Power Aware Routing in Mobile Ad Hoc Networks by using Power Aware Matrices

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ABSTRACT

Power consumption is a crucial design concern in Wireless ad hoc networks since wireless nodes are typically battery limited. It might not be possible to replace/recharge a mobile node that is powered by batteries. To take full advantage of life time of nodes, traffic should be routed in a way that power consumption is minimized. Power Aware Routing is a consideration in a way that it minimizes the energy consumption while routing the traffic, aims at minimizing the total power consumption of all the nodes in the network, minimizing the overhead etc. and thus, at maximizing the lifespan of the network using some Power Aware Routing Protocols. They minimize either the active communication energy required to transmit or receive packets or the inactive energy consumed when a mobile node stays idle but listens to the wireless medium for any possible communication requests from other nodes. Transmission power control, load distribution and power management approaches are used to minimize active communication energy.

General Terms

Network Security, Mobile Ad-Hoc Networks, Algorithms.

Keywords

Power Aware Routing, Transmission Power Control Approach; Load Distribution Approach;

1. INTRODUCTION

The main objective of power aware routing protocols is to minimize the power consumption and maximize the network lifetime. The network lifetime is defined up to the moment when a node runs out of its own battery power for the first time. If a node stops its operation, it can result in network partitioning and interrupt communication. The main objective of this paper is to make an explicit literature survey on power aware routing protocols based on transmission power control approach, load distribution approach and sleep/power down approach.

2. POWER AWARE ROUTING

Power Aware Model: The mobile nodes in MANET are connected to other mobile nodes. These mobile nodes are free to transmit, i.e. send or receive the data packets to or from other nodes respectively, and require power for such activities. There are 4 important power components [2]: (1) Transmission Power (2) Reception Power (3) Idle Power and (4) Overhearing Power [Fig. 2.1].Transmission Power- Whenever a node sends data packet to other nodes in the network, some amount of energy is required for transmission and such energy is called Transmission Energy (T_x) of that node and this energy is dependent on size of the data packet. On sending the data packet, some amount of power is consumed. The transmission energy is formulated as:

$$T_x = (330 * P_{length})/2 * 10^6$$

and

$$P_t = T_x / T_t$$

Where T_x is transmission energy, P_T is Transmission Power, T_t is the time taken to transmit a data packet and P length is the length of data packet in bits.

3. RECEPTION POWER

Whenever a node receives data packet from other nodes then some amount of energy is taken by the node to receive data packet, which is called Reception Energy(R_x). On receiving the data packet, some amount of power is consumed. Reception Energy is formulated as:

$$R_x = (230 * P\text{-length})/ 2 * 10^6 \text{ and } P_R = R_x / T_r,$$

Where R_x is the Reception Energy, P_R is the Reception Power, T_r is a time taken to receive data packet, and P-length is the length of data packet in bits. Idle Power-In this situation, node neither transmits nor receives any data packets. Power is consumed because it needs to listen to the wireless medium continuously in order to detect a packet that it should receive, so that the node can then switch into receiving mode from idle mode. Idle power is a wasted power that should be eliminated or reduced to a minimum. Thus, Idle Power is:

$$P_I = P_R,$$

Where P_I is Idle Power and P_R is Reception Power. Overhearing Power- In this case a node picks up the data packets that are destined to other nodes and this is called overhearing and it may consume power. This power is called overhearing power. Unnecessarily receiving such data packets will cause power consumption. Then power consumed in overhearing is:

$$P_{over} = P_R,$$

Where P_{over} is Overhearing Power and P_R is Reception Power.

4. POWER AWARE METRICS

The main objective of power aware metrics is to carefully share the cost of routing which will ensure that node and network life is increased. These power aware metrics [16] result in power efficient routes, which are detailed below. Minimize Energy consumed per packet: This is one of the most obvious metrics that conserves power efficiently.

Assume that some packet j traverses $n_1, ..., n_k$ nodes where n_1 is the source and n_k the destination. Let T(a, b) denote the energy consumed in transmitting and receiving one packet over one hop from a to b. Then the energy consumed for packet j is,

$$e_j = \sum_{i=1}^{k-1} T(n_i, n_{i+1})$$

Thus, the goal of this metric is to minimize e_j, for all j [Fig.2]. It is easy to see that this metric will minimize the average energy consumed per packet. In fact it is interesting to observe that, under light loads, the routes selected using this metric will be identical to routes selected by shortest-hop routing. This is not a surprising observation because, if we assume that T(a,b) = T = Constant, for all(a,b) ∈ E, where E is the set of all edges, then the power consumed is (k - 1)T. To minimize this value, we simply need to minimize k which is equivalent to finding the shortest-hop path. In some cases, however, the route selected using this metric may differ from the route selected by shortest-hop routing. Thus, if one or more nodes on the shortest-hop path are heavily loaded, the amount of energy spent in transmitting one packet over one hop will not be a constant since we may spend variable amount of energy (per hop) on contention. Thus, this metric will tend to route packets around congested areas (possibly increasing hop-count). One serious drawback of this metric is that nodes will tend to have widely differing energy consumption profiles resulting in early death of some of the nodes. Consider the network illustrated in Figure 3.Here, node 6 will be selected as the route for packets going from 0-3, 1-4 and 2-5. As a result, node 6 will spend its battery resources at a faster rate than the other nodes in the network and will be the first to die.

Maximum Time to Network Partition: One of the difficulties in implementing this metric is that given a network topology, using the max-flow-min-cut theorem, we can find a minimal set of nodes (the cut-set) the removal of which will cause the network to partition. The routes between these two partitions must go through one of these critical nodes.

A routing procedure therefore must divide the work among these nodes to maximize the life of the network. If we don't ensure that these nodes use up their power at equal rates, then we will observe that delays will increase as soon as one of these nodes dies. Problem is similar to the load balancing problem where tasks need to be sent to one of the many servers available so that the response time is minimized. This is known to be a NP-complete problem. Since nodes in different partitions independently take routing decisions, we cannot achieve the global balance required to maximize the network partition time while minimizing the average delay [2-5]. As the power consumption is dependent on the length of the packet, we cannot decide optimal routes without the knowledge of future packet arrivals. If all the packets are of

same length, then we can ensure equal power drain rate among these nodes by selecting these nodes in a round-robin fashion in routing. Minimum Variance in node power levels: This metric ensures that all the nodes in the network remain up and running together for as long as possible. This problem is similar to load sharing in distributed systems where the objective is to minimize response time while keeping the amount of unfinished work in all nodes the same. This is an intractable problem, because the execution times of future arrivals are not known. Join the Shortest Queue (JSQ) policy can be used to achieve this goal. Here each node sends traffic through a neighbor with the least amount of data waiting to be transmitted. If all packets are of same length, then we can achieve the equal power drain rate by choosing next hop in a round-robin fashion so that on the average, all nodes process equal number of packets.

5. MINIMIZE COST PER PACKET

This metric is used to maximize the life of all nodes in the network. The path selected using this metric should be such that nodes with depleted power reserves do not lie on many paths [14]. Let $f_i(x_i)$ be a function that denotes the node cost or weight of node I, where x_i represents the total energy spent by node i. The total cost of sending a packet along some path is the sum of costs at individual nodes from n_1 to n_k via intermediate nodes, $n_2, n3, n4, ..., n_{k-1}$ and can be represented as

$$c_j = \sum_{i=1}^{k-1} f_i(x_i)$$

The goal of this metric is to Minimize c_j, for all packets j. If f_i is a monotonically increasing function, then nodes will not be overused thus increasing their life, where f_i can be tailored to reflect a battery's remaining life time.

$$f_i(x_i) = (1/(1 - g(x_i)))$$

where $g(x_i)$ is the normalized battery capacity.

6. PAAODV PROTOCOL

Power Aware AODV (PAAODV) protocol for ad hoc networks is an enhancement of existing AODV ad hoc routing protocol. The main objective of PAAODV is to optimally reduce power consumption to a minimum power level in MANET without disruption of network connectivity. As a result of it, the overall power consumed in transmission of overhead packets is significantly reduced. The control messages used in AODV protocol is modified. PAAODV [21] works in two phases that is route-discovery and link-by-link power adjustment [8-9, 13]. In the route discovery process, different power levels are used to determine a route consuming minimum power for transmission of packets. In this case, a source node attempts first to discover a path with a low power level. Transmit power levels of nodes in an ad hoc network using PAAODV is controlled to minimum levels. Controlling the transmit power level is performed due to two reasons: (i) transmit power level is directly related to the available power at the node and (ii) network connectivity is significantly affected by transmit power. The basic principle of PAAODV is that nodes in the network should control the transmit power in order to maintain the network connectivity. As shown in Fig. 3.4, node p1 is transmitting a packet to node

p2 and node p3 is transmitting a packet to node p4. In Fig.4(a), both transmissions are successful since they do not interfere with each other. In Fig.4(b), communications interfere with each other due to high transmit power level and hence, cannot be successful. In Fig.4(c), as the transmit power is too low, the network connectivity fails and the communications fail too. Thus, for the communication to take place, the power level should be as low as possible, but at the same time, the connectivity should be maintained. This transmit power, regarded as minimum transmit power level, i.e. $P_{\min}$, can be calculated

$$P_{\min}(d) = p_{th}d^{\gamma}/K$$

Where d is the distance between two nodes, γ is the path loss component and 'K' is constant. Authors have assumed $\gamma = 4$ during implementation, which is the path loss component for a two-ray ground model. The value of P_{th} for IEEE based network is 3.653×10^{10} mW. So the minimum power consumption is calculated as:

$$E_{\min} = K_3 Dd^4 + K_2$$

Where $K_3 = 2.8 \times 10^{-10} \mu$ J/byte. The equation reveals that $E_{\min}$ depends upon d, the distance between two nodes. Otherwise for a fixed transmits power level, the power consumption can be calculated as:

$$E_{\max} = K_4 D + K_2$$

Where $K_4 = 1.62 \mu$ J/byte. Thus the amount of power saved can be obtained as:

$$S(D,d) = E_{\max} - E_{\min}$$

7. LOAD DISTRIBUTION APPROACH

The specific objective of load distribution approach[10] is to balance the energy usage of all mobile nodes by selecting a route with underutilized nodes rather than the shortest route. This may result in longer routes, but packets are routed only through energy rich intermediate nodes. Protocols based on this approach do not necessarily provide the lowest energy route,but prevent certain nodes from being overloaded and thus,ensures longer network lifetime. This subsection discusses two such protocols:Localized Energy-Aware Routing(LEAR) and Conditional Max-Min Battery Capacity Routing protocols. Fig.5 shows the detailed study about Power controller graph of initial 10 packets, Power graph for Packet arrivals, Packet flow graph and Aggregate Throughput.

8. CONCLUSION

Energy efficiency is one of the main problems in a MANET, especially in designing a routing protocol. In this paper, we performed an exclusive survey and classified a number of power-aware routing schemes. In many cases, it is difficult to compare them directly since each method has a different goal with different assumptions and employs different means to achieve the goal. When the transmission power is controllable, the optimal adjustment of the power level is essential not only for energy conservation but also for the interference control. When node density or traffic density is far from uniform, a load distribution approach must be employed to alleviate the energy imbalance problem. Therefore, more research is needed to combine and integrate some of the protocols presented in this paper to keep MANETs functioning for a longer duration.
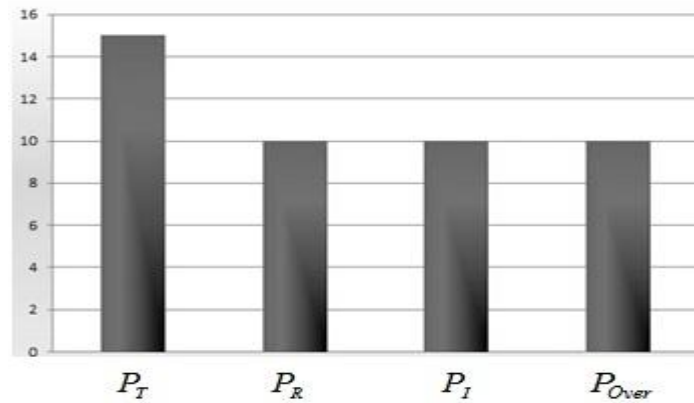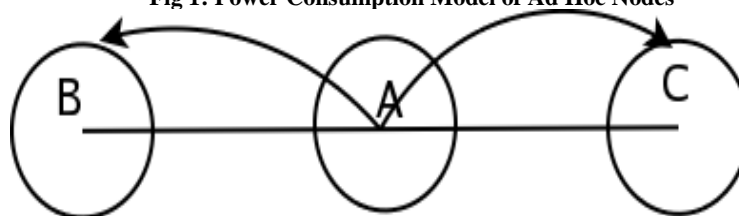

Fig 1: Power Consumption Model of Ad Hoc Nodes
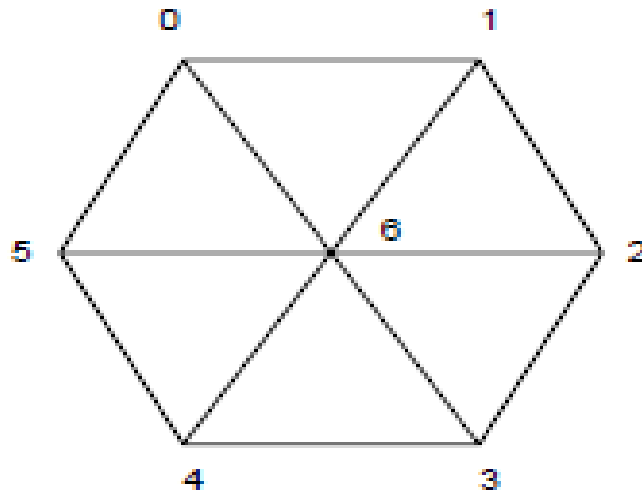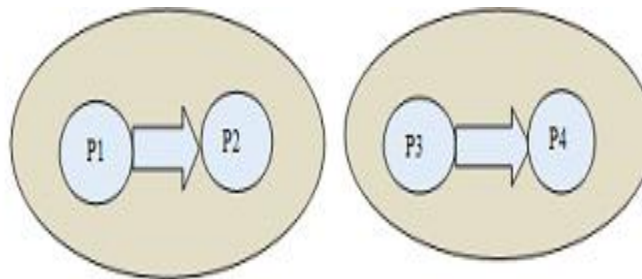

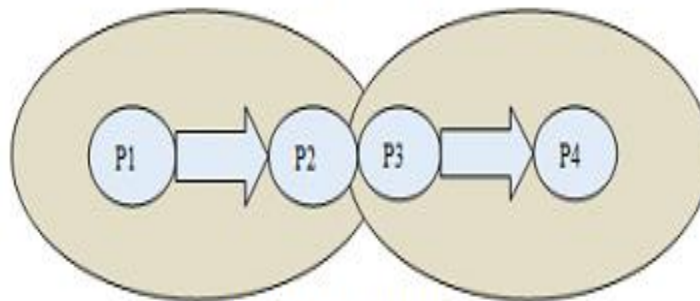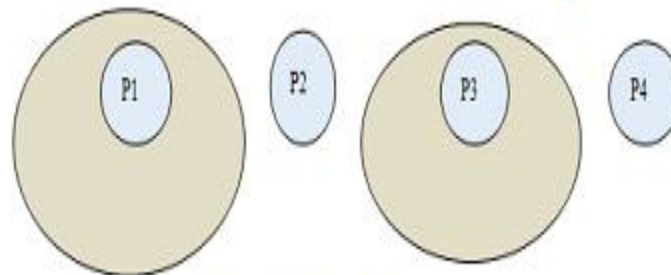**Fig 2: Unnecessary power consumption**

Fig 3: Energy Packet as a metric
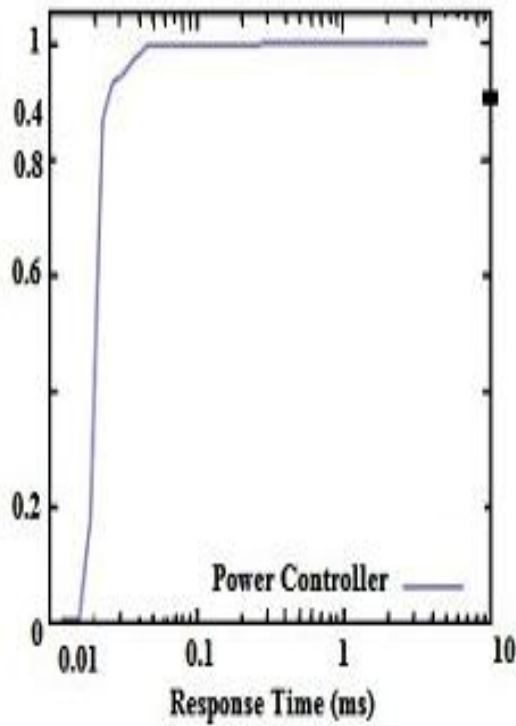

(a) Minimum transmit power
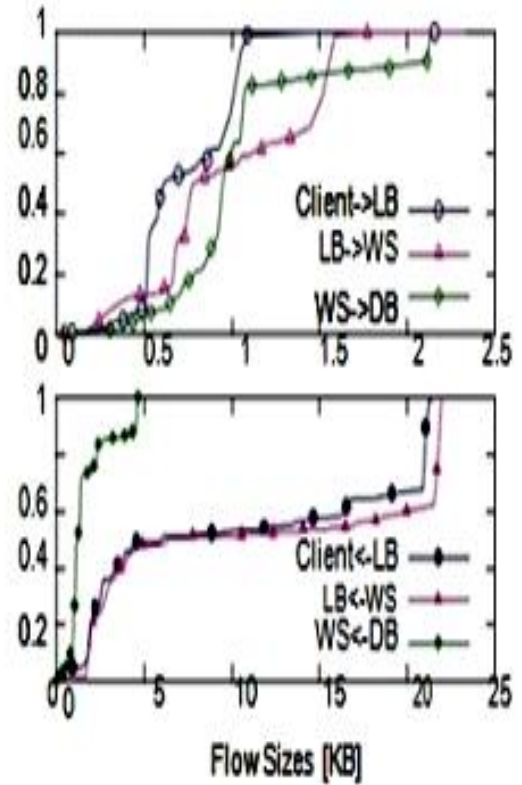

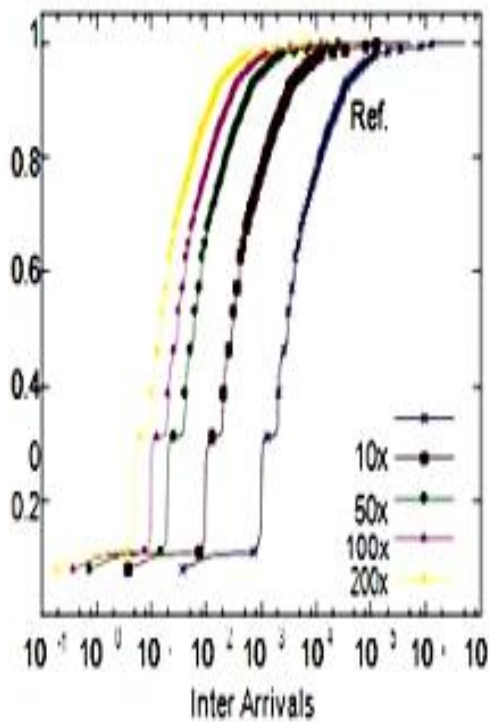(b) High transmit power

(c) Low transmit power

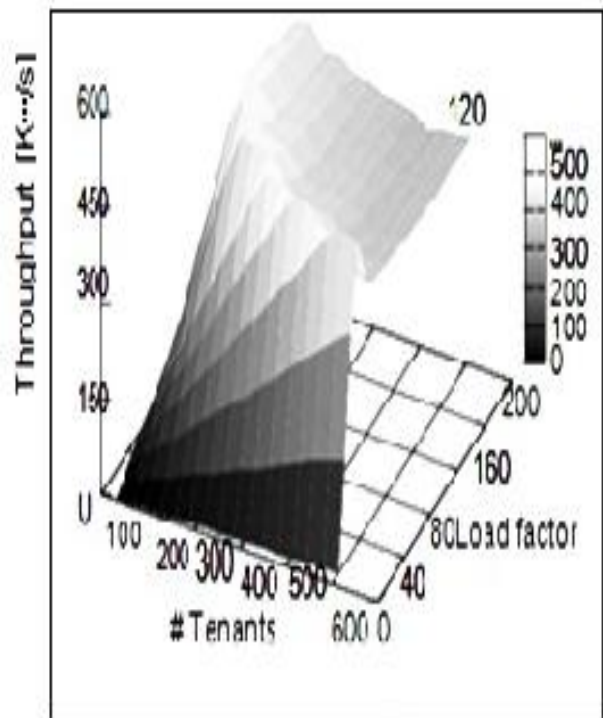**Fig 4: Effect of transmit power control on network connectivity**

(a) Power Controller Graph for initial 10 Packets

(c) Packets Flow Graph in KB

(b) Power Graph for Packets Arrivals

(d) Aggregate throughput of 600 Packets

Fig 5: Effect of power control for flow of packets and corresponding throughput on network connectivity

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