CHALENGES OF INTEGRATION OF SMART ANTENNAS IN AD HOC NETWORK

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Abstract: Due to the need for increasing exchange and share data, users demand easy connectivity and fast network wherever they are. Recently, users are interested in interconnecting all their personal electronic devices together using Mobile Ad Hoc NETwork (MANET). The capacity of ad hoc network can be limited because of interference. When a smart antennas system is integrated in such network, we can achieve significant spatial reuse, decreasing the interference and thereby increasing the capacity of the network. In this paper we examine the challenges at medium access control caused by integration of smart antennas system in ad hoc networks.

Keywords: MANET, MAC, Routing, Smart antennas.

1. INTRODUCTION

Firstly, A MANET was sponsored by the United States (U.S.) Defense Advanced Research Projects Agency (DARPA) in the early 1970s.and it was called packet radio system. The packet-radio systems predated the Internet and, indeed, were part of the motivation of the original Internet protocol (IP) suite. Later DARPA experiments included the Survivable Radio Network (SURAN) project, which took place in the 1980s. The third wave of academic activity on Wireless Ad-Hoc Networks started in the 1990s, especially with the wide usage of inexpensive 802.11 radio cards for personal computers[1].

A Mobile ad hoc network is a wireless network of mobile nodes connected by a wireless link without central control [2][3]. Each node in a MANET can move independently in any direction, therefore links to other devices will change frequently. And each node makes its decision based on the network situation, without any reference infrastructure and nodes can thus behave as routers or hosts.

The use of smart antennas in cellular networks has increased capacity by reducing interference and enabling spatial reuse of spectrum. Typically these antennas are deployed at base-stations in these networks to sectorize cells and focus transmissions in particular directions [4][5]. A Smart antennas is an array of antenna elements which provided by signal processing algorithms to improve the received signal [6][7].

In this paper: we review the smart antenna basics and models in section 2. Section 3 specifies the medium access control protocols for MANETs. Approaches proposed for directional medium access control is in section 4. Final section is conclusion.

2. SMART ANTENNA

Typically, an ad hoc network uses omnidirectional antennas which can transmit and receive signals equally from all directions. Since two nodes communicate using a given channel, all the other neighboring nodes keep silent. Thus the capacity of an ad hoc network that uses such antennas is limited[8].

Smart antennas allow the energy to be transmitted or received in a particular direction as opposed to disseminating energy in all directions[9]. Typically these antennas are deployed at base-stations in cellular networks to sectorize cells and focus transmissions in certain directions. A Mobile ad hoc network (MANET) consists of a set of wireless mobile stations (nodes) communicating through wireless channels, without any fixed backbone support. Its topology changes continuously and randomly without the aid of any centralized administration. The ability of smart antennas to direct their radiation energy toward the direction of the intended node while suppressing interference can significantly increase the network capacity compared to a network equipped with omnidirectional antennas because they allow the communication channel to be reused [10]. In other words, nodes with smart antennas focus only on the desired nodes and allow the neighboring nodes to communicate. In contrast nodes with omnidirectional antennas keep the neighboring nodes silent during their transmission as shown in Fig. 1

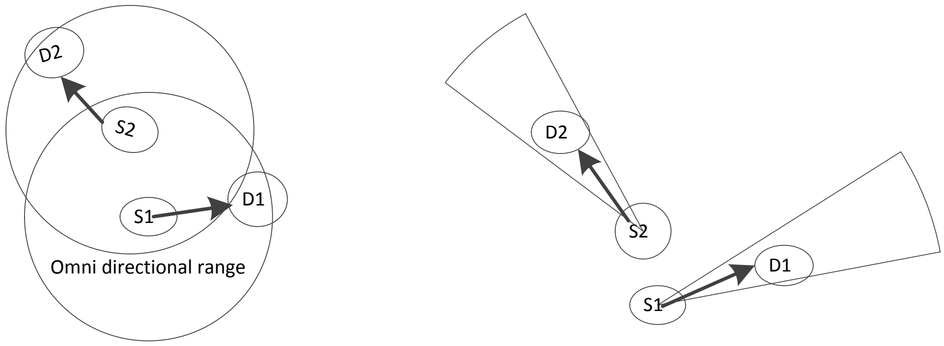

Fig. 1. Capacity of a network with omnidirectional antennas and a network with smart antennas

There are two types of directional antennas systems: the first one is switched beam (sectorized) antenna systems in which multiple fixed beams are possible. The switched beam systems presents a predetermined set of beams which can be selected as appropriate. For a switched beam antenna with K beams, the width of each beam is $2\pi/K$ radians. A directional transmission would then cover one of these k fixed sectors as illustrated in Fig. 2.

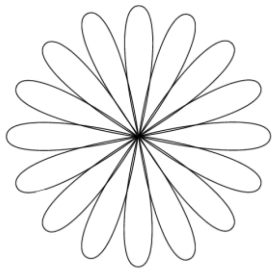

Fig. 2. Switched beam antenna system

The other type is steerable beam systems (adaptive) in which the main lobe of the antenna can be focused toward the user of interest and nulls in the direction of the interference. Thus, if a node wants to communicate with its neighbor, it can adaptively steer its beam so as to point the main lobe towards that neighbor in a mobile scenario as well [11].

Gain and directivity are intimately related in antennas. Gain is a measure of increase in power. The gain of a directional antenna is typically higher than that of an omni-directional antenna. Directional antennas can have larger directional range as compared to an omni-directional antenna[12]. The gain of a directional antenna in a particular direction $\vec{d}$ is defined as:

$$G(\vec{d}) = \eta \frac{U(\vec{d})}{U_{ave}} \quad (1)$$

Where η is the efficiency of the antenna which acounts for losses. $U(\vec{d})$ is the energy in the direction $\vec{d}$. U_{ave} is the energy over all directions.

The direction of peak gain is referred to the main lobe of the antenna.

3. MEDIUM ACCESS CONTROL FOR MANETS

The popular Carrier Sense Multiple Access/Collision Detection (CSMA/CD) MAC method is used for wired network. In CSMA/CD, when a node wants to send over the network, first it sense the wire medium whether it's idle or busy. If it's idle, the node sends its data with sensing the medium continually. Otherwise, the node delays its transmission to avoid a collision with existing packets. While in the wireless networks, the signal strength is inversely proportional to the square distance from the transmitter node, thus nodes, which are out of transmitter's range, can't sense the transmitted signal and may cause problems. For example, there are three nodes A, B, C. Node B is within the range of each nodes A and B, node C is out of the range of A. Node A wants to send to B, wherefore node A waits until the medium is idle, then A starts transmitting to B. Node C wants to send to node B while B is receiving data from A. But C can't sense the transmitted signal from A, thus C starts transmitting to B causing collision at node B. This problem is called hidden-terminal problem. Another problem when there are four nodes A, B, C, D. Nodes B and C are within the range of both nodes A and D, but D is out of A's range. While node B is transmitting data to node A, node C wants transmitting data to D. But C senses the transmitted signal from A, thus C delays its transmission to D. Even through a transmission from C does not interfere with the reception at node A, this case is called exposed terminal problem.

The Multiple Access Collision Avoidance (MACA) protocol uses two additional packets, Request To Send "RTS" and Clear To Send "CTS", to reduce the collision at receiver. These packet are shorter than data packets, however, they contain the length of the data frame that will follow. The IEEE 802.11 standard determines Distributed Coordination Function (DCF) which is used widely for infrastructureless network like MANETs to reduce the possibility of collisions. This MAC protocol dependes on the concept of Carrier Sense Multiple Access with Collission Avoidance (CSMA/CA)[13]. When the frame size exceeds a certain threshold, CSMA/CA allows nodes to exchange training frames before the data transfer as shown in Fig. 3 whose details can be found in [11]. A node can access the channel if the sensed signal is below a certain value which called threshold. If a node hears an RTS/CTS frame, it will set its Network Allocation Vector (NAV) to defer itself from access until the end of the ongoing data transmission. The IEEE 802.11 DCF uses a back off mechanism.

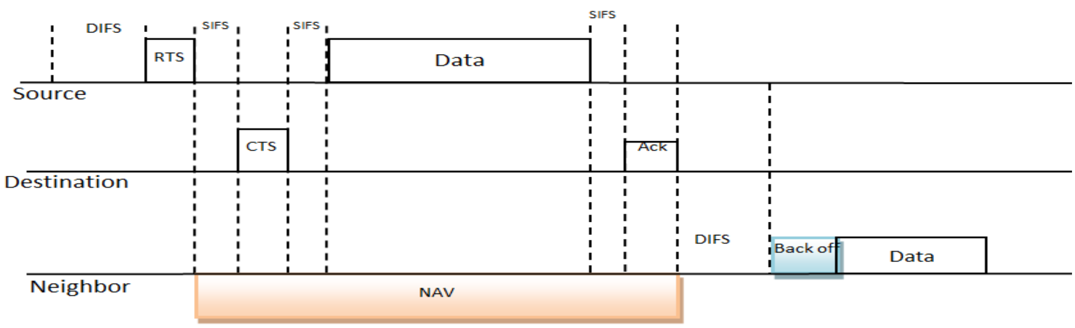

Fig. 3. The MAC protocol used for MANETs

4. MAC PROTOCOL USING DIRECTIONAL ANTENNAS

The paper supposes that there is a MANET of *n* Mobile Nodes (MNs), each MN has smart antennas with non-overlapping directions and all nodes use the same wireless channel. The antennas of a node cover all directions. The RTS and CTS messages are assumed to contain location information of both the sender and receiver; this in turn helps transmit (or receive) the DATA and ACK messages directionally[14].

There are two approaches proposed for directional medium access control in [12]: Aggressive Collision Avoidance approach and Conservative Collision Avoidance approach. In the the aggressive collision avoidance approach, a node can start a new transmission in spite of receiving an RTS or CTS sent by others nodes. The handshake is used only for ensuring that the receiver is not busy sending or receiving. While in conservative collision avoidance approach a node is always prevented from transmitting when it receives an RTS or CTS. The performance evaluation shows that both approaches outperform the IEEE 802.11 MAC with omnidirectional communications. These approaches suffer from high collisions rate because of their dependence on omnidirectional mode for the transmission or reception of control packets in order to establish directional links. Another approach had been studied in[15]. This is called Receiver Oriented Multiple Access (ROMA) which uses multi-beam antenna arrays (MBAA) as shown in Fig. 4. ROMA computes a link activation schedule in each time slot using two-hop topology information. Thereby a significant improvements on network throughput and delay can be achieved. However, ROMA does not take into account nodes mobility.

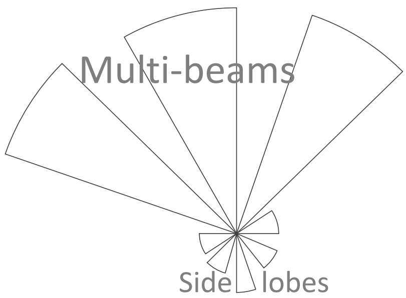

Fig. 4. The multi-beam Antenaa array

In [16] Location and Mobility Aware (LMA) MAC protocol is developed for Vehicular Ad hoc NETworks (VANETs). The predictive location and mobility of the vehicles are adopted to provide robust communication links while using the directional beams. The LMA protocol predicts the transmission angle between the transmitter and receiver. The predicted angle is not accurate, because the moving angle of the destination can be changed during the data transmission thus causing data loss. This protocol can be enhanced by using the Directional Beacon (DB) mechanism which makes the mobile nodes get the update of mobility information via DB after any change of one nodes moving angle or speed. If nodes move regularly, the predicted angle can be more accurate.

However, new challenges is appeared with the directional communications, such as deafness and hidden terminal problems. Two types of deafness is shown in the Fig. 5. The first scenario in the Fig. 5 shows that node N does not know about the transmission between S and D, so if it has a packet to send to node A it sends RTS but node N does not hear. In the second scenario, node N1 sets its DNAV for beam 3 because of receiving CTS from the destination. Node N2 sets DNAV for beams 4 and 2 because of receiving RTS and CTS. If node N2 has a packet to send to N1, it starts sending RTS to N1 from beam 1, thus the deafness is occurred.

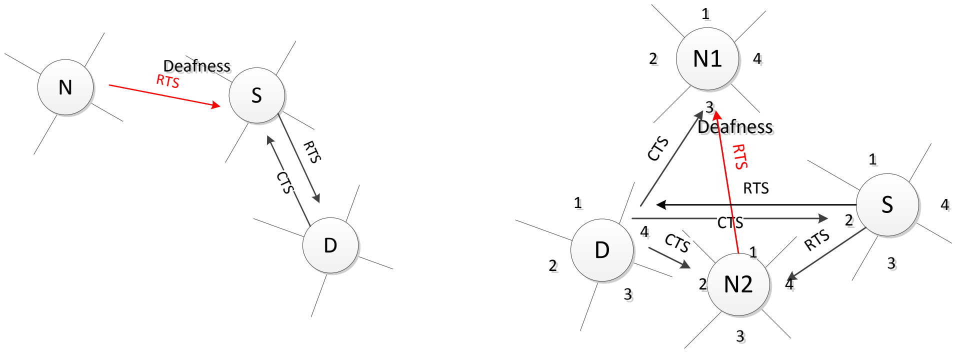

Fig. 5. Two scenarios of deafness

A new directional MAC protocol has been proposed in [7], it includes a new scheme to inform its neighbors who was deaf because of other communications. Thus it solves the deaf node problem. Moreover it prevents the hidden node problem. Each node has Multiple beam smart antenna (MBSA) with non-overlapping directions that covers all directions around the node(2π rad). If a node wants to send a packet, the RTS/CTS handshake is occurred directionally between the source and the destination. If it is completed, the communicating nodes send RTS/CTS simultaneously through all beams excepted the data communicating beams. Then they start transmitting data using the beam pointed each others and prevent the other beams from transmission and reception. when the neighbors hear a packet they set DNAV for that beam. After transmitting data, the idle neighbor of the node, which has just completed their transmission, will send a Neighbor Information Packet (NIP) to this nodes to be aware about ongoing communications in the network. Thus by using this method of simultaneous transmission of RTS/CTS and transmission of NIP, the deaf and hidden node problem are prevented.

5. CONCLUSION

In this paper we examine the challenges of integration of directional antennas in mobile ad hoc network. The medium access control protocol will have to be modified in order to exploit the use of such antennas for collision avoidance and spatial reuse.

Directional antennas allow the interference to be reduced and hence the overall capacity of ad hoc networks to be improved. However, the proposed protocols can not overcome some of the problems that arise due to the use of smart antennas. Challenges remain and the area is still open for future research.

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