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Dynamic Power Control MAC Protocol in Mobile Adhoc Networks

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ABSTRACT

In this paper, we propose a power saving scheme that improves the throughput and saves energy in mobile adhoc networks. This protocol sends all the packets RTS, CTS, DATA and ACK with optimum transmit power, which saves the energy, makes spatial reuse of the wireless channels, and achieves the better throughput. The advantage of using optimum power is significant reduction in carrier sensing range compared to the standard scheme. However this carrier sensing range is sufficient to avoid the interference among various nodes in the multi-hop routing. Avoiding collisions, improving spatial reuse and decreasing contentions between the nodes of adhoc networks save energy and improve the throughput. Through simulations we have shown that our proposed protocol shows better performance.

Keywords

Adhoc networks, IEEE 802.11, MAC protocol, power control, DPCP, DCF.

I. INTRODUCTION

Mobile adhoc networks (MANETs) are self-organizing networks which allow nodes to establish communication anytime and anywhere without the aid of a central infrastructure. . The network is adhoc because each node is willing to forward data to other nodes. The determination of which node forwards data to which node is made dynamically based on network connectivity.

The nodes in mobile adhoc networks are mobile, smaller in size and battery powered. There are various issues in these types of networks. Due to the mobility, the routing paths have to be updated all the time. Since nodes are wireless, factors such as multiple-access, signal fading, noise and interference can cause the effective throughput to be much smaller in the wireless networks. Since the nodes are battery powered, power consumption is an important issue. In this network even other nodes act as intermediate nodes in forwarding a packet, hence if one node goes down the overall network capacity reduces drastically. Lot of research is done in designing protocols which reduces power consumption of a node.

MAC protocol is a protocol used to ensure proper communication between two immediate nodes. It is responsible for resolving conflicts among different nodes for channel access. Its design should also address the issues caused by mobility of nodes and unreliable time varying channel.

In this paper, we proposed a new power control protocol which simultaneously improves the throughput and yields energy saving. The rest of this paper is organized as follows: Section 2 reviews the related work. Our proposed DPCP protocol is explained in section 3. Section 4 presents simulation results and comparison between protocols. Finally, section 5 concludes the work presented in this paper.

II. RELATED WORK

Power control has been studied primarily as a way to improve energy efficiency of MAC protocols for mobile adhoc networks [1] by addressing the issues of hidden node problem, exposed node problem, excessive power consumption and low network throughput.

IEEE 802.11 b STD DCF MAC protocol [2] is the standard protocol for wireless networks. This provides Distributed Coordination Function (DCF) to manage concurrent transmissions and channel contentions. This exchanges RTS and CTS messages to avoid the well known hidden terminal problem that causes interference. To overcome the problem of interfering with the ongoing transmission, all other nodes that hear the RTS or CTS message defer their transmission till the ongoing transmission is over [3].

However, in [4], [5] authors reveal that the transmission of nodes that exchanged RTS-CTS successfully, may collide with DATA-ACK transmission of other nodes that had not overheard the RTS-CTS. Several drawbacks of IEEE 802.11 have been identified in the past years. IEEE 802.11 uses maximum transmission power *Pmax* regardless of the distance between the transmitter and receiver. This gives inefficient use of energy, since a successful communication between a transmitter and receiver pairs with short distance is possible with much lesser power than *Pmax*. Most power control schemes for wireless adhoc networks have been proposed to reduce the energy consumption for increasing the life time of the network.

In [6, 7, 8, 9] nodes transmit RTS-CTS at maximum power, *Pmax*, but send DATA-ACK at minimum necessary power *Pmin*. The minimum necessary power *Pmin* varies for traffic pairs with different transmitter-receiver distance, and different

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interference levels at the receiver side. This scheme is referred to as the BASIC power control scheme. The authors [10] propose PCM (Power Control MAC) protocol that operates similarly to the basic power control scheme, except that the power level is periodically raised to *Pmax* from *Pmin* for a very short time during the transmission of the DATA packet. PCM achieves a comparable network throughput with IEEE 802.11 and consumes lower energy. In addition to power saving, the power control schemes also used to improve the spatial reuse of the wireless channel to increase the network throughput as in [11], [12]. However, these schemes require additional channel that will increase the complexity of the system.

Adaptive Power Controlled MAC Protocol [13] is a protocol proposed to reduce power consumption and also to increase the overall throughput of the network by allowing the nodes to transmit at low power levels enough for its desired destination to receive the packet. It is a power control i.e. depending upon received signal, transmission power is estimated. The estimated transmission power is given by formula (1).

$$P_t = \frac{P_{min} * P_t^{'}}{P_r^{'}}. \quad (1)$$

Where Pt' and Pr' are the transmission and received powers of the previous packet from the receiver to sender and we assume that the node knows the propagation constants. In this protocol all the packets RTS, CTS, DATA and ACK are sent at optimum power level. All these packets contain an extra field (transmission power level) which helps in estimating optimum power level. Due to this adaptation, the power consumption reduces drastically and since the transmission range is less for each communication, the number of simultaneous communicating pairs increase. Hence we get better network throughput and low power consumption. But due to different transmission powers of the nodes, the hidden node problem increases and more packets are lost through collisions thereby hampering effective throughput.

III. DYNAMIC POWER CONTROL PROTOCOL (DPCP)

1. PROPOSED PROTOCOL BASICS

Proposed DPCP protocol is similar to the adaptive power control protocol [13], all packets RTS, CTS, DATA and ACK are sent at optimum power level which is required for the destination node to receive correctly. In dynamic power control wireless MAC protocol RTS, CTS DATA and ACK are sent at optimum power computed based on formula (5), which is defined by the ongoing transmissions such that those communications may not hampered.

This means reserving more transmission area for the ongoing transmission even the distance between the transmitter and receiver is small. The objective behind using optimum power is to increase the sensing range for informing the neighbour nodes about ongoing transmission in order to reduce the interference and increase energy conservation.

But, increasing the carrier sensing range to maximum range affects the total throughput of the network, since some nodes in the maximum carrier sensing range can also transmit data successfully to its corresponding receiver without affecting the first ongoing transmission. It depends on the distance between the transmitter and the receiver for any optimum power lesser than the maximum power. This means, the ongoing transmission will be completely covered by the carrier sensing range. Any node in the carrier sensing range, but not in the RTS or CTS range will notice the transmission and therefore will defer its transmission request. According to IEEE 802.11DCF, this node will maintain a NAV (Network Allocation Vector), which indicates the remaining time of the ongoing transmission session. When the transmitter completes the data transfer, a node in the carrier sensing range goes to a back-off period to sense the medium again. If the transmitter that received the ACK, has more data to transmit, the node in the back-off mode will notice the medium busy and maintains another NAV period.

2. MODEL DESCRIPTION

The IEEE 802.11std is reliable MAC protocol. When a sending node transmits RTS, CTS, DATA and ACK packets, every exposed node receives the packet at received signal strength. The received signal strength, P_r at receiver using two ray propagation model is:

$$P_r = P_t G_t G_r [\frac{\lambda}{4\pi d_{ij}}]^2. \quad (2)$$

Where λ is the wavelength of carrier, d_{ij} is the distance between sender and receiver. G_t and G_r are unity gain of transmitting and receiving omni directional antennas respectively. The power P_t is the transmit power of the packet. The header fields of the packets RTS, CTS, DATA and ACK are modified to incorporate the transmission power level of the respective packet.

Thus when a node receives such packet, it gets the transmission power level P_t, the received power P_r is calculated by the physical layer and the value is send to MAC layer. Every node knows the minimum decoding power P_{decode} at which the packet can be decoded properly. Thus we get the desired optimum transmission power required so that packet is properly decoded at the receiver is given by the corresponding formulas as given below.

$$P_{tmin} = \frac{P_{decode}}{G_t G_r} [\frac{4\pi d_{ij}}{\lambda}]^2 * c. \quad (3)$$

However, we do not have information about distance [13] between two nodes then we can find out transmission power by the equation

$$P_{tmin} = \frac{P_{decode} * P_t' * C}{P_r'}. \quad (4)$$

$$P_{opt} \geq P_{tmin} \quad (5)$$

Where, P_{opt} is the discrete level greater than P_{tmin}, P_t' and P_r' are the transmission and received powers of the previous packet from that receiver to sender, respectively. C is a constant equal to 1.05 to compensate for the interference and noise.

In this scheme, the received signal strength information obtained and calculated at the physical layer and then, is passed to the MAC layer for data transmission. The optimum transmit power is computed using equation (5). This P_{tmin} is stored at each node in the table against the destination. In order to get the optimum transmit power, the header fields of packets RTS, CTS, DATA and ACK are modified to incorporate the transmit power level of the respective packets. Thus, when a node receives such packet, it gets the transmission power level P_t, the received power P_r is accessed from the physical layer and the calculated transmit power is pass to the MAC layer.

The node sending RTS inserts transmit power as an extra field in it so that the receiving node can tune to this power while sending its CTS packet. Subsequently by using the optimum transmit power level, the DATA packets from sender and ACK packet from receiver can also be transmitted.

3. PROPOSED PROTOCOL DESCRIPTION

The proposed power control protocol works in the following steps:

- Transmitter sends a RTS with the optimum transmit power level including the power level in the header of the RTS.
- Receiver decodes the RTS, finds transmit and observes receive power levels and calculates optimum transmit power using equation (5). The receiver attaches the transmit power to the CTS packet and transmits CTS using the optimum power level.
- The transmitter extracts the transmit power level and observes receive power and calculates optimum transmit power level. The transmitter adds optimum transmit power to the DATA header and sends the DATA packet at this power level.
- The receiver sends ACK using the optimum power level.

In power control algorithm, $P_t[L]$ is the set of power levels used for the transmission, where L is an integer varies from 1 to 10. The transmit power $P_t[L]$ is the maximum power level and the number of power levels in the set is 10.

IV. SIMULATION RESULTS AND ANALYSIS

We have evaluated performance of the DPCP through simulations. We simulated IEEE 802.11 and dynamic power control protocol (DPCP) using ns-2 [14]. Numerous simulations were run with same parameters and average of observed values was taken to reduce the estimation error.

Two-ray radio propagation model is used. We use 10 transmit power levels, 1mW, 2 mW, 3.45 mW, 4.8 mW, 7.25 mW, 10.6 mW, 15 mW, 36.6 mW, 75.8 mW and 281.8 mW, which roughly corresponds to the transmission ranges of 40 m, 60 m, 80 m, 90 m, 100 m, 110m, 120 m, 150 m, 180 m, and 250 m respectively. The detailed simulation parameters are mentioned in table I. Two parameters viz. network load and density – number of nodes in the area were varied in the simulations. Network load is the rate of generation of packets in the network.

Table 1. Simulation parameters

Traffic Pattern	Constant Bit Rate
Simulation Time	900 seconds
Total Connections	20, 25, 30, 35, 40, 45 and 50
Packet size	512 Bytes
Velocity	5 meters/second
Pause Time	10 seconds
Simulation Area	1500m by 300m
Total Nodes	25, 50, 75, 100, 125 Nodes

The performance of protocols has been evaluated in terms of throughput and energy consumption as function of number of nodes and packet generation rate. Constant bit rate (CBR) sources are assumed in the simulation.

Throughput is the number of kilobytes transferred successfully by the sender to the receiver successfully.

Energy consumed (in Joule) per 1 kilobyte data delivered is calculated as the total amount of transmitting and receiving energy consumption over all flows divided by the total data delivered by all the flows. The energy consumption of all the packets RTS, CTS, DATA and ACK are considered.

The simulation results are obtained for IEEE 802.11 and DPCP. Figure 1 shows the comparison of the throughput of IEEE 802.11 and DPCP. It shows that DPCP achieves higher throughput compared to IEEE 802.11 schemes. This is because DPCP uses smaller carrier sensing range compared to IEEE 802.11, therefore large number of nodes can transmit concurrently. However, DPCP gives increasing throughput as packet generation rate increases and saturate and remains constant after a particular point. As at low packet generation rate, less number of packets would be contending for the transmission, therefore throughput increases linearly and saturates at higher packet generation rate.

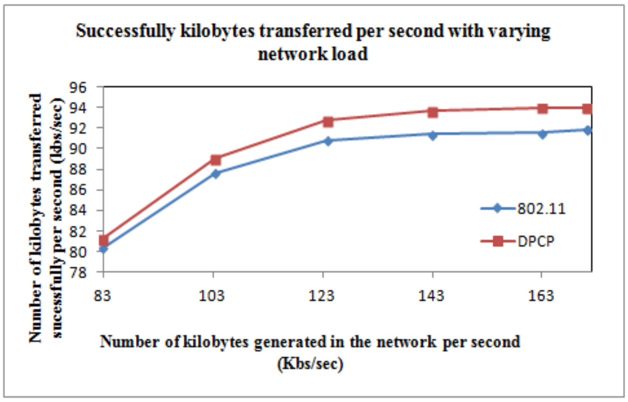

Figure 1: Successfully data transmitted vs traffic generated rate

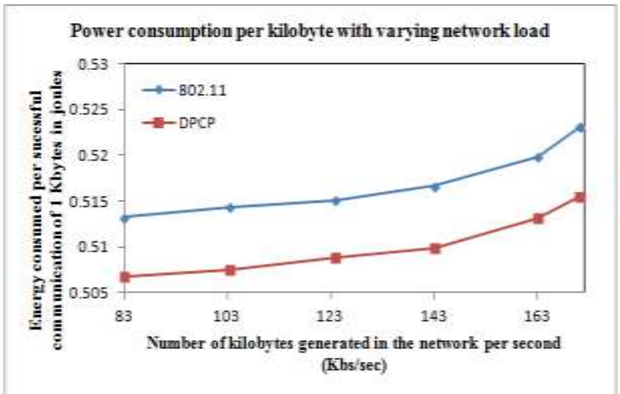

Figure 2: Average energy consumption (in Joule) per communication of 1kilobyte of data vs traffic generated rate

Figure 2 shows variation of energy consumed per successful communication of 1 kilobyte of data with increasing packet generation rate. Results show that power consumption per successful communication of 1 kilobyte of data is lesser in DPCP as compared to IEEE 802.11. It happens because in DPCP packets RTS, CTS, DATA and CTS are sent at optimum power, which is lesser than maximum transmit power. However, DPCP and IEEE 802.11 give increasing average energy consumption as network load increases This happens because reduction in transmit power also reduces the number of deferring nodes, and thus, more data can be delivered per joule.

In the figure 3, we see that the throughput per node decreases in both schemes with increase in node density because of contention and collisions of the packets. The throughput in DPCP is better than IEEE 802.11 std because of concurrent transmission of packets due to spatial reuse of the channel. This happens as RTS, CTS, DATA and ACK are transmitted at lower power in DPCP scheme.

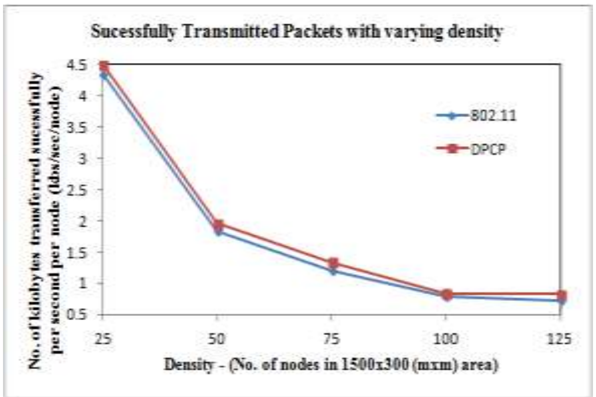

Figure 3: Successfully 1 kilobyte of data transmitted vs density

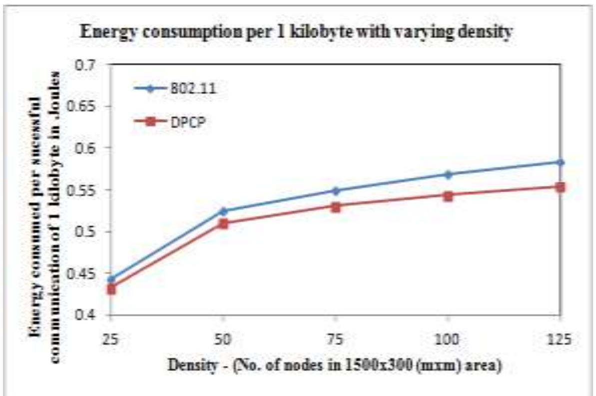

Figure 4: Average energy consumption (in Joule) per communication of 1kilobyte of data vs density

In figure 4, we observe that average energy consumption in communication of 1 kilobyte of data is lesser DPCP than IEEE 802.11 scheme as RTS, CTS, DATA and ACK are transmitted at lower power. As the node density increases, energy consumption per successfully transmitted 1 kilobyte of data increases in both schemes. This happens because contention and collision of the packets increases with increased node density results in increased energy consumption.

V. SUMMARY AND FUTURE WORK

In this paper we have proposed and evaluated the performance of a new power control protocol for wireless adhoc networks called Dynamic Power Control protocol (DPCP). This protocol transmits all the packets with the optimum transmission power. The optimum power is found based on reducing the carrier sensing range to increase throughput and reduce energy consumption. This reduces the number of unnecessary back-off nodes and allows successful concurrent transmissions to take place in the neighborhood of a receiver. We have compared the performance of the DPCP scheme with IEEE 802.11 std. We investigated its performance under different network loads and node density. Our simulation results showed that the DPCP scheme achieved more kilobytes of data transferred per second and reduction in energy consumed per successful communication of 1 kilobyte data in joules. This means that the DPCP scheme can achieves a high reduction in the energy consumption. On the other hand, the simulation results also indicate that the DPCP scheme improves the network throughput compared to IEEE 802.11 std. The DPCP protocol is mainly designed to save energy and improve the throughput.

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