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Power Sensitive Framework for Energy Efficient Wireless Ad-Hoc Network

Ravinder Singh, Sanjay Gurjar
Department of Electronics & Communication Engineering,
Bhagwant University,
Ajmer, India

Abstract-Ad hoc mobile devices today operate on batteries. Hence, power consumption becomes an important issue. To maximize the lifetime of ad hoc mobile networks, the power consumption rate of each node must be evenly distributed, and the overall transmission power for each connection request must be minimized. In this paper an algorithm known as varying threshold-conditional max/ min battery capacity routing (PAF) is proposed to select a route with minimum total transmission power among the possible routes between a source and a destination. When the battery capacity of all routes goes below the calculated threshold, the route with maximum battery life is selected for transmission, avoiding usage of nodes with least battery capacity. As the threshold gets calculated each time, it has the flexibility to choose the most efficient routing scheme for each transmission. In this paper we compare the performance of existing routing algorithms with our proposed algorithm PAF.

Keywords: Ad hoc network; Power efficiency; Threshold; Network lifetime,

I. INTRODUCTION

Ad-Hoc Networks are multi hop wireless networks with dynamic topological structure. They generally do not employ any form of fixed infrastructure or centralized administration. These types of networks are useful in any situation where temporary network connectivity is needed, such as in disaster relief. In multi-hop wireless ad-hoc networks, designing energy-efficient routing protocols is important because nodes have limited power. In the network each node communicates directly with its neighboring nodes to send a packet to a destination, a node forwards the packet to its neighbor, which in turn forwards it to its neighbor, and so on, until the packet reaches the destination. The partitioning time of the Ad hoc network depends on the transmission power used by the nodes and the battery capacity/willingness of the nodes to forward the packet. Transmission power depends on the location of the mobile nodes, which may change with time. The lack of battery in nodes can result in partitioning of the network, causing interruptions in communications between mobile hosts. Since mobile hosts are powered by batteries, efficient utilization of battery power is more important here than in cellular networks. There are several metrics that can be used in power aware routing [1] & [2]. Also while routing, we need to focus on minimizing transmission power because high transmission power can ultimately drain the batteries of the nodes. Both the transmission power and battery capacity have an important influence on the overall communication performance of the network.

II. RELATED WORK

Routing Criteria in Energy Aware Routing the design of ad hoc-specific routing protocols initially have had as a main criterion of minimum total transmission power. The prime deficiency of this criterion is that selecting the routes obeying the minimum transmission power principle does not protect nodes from being overused. This may lead to uneven loading of network nodes and result in an accelerated depletion of nodes common to several 'minimum total transmission' paths. The failure of nodes may lead to partitioning of network and halt/severely limit any further use of the network. The concept of 'lifetime of a network' thus arises as one of the parameters to be considered during the design of the protocol. The lifetime of a network may be defined as the instance at which the network is first partitioned or the instances any certain number of nodes deplete their energy. Then the protocols focus mainly on minimizing battery power variance among nodes [3] and thus are biased to define lifetime of network as per the second criteria. The deficiency of this criterion is that selecting the routes obeying the maximum battery life principle does not protect nodes from using high transmission power which also may lead to early network partitioning. Then protocols focus on using both the minimum total transmission power routing as well as maximum battery capacity routing principles by using a predefined value called threshold [4]. But these protocols have the biggest drawback of fixed threshold value, which may also lead early network partitioning in some cases. For further improvement we proposed a new algorithm which we will discuss later in this paper.

III. EXISTING POWER AWARE ROUTING PROTOCOLS

The 'Energy Aware' routing protocols can be classified on the basis on certain principles [1] & [5] out of which we are going to discuss some important ones as enumerated below.

1. Minimum Transmission power Routing-MTPR

In this routing scheme, we focus on reducing the transmission power only while transmitting data from source to destination. This protocol selects the route with the minimum total power, i.e. minimum sum of node-to-node transmission powers. Hence it is based upon a shortest path criterion in a transmission power sense. But this algorithm does not pay attention to load balancing or fairness in energy consumption, nodes that lie along common routes will experience a higher energy consumption rate and likely expire sooner. For further details please refer [4] & [6]

2. In Min-Max Battery Cost Routing-MMBCR

In Min-Max Battery Cost Routing-MMBCR [4] & [6], we focus on utilizing battery power in a more efficient manner. This routing algorithm truly maximizes each node's lifetime and prevents nodes from being overused for packet forwarding. This is accomplished by selecting the route with the maximum value of minimum remaining energies of all possible routing paths. Thus, it introduces fairness in the way nodes are used for relaying. In this algorithm does not necessarily choose minimum transmission power paths. This may actually reduce the lifetime of all nodes.

To solve these above discussed problems, routing protocols, like Conditional Max-Min Battery Capacity Routing-CMMBCR [4] and power efficient battery capacity routing-PEBCR [7] & [8] are developed which achieve both goals (maximize lifetime of node and use the battery fairly) simultaneously to some extent.

3. Conditional Max-Min Battery Capacity Routing-CMMBCR

The basic idea behind CMMBCR is that when all nodes in some possible routes between a source and a destination have sufficient remaining battery capacity, then a route with minimum total transmission power among these routes is chosen. However, if all routes have nodes with low battery capacity , MMBCR is chosen so that routes including nodes with the lowest battery capacity should be avoided to extend the lifetime of these nodes. That means once MMBCR is chosen, MTPR will never be implemented throughout the network lifetime. Here the performance highly depends on the fixed threshold value. Also a situation may arise where MTPR would be needed for better performance, but for fixed threshold it wouldn't be possible to choose MTPR instead of MMBCR. There is another drawback as when MTPR is chosen, battery power doesn't get considered and when MMBCR is chosen, transmission power doesn't get considered.

It would be worthy to go for variable threshold calculation by comparing the effectiveness of both MTPR and MMBCR routing & then selecting the most suitable one, rather than just considering one routing scheme for a particular interval. There should be the flexibility to choose the routing scheme which is more effective than the other one. Here comes the need for efficient and correct calculation of threshold value (which will be variable) that will allow the flexibility of choosing the more suitable routing scheme among MTPR and MMBCR each time, while transmitting. Here we propose our new protocol "varying threshold conditional min-max battery cost routing(PAF)" which implements the concept of the threshold that varies & get calculated for each transmission**.**

IV. PROPOSED POWER EFFICIENT BATTERY CAPACITY ROUTING ALGORITHM

The main objective was to maximize the life time of each node and use the battery fairly. However, these two goals cannot be achieved simultaneously by applying MTPR or MMBCR schemes. To resolve this problem, we use battery capacity, assuming that each node may have different transmission power. Instead of cost function as a route selection metric and introduce the power efficient battery capacity routing scheme.

The basic idea behind PAF is that when all nodes in some possible routes between a source and a destination have sufficient remaining battery capacity (i.e., above a threshold), a route with minimum total transmission power among those routes is chosen. Since less total power is required to forward packets for each connection, the relaying load for most nodes will be reduced, and their lifetime will be extended. However, if all routes have nodes with low battery capacity (i.e., below a threshold), routes including nodes with the lowest battery capacity should be avoided to extend the lifetime of these nodes and the route with maximum battery life will be selected.

V. PROPOSED ALGORITHM

Notations used

Bnj= Available Battery capacity of node "nj" Ri= Remaining battery capacity of route "i"
P(nj,nj+1) = Transmission power used from node *"nj"* to *"nj+1"*
Pi=Total transmission power of *route "i"* *k* = Route selected by MTPR

l = Route selected by MMBCR *Pl* = Transmission power of the route "l" selected by MMBCR *Rl*= Remaining battery capacity of the route "l" selected by MMBCR *Pk* = Transmission power consumed by the route "k" selected by MTPR
Rk = Remaining battery capacity of the route "k" selected by MTPR *BF* = Full battery capacity

Algorithm

Step 1:

Take a network in to consideration as input

Step 2:

Let S be the source and T be the destination.

Step 3:

Let A be the set of all available routes from S to T.

Step4:

Determine the S-T route by applying MTPR as follows .

The total transmission power for *route i*, *Pi*, can be derived from

$$pi = \sum_{j=1}^{D-1} (nj, nj+1), for\ all\ node\ nj\ \in Route\ i$$

Where, D= no. of nodes present on route i

S= n1

T= nD

Therefore, the desired route k can be obtained from the following result

$P_k = Min\ (pi)$ **,** $\forall\ i\ \in A\ i$

At the same time let's calculate the Remaining battery capacity of this *"route k "*.

E : the total number of nodes in *"route k "*

Bnj : the available battery power of node *'nj'*.

The battery capacity of *Route k,*

$R_k = Min(B_{nj})$, $\forall\ j\ \in \{1,2,3,4,..,E\}$

Step 5:

Determine the route by MMBCR as follows.

$\boldsymbol{nj}$: $\boldsymbol{The\ available\ battery\ power\ of\ node\ nj}$

The battery capacity of *'route i '*,

$Ri=Min(B_{nj})$, $\forall\ j\ \in\ \{1,2,3,4,..,D\}$,

Where D=no. of nodes present on the route $\boldsymbol{l}$

Then select the *'route I '* whose battery capacity is maximum. $Rl = Max\ (Ri)$, $\forall\ i\ \in A$

At the same time let's calculate the Total transmission power of this *'route l '* .

$\boldsymbol{Pl = \sum_{j=1}^{F-1} p(nj, nj+1)}$, $\forall\ \boldsymbol{node\ nj}\ \in \boldsymbol{Route\ l}$, where F= no. of nodes present on the route **l**

Step 6:

Calculate the varying threshold ψ as follows,

$\boldsymbol{If}\ \left(\frac{\boldsymbol{p1}}{\boldsymbol{r1}}\right) > \left(\frac{\boldsymbol{pk}}{\boldsymbol{rk}}\right)$,

$Threshold\ value, \varphi = \left|1 - [(\frac{pk}{rk})/(\frac{pl}{rl})]\right| * BF$

Else,

$Threshold\ value, \varphi = [(\frac{pl}{rl})/(\frac{pk}{rk})] * BF$

Step 7:

Let Q ⊏ A, be the set of all S-T routes whose available battery power is at least **φ**.i.e. ∀ i Є Q, , Ri(t) ≥ **φ**

Then, the following route selection principle is used:

If Q ≠ Φ

select the 'route k ' in Q that has the minimum total transmission power.

Pk = min {Pi | i Є Q}

PAF resorts to MTPR.

Otherwise,

select ' route l ' whose battery capacity is the maximum, i.e., Rl = min {Ri | i Є A}

VTCMMBCR resorts to MMBCR

Step 8

End of the algorithm.

VI. PERFORMANCE ANALYSIS AND SIMULATION RESULTS

The simulations related to our proposed algorithm PAF, using MATLAB [1].All nodes are assumed to have the same amount of battery capacity at the beginning of simulation process. At each instant of time the nodes are moving dynamically. The simulation stops when there are no nodes or there is only one node with finite battery capacity and therefore no destination. At the beginning of each simulation time slot, each mobile host randomly chooses a new direction and route requests are generated. When a request occurs, two nodes are randomly selected as source and destination and packet transfer occurs between them. The route through which this transfer occurs is selected either by MTPR / MMBCR depending on their corresponding effectiveness and the calculated threshold, as per the above algorithm. Here "Effectiveness" of any routing scheme denotes the ratio between total transmission power and remaining battery capacity / battery life of the route selected by that routing scheme.

The power consumed by the nodes while transmission is calculated and then deducted from the previous powers of those nodes. After some random transfers battery power reduces to zero for some nodes and they are not taken into consideration further. The expiration time is defined as the time when a node exhausts its battery capacity. Fig.1 illustrates the expiration time vs. expiration sequence for 8 nodes each moving with velocity 1 m/sec. Fig.2 illustrates the expiration time vs. expiration sequence for 8 nodes each moving with velocity 4 m/sec. Fig. 3 illustrates the expiration time vs. expiration sequence for 15 nodes each moving with velocity 4 m/sec. The expiration time of each node is recorded in seconds. The expiration sequence is sorted according to expiration time of each node.

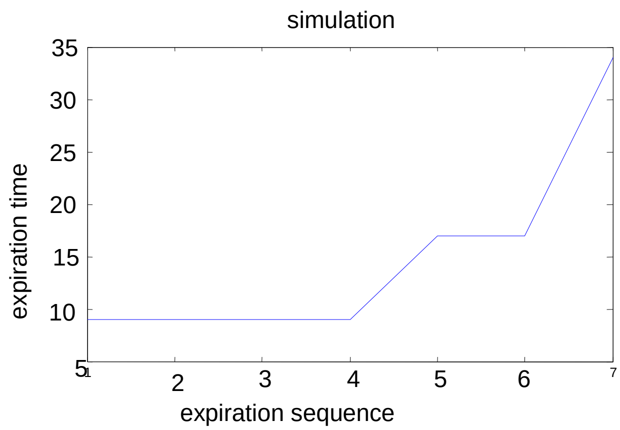

Figure. 1 number of nodes = 8 and speed=1m/sec

8 number of nodes are distributed in a space of 8 * 8. They move randomly at a velocity of 1 m/sec . Each were given an initial battery power of 2 units. It took about 45 seconds for all nodes in the network to get exhausted.

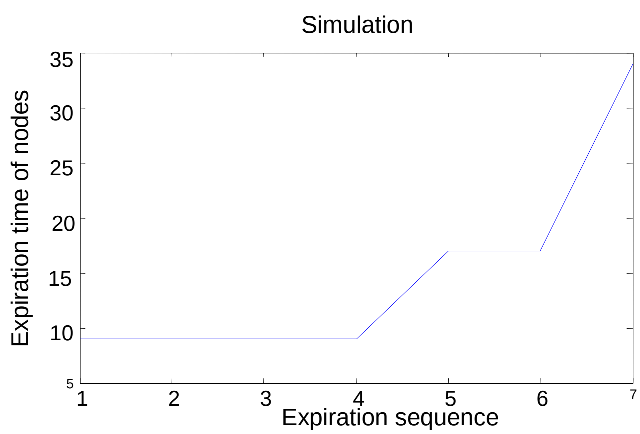

Figure.2 number of nodes = 8 and peed=4m/sec

Here also 8 number of nodes are distributed in a space of 8 * 8. They move randomly at a velocity of 1 m/sec . Each were given an initial battery power of 2 units. It took about 34 seconds for all nodes in the network to get exhausted.

Various graphs were plotted for a set of different number of nodes moving with a constant velocity with varying initial power content.

Fig.3 gives the exhaust time for networks with number of nodes 4,8 and 10. In each case nodes move with a constant velocity of 1m/sec. This simulation was performed thrice with 3 different initial power contents of 1 unit, 2 units and 3 units.

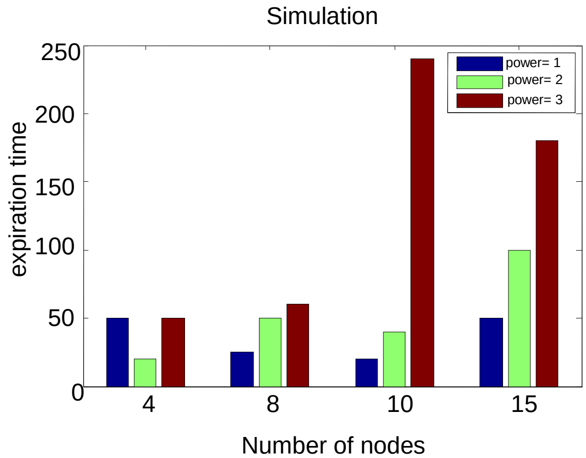

Figure.3 shows the simulation

Again speed was varied keeping the initial power content constant for sets of nodes.

Fig.4 gives us the total exhaust time of networks of nodes 4,8,10 and 15. In each case the initial power content was made fixed at 2 units but the velocity of nodes were varied as 1m/sec,2m/sec and 4m/sec.

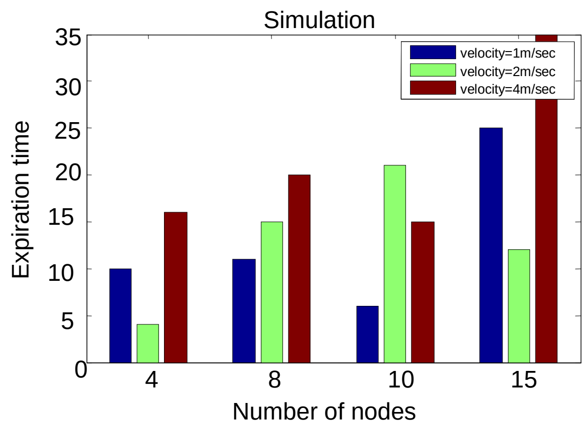

Figure. 4: shows total exhaust time

Fig.5 gives the network partitioning time for each routing algorithm with 8 number of nodes. In each case nodes move with a constant velocity of 4m/sec.

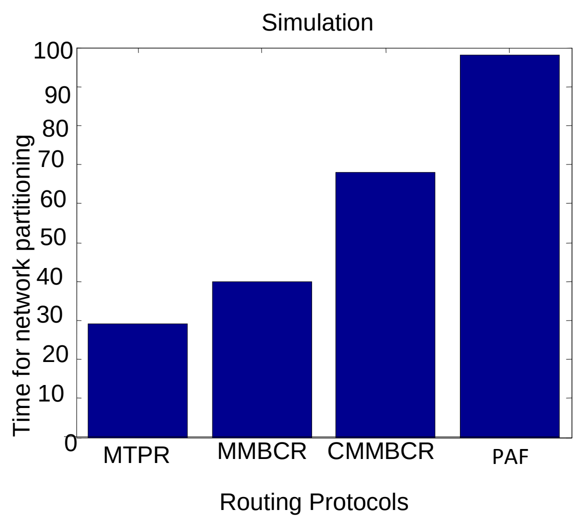

Figure.5 shows the network partitioning

VII. CONCLUSION

Most protocols have concentrated on how to quickly reorganize the ad hoc network during times of mobility and how to find the best route without increasing control overhead. However, since mobile hosts have limited battery resources, ad hoc mobile networks should consume battery power more carefully and efficiently to prolong network operation lifetime. Although performance metrics such as end-to-end throughput and delay are important, one cannot design a well-tailored ad hoc routing protocol with only these metrics. Battery power capacity, transmission power consumption, stability of routes, and so on should be considered as well. For that several protocols have been used, most of which we have discussed above. For further improvement on those protocols we proposed the protocol PAF. From our simulation results, we discover that if nodes in an ad hoc wireless network expend most of their power on communication-related applications, power aware routing protocols, like Varying Threshold Max-Min Battery Capacity Routing can prevent loss of battery power as well as total transmission power used while transmitting a packet from a node to another node. But as we discussed above, it can't prevent both transmission power loss and battery loss simultaneously. It has the flexibility to choose the most power efficient protocol each time while transmitting, and therefore increases the average life of nodes most of the times.

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