

Optimizing Power at the Physical Layer in a Wireless Ad Hoc Network

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ABSTRACT

In this paper, we describe a method to optimize power in an Ad Hoc wireless system. Previous work has concentrated in optimizing power at the network and transport layer. We present power optimization at the Physical Layer of the ad hoc protocol stack. It has been shown that adopting a variable transmission power policy based on device positioning in the protocol can save a significant amount of energy. The initial simulation indicates about 40% saving for 200 nodes in the network compared to the constant power transmission method.

1. INTRODUCTION

An Ad hoc wireless network is a multi-hop network in which nodes communicate with each other cooperatively to maintain network connectivity. Nodes in an ad hoc network communicate via radio and all the nodes share this radio channel. This kind of a network is useful in a situation where, temporary network connectivity is needed such as disaster relief, war etc. But deploying such a network poses significant challenges imposed by technology and environment. Because of the nature of ad hoc network it is necessary that all the nodes are small and light weighted. And since they are operated by battery they must conserve power for extended battery life. Past researches on ad hoc networks has focused on optimizing power at the hardware and operating system level. But significant amount of energy is wasted at different layers in the protocol stack. In [7] conserving power by turning off the nodes when it is not in use has been studied. The authors in [8, 10] have discussed different Power-Aware Broadcasting Metrics. In [5] Doshi and Brown have illustrated how to conserve power in the network layer by implementing dynamic route discovery of minimum energy routes. But not much work has been done to reduce power in the physical layer.

This work has the following contribution:

- An optimizing technique has been presented to control the transmission power at the physical layer based on the positioning of network element.

- Through simulation, comparisons have been made between the constant power protocol and the variable power protocol for different node densities, network area and distance indices.

The remainder of the paper is organized as follows. The next section gives an outline of our hypothesis and provides a motivation example. In Section 3, we provide the theory behind our hypothesis. Section 4 discusses our implementation approach and simulation results for different set of node and area configurations. We conclude our work in Section 5

2. Optimal Power Transmission Approach

We consider the transmit power control as an important issue in wireless ad hoc networks for the following reasons

- It has an impact on battery life.
- It has an impact on the traffic carrying capacity of the network.

***Solution to Optimize power consumption at the physical layer:** Variable Power Transmission (VPT) protocol dynamically calculates the positioning of its communication target to control transmission power level so as to conserve energy.*

Transmit power control works on the concept that when a node wants to transmit to a destination node it is not necessary to transmit at the same transmission power as that of the farthest node. In [4] the authors stated that the common power transmission scheme is the optimal method of transmission in ad hoc network. But this constant Power Transmission Protocol can lead to substantial power wastage especially in a ad hoc environment where maximum number of node are relatively near each other. In Figure 1 a simple ad hoc network environment with three nodes N1, N2 and N3 are shown with appropriate transmission power range. It may be observed that there is no need for node N1 to broadcast at 20mW power to send packets to the neighboring node N2, if N2 is within a range of 2mW. Just using required power while transmitting, a significant energy can be saved. This becomes significant when the number of transmissions is large. It may be shown that after node N1 transmits to node N2 and N3, the power consumed using VPT protocol can be 22mW whereas the CPT protocol may consume 40mW.

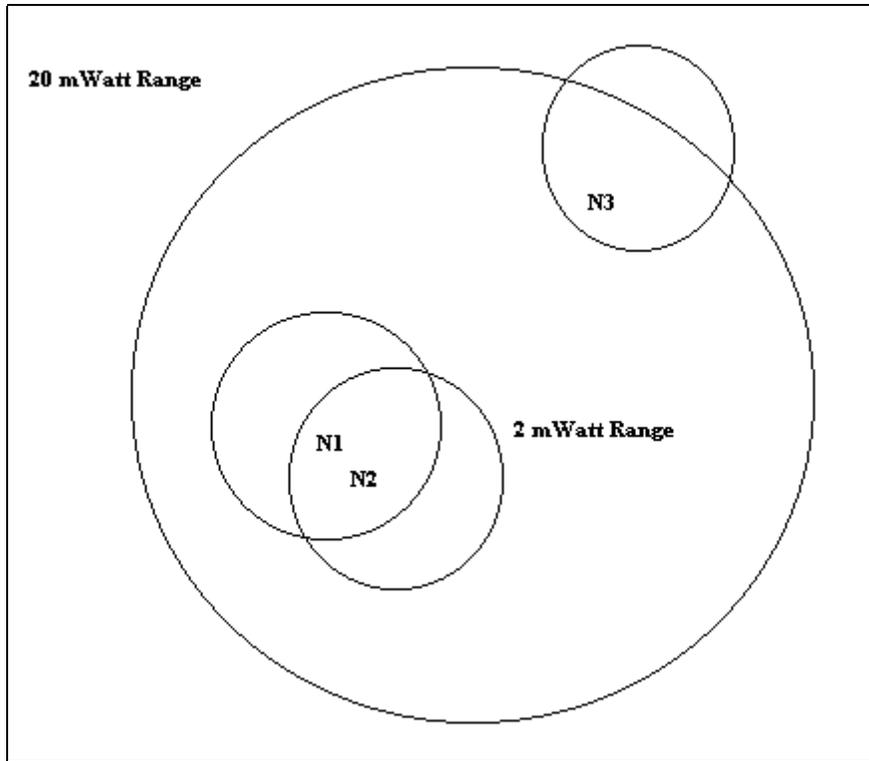


Figure 1: Need for Transmit Power Control

Also, constant power transmission technique can result in interference among other transmissions reducing the data carrying capacity of the network. Suppose N1 wants to send a packet to N2 and at the same time N3 wants to transmit to its neighboring nodes but all of them send power at their maximum power level under CPT protocol. This results into multi-interface due to one another. On the other hand, using VPT protocol, most of the nodes would not reach undesired targets to cause interferences

3. Problem Formulations and Theoretical Basis

We provide a theoretical basis to VPT approach and compare it with CPT method here.

3.1 Distance Index (n)

Distance Index is used to calculate the transmission power based on the distance between the nodes. This is based on the concept that power can be related to distance because when the distance between two nodes increase then the power needed for communication between the two nodes also increase.

When the actual transmission power is proportional to the distance power, then we have

$$P_{t_actual} (\text{actual transmission power}) \propto (\text{distance})^n \quad - (1)$$

$$Pt_unit_Consume = Pt_Constant / (0.1) * ((max_distance) ^n) - (2)$$

$$Pt_actual = Pt_unit_Consume * (distance) ^n - (3)$$

Where

- Pt_unit_Consume is the power consumed for unit distance.
- Pt_Constant is the constant power used in the existing algorithm.
- Pt_actual is actual transmission power with the final transmission takes place.
- The factor of (0.1) in Equation 2 is introduced because when the distance is very small then the transmission power becomes too low and it becomes very susceptible to noise.

We are using three distance indices in our simulations (n = 2, 3 and 4) for accuracy. We also adopt the following two conditional statements for the purpose of threshold.

1. If (Pt_actual > Pt_Constant)

Then (Pt_actual = Pt_Constant)

It is applied to the case when the distance of the destination node is very large. As a result of using factor 0.1, for large distances, we may end up with Pt_actual > Pt_constant. But we know that the maximum power needed to transmit to the furthest node is Pt_Constant, so we can replace that corresponding Pt_actual with Pt_Constant.

2. If (Pt_actual < Pt_Min)

then (Pt_actual = Pt_Min)

This situation arises when the destination node is very near the transmitting node, which leads to the transmission power to be very low and possibility of noise overriding the signals. So in that case we replace the Pt_actual with Pt_Min.

Figure 2 is a theoretical plot of power consumption Vs number of transmissions, which shows the plots for different distance indices. As we can see the total power consumed for small number of transmissions is the same as in case of Common Power Transmission. But when the number of transmission increases the CPT scheme consumes more power than the VPT adopted protocol.

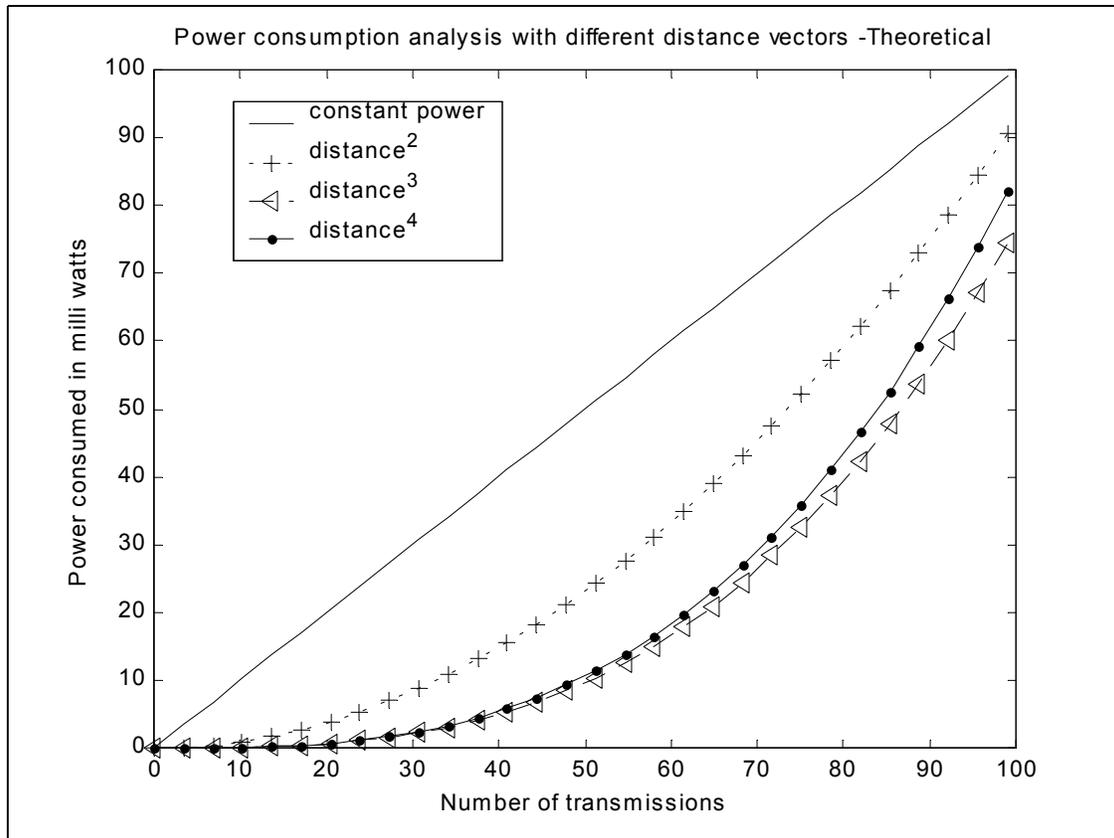


Figure 2: Power Consumption Analysis with different Distance indices.

4. Experiments and Results

Based on above hypothesis, we have performed simulation for different node densities, with different sized network area and different distance indices. It has been assumed that each node knows its own coordinates.

The NS2 network simulator is used as simulation environment. The various Simulation parameters used are *area, number of nodes and distance indices*.

4.1. Power Consumption analysis for Different Network Areas

Here the area in which the ad hoc network is deployed is varied with Number of Nodes and Distance Index are constant parameters. The number of nodes in the network was taken as 100 with distance index $n = 2$. The simulation results are provided in Table 1. We have generated the results using a seed of 1.0 and CBR of 4.0 and maximum connections of around 50%.

From Table 1, we can make the following inferences: For very small area, the efficiency (Efficiency in our case may be defined in percentage of the ratio of the total power consumed in VPT to that of CPT) is high and it decreases as the ad hoc network area increases. This is because when the area is small, the number of transmissions is high as more nodes fall near each other compared to when the area is large. We can also see that as the area increases the efficiency becomes stable.

For areas of 600*600, 800*800, and 1000*1000 square meters, the efficiency is found to be approximately 38%.

4.2 Power Consumption Analysis for Different Node Densities

In this experiment, the numbers of nodes were varied but keeping the other two parameters, the network area and distance index constant. The network area used here is 800 * 800 square meters with distance index $n=2$ again. The results are shown in Table 2 and Figure 3.

The Simulation results for 10, 100, 200 and 500 nodes in the targeted region are plotted in Figure 3. We can notice that as we increase the number of nodes the number of transmission increases.

Table 1: Power Consumption Analysis for Different Network Areas. (Distance Index $n=2$)

Area (meter* meter)	Power Consumption in Common Power Metric (watts)	Power Consumption in Variable Power Metric (watts)	Efficiency (%)	Number of Transmissions
200*200	2.0426	1..203	51.5	11608
400*400	0.615185	0.32912	46.5	2119
600*600	0.17335	0.10575	39	957
800*800	0.165314	0.102495	38	900
1000*1000	0.102636	0.06343	38.2	810

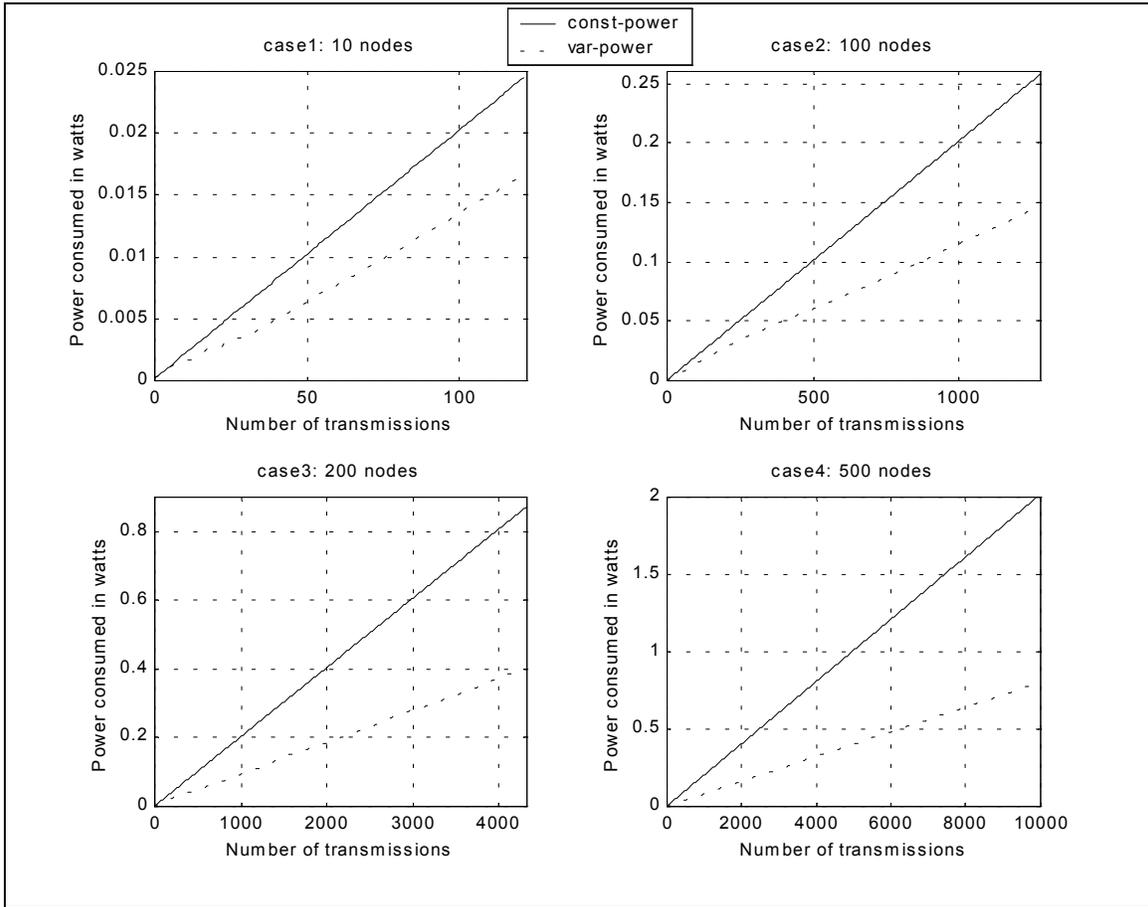


Figure 3: Power Consumption Analysis in an Environment with (1) 10 Nodes, (2) 100 Nodes, (3) Nodes 200, (4) Nodes 500

Table 2: Power Consumption Analysis for Different Node Densities (Distance Index $n=2$)

Number of Nodes	Power Consumption in Common Power Metric (watts)	Power Consumption in Variable Power Metric (watts)	Efficiency (%)	Number of Transmissions
10	0.024522	0.0191	22	122
30	0.076795	0.0522	32	368
50	0.13194	0.0839	36	652
100	0.257499	0.1571	39	1279
200	0.832741	0.4830	42	4330

4.3 Speed

The simulation shows there is hardly any effect of node speed on power consumption. This is because in an ad hoc network the nodes move very slowly and the region of activities are small. For every transmission our algorithm obtains the destination node's coordinates very fast.

4.4 Power Consumption Analysis with Different Distance Indices

We performed the simulation for different distance indices, keeping the number of nodes in the simulation environment constant as ten and area as 800*800 square meters. The simulation results are shown in Figure 4. As we can see the distance index of fourth power of distance provides us with the maximum power optimization, followed by the distance index of the third power and second power. This somewhat does not match with the theoretical results (Figure 2) where the maximum optimization is obtained with the distance index of the third power. This discrepancy may be contributed to the fact that the theoretical simulation did not take in account of P_{t_Min} and the case when P_{t_actual} is more than $P_{t_Constant}$.

5. Conclusion:

In this paper we have developed an intuitive method to optimize power at the physical layer by varying the transmit power with the knowledge of the destination node's coordinates. It has been found that power optimization using Variable Power Technique appears to be better than the protocol using Constant Power Technique. It may be noted that the Variable Power Metric has other implications as well. Every time a node transmits at higher power to another node, it may cause interference to the packets transmitted by other nodes. Thus, there is a loss of several such packets on the link. This has a negative impact on the congestion control algorithm regulating the flow from source to destination via the intermediate relay node. These problems can be reduced using the Variable Power Metric.

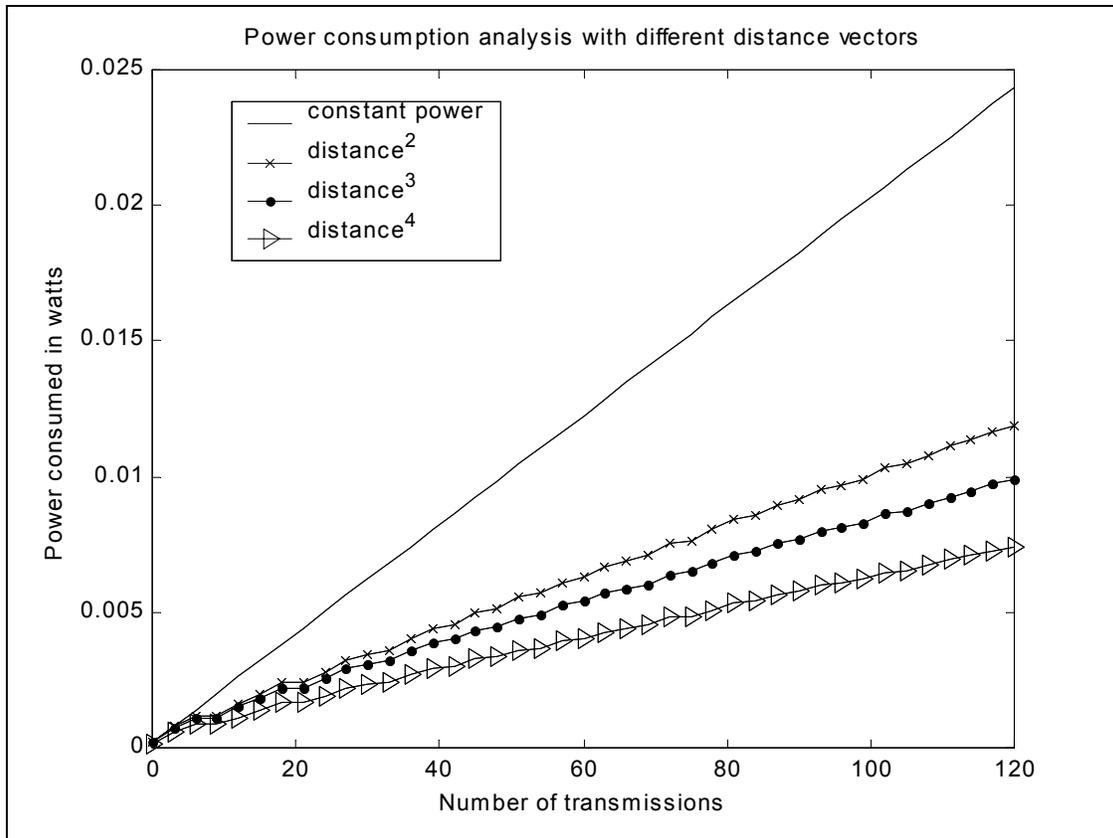


Figure 4: Power Consumption Analysis with different Distance Index

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