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A Review of Power Aware Routing in Wireless Ad-hoc Networks

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***Abstract*— This Development of the efficient power aware protocol is the need of today's adhoc networks. Although developing battery efficient systems that have low cost and complexity, remains a crucial issue. In order to facilitate communication within a mobile adhoc network, an efficient routing protocol is required to discover routes between mobile nodes. Power is one of the most important design criteria for adhoc 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. Much research efforts have been devoted to develop energy aware routing protocols. In this paper we propose an efficient algorithm, which maximizes the network lifetime by minimizing the power consumption during the source to destination route**
Establishment.

***Keywords*—Power, Ad hoc networks, Routing Protocols, Network Lifetime.**

I. INTRODUCTION

A mobile ad hoc network (MANET) [1] is an autonomous system of mobile nodes (and associated hosts) connected by wireless links. Each node operates not only as an end-system, but also as a node to forward the packets. The nodes are free to move about and organize themselves into a network. The main application of mobile ad hoc network is in emergency rescue operations and battlefields. This paper addresses the problem of power awareness routing to increase lifetime of overall network. Since nodes in mobile ad hoc network can move randomly, the topology may change arbitrarily and frequently at unpredictable times. Transmission and reception parameters may also impact the topology. Therefore it is very difficult to find and maintain an optimal power aware route. In this work a scheme has been proposed to maximize the network lifetime and minimizes the power consumption during the source to destination route establishment. Proposed work is aimed to provide efficient power aware routing considering real and non-real time data transfer. Rest of the paper is organized as follows: Section 2 gives an idea of problem and discusses the study on the related work. In section 3 working of the proposed power aware routing scheme have been given in detail. Section 4 presents simulation framework and results and Section 5 concludes the paper.

II. PROBLEM DEFINITION AND RELATED WORK

The nodes in an adhoc network are constrained by battery power for their operation. To route a packet from a source to a destination involves a sufficient number of intermediate nodes.

Hence, battery power of a node is a precious resource that must be used efficiently in order to avoid early termination of a node or a network. Thus, energy management is an important issue in such networks. Efficient battery management [9-11], transmission power management [12-14] and system power management [15-16] are the major means of increasing the life of a node. These management schemes deals in the management of energy resources. by controlling the early depletion of the battery, adjust the transmission power to decide the proper power level of a node and incorporate the low power strategies into the protocols used in various layers of protocol stack. There are so many issues and solutions which witnesses the need of energy management in adhoc wireless networks. 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 are as, 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 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, 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. 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 [2]. Transmission power control and load distribution are two approaches to minimize the active communication energy, and sleep/power-down 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. Different energy-related metrics that have been used to determine energy efficient routing path: Energy consumed/packet, Time to network partition, Variance in node power levels, Cost/packet, and Maximum node cost. Some research proposals, which are based on transmission power control approach, are discussed in [3-6]. Flow argumentation Routing (FAR) [3] which assumes a static network and finds the optimal routing path for a given source-destination pair that minimizes the sum of link costs along the path, Online Max-Min (OMM) [4] which achieves the same goal without knowing the data generation rate in advance. Power aware Localized Routing (PLR) [5] is a localized, fully distributed energy aware routing algorithm but it assumes that a source node has the location information of its neighbors and the destination and Minimum Energy Routing (MER) [6] addresses issues like obtaining accurate power information, associated overheads, maintenance of the minimum energy routes in the presence of mobility and implements the transmission power control mechanism in DSR and IEEE 802.11 MAC protocol. Few proposals to consider load distribution approach are given in [7, 8]. Localized Energy Aware Routing (LEAR) Protocol [7] is based on DSR but modifies the route discovery procedure for balanced energy consumption. In LEAR, a node determines whether to forward the route-request message or not depending on its residual battery power (Er). Conditional max-min battery capacity routing (CMMBCR) Protocol [8] uses the concept of a threshold to maximize the lifetime of each node and to use the battery fairly.

III. POWER AWARE ROUTING: PAR

The proposed algorithm maximizes the network lifetime & minimizes the power consumption during the source to destination route establishment. This algorithm takes special care to transfer both real time and non-real traffic by providing energy efficient and less congested path between a source and destination pair. Algorithm focuses on 3 parameters:

1) Accumulated Energy of a path

$$E_{ij} = \sum_{i=1}^{j-1} E_i \qquad (1)$$

Ei is the residual energy of an intermediate node *i* and *Eij* is the total energy of a path from node *i to* node *j*

2) Status of Battery Lifetime (*B_S)*

a. Non Real Time (*NRT*)

b. Real time (*RT*).

3.1 Parameters on each node:

Each node has 3 variables: *Node_ID*, Battery Status (*B_S*) and Traffic Level (*T_L*), *Number of Weak Nodes (WNs).*

Battery status is further divided into 3 categories:

1) If (Battery Status < 20%) Then Set *B_S* = 1

2) If (20% <=Battery Status <=60%) Then Set *B_S* = 2

3) If (Battery Status >=60%) Then Set *B_S* = 3.

3.2 Parameters to Concern during Route Search:

At the time of route discovery, a route request (RREQ) packet broadcasted by the source. The header of the RREQ packet includes <source_id, destination_id, *T_O_L* (type of data to be transfer), *T_B_S* (Total Battery Status), *T_T_L* (Total Traffic Level), *WNs (number of weak nodes)* and *Node_IDs*.

3.3 Calculation of Total Battery Status (T_B_S)

Initially *T_B_S* = 0 and *WN=0* at source node. As RREQ packet propagates along the path, *T_B_S* is updated at each intermediate node *i* as follows:

If (*B_Si* == 3) *Then T_B_S* = *T_B_S* + 3

Else-if (*B_Si* == 2)

Then T_B_S = *T_B_S* + 1

Else-if (*B_Si* == 1)

WN= WN + 1

Here WN represents a weak node which has the energy less than 20%.

3.4 Calculation of Total Traffic level (T_T_L)

1) At a source node, Initially *T_T_L* = 0.

2) At the time of route discovery, add traffic status of each intermediate node to *T_T_L*. Here traffic level (T_L) of a node is considered as number of packets buffered in the interface queue of the node.

3.5 Route Selection Criteria at Destination Side

The destination waits for a threshold time (T*th*) after a RREQ packet arrives. During that time, the destination determines the link status ratio of the route for every arrived RREQ packet. Destination stores all possible route request for a certain amount of time. When the complete timer expires the destination node selects the route with the required link status ratio and replies for a path accordingly. Here link status ratio of a path is calculated using equation (2):

$$R = E_{ij} / H_n \qquad (2)$$

Where is the total energy of a path from node i to node j as given in equation (1). Is number of intermediate hops along the path *.Eij Hn*

3.6 Energy Consumption Model

Energy consumption of a node after time t is calculated using equation (3):

$$E_{c(t)} = N_t * \alpha + N_r * \beta \qquad (3)$$

Where

Ec(*t*) , energy consumed by a node after time t.

Nt , no. of packets transmitted by the node after time t.

Nr , no. of packets received by the node after time t.

α and β are constant factors having a value between *0* and *1*.

If E is the initial energy of a node, the remaining energy of a node at time t, is calculated using equation (4):

$$E_{r(t)} = E - E_{c(t)} \qquad (4)$$

Algorithm: PAR

If $(T\_O\_L == NRT)$
Let N different values of R are received, where $R \geq 1$

if $(N == 0)$
Send negative acknowledgement to the source that path can not be established.

else-if $(N == 1)$
Acknowledge the source with this path.

else-if $(N > 1)$
if (WN= =0)
Select the path with $\min\{T\_T\_L\}$, acknowledge the source with the selected path.
Otherwise,
Select a path with less no. of WNs.

else-if $(T\_O\_L == RT)$

Let N different values of R are received, where $R \geq 2$

If $(N == 0)$
Send negative acknowledgement informing that no such path is possible for RT. Also inform about the availability of best NRT path. If source will be interested, it may use it for forwarding its data.

else-if $(N == 1)$
Acknowledge the source with this path.

else-if $(N > 1)$
Select the path with Min $\{T\_T\_L\}$ and acknowledge the source with the selected path.

Value of Link Status Ratio R has been chosen more than or equal to one for NRT and more than or equal to two for RT. These values have been used in simulation after analyzing a lot of examples over different network scenarios. With these values of R , nodes have been used efficiently with different energy status, and paths are selected efficiently to support Real and Non real time traffic.

IV SIMULATION AND RESULTS

The simulation results presented in this paper has been obtained using the *ns-2* simulator (version *ns-2.29*) [17]. Simulations are run over a 1000m * 1000m square flat topology. The number of wireless mobile nodes is fixed to 100. 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. Each of the 100 nodes has a 100 Joules of energy at the start of every simulation, while varying the number of traffic sources from 10 to 90. The corresponding number for traffic connections were 20, 33, 43 and 54.Identical mobility and traffic scenarios are used across the protocol variations.

TABLE 1. Simulation Parameter for PAR, 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
Data Rate	2 Mbps
Transmission Range	250 mtr.
Area	1000*1000 mP[2P]
Packet size	512 byte

A detailed discussion on results over the energy efficiency of the PAR, AODV and DSR is given for different performance metrics as follows.

4.1. 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: Nodes: 100, Pause Time: 0 sec, No. of Sources: 10-90

As Shown in Fig 1Total energy consumption for AODV is less than DSR form low traffic condition to high traffic and the performance of PAR is better than both AODV and DSR as it is consuming less energy as compare to other two protocols for varying number of sources.

Scenario 2: Nodes: 100, Pause Time: 500 sec, Sources: 10-90

A scenario for 100 nodes and 500 pause time has been evaluated for varying no. of sources from 10-90 and the results are shown in fig 2. As fig depicts, in the initial stage of the simulation PAR consume more energy as compare to DSR but later on it has less energy consumption as compare to AODV and DSR, while AODV and DSR do not have a clear edge over other in terms of energy consumption. The smooth curve is obtained for PAR in terms of energy consumption, which shows proper distribution of energy among nodes.

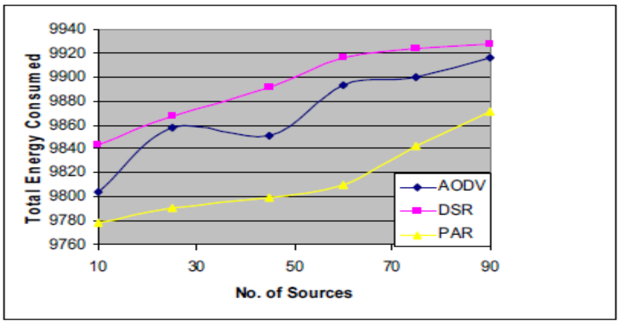

Fig 1 : Total Energy Consumed Vs No. of Sources

4.2. 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; Sources: 10-45, nodes: 100

It can be observed from Fig 3 that for 0 pause time and various no. of sources, a random death of nodes has been observed of the total nodes till the end of simulation run in case of AODV, DSR and PAR. No clear edge can be defined in terms of traffic or number of sources between AODV and DSR but PAR outperforms both the protocols throughout the simulation. As it can be seen in the fig that for less number of sources (10-17). total deaths reported in DSR are more as compare to AODV and PAR but for number of sources (17-22) AODV is poor as there are more dead nodes reported as compare to DSR, PAR is still better. But for all the cases of more than 30 sources at a time DSR is better than AODV as less deaths are reported as compare to AODV. But PAR is good for a large network of 100 nodes in heavy traffic conditions (more than 30 sources).

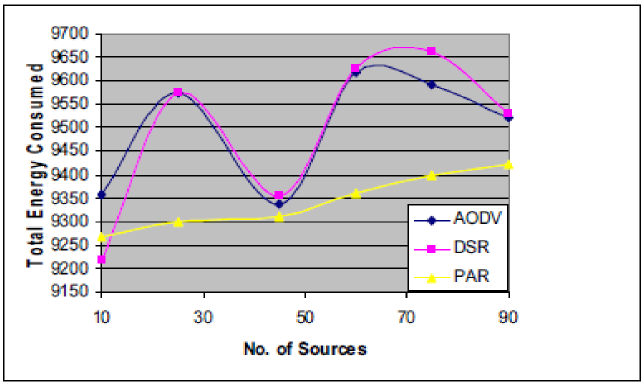

***Fig 2:** Total Energy Consumed for pause time 500 seconds, 100 nodes*

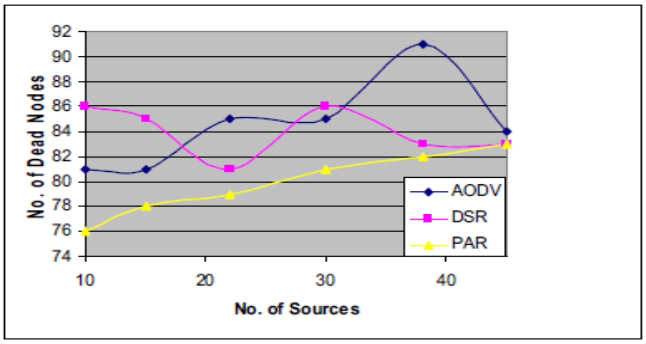

Fig 3: Exhausted nodes for 100 nodes, pause time 0 seconds

4.3. 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.

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

Termination rates of AODV, PAR and DSR is shown in Fig. 5. It can be observed that more deaths are observed in DSR with 0 pause time as compare to all other scenes. Even PAR with 0 pause time is not as effective as DSR and AODV and PAR with both 0 and 500 pause time. But PAR with 500 pause time, termination rate of nodes is quite less as compare to other counterparts, because PAR with 500 pause time is running for more simulation time as compare to others.

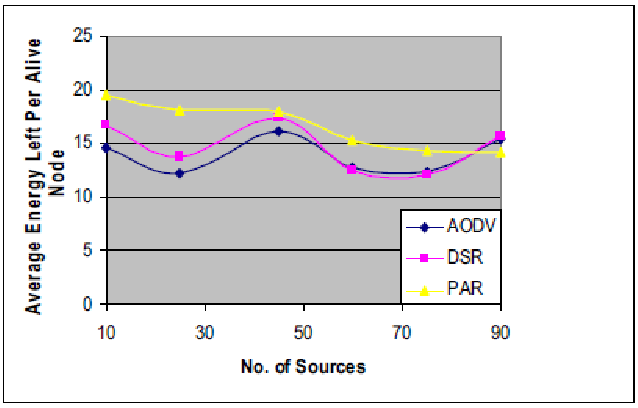

Fig 4: Average Energy Left Per Alive Node for 500 pause time

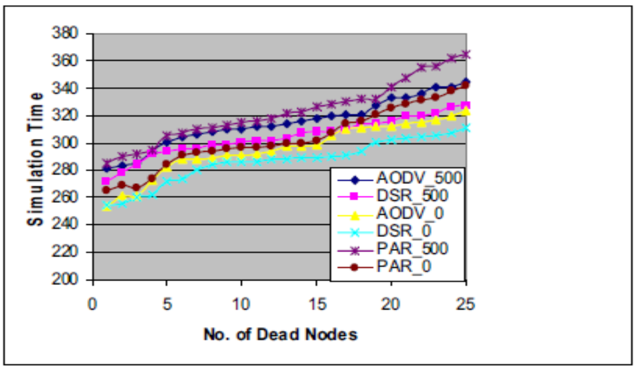

Fig 5: Node Termination rate for pause time 0 and 500 sec, 10 sources.

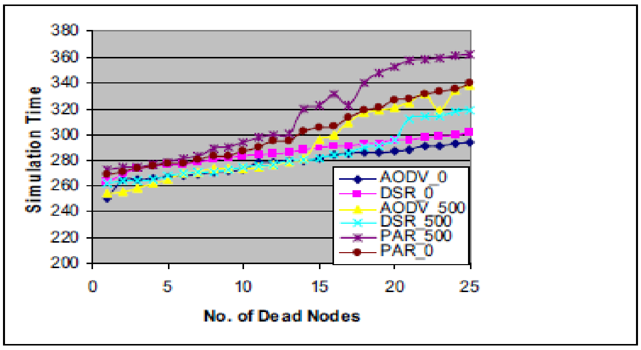

Fig 6: Node Termination rate for pause time 0 and 500 sec, 45 sources.

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

It is evident from Fig. 6 that termination rates of DSR for pause times of 0 & 500 seconds is greater than that of AODV and PAR when the network consist of 45 sources. But in PAR, node termination rate is less as compare to AODV and DSR, with both 0 and 500 pause time. It shows that PAR will run for longer time as compare to other schemes at higher speed and varying number of sources (traffic variation).

V. Conclusion

Energy efficiency is one of the main problems in a mobile ad hoc network, especially designing a routing protocol. The proposed work aims at discovering an efficient power aware routing scheme in MANETs which can support both real and non-real time traffic. Simulation result shows that the proposed scheme PAR is outperforms in terms of different energy related parameters over AODV and DSR even in high mobility scenarios. At the time route selection PAR take care of crucial things like traffic level on the path, battery status of the path, and type of request from user side. With these factors in consideration PAR always select less congested and more stable route for data delivery. Although this scheme can somewhat enhance the latency of the data transfer but it results in a significant power saving and long lasting routes. This scheme is one of its types in adhoc networks which can provide different routes for different type of data transfer and ultimately increases the network lifetime. The process of checking the proposed scheme is on for more sparse mediums and real life scenarios and also for other metrics like Path optimality, Link layer overhead, total energy consumed etc.

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