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SURVEY: CLASSIFICATION OF MAC PROTOCOLS WITH DIRECTIONAL ANTENNA IN WIRELESS AD-HOC NETWORKS

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Abstract: The Directional antenna technology is a promising solution to many challenges facing wireless ad hoc networks like throughput and high antenna gain. There are also many problems like deafness problem, exposed terminal problem, hidden terminal problem, high energy consumption and they cause the degradation of overall performance. To solve these problems different MAC protocols are used. In this paper, discusses classification of the wireless MAC protocols using directional antennas .
Keyword: Medium Access Control, Directional Antennas, Wireless Ad hoc Networks, Hidden terminal, Exposed terminal, Defness.

I. INTRODUCTION

Directional antennas can increase spatial reuse and provide higher gain and reduce interference. Increasing spatial reuse and transmission range will enhance the network capacity [1]. To fully leverage the benefits that directional antennas can bring, well designed medium access control (MAC) protocols should be deployed. However, since multiple devices can access the airborne and broadcast wireless medium at the same time, the conflicts caused by simultaneous access cannot be avoided. Besides the existing problems in wireless networks with omni directional antennas, such as hidden/ exposed terminal [5], new challenging issues related to directivity have arisen when using directional antennas. The MAC protocols with directional antennas have been studied extensively in recent years. Moreover many protocols have given descriptions of directional antennas. Therefore, Here survey the various MAC protocols using directional antennas and compare them on the basis of antenna types, properties of antennas, node mobility and performance issues, etc. This paper is organized as follows. First, we provide a brief introduction to antennas and their classification in Section 2.Then introduce the MAC issues caused by directional antennas in Section 3. Section 4 gives the classification of directional MAC protocols and describes them. Comparison of the protocols in Section 5. Section 6 conclusion.

II. OVERVIEW OF ANTENNAS

A. Omni-directional Antenna

An omni-directional antenna [12] scheme may provide more connecting nodes than a directional antenna scheme if nodes in a network are located within each other's transmission range. However, closely located nodes are very likely to face co-channel interference during simultaneous transmission. The number of collisions and packet drops increases and hence the network performance degrades. Omni-directional antennas radiate energy in all directions for a given transmission power. The range using omni-directional antennas is lower than when using directional antennas.

B. Steerable Antenna

Steerable Antenna is directional antennas and has the ability to direct the beam in a particular direction. In Steerable antenna whose major lobe can be readily shifted in direction. The beam cannot be focused to the specific angle of the receiver [12]. Steerable antenna has a capability to do above mentioned task. Even steerable antennas are complete setup up of a number of antenna elements. Steerable antenna system have a logic combines the antenna elements in such a way that the beam is directed towards any given angle. These antennas are also capable to minimize the obstruction from the unwanted nodes. By mixing the antenna elements in such a way that main lobe, side lobes and tail lobe is not intended towards the interferer, then antenna reduces the interference.

C. Switched beam antennas

In switched beam antennas, space is divided into a fixed number of equally divided sectors. Each antenna element transmits a beam such that covers one sector. The switched beam antenna is the simplest smart directional antenna. Switched Beam Antennas are simpler and cheaper than steerable antennas. The main disadvantage of the switched beam antenna is the permanent nature of the beams. These beams cannot be focused to the specific angle of the receiver.

D. Adaptive array antenna

The signals are processed adaptively by a combining network and summed to create a steerable radiation pattern. The Direction of arrival algorithm for signal reception is applied for signal transmission/reception and continuous tracking. Besides the capabilities to change antenna pattern dynamically to adjust to noise, interference and multipath, the antenna can also place nulls to the direction of the interferences and offer more comprehensive interference rejection. Similar to adaptive array antenna, the DoA algorithm is also used in dynamically phased array. Since null capability is not assumed, the phase array antenna is limited in interference suppression.

E. Directional Antennas

Directional antenna is an antenna which radiates or receives greater power in one or more directions allowing for increased performance and reduced interference from

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unwanted sources. Directional antennas usually exhibit unidirectional properties. In other words, their maximum gain occurs in a single direction. So-called bidirectional antennas have two high-gain directions, usually oriented opposite to each other in space.

III. MAC ISSUES WITH DIRECTIONAL ANTENNAS

The capabilities of directional antennas are typically not fully exploited when using conventional MAC protocols, such as IEEE 802.11. In fact, the network performance may even deteriorate due to issues specific to directional antennas. In the following sections, summarize the major problems.

A. Hidden terminal problem

Unlike the omni directional counterpart, in directional antenna networks, the hidden terminals [6] are located close to the source node. Theoretically, all nodes that are located within the destination node's coverage area and are away from the source node's coverage area are hidden terminals. The shaded area Ah in Fig. 1 indicates the area at which hidden terminals may exist. Hidden terminals can severely degrade the network performance. Unfortunately, the standard RTS/CTS mechanism fails to completely solve the problem, as nodes in Ah may initiate transmissions during the time the source node transmits the RTS, as discussed in [4] and [5]. The exposed-terminal problem needs more attention in directional antenna networks. For example, if using ORTS and/or OCTS, nodes will unnecessarily block the sectors that can be used for concurrent transmissions; thus, it will waste the chance for higher spatial multiplexing gain, which defeats the purpose of using directional antenna.

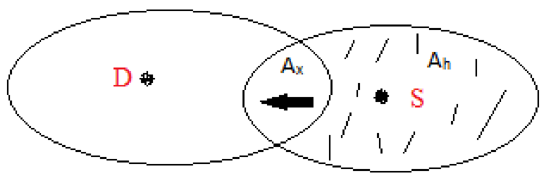

Fig.1 Hidden terminal problem

B. Deafness Problem

The deafness problem occurs when nodes use directional antennas in ad hoc networks. It happens when a source node fails to communicate with its intended destination, which is pointing at a different direction for transmitting or receiving. For example, node E in Fig.2 is trying to communicate with node S whereas S is beam formed toward node D. As a result, node E will double its back off time for retransmission, as it concludes that a collision has occurred. Even worse, when node E reaches the retry limit, it concludes that node S is unreachable.

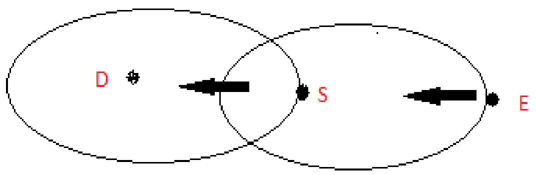

Fig 2. Deafness

C. Asymmetry-in-Gain Problem

When using two different types of transmissions on same antenna, e.g., a directional transmission for data packets and an omni directional transmission for control packets such as RTS/CTS, different transmission ranges lead to the asymmetry in gain problem. The transmission range of a directed signal and the transmission range of an omni directional radiated signal are not identical. As a result, the control packets omni directionally transmitted will not reach all the desired nodes.

IV. CLASSIFICATION OF MAC PROTOCOLS

There are few classifications, based on different features of the protocols

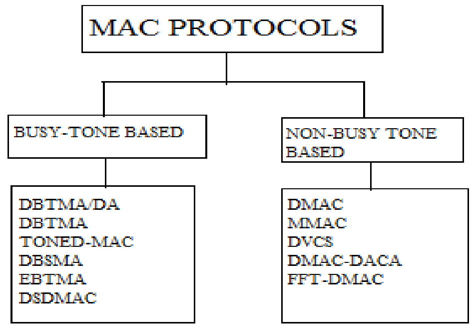

Fig 3. Classification of MAC protocol

A. Busy tone based MAC protocols

Huang et al proposed[8] DBTMA, a single channel is split into two channels one is data channel for data frames and second is a control channel for control frames. In addition ,two busy tones, transmit busy tone (BTt) and receive busy tone (BTr),are assigned two seprate single frequencies in control channel. A node that is transmitting/ receving data turns on BTt/BTr , which can heard by all nodes within its transmission range. By using the dual Busy tones DBTMA reserves the channel in both directions, which distinguishes itself from other wireless MAC protocols. It is very efficient to solve Hidden node problem. Dual-Busy-Tone Multiple Access with Directional Antennas (DBTMA/DA), which was proposed by Huang et al. [8], is a modified version of the Dual Busy-Tone Multiple Access (DBTMA) in [17] to accommodate the nodes with directional antennas. As in the original DBTMA, the DBTMA/DA uses two distinctive busy tones: a transmitter's busy tone (BTt) and a receiver's busy tone (BTr). The receiver turns on its BTr upon receiving the RTS packet, whereas the transmitter turns on its BTt upon receiving the CTS packet. Therefore, hidden terminals are notified after the CTS is being transmitted by the receiving node, leading to a large gap during which several collisions may occur. The tone-based DMAC (Toned MAC) protocol proposed in [9] uses two separated channels, i.e., a data channel and a control channel. While the data channel is used to transmit the RTS/CTS/DATA/ACK packets, the control channel is used to transmit a busy tone signal. A unique busy tone is assigned to each wireless node, and

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therefore, it can be identified, and each node should maintain a hash function for all neighbors' locations. When a source node has data to transmit, it transmits a directional RTS packet toward its destination immediately after sensing the medium at the intended direction. The destination node in response replies with a directional CTS packet back to the source node. The source and destination nodes continue with exchanging the actual data at the specified directions, and meanwhile, they omni directionally transmit a busy tone. If the source node detects a busy tone rather than receive a CTS packet, it then concludes a deafness situation. The protocol can identify some deafness situations; however, there are chances to miss the busy-tone signal from either or both the source and destination nodes, which do not guarantee a deafness-free protocol. In addition, to avoid the hidden-terminal problem, the busy-tone signal needs to be simultaneously transmitted as the RTS packet, and it also needs to be sensed before any other transmission. In [10], the busy-tone signal to be transmitted by the destination node toward the direction of the source node only is proposed. The communication first starts with a DRTS/DCTS PACKET exchange in a directional manner. The redundant busy-tone signal would serve as another way to inform other nodes of the ongoing transmission in case they missed the DCTS packet. However, the deafness problem, which degrades the performance of the protocol, has not been addressed. Dual-sensing directional MAC (DSDMAC) protocol [14] uses two well-separated wireless channels, a data channel and a busy-tone channel. The data channel carries the data packets and the RTS, CTS, and ACK packets on a specified direction (DRTS, DCTS, DDATA, and DACK). On the other hand, the busy-tone channel will be used to transmit a sine-wave busy-tone signal on all other directions. DSDMAC based on the dual-sensing strategy to identify deafness, resolve the hidden-terminal problem, and avoid unnecessary blocking., DSDMAC protocol achieve much higher network throughput and lower delay utilizing the spatial multiplexing gain of the directional antennas. Ahmad et al [20]proposed Enhanced busy tone Assisted medium acess control (MAC) protocol. In EBTMA Mac protocol use a two well separated wireless channels a data channels and a busy tone channel. The Data channel is used to transmit data packets as well as RTS,CTS and ACK packets. The busy tone channel is used to transmit a sine wave busy tone signal at twice the data signal transmition range. EBTMA protocol can achive better performance in terms of throughput and delay in wireless multihop ad hoc networks. Directional Busy Signal Multiple Access (DBSMA) protocol .It based on busy tone principle that meets these requirements in DBSMA, all the transmissions, receptions, and idle listening are directional. The need to listen in many directions when in an idle state is achieved by constantly changing the listen direction to cover the whole space. In this protocol novel directional back-off mechanism in which every node maintains independent back-off windows for each direction and show how it yields better performance. DBSMA is well suited for ad-hoc multi-hop networks with directional antennas.

B. Non Busy tone Based MAC protocol

The directional MAC (DMAC) proposed in [11] is one of the earliest protocols that support directional antenna. Based on a modified 802.11 MAC protocol, DMAC uses a per-sector blocking mechanism to block a sector once it senses a request-to-send (RTS) or clear-to-send (CTS) packet. A node can transmit its RTS packet in an omni directional fashion when none of its sectors is blocked; otherwise, it beams toward its destination. The omni directional transmissions may cause unnecessary blocking, and the protocol requires knowledge of neighbors' locations. In [15], a multihop RTS MAC (MMAC) protocol is proposed where all packets including RTS/CTS should use directional transmission (DRTS/DCTS). Nodes, however, may listen in an omni dirctional mode while they are idle. The deafness problem still exists as not all neighboring nodes can receive the DRTS and DCTS. The Directional Virtual Carrier Sensing protocol was proposed by in [16], which assumed a steerable antenna system to point at any specified direction. Each node maintains a list of neighbors and their directions based on the address of arrival (AoA) of any sensed signal. The AoA information is used to directly beam RTS packets to their destinations. If no location information exists, the RTS packets are omni directionally transmitted. A directional version of the network allocation vector is maintained for channel reservation. The protocol handles some basic functions required to support the directional antenna, and it cannot handle the hidden-terminal and deafness problems. DMAC protocol with Deafness Avoidance and Collision Avoidance (DMAC-DACA) protocol [13] is the basic directional RTS/CTS exchange is followed by sweeping RTS/CTS counterclockwise to inform all the neighbors about the upcoming communication. Deafness is avoided using a deafness neighbor table that uses the sweeping RTS/CTS to record the deafness duration of neighboring nodes. The location information, retrieved by GPS, is added to the RTS/CTS frames. Using this information, the node that receives RTS/CTS can update the record in its deafness neighbor table if any of the neighbors is in the coverage area of the upcoming transmission. The DMAC-DACA protocol performs collision avoidance through the DNAV mechanism. Li Ying et al [21]proposed FFT (Flip Flop tone) –DMAC protocol, a tone based MAC protocol using directional antennas .It uses two pairs flip-flop tone. The first pair of tone is sent omni directionally to reach every neighboring node to announce the start and the end of the communication. The second pair of tone is sent directionally towards sender. It provide s a good solution for the deafness problem and hidden node problem.

V. COMPARISONS OF DIRECTIONAL MAC PROTOCOLS

In table 1. summarized the common features of the different categories of MAC protocols and also compare them. Many early protocols used the directional antenna . The benefits of directional antennas by using only directional transmission/reception in the networks. This will dramatically increase the coverage range of nodes and

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improve the network performance. New problems of location dependent carrier sense such as hidden terminal and deafness have arisen and they have also been solved or alleviated.

Table 1. Comparison Of The MAC protocols

Protocols	RTS	CTS	DATA/ACK	Busy tone based	Hidden terminal problem solve	Exposed terminal problem solve	Defness problem solve	Channels
DMAC	Directional	Omni-Directional	Directional	No	no	no	no	single
MMAC	Directional	Directional	Directional	No	-	-	no	single
DVCS	Directional	Directional	Directional	No	no	-	no	single
DMAC-DACA	Multi-Directional	Multi-Directional	Directional	no	yes	-	yes	single
FFT DMAC	Directional	-	Directional	no	yes	no	yes	multi
DBTMA	Omni-Directional	Directional	Directional	yes	yes	no	no	multi
DBTMA/DA	Omni-Directional	Directional	Directional	yes	yes	yes	no	Multi
Toned DMAC	Directional	Directional	Directional	yes	yes	no	yes	multi
EBTMA	Directional	Directional	Directional	yes	yes	no	yes	multi
DBSMA	Directional	Directional	Directional	yes	-	-	-	multi
DSDMAC	Directional	Directional	Directional	yes	yes	yes	yes	multi

VI. CONCLUSION

In this survey paper presented MAC protocols in wireless ad hoc networks with directional antennas. The MAC protocols were designed to exploit the benefits of directional antennas and overcome the directional antenna problems. Here enlisted and discussed the main challenges facing MAC protocols in wireless ad hoc networks with directional antennas. MAC protocols are comparatively analyzed based on busy tone and Non busy tone based Mac Protocols. Busy Tone base MAC protocols are DBTMA, Tone-DMAC,DSDMAC,EBTMA,DBSMA and non Busy tone based MAC protocols are DMAC,MMAC,DVCS,FFTMAC.A common design method is exchange DATA and ACK packets directionally, there are many variations in the transmission of RTS/CTS packets. The uni-directional RTS/CTS handshakes achieve higher spatial reuse and longer communications range but some problems occures when directional antenna used, like Hidden terminal ,exposed terminal and defness problem. These problems reduce by using different MAC protocols.

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