Performance Comparisons of Directional MAC Protocols for Wireless Ad Hoc Network

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ABSTRACT
The directional antennas increase the spatial reuse, improve the transmission reliability, extend the transmission range and/or save the power consumption in the network. However, with directional antenna's advantages, some serious issues like deaf and hidden node problem come. Due to these issues, we fail to get full exploitation of directional antennas. Several directional MAC protocol suggested in last decays to take full benefits of the antenna. In this paper, we simulate some directional MAC protocol with the help of OPNET 14.5. We compare the simulation results of those directional MAC protocols in the terms of throughput and delay metric.

Keywords
WLAN, Directional MAC, ad hoc network, Directional antenna

1. INTRODUCTION
Traditional wireless network's nodes are designed for Omni directional antenna and only one transmission can done at a time[1]. Therefore, with omnidirectional antenna, the large portion of the network is unnecessary unused. Moreover , when the density of network increases the performance decreases due to collision and interference [2], [3]. Therefore, nowadays the use of directional antenna with wireless network's nodes is more popular because of its directional transmission [4], [5], [6], [7], [8], [9]. The directional transmission increases spatial reuse in the network, so the network performance increases. Directional antenna can points their beam in particular direction, so the interference from other direction cannot be disturbs the communication. Moreover, A directional antenna has higher antenna gain in a particular direction than omni directional antenna [4], [5]. Thus a node gets higher transmission range in a direction due to higher antenna gain. With the advantages, directional antenna brings some serious issues such as deaf and hidden node problem [5], [9]. Its blurred the advantages of the directional antenna. Therefore, several directional medium access control (DMAC) protocols proposed to solve the above mentioned issues.

In this paper we simulate some popular directional MAC protocols and evaluate the results in the terms of throughput and delay. For simulation we used OPNET 14.5 [10]. OPNET provides us the virtual environment of the network.

The rest of this paper is organized as follows: Section 2 discusses the some popular directional MAC protocols. Section 3 discusses the simulation setup. Section 4 evaluates the simulation results and Section 5 concludes our work.

2. THE DIRECTIONAL MAC PROTOCOLS
In this section we discuss the some directional MAC protocols. In the wireless ad hoc network there are several DMAC protocols. It is very difficult to choose some DMAC protocols for evaluation. We are trying to choose some DMAC protocol for our comparison.

2.1 DMAC1
Chaudhury et. al [6] proposed a scheme to increase spatial reuse in the network by using the directional antenna. They exploits the characteristics of directional antenna and points the issues such as deaf and hidden node problem occurs with directional antenna. Their proposed scheme, uses multi-hop RTSs to establish links between distant nodes, and then transmits CTS, DATA and ACK over a single hop. In their scheme they divided the neighbors in two categories. First is directional to directional neighbor is called DD neighbor, the second one is directional to omni neighbor is called DO neighbor. If a node has packet to transmits, first it sends RTS to the destined node by using their DO neighbor and after the hearing of RTS, the receiver node points their beam towards the sender and sends CTS as response. Then directional DATA transmission starts.

Figure 1 depicted the working process of DMAC1. In the figure we can see that if node A has packet for node F. its send RTS to node F by using their DO neighbor route A-B-C-F. After hearing the RTS from node A, node F points their beam towards node A and they starts their data communication directionally.

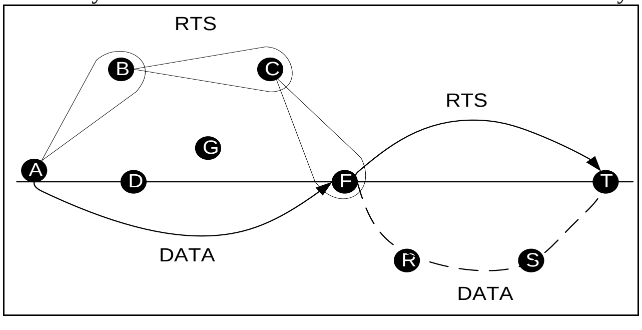

Figure 1: Working procedure of DMAC1

2.2 DMAC2

Gossain et al [7], proposed a scheme “cross-layer directional antenna MAC protocol for wireless ad hoc networks” to reduce the Deafness problems in the networks using directional antennas. They also address the issue of deafness with directional antenna. In their scheme first they send RTS only towards the destined node, if the node response with CTS, then the sender and receiver both sends circular RTS and CTS respectively towards their vicinity. After successful transmission of circular RTS/CTS, they start their directional DATA transmission.

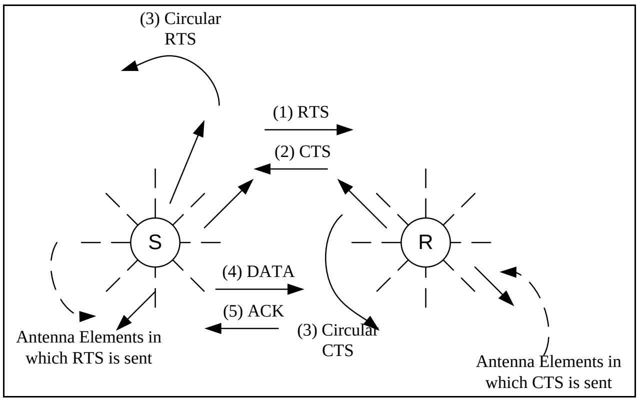

Figure 2: Working Procedure of DMAC2

The working procedure of DMAC2 depicted in Figure 2. In the figure we can see, the sender node S sends RTS and the receiver node replies with CTS in step 1 and step 2 respectively. After the success full RTS/CTS handshake node S and node R sends circular RTS and CTS respectively in step 3. After sending the RTS/CTS to vicinity, node S transmits DATA in step 4. After receiving the data successfully, node R sends ACK in step 5.

2.3 DMAC3

Jallari et al [11] proposes a MAC protocol that incorporates circular RTS and CTS transmissions. They shows that the circular transmission of the control messages helps avoid collisions of both DATA and ACK packets from hidden terminals. In their scheme the all transmission is directional. If a node has packet it transmits RTS towards the destined node. After transmitting the RTS, the node shifts the beam on the right and sends the same RTS message with other beam and so on. Finally, the sequential transmissions circularly cover the entire area around the transmitters. Then the sender node waits for CTS in omni directional mode. The receiver node replies with CTS towards sender node. After sending the CTS to sender, the receiver node also sends circular CTS to its vicinity similar to sender node by shifting its beam.

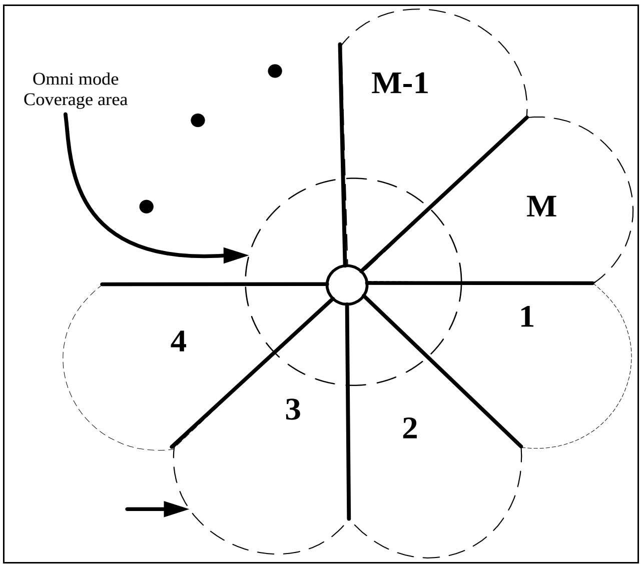

Figure 3: Working procedure for DMAC3

Figure 3 shows the working procedure of DMAC3. In the figure, a node transmits RTS to its destined node thorough beam number 3, and then it shifts the beam to sector 2 and sends RTS again then sector 1 and so on. Finally, the nodes transmit RTS circularly around the node. The receiver node receives the RTS, because it is in omni mode, transmits CTS towards the sender, then similar to sender node its transmit CTS circularly to its vicinity, then the starts DATA transmission.

2.4 DMAC4

Alam et al [5] proposes a scheme to reduce the hidden and deaf node problem in the network. In their scheme, the nodes are mounted with multibeam smart antenna (MBSA). In their scheme, if a node has packet it transmits RTS^1 towards destined node. After successful RTS/CTS handshake the sender and receiver node transmit their RTS^2 and CTS^2 by using their other beams to inform their vicinity. They address issues of use of directional antenna in detail. To reduce the hidden node problem due to unawareness of the ongoing communication, they propose, the transmission of Neighbor Information Packet (NIP).

The working procedure of DMAC4 depicted in Figure 4. In the figure node F and G starts directional communication while node A and B is communicating. Since node A B is busy, they are unaware about the impending communication of node F G. The node C and E sets their DNAV for the both communication (node pair AB and FG). Node AB finish their communication while the node FG still communicating. After completing the AB’s communication the idle node C and E sends NIP toward them. The NIP contains the remaining duration of node FG’s communication. After receiving the NIP the node A and B sets their DNAV for node FG.

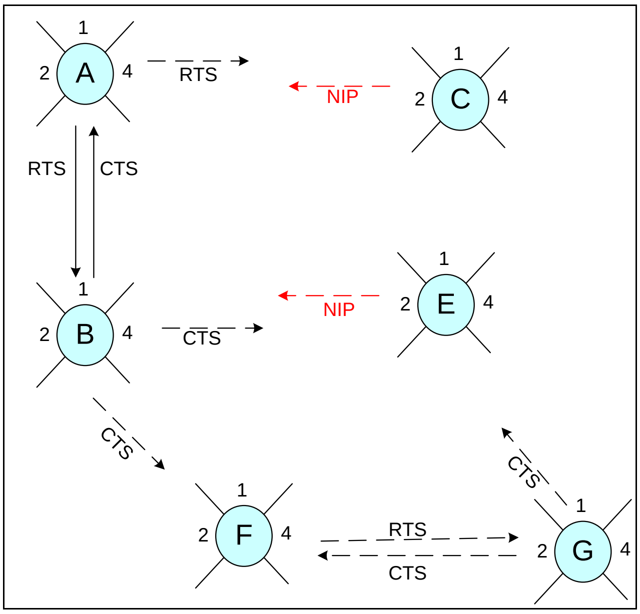

Figure 4: Working procedure for DMAC4 [5]

3. SIMULATION SETUP

In this section we discuss about our simulation setup. For simulation we use OPNET 14.5 [10]. OPNET provides virtual environment of network scenario. It provides several editors such as antenna pattern editor, node editor, process editor, and packet format editor etc. to give real scenario of the network. For our simulation, we design antenna in antenna pattern editor, node model in node editor. We modify the MAC process model in function block of process editor as per our requirement. The structures of node model for our simulation depicted in Figure 5.

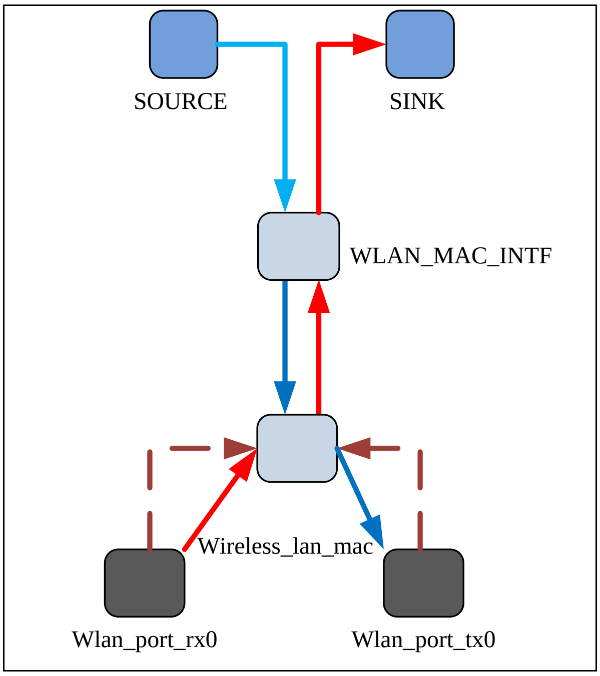

Figure 5: Node model for our simulation

We design a simulation scenario of 50 nodes, randomly distributed in 500 × 500 m^2 area. The half node in the network is sender node and the half one is receiver. Figure 6 depicted the simulation scenario of for the above discussed DMAC protocols. Each simulation runs for 600s. The result is the average of 10 runs with random seeds.

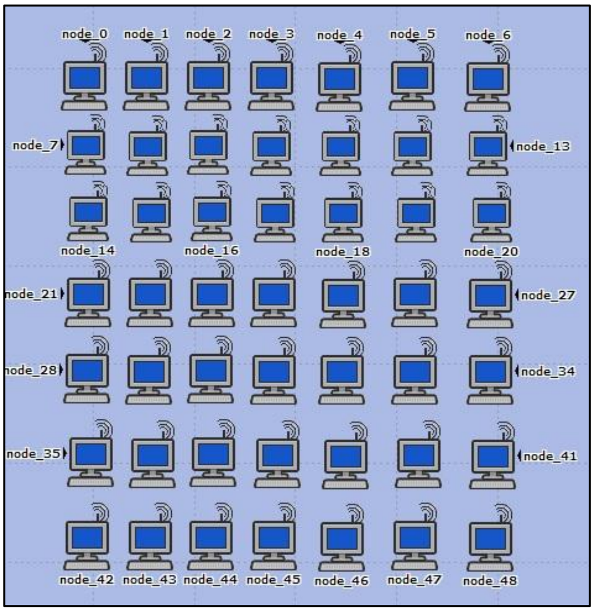

Figure 6: Simulation Scenario

For the simulation, we change in the MAC process model given default in OPNET as per DMAC requires.

4. PERFORMANCE EVALUATION

In this section we compare the results of the DMAC protocols in the terms of throughput and delay.

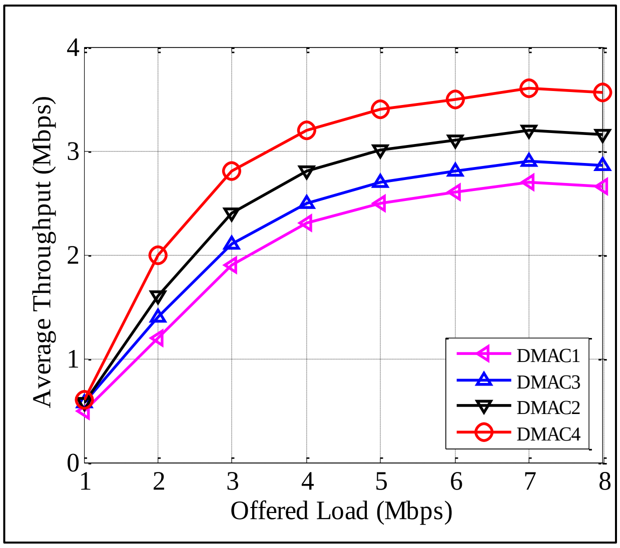

Figure 7: Average Throughput vs. Offered Load

Figure 7 depicted the average throughput vs. offered load of our simulation results. In the figure the DMAC performance is best among them because they mount multibeam smart antenna at the node. The DMAC1 performance is lowest because use of dual routing system for channel reservation and data transmission. DMAC2 performance is better than DMAC1 and DMAC3 because of its circular transmission decreases the hidden and deaf node problem.

Figure 8 shows the curve of average delay vs. offered load. In the figure we can see that the delay of DMAC4 is lowest because of multibeam smart antenna. The delay of DMAC2 is greater than that of DMAC4 and DMAC3 because of its circular transmission takes time according to number of beams. The delay of DMAC1 is highest because of the DO neighbor route take time to forward the RTS message to destined node.

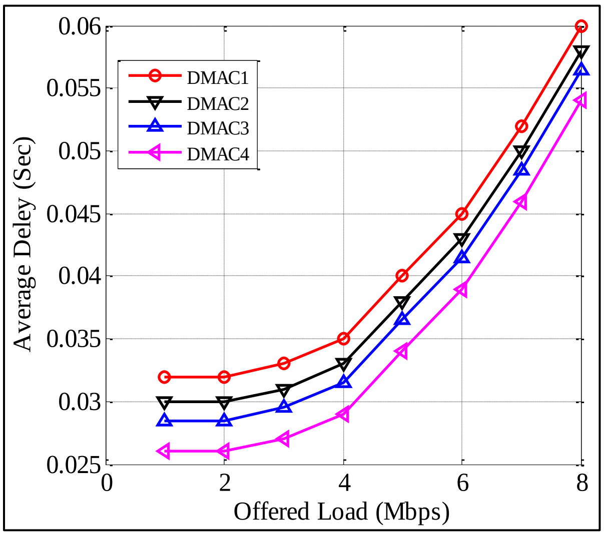

Figure 8: Average Delay vs. Offered Load

5. CONCLUSION

This paper evaluates performance of the some DMAC protocols in terms of throughput and delay, by using OPNET simulation tool. We found the performance of DMAC4 is best among them and the DMAC1 performance is worst. The simulation results indicate that if we use directional antenna, the overall throughput is increases in the network. The results validate that the use of directional antenna increases the spatial reuse.

6. ACKNOWLEDGEMENTS

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