Power Consumption Control in MANETs

D. Sharath, Shivashankar, G. Devaraju and Dr.H.N. Suresh

***Abstract*---** *A few reasons for energy management in MANETs are limited energy of the nodes, difficulties in replacing the batteries, lack of central coordination, constraints on the battery source, selection of optimum transmission power, and channel utilization. Finally at the network layer, issues which are open areas, designing of an efficient routing algorithm that increases the network lifetime by selecting an optimal relay node. The prime concern of this paper is to develop an efficient routing protocol for the adhoc networks which may take care of energy needs and as well as proper handling of real and non real time data as per their need. This paper proposes a new scheme called Power Efficient Routing DSR (PERDSR) to improve existing on-demand routing protocols by introducing the Power efficient scheme in whole Mobile Adhoc Network (MANET). Some multi-path routing algorithm in MANET, simultaneously send information to the destination through several directions to reduce end-to-end delay. In all these algorithms, the sent traffic through a path affects the adjacent path and unintentionally increases the delay due to the use of adjacent paths. Because, there are repetitive competitions among neighboring nodes, in order to obtain the joint channel in adjacent paths. The scheme establishes quick adaptation to distributed processing, dynamic linking and low processing at all times. This scheme uses the concept of Power awareness among route selection nodes by checking power status of each node in the topology which insures fast selection of routes with minimal efforts and faster recovery. In route discovery phase, PERDSR selects the bandwidth and energy constraints are built into the DSR route discovery mechanism. The main goal of PERDSR is not only to extend the lifetime of each node, but also to prolong the lifetime of each connection. Using the ns-2 simulator, we compared PERDSR against MMBCR and DSR protocols.*

***Index Terms*---** *MANET, PERDSR, Network Lifetime, Packet Delivery Ratio*

I. Problem Definition and Introduction

A mobile ad hoc network (MANET) is a self-configuring infrastructureless network of mobile devices connected by wireless. *Ad hoc* is Latin and means "for this purpose". Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. MANETs are a kind of wireless ad hoc networks that usually has a routable networking environment on top of a Link Layer ad hoc network. The growth of laptops and 802.11/Wi-Fi wireless networking have made MANETs a popular research topic since the mid-1990s. Many academic papers evaluate protocols and their abilities, assuming varying degrees of mobility within a bounded space, usually with all nodes within a few hops of each other. Different protocols are then evaluated based on measure such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput etc.

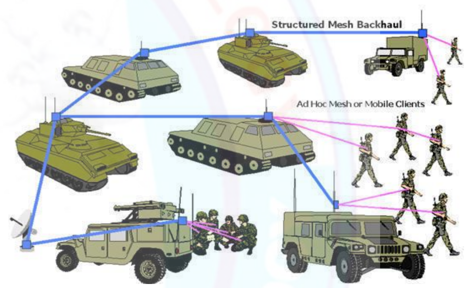

Fig. 1: Example of Ad Hoc Network

Fig. 1 Shows that Ad-hoc Networks are Self-Organizing Multi-Hop Wireless Networks

"Ad Hoc" is actually a Latin phrase that means "for this purpose." It is often used to describe solutions that are developed on-the-fly for a specific purpose. In computer networking, an ad hoc network refers to a network connection established for a single session and does not require a router or a wireless base station. Basically, an ad hoc network is a temporary network connection created for a specific purpose (such as transferring data from one computer to another). If the network is set up for a longer period of time, it is just a plain old local area network (LAN).

A. Routing Protocols

Routing protocols between any pair of nodes within an ad hoc network can be difficult because the nodes can move randomly and can also join or leave the network. This means that an optimal route at a certain time may not work seconds later. Discussed below are three categories that existing ad-hoc network routing protocols fall into:

D. Sharath, M. Tech. 2nd Sem, Dr.AIT, Bangalore, India. E-mail:sharathd006@gmail.com
Shivashankar, Dr.AIT, Bangalore, India. E-mail: nshivu_ss@rediffmail.com
G. Devaraju, Dr.AIT, Bangalore, India. E-mail: g_devaraju_05@yahoo.co.in
Dr.H.N. Suresh, BIT, Bangalore, India. E-mail: hn.suresh@rediffmail.com

1. Table Driven Protocols: able Driven Routing Protocols, also known as Proactive Protocols, work out routes in the background independent of traffic demands. Each node uses routing information to store the location information of other nodes in the network and this information is then used to move data among different nodes in the network. This type of protocol is slow to converge and may be prone to routing loops. These protocols keep a constant overview of the network and this can be a disadvantage as they may react to change in the network topology even if no traffic is affected by the topology modification which could create unnecessary overhead. Even in a network with little data traffic, Table Driven Protocols will use limited resources such as power and link bandwidth therefore they might not be considered an effective routing solution for Ad-hoc Networks. Fisheye State Routing is an example of a Table Driven Protocol.

2. On Demand Protocols: On Demand Routing Protocols, also known as Reactive Protocols, establish routes between nodes only when they are required to route data packets. There is no updating of every possible route in the network instead it focuses on routes that are being used or being set up. When a route is required by a source node to a destination for which it does not have route information, it starts a route discovery process which goes from one node to the other until it arrives at the destination or a node in-between has a route to the destination. On Demand protocols are generally considered efficient when the route discovery is less frequent than the data transfer because the network traffic caused by the route discovery step is low compared to the total communication bandwidth. This makes On Demand Protocols more suited to large networks with light traffic and low mobility. An example of an On Demand Protocol is Dynamic Source Routing.[9]

3. Hybrid Protocols: Hybrid Routing Protocols combine Table Based Routing Protocols with On Demand Routing Protocols. They use distance-vectors for more precise metrics to establish the best paths to destination networks, and report routing information only when there is a change in the topology of the network. Each node in the network has its own routing zone, the size of which is defined by a zone radius, which is defined by a metric such as the number of hops. Each node keeps a record of routing information for its own zone. Zone Routing Protocol (ZRP) is an example of a Hybrid routing protocol.[10]

B. Applications in Ad Hoc Network

Mobile ad hoc networks are the future of wireless networks. Why? Because they're practical, versatile, simple, easy to use and inexpensive! We will be living in a world where our network instantly updates and reconfigures itself to keep us connected anywhere we go. These networks provide a new approach for wireless communication and by operating in a license free frequency band prove to be relatively inexpensive. With the current trend of society's demand for information at out fingertips, we will see our future living environments requiring communication networks between the many devices we use in day to day living, allowing them to talk to each other.

For example devices like personal digital assistants and mobile phones being able to receive instant messages from a home device. Such as a refrigerator sending a message to a PDA to update its shopping list; notifying that it's run out of milk. Or washing machines and ovens sending a report to say the clothes are finished or the chicken's cooked. Like wise, in education ad hoc networks may be deployed for student laptops interacting with the lecturer during classes.

Also wireless public access for dense urban areas (Nokia RoofTopT): A wireless broadband solution for residential markets, based on a multi-hop Ad-Hoc (mesh) networking

Or similarly, ad hoc networks for cars, sending instant traffic reports and other information. Sensors and robots forming multimedia network that allows remote visualization and control, multiple airborne routers (from tiny robots to blimps) automatically providing connectivity and capacity where needed (e.g., at a football game); an ad hoc network of spacecrafts around and in transit between the Earth and Mars.

II. SOME OF THE RELATED RESEARCH WORK

A few reasons for energy management in MANETs[1-3] are Limited Energy of the nodes, Difficulties in Replacing the Batteries, Lack of Central Coordination, Constraints on the Battery Source, Selection of optimum Transmission Power, and Channel utilization. Finally at the network layer, issues which are open areas, designing of an efficient routing algorithm that increases the network lifetime by selecting an optimal relay node. The prime concern of this paper is to develop an efficient routing protocol for the adhoc networks which may take care of energy needs and as well as proper handling of real and non real time data as per their need. The power at the network layer can be conserved by reducing the power consumed for two main operations, namely, communication and computation. The communication related power consumption[4-5] is mainly due to the transmit-receive module present in the nodes. Whenever a node remains active, that is, during transmission or reception of a packet, power gets consumed. Even when the node is not actively participating in communication[7-8], but is in the listening mode waiting for the packets, the battery keeps discharging. The computation power refers to the power spent in calculations that take place in the nodes during routing and power adjustments. The following section discusses some of the power-efficient routing algorithms[13]. In general, a routing protocol which does not require large tables to be downloaded or greater number of calculations is preferable, also, reducing the amount of data compression that is done before transmission may decrease the communication power buy ultimately increases the number of computation tasks. Hence a balance must be reached between the number of computation and communication tasks performed by the node, which are contradictory to each other.

Many research efforts have been devoted for developing power aware routing protocols. Different approaches can be applied to achieve the target [10-11]. Transmission power control and load distribution are two approaches to minimize the active communication energy, and sleep/power-down

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mode is used to minimize energy during inactivity. The primary focus of the above two approaches is to minimize energy consumption of individual node. The load distribution method balances the energy usage among the nodes and maximizes the network lifetime by avoiding over-utilized nodes at the time of selecting a routing path. In transmission power control approach, stronger transmission power increases the transmission range and reduces the hop count to the destination, while weaker transmission power makes the topology sparse, which may result in network partitioning and high end-to-end delay due to a larger hop count.

III. DESIGN AND IMPLEMENTATION OF PROPOSED PERDSR

A. *Existing Dynamic Source Routing (DSR) Protocol Mechanism*

DSR is a routing protocol designed for MANETs. It is a source-routing protocol and composed of two main mechanisms: route discovery and route maintenance. In the process of route discovery, a route request is send from a node *S* to a node *D* by broadcast, only when *S* attempts to send a packet to *D* and has no available route to *D* in its route cache. So the node *S* does not always know a route to *D* and the route request proceeds completely on-demand to reduce the routing overhead. Intermediate nodes piggyback their ID into the source route included in the route request message and relay that route request by broadcast, if they do not know an available path to *D*. When the route request reaches *D* or some intermediate node which knows the route to *D* (by checking its route cache), a route reply is uni-casted to *S* with the complete path from *S* to *D*. Nodes could receive the same route request more than one time, but only the first one will be handled. Node *S* could also receive multiple routing replies. The first arrival route is used immediately. If in the following routing replies, a shorter path from *S* to *D* is included, the new route will be used instead of the old one. If *S* cannot receive a route reply after a period time, the route request will be resent until a path to *D* is finally discovered. Route maintenance is the mechanism by which node *S* is able to detect, while using a source route to *D*, if the network topology has changed such that it can no longer use its route to *D* because a link along the route no longer works. When route maintenance indicates a source route is broken, *S* can attempt to use any other route it happens to know to *D*, or can invoke route discovery again to find a new route for subsequent packets to *D*. Route maintenance is used only when *S* is actually sending packets to *D*.

B. *Min-Max Battery Cost Routing Mechanism*

Min-Max Battery Cost Routing (MMBCR), which considers the residual battery power capacity of nodes as the metric in order to extend the nodes lifetime. MMBCR allows the nodes with high residual capacity to participate in the routing process more often than the nodes with low residual capacity. In every possible path, there exists a weakest node which has the minimum residual battery capacity. Hence, MMBCR tries to choose a path whose weakest node has the maximum remaining power among the weakest nodes in other possible routes to the same destination. However, MMBCR does not guarantee that the total transmission power is minimized over a chosen route.

C. *Implementation of Proposed PERDSR Mechanism*

The suggested algorithm has been designed and implemented based on DSR algorithm. The DSR algorithm is considered to be in the class of on-demand routing algorithms in which routing process takes place hop by hop. In this way, each node has a path table in which received packet's information are saved.

As it is mentioned in the introduction, the proposed algorithm tries to discover zone disjoint paths between source and destination in order to send information simultaneously. If there is possibly no neighboring between two nodes in two distinct paths, the paths are called area distinct. Briefly, the proposed algorithm counts the number of active neighbors for each path, and finally it chooses some paths for sending information in which each node has lower number of active neighbors all together. Here, active neighbors of a node are defined as nodes that have previously received the RREQ. There is this possibility that source and destination choose another path with nodes to exchange information; thus, information exchanging depends on this path. In fact, these two nodes are on two disjoint but adjacent paths.

D. *Power Aware Model in PERDSR*

For the purpose of evaluating the effect of overhearing, we modified the ns-2 energy model to account for overhearing. The total amount of energy, $E(n_i)$, consumed at a node n_i is determined as:

$$E(n_i) = E_{tx}(n_i) + E_{rx}(n_i) + N\text{-}1) * E_0(n_i) \qquad (1)$$

where E_{tx}, E_{rx}, and E_0 denote the amount of energy expenditure by transmission, reception, and overhearing of a packet, respectively. *N* represents the average number of neighboring nodes affected by a transmission from node n_i. eq.(1) implies that when the network is more dense, the packet overhearing causes more energy consumption.

When a node is about to send data to a specific destination and it does not find a valid path to its destination, the node runs the path discovery process by producing and sending RREQ packet to its neighbors. In this RREQ packet, the initial value of zero will be assigned to ActiveNeighborCount field. Therefore, source neighbor nodes receive RREQ packet, set their names as the founders of one of the paths and reversely put the path specifications into the path table. But before resending the RREQ packet, the neighbor nodes request query path from their neighbors. Then they increase the value of ActiveNeighborCount in RREQ packet for those neighbors which have a positive answer to this question. For this query, nodes use some packets with titles of RREQ_Query and RREQ_Query_Reply. Actually, the query node sends the RREQ_Query packet to its neighbors and after specific time period (which is calculated by a clock) waits for neighbors' responses to the question. On the other hand, all neighboring nodes are required to search the specification of RREQ in

RREQ_Seen table after receiving the query packet. If neighboring nodes have already observed this RREQ, they reply a positive response to the query node. The response to query is performed by the production and transmission of RREQ_Query_Reply packet. Finally, after the time expiration, the node that has created the query broadcasts the RREQ packet to continue the discovery process.

Once again, we analyze the behavior of queried node. Since the repeated RREQ packets aren't removed in discovery of multiple paths, it is possible for a node to receive the RREQ packet for the second time. Therefore, it initiates the query process to discover new possible neighbors for the second time to. But obviously, only new neighbors need to consider this query important and old neighbors shouldn't answer to this repeated query. Thus, those nodes that receive the query packet keep the address and details of the query node and the queried RREQ packet in Query_Seen table. If a node receives a query packet for the first time, it sends a RREQ_Query_Reply packet to inform query node after recording a query's specifications. But if this query has already been received from the same node, it is not noticed.

Suggested algorithm at source node:

1. If you have data to send and you don't have a valid path to that destination, broadcast the RREQ packet.
2. Wait for RREP to arrive.
3. In case of receiving the first RREP, wait for a while and then choose those paths among received paths that have the lowest number of neighbors. After wards, start sending data via this path.

Suggested algorithm at destination node:

1. Send the corresponding path PPEP for all the nodes that you have received the RREQ packets.

Suggested algorithm at intermediate node:

1. If you received the RREQ packet and this packet is acceptable, do the following steps.

Otherwise, dismiss the packet.

a. Put this packet's specification into the RREQ_Seen table.

b. Prepare the RREQ_QUERY packet and assign it a value.

c. There is a question on this packet that asks: Have you seen such a request packet before?

d. Send the RREQ_Query packet to your neighbors

e. Wait a specific period of time for your neighbors to reply

f. Increase the ActiveNeighborCount with regard to the number of accepted replies.

g. Rebroadcast the RREQ packet

2. When you received the RREQ_Query packet, perform the following actions:

a. With regard to the RREQ_Seen table, if you have not seen this RREQ before, dismiss the packet and don't consider it.

b. According to the REQ_Seen table, if you have seen this RREQ before, inform the query node by sending a RREQ_Query_Reply packet then add one unite to the After_A_N_C field of the corresponding RREQ in its RREQ_Seen table.

3. If you have received the RREQ_Qeury_Reply packet, add one unite to this RREQ's AvtiveNeighborCount field.

4. When you receive the RREP packet, add the corresponding after_a_n_c to activeneighborcount field of RREP packet and send it.

E. Route Selection

When RREQ receives at the neighbour node, it forwards a RREP packet back to the source. Otherwise, it rebroadcasts the RREQ. If they may receive a processed RREQ, they discard the RREQ and do not forward it. If RREQ of multiple paths are received at source node, it stored by the hop count value. In PERDSR the route is selected on the basis of minimum number of hops. But the PERDSR protocol select the best path by sorting multi-route in descending order of nodal residual energy and bandwidth and the data packets are forwarded by using the maximal nodal residual energy. The extended Route Request packet of PERDSR is shown in table 1.

Table 1: Extended Route Request Message

S A	D A	Seq. No	Hop Count	Time out	Band width	Min_Energy

In PERDSR routing discovery process, the source node in the network sends the extended Route Request (RREQ) message to the destination node through number of intermediate nodes. The data transmission in wireless network can be directly within one hop or through number of intermediate nodes. The extended Route Request (RREQ) message contains the source and destination node IP address, Advertised Hop count value, Timeout value, Bandwidth of the link (Bandwidth) and Minimum Energy value. The computed bandwidth and minimal nodal energy is greater than the threshold value of bandwidth and energy then only the RREQ message forward to the next neighbor node otherwise it discarded. When the RREQ message arrive at next node, the bandwidth and minimal nodal energy is updated into the route list entries.

IV. ANALYSIS OF EXPERIMENTAL RESULTS

For evaluating PERDSR, simulation results are obtained by experiments with different energy levels, different traffic loads and different movement patterns of nodes. In the first set of experiments, every node is given a battery with full capacity initially. In this scenario, no nodes turn off due to running out of energy. This is to test the routing performance of PERDSR in a regular network scenario. A total of 300 CBR streams are generated within the 1500-second simulation time.

Extensive simulations were conducted using NS-2.33. The simulated network consisted of 100 nodes randomly scattered in a 1000x1000m area at the beginning of the simulation. The tool *setdest* was used to produce mobility scenarios, where nodes are moving at six different uniform speeds ranging between 0 to 25 m/s. Table 2shows the simulation parameter setting for the protocol evaluation. These were generated using the tool *PERDSR.tcl*, with the following parameters:

Table 2: Simulation Parameters

Topographical Area	1000X1000
Channel type	Wireless Channel
Radio-propagation model	TwoRayGround
Network interface type	Phy/WirelessPhy
MAC type	802_11g
txPower	0.2W
rxPower	0.1W
idlePower	0.001W
Initial energy of a Node	2000J
Routing protocols	DSR/MMBCR/PERDSR
Number of mobile nodes	100
Mobility	0 to 25m/s

A. *Power Aware Metrics*

1) *Packet Delivery Ratio*

The ratio of the data packets delivered to the destination to those generated by CBR sources. This metric illustrates the effectiveness of best effort routing protocols. This performance measure also determines the completeness and correctness of the routing protocol. If F is fraction of successfully delivered packets, C is total number of flows, f is id, R is packets received from f and T is transmitted from f, then F can be determined by

$$F = \frac{1}{C}\sum_{f=1}^{c}\frac{R_f}{T_f} \qquad (2)$$

Packet delivery ratio for PERDSR, MMBCR and DSR protocols is shown in fig.2, where speed of mobility taken into account is up to 50 meters/second with a pause time of 10 seconds. At low speeds of nodes, all three protocols demonstrate higher throughput. However, higher speeds may lead to frequent changes in links and probable link failures, ultimately reducing throughput. It can be observed from figure 1, that packet delivery ratio in PERDSR is 95%, MMBCR is 86% and DSR performs 76% for high mobility up to 100 m/s.

Packet delivery ratio with respect to number of nodes for different mobile speeds is represented in fig.3. In fig.3, for mobile speed of 25 m/s, PERDSR shows 65% improvement over DRS and MMBCR protocols. Please note that in the simulation, number of nodes is set up to 100. As number speed of mobility increases, packet delivery ration decreases. But PERDSR maintains little bit constant packet delivery ration than DSR and MMBCR.

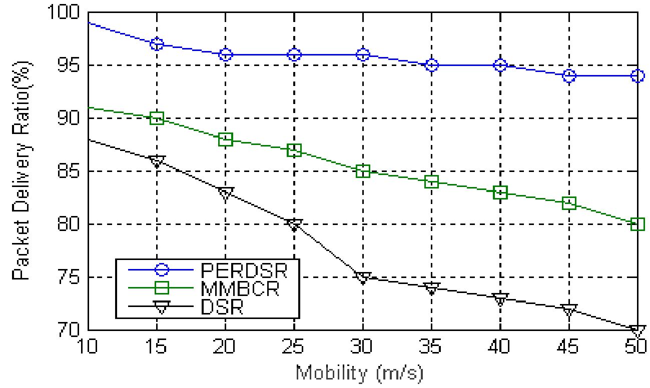

Fig. 2: Effect of Mobility on Packet Delivery Ratio

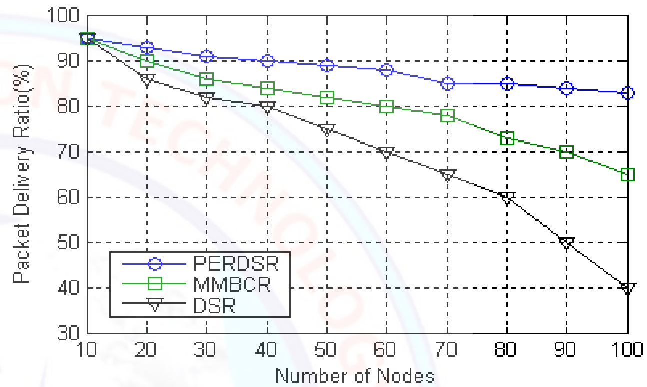

Fig. 3: Effect of Number of Node on Packet Delivery Ratio VS mobility 10 m/s

2) *End-to-End Delay*

Average end-to-end delay is the delay experienced by the successfully delivered packets in reaching their destinations. This is a good metric for comparing protocols. This denotes how efficient the underlying routing algorithm is, because delay primarily depends on optimality of path chosen.

$$Average\ End\ to\ End\ delay = \frac{1}{S}\sum_{i=1}^{s}(r_i - s_i) \qquad (9)$$

where S is number of packets received successfully, r_i is time at which packet is received and s_i is time at which it is sent, i is unique packet identifier.

Fig.4 shows the performance of the end-to-end delay under various mobility speeds. DSR had higher end-to-end delay than the MMBCR and PERDSR because DSR had a longer routing path from the source node to the destination node. However, PERDSR can found the more stable path. This is because our reliable path scheme will increase the end-to-end delay.

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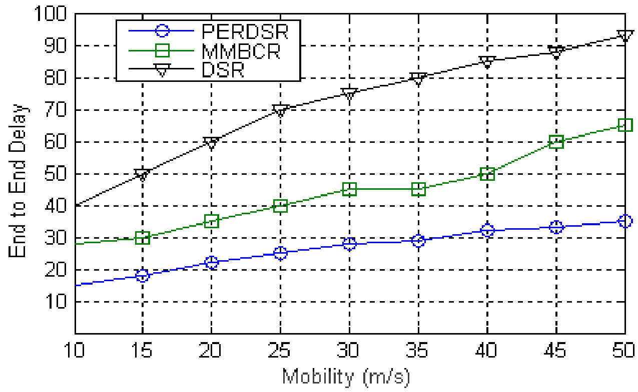

Fig. 4: End-to-End Delay vs. Mobility Speed

3) Node Lifetime

In MANET, nodes may happen to die out. Fig.5 shows the number of nodes which die at some time instants using PERDSR, MMBCR and DSR protocols. It can be clearly noticed that nodes in DRS die earlier than PERDSR and MMBCR. It happens during forwarding of the query packet, when the power level of an intermediate node is found to be less than that mentioned in the power aware extension for power in the query packet. As data packet and time increases, due to lack of battery power number of mobile nodes dies.

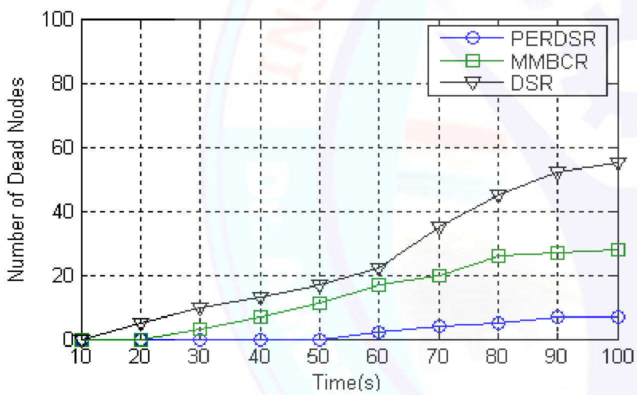

Fig. 5: Number of Nodes Dead Versus Time

V. CONCLUSION

Development of the efficient power aware protocol is the need of today's ad hoc networks. Although developing battery efficient systems that have low cost and complexity, remains a crucial issue. In order to facilitate communication within a mobile ad hoc network, an efficient routing protocol is required to discover routes between mobile nodes. Power is one of the most important design criteria for ad hoc networks as batteries provide limited working capacity to the mobile nodes. Power failure of a mobile node not only affects the node itself but also its ability to forward packets on behalf of others and hence affects the overall network lifetime. The performance of PERDSR protocol increases the network life time by 60 to 70% as compared DSR and MMBCR and its counterparts and causes slight overhead in route selection initially. Overall, we conclude that our mechanism demonstrates significant benefits at high traffic and high mobility scenarios. We expect that these scenarios will be common in ad hoc networking applications.

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