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Throughput Based Power Consumption Protocol in Wireless MANET

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Abstract: Power conservation is a major issue in wireless Mobile Ad Hoc Networks (MANET), as most of the nodes are battery powered. Power control is not related to any particular layer, since we can apply power conservation methods in all layers. But most of the power control mechanisms are working in MAC layer. In this paper we designed a Power Control MAC protocol for wireless MANET. Our first aim is to control the overall power consumption and the second was improve the throughput of the network. Thus our protocol includes two phases; in the first phase we reduce the power consumption and in the second phase we improve the aggregate throughput of the network. Our work is based on the IEEE 802.11 MAC protocol. We added an additional field to the RTS (Request To Send) and CTS (Clear To Send) control packets (PRTS in RTS packet to indicate the power used to send RTS packet and PData in the CTS packet to indicate the power with which sender can send DATA packet) for the design purpose. For reducing the power consumption we used the following method: We send the RTS packet with maximum or default power. Our results show the improvement in spatial reusability increases the aggregate throughput of the network.

Keywords: Wireless MANET, Power Consumption Protocol, MAC Protocol.

I. INTRODUCTION

A mobile ad hoc network (MANET) is a self-configuring infrastructure less network of mobile devices connected by wireless links. They offer quick and easy network deployment in situations where it is not possible otherwise. Ad-hoc is a Latin word, which means "for this only." Mobile ad hoc network is an autonomous system of mobile nodes connected by wireless links. Each node operates as an end system and a router for all other nodes in the network. Nodes in mobile ad hoc networks are free to move and organize themselves in an arbitrary fashion. Each node is free to roam about while communication with others. The path between each pair of the nodes may have multiple links and the radio between them can be heterogeneous. An ad hoc network is similar to a cellular network but is not infrastructure based, i.e., there are no coordinator or base stations present in an ad hoc network. In a cellular network base stations are present.

Since the devices used in an ad hoc network are mostly battery powered, power conservation is a major issue of such networks. The following principles may serve as general guidelines for power conservation in MAC protocols. First, collisions, a cause of expensive retransmissions should be avoided as far as possible. Second, the nodes should be kept in standby mode or sleep mode whenever possible. Third, instead of using the maximum power, the transmitter should use a lower power that is enough for the receiver node to receive the transmission. The MAC protocols can be classified into two: Power management protocols (using alternative sleep and wake up modes for nodes) and power control protocols (variation in transmit power). The nodes in the ad hoc network remain in one of the three possible states: active, idle or sleep. Power consumption in sleep state is less compared to other two states. So we keep some of the nodes those are not participating in data transmission in sleep mode. In a network power is consumed during computation and transmission of packet, but computation power is negligible as compared to transmission power cost. Hence efforts are made to control the transmission power by incorporating different power control mechanisms [1] and [2].

In this paper we have designed a MAC protocol for reducing the power consumed by each and every node. This protocol also increases the aggregate throughput of the wireless network. The power control approach discussed above is used for the design of the protocol. For improving the throughput, we should improve the spatial reuse of the network.

Mobile Ad Hoc networks find its applications in many areas and are useful for many cases. But it faces some problems due to limited battery power of the mobile nodes. Since all mobile nodes are battery powered, we have to use the power efficiently. We can reduce the power consumption by controlling the power used to transmit the different control and data packets. A disadvantage of the power control protocols is the degradation in the network throughput. The objective of this paper is to reduce the power consumption of mobile nodes and also improve the aggregate throughput of the wireless network.

II. BACKGROUND

A. Design Issues of Mobile Ad Hoc Networks

The major design issues of a mobile ad hoc network are:

a. Medium Access Scheme:

The main responsibility of a MAC protocol in ad hoc network is the distributed arbitration of shared channel for transmission of packets. There are a lot of issues we have to consider while designing a MAC protocol. Some of them are as follows. We need to find solution for hidden and exposed terminal problems should try to improve the throughput of the system, should minimize the packet transmission delay etc. Support for power control at the MAC layer is very important in the ad hoc network environment. A MAC protocol should be able to provide mechanisms for resource reservation, real time traffic support and Qos.

b. Routing:

The major responsibilities of a routing protocol include exchanging the route information, finding a feasible path based on different criteria, gathering information about path break, utilizing minimum band width etc. The challenges that a routing protocol faces are mobility, bandwidth constraint, shared channel etc. It should provide security and privacy, minimum control overhead, scalability and Qos.

c. Quality of Service Provisioning:

QoS is a performance level of service offered by a network. Rendering QoS in ad hoc networks can be on per flow, per link or per node basis. QoS parameters change from application to applications. Security, reliability, availability, delay and channel utilization are the common QoS parameters

d. Self organization:

An important property that an ad hoc network should exhibit is organizing and maintaining the network by itself. The major activities required to perform the self organization are neighbor discovery, topology organization and topology reorganization.

e. Security:

The lack of central coordination and shared wireless medium makes the mobile ad hoc networks vulnerable to attacks. So the security of communication is more important in ad hoc networks. Denial of service attack, resource consumption attacks, information disclosure attack and interference attacks are the common security threats exists in ad hoc networks.

f. Energy Management:

Energy management is the process of managing the sources and consumers of energy in a node or in a network as a whole for enhancing the life time of the network. Energy management can be classified into transmission power management, battery energy management, processor power management and devices power management [1] and [3] and [5].

B. Power Conservation in MANET:

Since nodes in an ad hoc network are limited battery powered, power management is an important issue in such networks. Battery power is a precious resource that should be used effectively in order to avoid the early termination of nodes. Power management deals with the process of managing resources by means of controlling the battery discharge, adjusting the transmission power, and scheduling of power sources so as to increase the life time of nodes in the ad hoc networks. Battery management, transmission power management and system power management are three major methods to increase the life time of nodes.

a. Need for Power Management in Ad Hoc Networks:

The main reasons for power management in ad hoc networks are the following:

b. Limited Energy Reserve:

The main reason for the development of ad hoc networks is to provide a communication infrastructure in environments where the setting up of fixed infrastructure is impossible. Ad hoc networks have very limited power resources. The increasing gap between the power consumption requirements and power availability adds to the importance of energy management.

c. Difficulties in Replacing Batteries:

In some situations, it is very difficult to replace or recharge batteries. Power conservation is essential in such situations.

d. Lack of Central Coordination:

The lack of central coordination necessitates some of the intermediate node to act as relay nodes. If the proportion of relay traffic is more, it may lead to a faster depletion of power source.

e. Constraints on the Battery Source:

Batteries will increase the size of the mobile nodes. If we reduce the size of the battery, it will results in less capacity. So in addition to reducing the size of the battery, energy management techniques are necessary.

f. Selection of Optimal Transmission Power:

The transmission power determines the reach ability of the nodes. With an increase in transmission power, the battery charge also will increase. So it is necessary to select an optimum transmission power for effectively utilize the battery power.

g. Channel Utilization:

The frequency reuse will increase with the reduction in transmission power. Power control is required to maintain the required SIR at receiver and to increase the channel reusability [2] and [4] and [7].

C. Power Conservation Approaches:

Two mechanisms affect energy consumption: power control and power management. If these mechanisms are not used wisely, the overall effect could be an increase in energy consumption or reduced communication in the network.

a. Power Control:

The aim of communication-time power conservation is to reduce the amount of power used by individual nodes and by the aggregation of all nodes to transmit data through the ad hoc network. Two components determine the cost of communication in the network. First one is direct node to node communication or transmission. The transmission rate can be adapted by the sender. Second is forwarding of data through the networks. In the first case we can use the power control techniques to conserve the power. Whereas in the second case we can use the energy efficient routing schemes.

Current technology supports power control by enabling the adaptation of power levels at individual nodes in an ad hoc network. Since the power required transmitting between two nodes increases with the distance between the sender and the receiver, the power level directly affects the cost of communication. The power level defines the communication range of the node and the topology of the network. Due to the impact on network topology, artificially limiting the power level to a maximum transmit power level at individual nodes is called topology control.

MAC layer protocols coordinate all nodes within transmission range of both the sender and the receiver. In the MAC protocols, the channel is reserved through the transmission of RTS and CTS messages. Node other than the destination node that hears these messages backs o®, allowing the reserving nodes to communicate undisturbed. The power level at which these control messages are sent defines the area in which other nodes are silenced, and so defines the spatial reuse in the network. Topology control determines the maximum power level for each node in the network. So topology control protocols minimize power levels increase spatial reuse, reducing contention in the network and reducing energy consumption due to interference and contention. The use of different power levels increases the potential capacity of the network.

Once the communication range of a node has been defined by the specific topology control protocol, the power level for data communication can be determined on a per-link or even per-packet basis. If the receiver is inside the communication range defined by the specific topology control protocol, energy can be saved by transmitting data at a lower power level determined by the distance between the sender and the receiver and the characteristics of the wireless communication channel.

Power aware routing reduces the power consumption by finding the power efficient routes. At the network layer, routing algorithms must select routes that minimize the total power needed to forward packets through the network, so-called minimum energy routing. Minimum energy routing is not optimal because it leads to energy depletion of nodes along frequently used routes and causing network partitions [3] and [6] and [8].

b. Power Management

Idle-time power conservation spans across all layers of the communication protocol stack. Each layer has different mechanisms to support power conservation. MAC layer protocols can save the power by keeping the nodes in short term idle periods. Power management protocols integrate global information based on topology or traffic characteristics to determine transitions between active mode and power save mode. In ad hoc networks, the listening cost is only slightly lower than the receiving cost. Listening costs can be reduced by shutting off the device or placing the device in a low-power state when there is no active communication.

The low-power state turns off the receiver inside the device, essentially placing the device in a suspended state from which it can be resumed relatively quickly. But the time taken to resume a node from completely off state is much more and may consume more energy.

The aim of any device suspension protocol is to remain awake the node when there is active communication and otherwise suspend. Since both the sender and receiver must be awake to transmit and receive, it is necessary to ensure an overlap between a wake times for nodes with pending communication.

Different methods such as periodic resume and triggered resume can be used when to resume a node to listen the channel. In periodic resume, the node is suspend the nodes most of the time and periodically resumes checking if any packet destined to it. If a node has some packets destined for it, it remains awake until there are no more packets or until the end of the cycle.

In triggered resume method to avoid the need for periodic suspend/resume cycles, a second control channel can be used to tell the receiving node when to wake up, while the main channel is used to transmit the message [9] and [10].

III. PROPOSED TECHNIQUES

In power control protocols, since nodes use different power for different transmissions, there is a chance to reduce the throughput of the entire network. A power control protocol can improve the throughput over IEEE 802.11 by creating better spatial reuse in the network. In order to alleviate the throughput degradation problem, we improve the virtual carrier sensing approach used in IEEE 802.11. It improves the throughput of our network.

Protocol Assumptions our main motivation is to reduce the power consumption of each and every node. In addition to it we should have to improve the aggregate throughput.

A. Protocol Assumptions and System Model:

In this model, nodes are randomly deployed in a geographical area. It is assumed that nodes are stationary, homogeneous and use Omni directional antenna for transmission. The other assumptions we used in our protocol are as follows.

The gain between two nodes is same in both directions. The channel gain is stationary for the duration of the control and data packet transmission periods. The propagation model used is the two ray ground reflection model. The relationship between transmitted power and the received power can be represented as follows:

$$P_r = P_t * G_{tr}$$

Where, G_{tr} is the gain from the transmitter to the receiver. The received power at a distance d can be calculated as:

$$P_r = (P_t G_t G_r H^2{}_t H_r) / d^4 L$$

Where, *Ht* and *Hr* are heights of transmitter and receiver antennas and is same for every antenna. L is the system loss factor which is set to 1.

B. Protocol Description:

Our protocol is a power control MAC protocol with improved throughput. Our aim was to reduce the power consumption of each node in the network and in addition to it improve the aggregate throughput of the network. The protocol is organized as two phases. The first phase is used to reduce the power consumption of nodes and the second phase for improving the throughput of the network.

C. Reduce the power consumption:

Like most of the power control protocols, here also the power can be reduced by send the packets with optimum power. All of the existing power control MAC protocols were sending the RTS and CTS packets with maximum (default) power and the DATA and ACK packets using the minimum power. Instead of this, here we send the RTS with default power and CTS, DATA and ACK packets with optimum power.

This protocol requires the addition of a field to the RTS and CTS control packets. The structure of the existing and proposed RTS packet is as shown below:

Frame Control	Duration	RA	TA	CRC

RTS format in PCM

Frame Control	Duration	RA	TA	CRC	PRTS

RTS format in proposed PCM Scheme

Figure1: Structure of RTS Frames

The structure of the existing and proposed CTS packet is as shown below:

Frame Control	Duration	RA	CRC

CTS format in PCM

Frame Control	Duration	RA	CRC	PData

CTS format in proposed PCM Scheme

Figure2: Structure of CTS Frames

The working procedure of the protocol is described as follows:

a. The transmitter send the RTS packet containing the value of P_{RTS} at a transmitted power level P_{RTS}.
b. The receiver will receive the RTS frame at a received power *Pr*.
c. The receiver will take the RTS transmitted power P_{RTS} from the received RTS packet.
d. After determining the P_{RTS} and *Pr*, the CTS transmission power P_{CTS} and data transmission *PData* can be calculate.
e. The receiver sends out the CTS containing the value of *PData* at a transmitted power P_{CTS}.
f. The transmitter will send the data frames to the receiver at the transmitted power *PData* which is the value obtained from the *PData* field of the immediately previous CTS frame.
g. The receiver after receiving the DATA frame will send an ACK frame with a power that is used to send the CTS frame. Using *PRTS* and *Pr*, the CTS transmission power *PCTS* can be calculated as follows:

$$P_{CTS} = (P_{RTS}/ P_r) * R_{th}$$

Where, *Rth* is the receiving threshold (minimum signal strength at which the receiver can decode the signal). After calculating the *PCTS*, that value will assigned to the *PData* field of the CTS frame and the CTS frame will send with the power *PCTS*.

D. Improve the Throughput

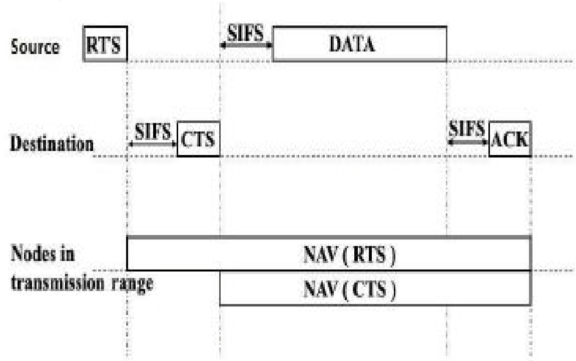
In 802.11 virtual carrier sensing mechanism, if a node overhear an RTS or CTS packet, the node which over hear the packet assumes the channel as busy and set it's Network Allocation Vector (NAV). Thus if that over heard node has any packet to send, it defer the transmission for a duration. Here we improved this virtual carrier sensing mechanism.

A node can over hear an RTS packet only or a CTS packet only or can overhear both RTS and CTS packet. In our protocol since the CTS transmission range is less compared to the RTS transmission range. So there is a chance that a node overhears RTS packets only. Suppose a node over hear the RTS packet only and it has a CTS packet to send, it will send that packet immediately. It is possible because it won't affect the ongoing transmission.

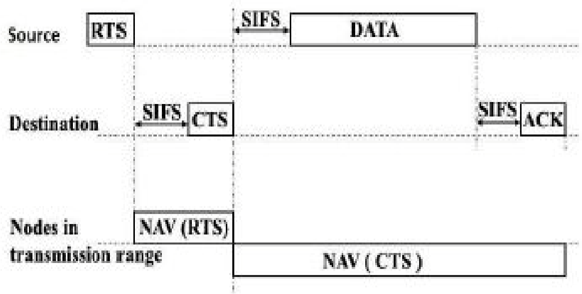
E. The Modified Virtual Carrier Sense (VCS) Scheme

The Figure 3 (a) and (b) below shows the setting of NAV in 802.11 and proposed scheme. The modified Virtual Carrier Sensing Scheme is discussed as follows:

a. In addition to NAV used in 802.11 MAC VCS, we use another parameter NAVR
b. If a node in the transmission range overhears an RTS frame, it will set its NAV to a slot time and the NAVR to the value in the duration field of RTS frame received. A slot time is the time it takes a node to recognize a channel as busy or idle plus the time it takes to process a frame, prepare a response, and transmit it and for it to propagate to the receiving station.
c. If the node overhears the CTS frame before the NAV expires, it will set the NAV using the value in the duration field of the CTS frame.
d. If the node in the transmission range wants to send a frame, it will check.



(a) 802.11 MAC



(b) Proposed Scheme

Figure3: Setting the NAV in 802.11 and Proposed Scheme the frame type.

e. If it is an RTS frame it will check if NAVR expires or not. If NAVR expires, it can send the RTS frame. Otherwise it will wait for a back off time. If it is a CTS, DATA or ACK frame, it will check the NAV and if NAV expires to zero, it can send that frame.

IV. RESULTS

We simulated the same scenario using both PCM (power Consumption MAC) and proposed concept and observed changes in power consumption and Throughput. We repeated the experiment with scenarios having different packet size for both PCM and the proposed protocol (PCMIT). In all scenarios, application is made between source node 1 and destination node 50. The figure 4 shows power consumed for the simulation of PCM protocol and the proposed protocol respectively. As shown in the results there is a difference in the power consumption between the two concepts, the power consumption in proposed scheme is better compared to that of PCM.

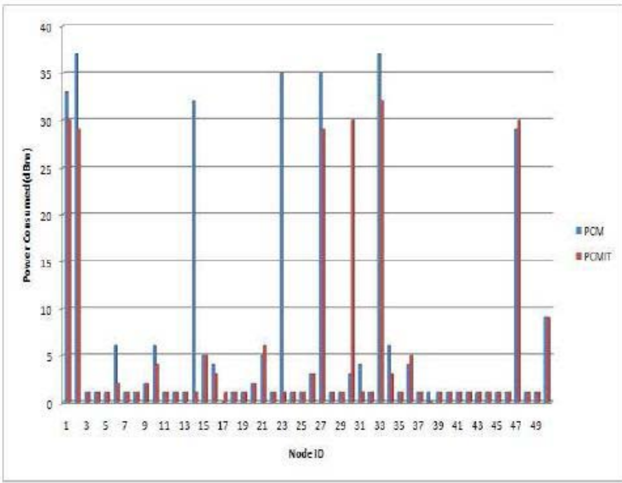


Figure4: Power consumption of each node in PCM vs Proposed Scheme

Now we run the same scenario with different packet size and analyze the throughput obtained in each run. Then we plot a graph which compares the throughput obtained in PCM and proposed scheme for different packet size. Figure 5 shows the comparison of throughput for the existing and our proposed protocol. We can find that the throughput of proposed scheme increased compared to that of PCM.

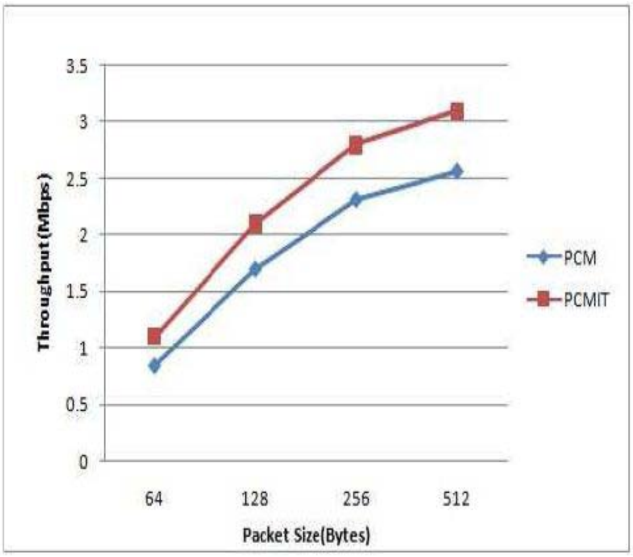


Figure5: Throughput obtained in PCM and Proposed scheme for different packet sizes

V. CONCLUSION AND FUTURE WORKS

In this paper we have designed a power control MAC protocol for wireless Mobile Ad Hoc Networks. We considered a network environment where every node participate in data transmission and applied a power control concept in that environment. The main goal of this work was to understand the different power conservation techniques in wireless MANET and propose a protocol to achieve this goal. Here we have proposed a power control MAC protocol for wireless mobile ad hoc networks which reduce the power consumption and increase the aggregate throughput. We have modified the 802.11 MAC protocol to achieve our goal. For reduce the power consumption we have used the transmission power control techniques. For improve the throughput, we need to improve the spatial reuse of the network. Improvement in spatial reuse will make more simultaneous transmission possible and which will improve the throughput of the network. For that purpose we have made some modifications in the virtual carrier sensing scheme of 802.11 MAC. In our work we consider a stable network environment. Mobility of the nodes did not take into consideration. In future works we can consider the mobility of the nodes to make it more suitable for wireless mobile ad hoc networks.

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