QoS ENHANCEMENT IN MANET BY DIRECTIONAL POWER CONTROL

In this paper, the 4-Way Directional Power Control with Recoil Loop (4WDPCRL) protocol for power control of directional antennas is presented. We propose the scheme with using of control packets (RTS/CTS/DATA/ACK) for exchanging information about node’s transmitted energy. Whenever the frame is received, the appropriate power for transmitted frame is computed. This information is stored together with updated information about position of node to the table. If a new transmission occurs, the node sends packet with updated information about position and appropriate power. The simulation results show that the throughput and energy consumption of the proposed protocol was improved compared to IEEE 802.11 MAC protocol with omni-directional antenna and DMAC protocol with directional antenna.

Keywords: MANET, directional antenna, power control, IEEE 802.11.

1. Introduction

One of the main targets in designing mobile ad hoc networks (MANET) is how to enhance the network throughput while maintaining low energy consumption for packet processing and communications. One approach how to increase throughput is to use directional antenna. With directional antennas, a transmitter can concentrate most of its power towards the destination and reduce interference to nodes in the vicinity. This leads to extended communication range, increased spatial reuse and less interference to other ongoing transmissions. However, to control this antenna the effective directional MAC protocol is needed. A lot of researches are engaged to design an effective directional MAC protocol [1 and 2]. However, most of them assume transmitting signal without any power control mechanism. Although directional antenna and power control by themselves can improve spatial reuse considerably, only when both are employed simultaneously the full potential capacity is realized [3 - 6].

In this paper, we propose a new MAC protocol called 4-Way Directional Power Control with Recoil Loop (4WDPCRL). This protocol uses a directional virtual carrier sensing (DVCS) mechanism [7] to effectively control the directional antenna. Moreover, the power control mechanism is used. If a new transmission occurs, the node sends control packets (RTS, CTS, ACK) and DATA packets to exchange information about the transmission energy. Whenever the frame is received, the appropriate power for its transmission is computed. This information is stored together with updated angle of arrival (AoA) information about a position of node to the neighbor table. This table includes every node in the network with actual information about position and appropriate power. If a destination node doesn’t receive a RTS packet, the source node sets value of transmitting power to maximal transmitting level to re-establish the connection. This leads to increased spatial reuse, less interference to other ongoing transmissions and saving the energy.

This paper is organized as follows. The proposed directional power control MAC protocol is presented in Section 2. In Section 3 the proposed protocol in more details is presented. Section 4 presents simulation environment and simulation results and section 5 provides the conclusion.

2. The Proposed Directional Power Control MAC Protocol

Interference Estimation Using Analytical Model

Preliminaries

A flat-top model of a directional antenna for determining the interference is shown in Fig. 1, where R denotes the maximal permitted transmission range of node A, θ is the beam width of the main lobe. This model is simplified, since the side lobes are not used [8].

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Therefore, the total interference for node A is given by

\[ I_{\text{total}} = \rho \theta \left( \int_0^R I_1(r) \, dr + \int_R^\infty I_2(r) \, dr \right) \]  

where \( \rho \) is the uniform active node density, determined by the number of active nodes in the whole network divided by the area of distribution of all nodes in the network (nodes per square meter).

If the node with which node A is communicating is located at distance \( d \), then the signal-to-interference ratio (SIR) at A will be given by

\[ \text{SIR} = \frac{(P_i h^2) / d^4}{I_{\text{total}}} \]  

### Power Control Mechanism

For the correct reception of messages by 4-way handshake (RTS/CTS/DATA/ACK), it is needed that power of received packet must be higher than \( P_{\text{th}} \), where \( P_{\text{th}} \) is the minimum power threshold required to receive the packet correctly.

\[
\begin{align*}
P_{\text{RTS}} &\geq P_{\text{th}} \\
Pt_{\text{CTS}} &\geq P_{\text{th}} \\
Pt_{\text{DATA}} &\geq P_{\text{th}} \\
Pt_{\text{ACK}} &\geq P_{\text{th}}
\end{align*}
\]  

where \( P_{\text{RTS}}, P_{\text{CTS}}, P_{\text{DATA}}, P_{\text{ACK}} \) are values of the received power of RTS, CTS, DATA and ACK packets. In NS-2 simulator the value \( P_{\text{th}} = R_{\text{Rx threshold}} \).

To calculate the effective transmission powers \( Pt_{\text{CTS}}, Pt_{\text{DATA}}, Pt_{\text{ACK}} \) the following equations are used

\[
\begin{align*}
Pt_{\text{CTS}} &= Pt_{\text{RTS}} - (P_{\text{RTS}} - P_{\text{th}}) \\
Pt_{\text{DATA}} &= Pt_{\text{CTS}} - (P_{\text{CTS}} - P_{\text{th}}) \\
Pt_{\text{ACK}} &= Pt_{\text{DATA}} - (P_{\text{DATA}} - P_{\text{th}}) \\
Pt_{\text{F-RS}} &= Pt_{\text{ACK}} - (P_{\text{ACK}} - P_{\text{th}})
\end{align*}
\]  

### 3. Four Way Directional Power Control with Recoil Loop

To explain the operation of the 4WDPCRL protocol, we use a simple scenario with only two nodes, where node A wants to send data to node B. The basic principle of the 4WDPCRL algorithm can be divided into the following five steps:
1. Step - Sending RTS packet

Node A first checks the information about the location of node B in the neighbor table. This information is estimated by using AoA or RSS (Received Signal Strength) mechanisms. However, this information is not obtained at the beginning of the transmission and, therefore, RTS packet is sent by using omnidirectional antenna. Before node A will transmit the packet, it checks the information about value of transmission power for efficient packet transport to node B from previous transmission. This information is not obtained at the beginning, so RTS packet is sent by using the maximum power $P_{\text{max}}$. Information about transmission power $P_{t_{\text{RTS}}} = P_{\text{max}}$ is encapsulated inside the RTS packet and also it is saved to the table. The flow graph of sending RTS packet is shown in Fig. 2.

2. Step - Receiving RTS packet and sending CTS packet

Node B receives the RTS packet if the (7) condition is satisfied. If not, the packet is discarded. Node B records the information about the location of node A into the neighbor table, depending on fact which sector of the antenna received the maximum level of signal. Subsequently, the node B measures the value of received power $P_{r_{\text{RTS}}}$. Node also “knows” the value of which RTS packet was sent (value is encapsulated in the RTS packet). Based on information about $P_{r_{\text{RTS}}}$ and $P_{t_{\text{RTS}}}$, node B computes the value of the effective transmitting power $P_{t_{\text{CTS}}}$ for CTS packet by using (8). This value is encapsulated in the CTS packet and saved to the table. The node B then sends directional CTS packet using (8). The flow graph of receiving the RTS packet and sending CTS packet is shown in Fig. 3.

3. Step - Receiving CTS packet and sending DATA packet

4. Step - Receiving DATA packet and sending ACK packet

Both steps are the same as the previous one, so only flow graphs are shown in Figs. 4 and 5.
4. Performance Evaluation

Simulation Setup

The NS-2 simulator was used to evaluate the performance of our proposed protocol scheme. We compared the proposed power control scheme with IEEE 802.11 MAC (omni-directional antenna) and D-MAC (directional antenna) schemes. The directional antenna was used as a switched beam antenna (divided to 12 antenna sectors) with a flat top radiation pattern. The simulation model consisted of 30 wireless nodes randomly placed in an area of 1000 x 1000 m. NS-2 mobility model was used, where nodes’ speed was changed from 0 to 5 m/s with 1 m/s step. As a traffic model, 10 Constant Bit Rate (CBR) flows with the packet size of 512 bytes were used. The packets generation rate (number of packets per second) was randomly changed. Simulation parameters are summarized in Table 1.

As the routing function is not allowed, nodes that want to start communication with each other were located in their own communication range.

Results and Analysis

Figure 7 shows simulation results of average network throughput for 10 data flows, where speed of nodes was changed. The lowest value of average throughput for all speeds was achieved by using IEEE 802.11 MAC protocol with omni-directional antennas. For 0 m/s the proposed protocol enhanced throughput about 66.7% compared to IEEE 802.11 MAC protocol and for 5 m/s the enhancement was up to 58.4%. This enhancement in network throughput was achieved by increasing the number of simultaneous transmissions by minimization of interference.
Figure 8 shows the values of packet error rate (PER) for three different MAC protocols. From the results we can see that the best result was reached by 4WDPCRL protocol. This enhancement in PER is achieved by minimized interference.

The average energy consumption per node is shown in Fig. 9. The results show that the highest values of energy consumption were reached with IEEE 802.11 MAC protocol. The best value was again achieved by using 4WDPCRL protocol. The enhancement in the energy consumption is achieved by integration of a power control scheme.

5. Conclusions

In this paper, a new power controlled directional MAC protocol for MANET networks, named 4-Way Directional Power Control with Recoil Loop (4WDPCRL) was proposed. At the beginning of the transmission only the first RTS packet is transmitted omni directionally and with maximal power, other packets are sent directionally and with effective transmission power used. By using loopback, the interference at the start of the new transmission between the same nodes was optimized because both nodes had already included location information and information about effective transmitter power. This leads to
minimizing the interference, to improved spatial reuse and also to saving energy, which is very limited in MANET networks.

The rest of the paper gives the comparison of the proposed 4WDPCRL protocol with both widely used DMAC and IEEE 802.11 MAC protocols. On the basis of simulation results we can say that our proposed protocol outperforms both widely used IEEE 802.11 MAC and DMAC protocols in chosen quality of service parameters - throughput and energy consumption.

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