POWER CONTROL AND PERFORMANCE IMPROVEMENT OF INFRASTRUCTURELESS NETWORKS USING DIRECTIONAL ANTENNAS

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ABSTRACT

Infrastructureless networks are the collection of two or more nodes, which are connected in decentralized manner for enabling wireless communication. In infrastructureless networks any node can move at any time so these types of networks require routing protocols those have dynamically changing topology. There are many approaches have been proposed by researchers to improve the system performances of infrastructureless networks. These approaches include the use of directional antennas & power control mechanisms. Actually, directional antennas could be used for transmitting as well as receiving but mostly researchers consider only directional transmission. In this work, a power controlled directional medium access control protocol has been proposed, which enables both directional transmission and reception of data and control packets. The performance of our protocol has been evaluated in heterogeneous infrastructureless scenario and results show that how much performance enhancement can be achieved by using directional antennas and power control mechanism.

KEYWORDS

DVCS, DVCSCP, MAC, IEEE802.11, QualNet.

1. INTRODUCTION

Wireless ad hoc networks are the collections of wireless nodes, forming a temporary network without centralized administration or without pre-existing infrastructure, so these networks called infrastructureless networks. In last decade, various methods have been developed to improve the utilization of shared channels and also to increase network throughput, which mainly involve replacing the transceiver system (means replacing omni antennas with directional antennas) and controlling packet transmission power adequately. There are many advantages of using directional antennas in wireless communication system and they play very important role in 3G & 4G systems. These are also called smart antennas.

However, with the simply use of directional antennas, there is no satisfactory improvement achieved but sometimes it deteriorates performance of network due to several problems like deafness problem & hidden terminal problems etc. So the designing of new MAC protocols that could better utilize the advantages of these antennas becomes an interesting research area.

2. RELATED WORK

A DMAC (Directional MAC) scheme is proposed in [1]. This scheme simply utilizes GPS (Global Positioning System) as additional device to get local information. It transmits RTS (request to send), ACK and DATA directionally and alternatively transmits CTS (clear to send) omnidirectionally depending on whether the antenna pattern of the transmitter is blocked. An enhancement of the DMAC protocol is introduced in [2] that is MMAC (Multi-hop RTS MAC) scheme. In [3], a new carrier sensing protocol is designed, called DVCS (Directional Virtual Carrier Sensing). This scheme enables both directional transmission and directional reception. Instead of using GPS devices to locate each node, this scheme estimates the node location information by running DoA (Directional of Arrival) algorithm. We can improve the performance of infrastructureless networks by integrating transmission power control algorithm into DMAC protocols. Many power control mechanism have been proposed [4, 5, 6, 7, 8] that are based on directional antennas. In this work, we propose a power controlled directional medium access control protocol which enables both directional transmission and reception of data and control packets (RTS/CTSIDATAIACK packets). We evaluate the performance of our protocol in both homogeneous (all the users have directional antennas) and heterogeneous (some users have directional antennas) ad hoc scenarios by computer simulations.

3. THE PROPOSED MAC PROTOCOL

We propose a directional antenna based MAC protocol with controlled power, by incorporating a power control scheme into pre-existing DVCS protocol and name our protocol Directional Virtual Carrier Sensing with Controlled Power protocol (DVCSCP). The reason for choosing DVCS is, it performs very well in heterogeneous ad hoc networks. This protocol enables the nodes equipped with directional antennas to be work with the nodes running under the 802.11 MAC with omni antennas. The algorithm to be incorporated, for power control is similar to [4,5]. However, our proposed scheme supports power control for both data and control packets (ACK and CTS) packets. To explain the operation of the DVCSCP protocol, we use a simple scenario with only two nodes in the system as illustrated in Fig. 1.

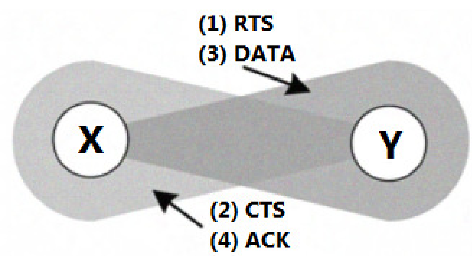

Figure 1: Packets transmission using DVCSCP

We assume that node X wants to send data to Node Y and it finds an estimated AOA (angle of arrival) for node Y in its cache. In first step, the antenna pattern is adjusted by node X towards the direction of the cached AOA, that may be little differ than the exact direction of node Y since node X or Y probably changed their relative locations due to mobility. Following this, node X sends the Directional RTS (DRTS) to node Y at a maximum power and encapsulates this transmission power Tx_Power_dBm (noted P_T) inside the DRTS packet. To do this, DRTS packet's format has to be modified. Node Y senses the DRTS packet and adjusts its antenna pattern to receive maximum power. After successful reception of DRTS, node Y locks the pattern for upcoming transmission and checks the received RTS power Rx_Power_dBm (noted P_R) and must use P_R to extract Tx_Power_dBm from the DRTS packet. Note that, the received power for node Y to receive packet must be greater than Rx_Sensitivity (noted R_s), which is the minimum power threshold required to receive the packet correctly.

$$P_R = P_T + G_T - P_{PL} + G_R - R_N - P_{fm} \qquad (1)$$

Where,
G_T: Ttransmit antenna gain
P_{PL}: Power lost due to the path-loss
G_R: Receive antenna gain
R_N: Power lost due to the noise at the receiver
P_{fm}: Fading margin.
Then, node Y computes γ, which is the difference between the received power and its threshold, means $\gamma = P_R - R_s$. Node Y then encapsulates γ into its DCTS packet and then transmits DCTS packet back to node X using a reduced power Power_CTS (P_{CTS}).

During the second step, when DCTS packet received by node X, its antenna pattern is re-adjusted to maximize the receiving power and then locks this pattern until the completion of the transmission of ACK packet. The angle of arrival of node Y stored in node X will also be updated. The beamforming operation on both sides correctly adjusts the directional antennas. After this, node X extracts value of γ from received DCTS packet and determines the appropriate power for transmitting data packets (denoted Power_data, P_{data}) using (2).

$$P_{data} = dBTomW(P_T - \gamma)\ A_{data} \qquad (2)$$

Where,
dBTomW : denotes a function used to transfer value in dB to value in mW, $dBTomW(x) = 10^{(x/10)}$.
A_{data} : represents amplified coefficient used for data transmission.
The reason of using amplified coefficients is to take account of various performance degrading effects i.e. unexpected interference, mobility and fading. Node Y then uses P_{data} for data transmission. For calculating the required power for CTS and ACK transmissions, we used same method as used in second step except that when computing the values of P_{CTS} and P_{ACK} we used a larger value for A_{CTS} and A_{ACK} respectively, aiming to decrease the probability of corruption of CTS and ACK.
After successful completion of ACK transmission, the third step comes, when both Tx and Rx sides unlock their beam patterns.

4. PERFORMANCE EVALUATION

We evaluate the performance of proposed DVCSCP protocol and compare it with IEEE 802.11b protocol and DVCS protocol (without power control). The software used for simulation is QualNet 4.5.1 [10], distributed by Scalable Network Technologies, Inc. This work is evaluated with full IP protocols & with more actual directional antenna model. Table 1 gives detail about parameters used in our simulation.

Table 1: Parameters used in simulation

Parameters	Description
Path loss model	two-ray model
Field temperature	290K
Radio type	802.11b
Data rate	2Mbps with DBPSK modulation
Directional antenna gain	15dBi
Routing protocol	AODV
Transmission power	16 dBm
Receiver sensitivity	89.0 dBm
CBR packet size	512 bytes
Amplified coefficient for CTS and ACK	1.15
Amplified coefficient for Data	1.10
Height of both omni antennas and steerable directional antennas	1.5 meters
Directional NAV delta Angel	37 degree
AOA cache expiration time	2s
Directional beamwidth	45 degrees

We take two scenarios for simulations; one is randomly generated homogeneous topology and second is more realistic heterogeneous adhoc scenario. In first topology, 45 nodes are randomly placed over a 1500 x 1500 m flat terrain. Out of ten nodes, one is randomly selected as the source & each destination node is also randomly selected from 45 nodes. In this, directional antenna is used as an electronically steerable antenna which includes a circular antenna array with 6 isotropic antenna elements. In second, we take 50 nodes which are randomly placed over a 1500 x 1500 m flat terrain. In this scenario, 33 nodes are equipped with the directional antennas and run DVCSCP or DVCS protocol. The other 17 nodes are equipped with omni antennas and run the 802.11b protocol. 9 CBR traffic flows are set randomly. In this work, we measure the mean value of the throughput which is average throughput of all the traffic flows in network. For the consumption of power, we take into consideration only the consumed power for the purpose of transmission. We also measure the mean value of the power consumed which is the average power consumption for the transmission of RTS/CTS/DATA/ACK packets of all the communicating nodes in the network.

5. RESULT & DISCUSSIONS

Fig. 2 & Fig. 3 show the performance comparison for randomly generated homogeneous topology. The network throughput is shown in fig. 2 and it is clear from the figure that our proposed DVCSCP protocol achieves up to 16% over DVCS and 99.3% over IEEE 802.11b. This enhancement in network throughput is achieved by increasing the number of simultaneous transmissions and largely minimized interference. Fig. 3 shows the power consumption comparison. Our proposed DVCSCP protocol has power consumption that is about 17% of that of 802.11b scheme & 36% of that of DVCS. This power saving is attributed to the power control mechanism & to the directional antenna gain.

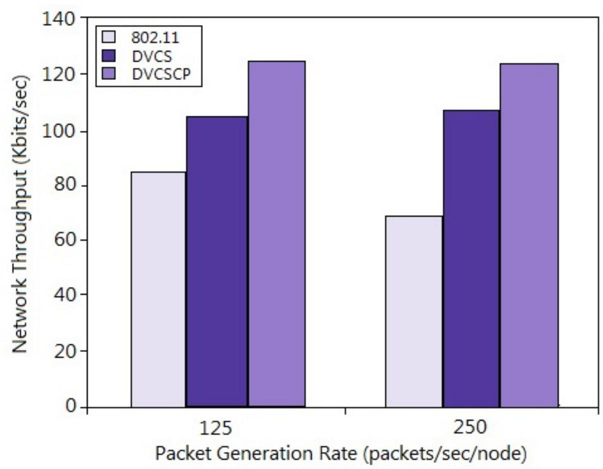

Figure 2. Network Throughput in scenario 1.

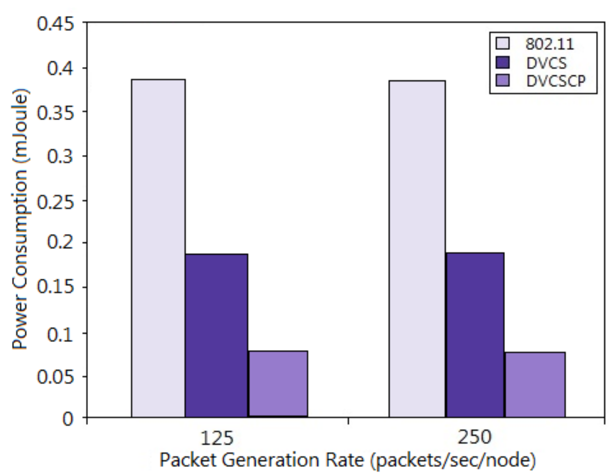

Figure 3. Power consumption in scenario 1.

The performance comparison of heterogeneous scenario is shown in fig. 4 & fig. 5. We vary the packets generation rate (number of packets per second) from 1 pps to 1250 pps. From figures, we can say that as the packet generation rate exceeds over 50 pps, then there is an improvement in throughput in DVCSCP protocol and also DVCSCP protocol always consumes less power than that of DVCS protocol. When packet seeding rate is 1000 pps, then DVCSCP protocol improves the network throughput by about 36% and achieves a 66.5% reduction in the transmission power consumption as compared with DVCS protocol. The enhancement in the performance is attributed to integration of our mechanism (power control scheme). This mechanism enables the adjustment of transmitting power for DATA, ACK & CTS packets and therefore there is reduction in energy consumption of both transmitting and Receiving nodes, as well as this enables reduction in the interference to their neighbour nodes, so that there is improvement in system throughput.

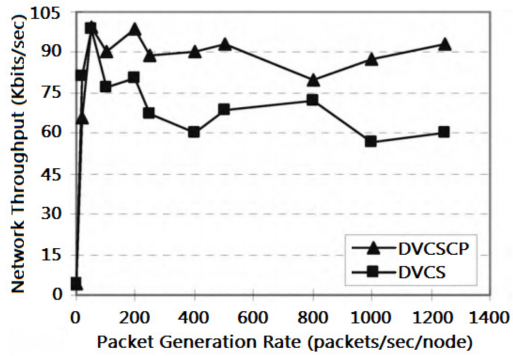

Figure 4. Network Throughput in scenario 2.

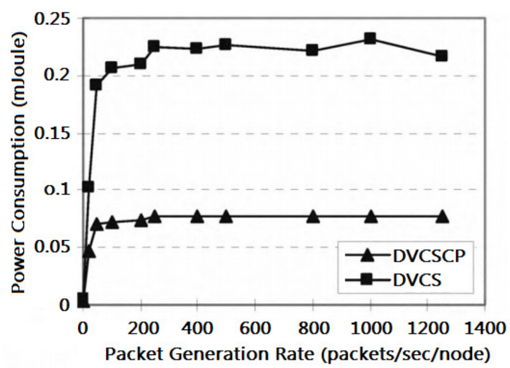

Figure 5. Power consumption in scenario 2.

6. CONCLUSIONS

In this work, we propose a power controlled directional MAC protocol which enable both transmission and reception of both data and control packets and also could work well in both homogeneous and heterogeneous ad hoc networks. We use QualNet simulator, for performance evaluation of proposed protocol in realistic situations. The rest of the paper gives the comparison of DVCSCP protocol with the DVCS protocol & IEEE 802.11b protocol. On the basis of simulation result we can say that our proposed protocol enhances throughput about 99.3% than that of the IEEE 802.11b protocol and up to 36% over the throughput of DVCS protocol. Our proposed protocol reduces the power consumption up to 66.6% compared with DVCS protocol & up to 83% compared with IEEE 802.11b protocol.

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