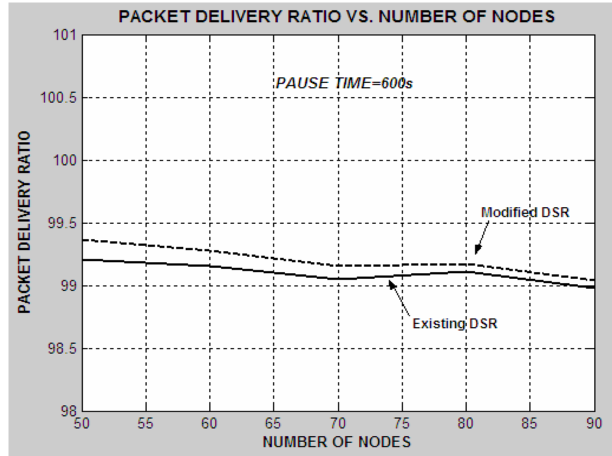

Figure.7 Packet Delivery ratio Vs. No. Of nodes for a pause time of 600 s

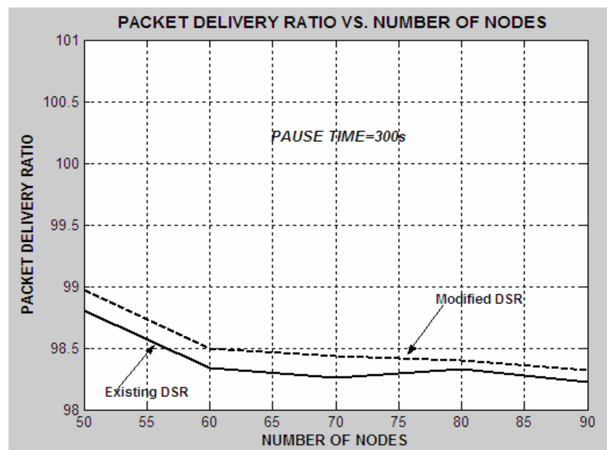

Figure.8 Packet Delivery ratio Vs. No. Of nodes for a pause time of 300 s.

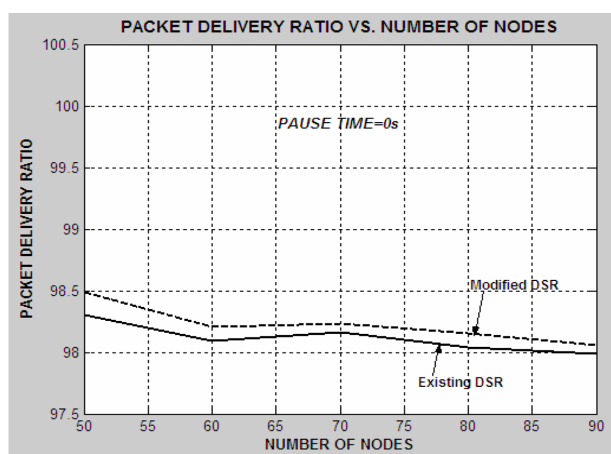

Figure.9 Packet Delivery ratio Vs. No. Of nodes for a pause time of 0s

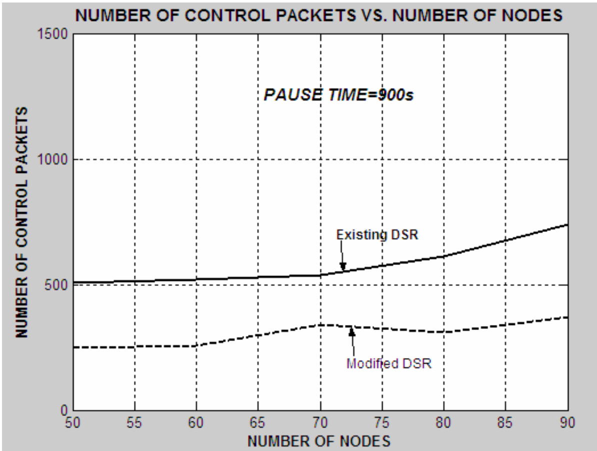

Figure.10 Number of Control Packets vs. No. Of nodes for a pause time of 900 s.

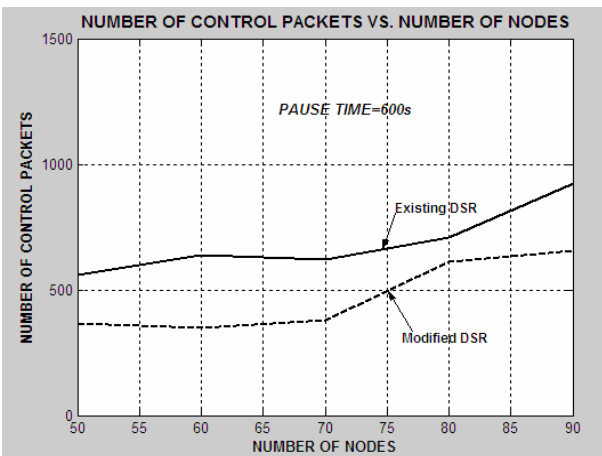

Figure.11 Number of Control Packets vs. No. Of nodes foa pause time of 600 s

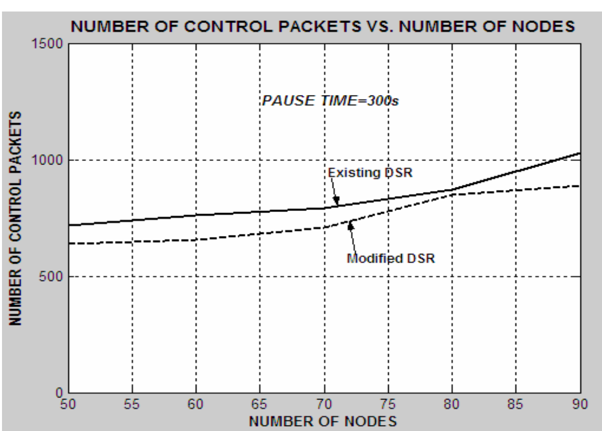

Figure.12 Number of Control Packets vs. No. Of nodes for a pause time of 300 s

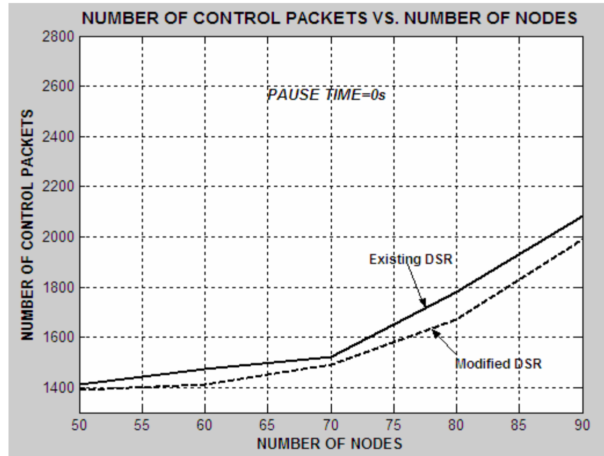

Figure.13 Number of Control Packets vs. No. Of nodes for a pause time of 0 s

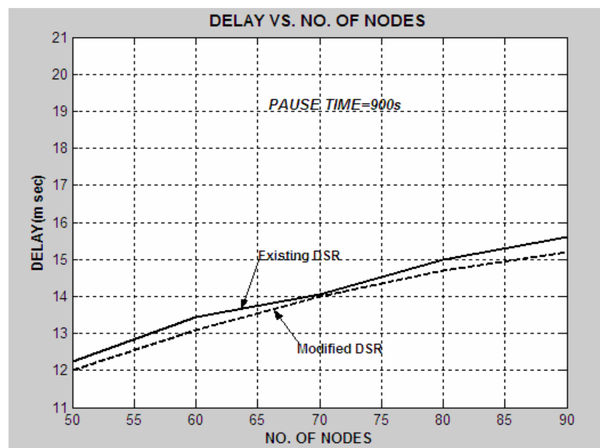

Figure.14 Delay Vs. No. Of nodes for a pause time of 900 s

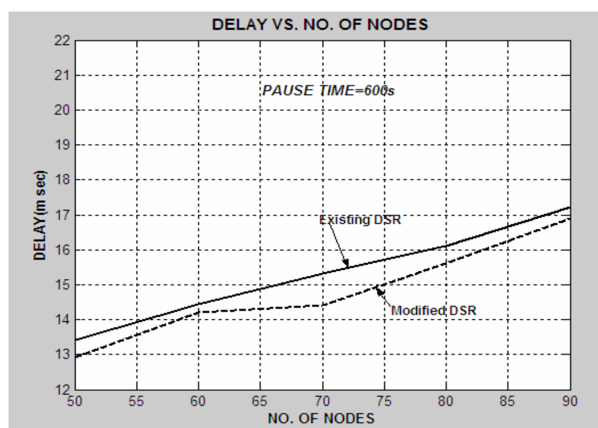

Figure.15 Delay Vs. No. Of nodes for a pause time of 600 s

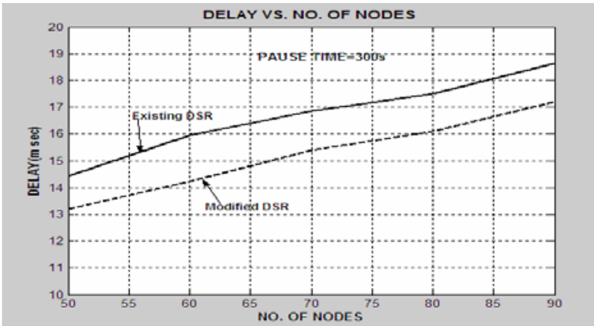

Figure.16 Delay vs. No. Of nodes for a pause time of 300 s

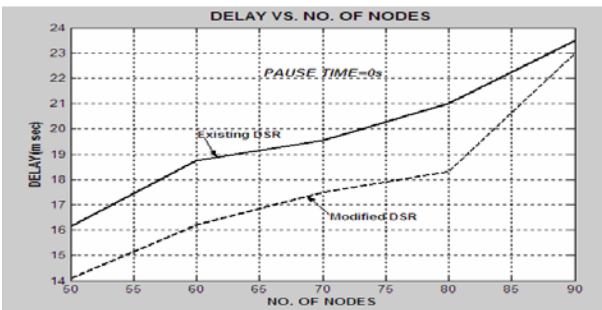

Figure.17 Delay Vs. No. Of nodes for a pause time of 0 s

The end-to-end delay is the time taken by a data packet to reach destination from the source. As the number of nodes increases, the complexity of the network increases and hence the end-to-end delay increases. As the pause time decreases, the mobility increases, which increases the probability of link failures and hence the end-to-end delay increases. In MDSR, the header of the data packet is reduced and the route cache is limited to contain the addresses of only the previous node, source and destination nodes which improve the processing capacity of the nodes. This reduces the processing time of the nodes which in turn reduces the end-to-end delay when MDSR is compared to existing DSR.

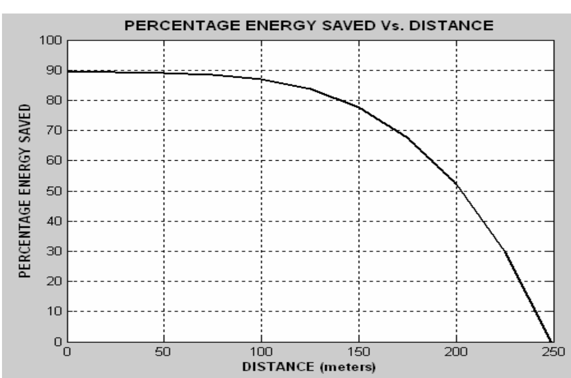

Figure.18 Energy consumption variation with respect to Distance of separation between the nodes

Figure.18 shows the change in the percentage energy saving in accordance with the distance between the adjacent nodes for the modified DSR .It is observed that more energy is saved when the distance of separation is less and hence, an effective energy management is obtained in the modified DSR while in the existing DSR there is no energy management since the transmitting energy is constant regardless of the distance between the adjacent nodes.

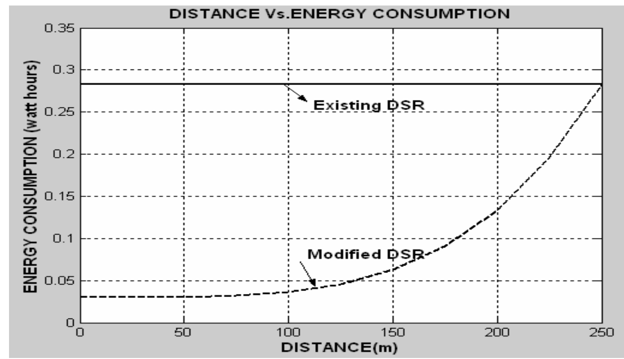

Figure.19 Percentage energy saving with respect to the distance between the adjacent nodes for energy efficient MDSR compared to DSR

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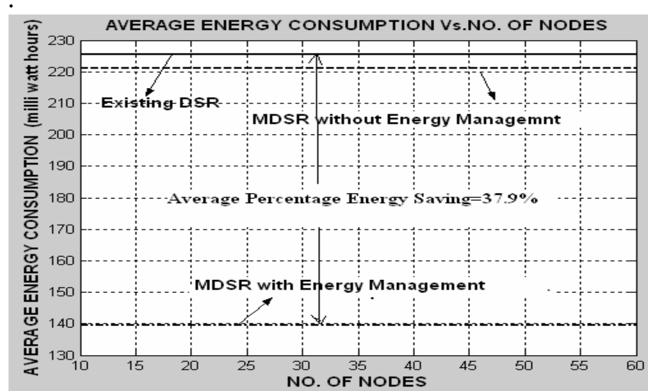

Figure.20 Comparison of existing DSR, MDSR without energy management and MDSR with energy management

In Figure.19 it is observed that irrespective of the number of nodes in the network, the modified DSR shows an average percentage energy saving of 37.9 % in comparison to the existing DSR .This efficient energy saving results due to the reduction in the number of control packets and also due to the variation of the transmit power between two nodes as a function of the distance between the adjacent nodes rather than the constant power used for transmission between nodes irrespective of the distance between them as in the existing DSR.

Figure20 shows a comparison between the existing DSR, modified DSR before energy management and MDSR after energy management for varying network densities. It is observed that MDSR due to overhead and delay reduction gives a better energy management than the existing DSR but MDSR with energy management still enhances the energy consumption. It may also be seen that the power is almost independent of the density of the network connections in all the three cases. Thus it may be justified that the MDSR after energy management becomes an energy efficient protocol for mobile ad hoc networks.

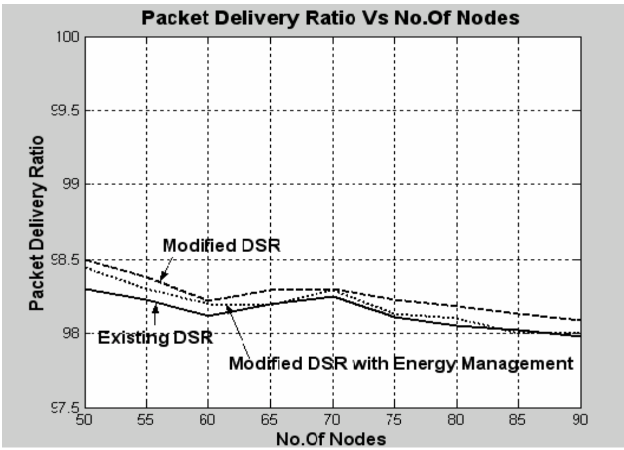

Figure.21Packet Delivery Ratio For Energy Efficient MDSR Compared to DSR

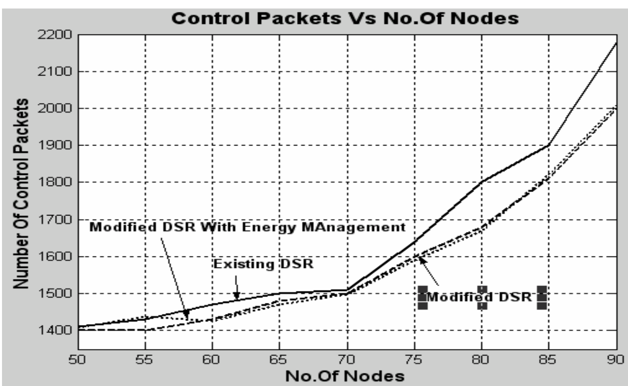

Figure.22 Number Of Control packets For Energy Efficient MDSR compared to DSR

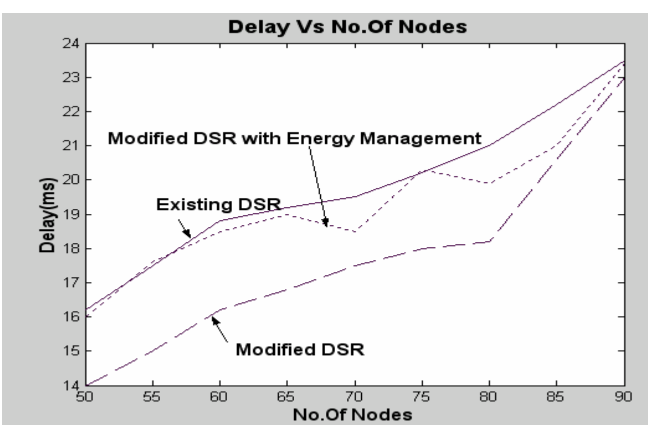

Figure.23 Comparison Of Delay for Energy Efficient MDSR,MDSR and Existing DSR

Figure21,Figure.22 and Figure23 show the comparison among exiting DSR, Modified DSR and Modified DSR with energy management for packet delivery ratio, number of control packets and delay. There is no much change in packet delivery ratio before energy management and after energy management when number of nodes is less in network. As number of nodes increases PDR has decreased and same as existing DSR. Regarding the number of control packets there is no significant change. Delay has increased after incorporation of energy management.

5. CONCLUSIONS

It is observed that the modifications brought about in the existing DSR reduces the end to end delay and the number of control packets which is the sum of Route Request, Route Reply and Route Error packets while it is observed that the modifications do not reduce the packet delivery ratio. The average percentage energy saved per node is found to be 37.9 %.Thus there is an enhancement of energy management in the DSR protocol due to the modifications made and hence it can be considered a energy efficient protocol.

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