Analysis of DMAC Protocols in Wireless Ad Hoc Networks

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Abstract

In present era of technological advances wireless communication has reached a new milestone where all sorts of networks need better and better performance to cope with the drastically changes in volume of traffic and services on the on the network. The wireless ad hoc network has travelled to new destination where almost all the protocols being used presently are replacing omnidirectional antennas with directional antennas to save energy and increase spatial use. In view of using directional antennas in directional MAC protocols the new challenges have erupted even when performance has been enhanced quite satisfactorily. In this paper effect of directional antenna on MAC protocols have been analysed on the basis of their throughput and other performance parameters and drawback like hidden terminal, exposed terminal, and deafness have been investigated in this work.

Keywords

MAC, Hidden Terminal, Exposed Terminal, Deafness, Throghput.

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Introduction

Wireless ad hoc network need no central control while communication within network and control signals are exchanged before decimating the data to the destination. In traditional networks the energy was transmitted using omnidirectional antennas. However, latter on hybrid concept of omnidirectional and directional antennas was used for establishing contact and transmitting data from source to destination. In this process the changeover of antenna was taking place after getting clearance from destination or intermediate station, which was created delay and sometimes loss of information. However, there was significant improvement in the network performance using this concept at MAC layer, this protocol was defined as directional MAC protocol. Thereafter many modifications were done on the basis of pros and cons with respect to the usability and applicability of the network scenarios. Though directional antennas have been used in wireless communication systems for a long time but concrete and realistic applications of directional and smart antennas in wireless ad hoc networks have emerged just in recent years only in cellular mobile communication and ad hoc networks. Directional antennas provide number of benefits, such as increased transmission range, higher gains, Spatial reuse and low interferences. Wireless medium access control schemes and mechanism play a major role in ensuring the efficient and judicious sharing of wireless resources between various nodes and sectors. Therefore there has been numerous research works on mechanisms at the wireless medium access layer by using directional antennas. The new features of MAC with directional antennas can cause not only location dependent carrier sensing problems, which have appeared in omnidirectional wireless networks, but also novel issues related to directional antennas. In this paper, an introduction of directional antennas is given. We give a classification of the current wireless MAC protocols using directional antennas. We also present different MAC protocols and compare them. This survey discusses the challenges in the design of these MAC protocols.

Background and Overview

It is evident from the existing protocols being used for wireless ad hoc networks that omnidirectional antenna has simplicity but lacks in performance due to wastage of energy and communication with only one in the particular radiating area and not allowing other nodes to communicate. The directional antennas have been replacing this technology and gave quite satisfactory results in terms of spatial reuse and power requirement. Further to this Advances in beam forming technology have allowed to revisit some of the problems in wireless networking, which have given hope of greater spatial reuse and longer communication range are potential benefits of utilizing directional antennas. However, drawbacks exist due to New kinds of problems due to use of directional antennas such as hidden terminal, exposed terminal and deafness problems, which arise, as product of mitigating other problem, and were absent when using Omni directional antennas [1].

The IEEE 802.11 standard is the most dominant MAC protocol for ad hoc networks being used currently. This protocol in general follows the CSMA/CA protocol paradigm, which also allows for the exchange of RTS/CTS handshake packets between the transmitter and the receiver stations or nodes. These control packets are used to reserve a transmission floor for the subsequent data and acknowledgment (ACK) packets. The nodes transmit their control and data packets at a fixed power level, which also prevents all other potentially interfering nodes from starting their own transmissions and other nodes that hears the RTS or the CTS control signal defers its transmission for ongoing transmission to be over. Traditional MAC protocols have been designed using Omni-directional assumption [2,3] and are not suitable for use over directional antennas. Thus design of an efficient MAC protocol with directional antennas is a crucial issue and needs exhaustive investigation and analysis for suitability and scalability. In [4] authors have identified problems with directional antennas, the new types of hidden node problems has arised while suggesting DMAC for better performance. In addition, while doing away with this problem some other problems may arise hence needs care while suggesting new paradigm. In [5–7] new concept of DMAC protocol was suggested by authors but still it lacks in performance as new problem of and fundamental issues such as node deafness and the determination of neighbors' locations have to be properly handled. Deafness is defined as the phenomenon when a node is unable to communicate with another node, due to beam formed in a different direction for communicating to third node in its area of coverage. As explained here, deafness is a serious issue in directional antennas as it may considerably impact performance. It is assumed that the underlying CSMA/CA-like MAC layer protocols, such as MACAW [8] or DBTMA [11], provide reliable shared access to the uncast channel, and tried to solve the problems of hidden and exposed terminals. In [9] authors have analysed the effect of hidden and exposed terminal problems in ad hoc networks while concentrating on distributed medium access control protocols like CSMA and various modifications thereon. The 802.11DCF has been investigated in detail for effect on communication while using directional antennas in the proposed method. In [10] authors have addressed hidden terminal and deafness problems while using directional antennas in designing MAC protocols for wireless ad hoc networks. Authors have explained various scenarios for deafness and directional hidden terminal problem by using graphical and other structural representations and have also discussed antenna model with various assumptions. Solution for hidden terminal problem has also been suggested in this work. The basic model of DMAC protocol is dependent on IEEE 802.11 and needs overview to be discussed in this paper.

Brief Overview of IEEE 802.11

In principle, many of the proposed protocols are similar to IEEE 802.11, carefully adapted for use over directional antennas. Authors in [3–5] have presented a brief and concise overview of IEEE 802.11, and have also discussed of the existing protocols for directional medium access control. In the IEEE 802.11 MAC protocol an exchange of control signals request to send (RTS)/clear to send (CTS) precedes DATA communication. Both RTS and CTS packets contain the proposed duration of transmission. Nodes located in the vicinity of communicating nodes, which overhear either of these control packets, must themselves defer transmission for the proposed duration. The process of self-deferring of transmission is sometimes called Virtual Carrier Sensing and has been implemented using the Network Allocation Vector (NAV). A node updates the value of the NAV with the duration field specified in the RTS or CTS. Thus the area covered by the transmission range of the sender and receiver is reserved for data transfer, to overcome the hidden terminal problem [16]. IEEE 802.11 is a CSMA/CA protocol that performs carrier sensing physically before initiating transmission on the network. On confirmation that the channel is sensed as idle for DIFS (DCF interframe spacing) duration, 802.11 invokes a backoff mechanism for contention resolution. A node S chooses a random backoff interval from a range [0, CW], where CW is called the Contention Window. Contention window is initialized to the its CWmin value. Sender node then decrements the backoff counter once every idle "slot time". When the backoff counter reaches 0, sender node transmits the RTS packet. If the transmission from sender collides with some other transmission (collision is detected by the absence of a CTS), Sender doubles its CW, counts down a newly chosen backoff interval, and attempts retransmission. For each collision the contention window is doubled each time till it reaches a maximum threshold, called CWmax. While in the back off stage, if a node senses the channel as busy, it freezes its backoff counter. When the channel is once again idle for a duration called DIFS, the node continues counting down from its previous (frozen) value.

The design of IEEE 802.11 generally assumes an omni-directional antenna at the physical layer. Although 802.11 may operate correctly when using directional antennas also, performance may get affected according to use. Recently, several MAC protocols have been proposed that suitably adapt 802.11 for beam forming antennas. Ko et al. have proposed to transmit an RTS directionally, only if the RTS does not collide with other ongoing communications. Nasipuri et al.[12] proposes to reduce the interference in the wireless channel by communicating directionally. However, their proposals require the transmission of omni-directional CTS to inform the receiver's neighborhood about the imminent dialog. This offsets spatial reuse a key advantage of using directional antennas apart from many others. An interesting idea they use RTS/CTS to inform the neighborhood about the beam indices to be used for the imminent communication. Based on this information, neighbors of the communicating nodes decide which beams may be used for initiating their own RTS packets[13].

In principle, DMAC is similar to IEEE 802.11, adapted for use over directional antennas. In describing DMAC, we refer to a sender node as S and the receiver node as R. When using DMAC, physical carrier-sense is performed in the directional mode, using the same beam that must be used for the immediate communication. If the carrier is sensed idle for a DIFS duration, DMAC requires the node to choose a backoff interval, in a fashion similar to 802.11. The sender must remain in the directional mode while counting down its backoff counter this will be referred as directional backoff. If the carrier is sensed busy during the count-down, the node defers transmission for later and switches back to the omnidirectional mode. If the carrier remains idle, the sender node initiates channel reservation[14]. Channel reservation in DMAC is performed using an RTS/CTS handshake, both being transmitted directionally. Sender transmits a directional RTS (DRTS) meant for the receiver. An idle node listens to the channel omni directionally. When it receives a signal arriving from a particular direction, it locks on to that signal and receives it. Assuming that receiver was idle, it receives the DRTS from sender. Using a suitable beam to reply to sender, node R transmits a directional CTS (DCTS)[15].

Nodes, other than Sender and Receiver, that overhear the RTS and/or CTS, remember the directions from which the reservation messages arrived. These nodes defer their own transmissions in these directions, for the proposed duration of transmission between Sender and Receiver.

A study of the deafness issue is given in[4] but no solution is provided. In this paper, we have studied the deafness issue in detail outlining different factors which contribute to deafness and its impact in a switched beam antenna system. We have also proposed two proactive approaches to handle deafness scenarios, wherein a node willing to send an RTS1 first estimates if its destination is deaf to the antenna beam being used to reply the CTS. If so, it defers the transmission of its RTS. This estimation is done based on its destination's location information and knowledge of ongoing transmissions in its neighborhood. To this end, we have assumed that nodes are aware of the location information of its neighbors, as in[4,6]. Also, our proposed schemes are transparent to the type of the MAC scheme being used. By type of MAC scheme we mean the way control packets (RTS/CTS) are sent. If an RTS is sequentially sent through all antenna beams, it is referred to as Omni-directional RTS (ORTS), whereas it is referred as directional RTS (DRTS) if it is sent only towards its intended destination (as in DMAC[4]). Similarly, CTS may be OCTS or DCTS. In addition, in proposed MAC extensions, we have tuned IEEE

802.11 Short Retry Limit (SRL) for directional environment. A source node X now tries to learn if the absence of a reply from some destination Y was because of deafness; and if so, it handles SRL differently.

The exchange of DATA/ACK packets is similar to 802.11, except that they are transmitted directionally. After transmitting the RTS, the sender S waits for the CTS, using the beam that it had used to transmit the RTS. If the CTS arrive within CTS-timeout duration, S transmits the DATA packet directionally. R acknowledges successful data reception with a directional ACK. If the CTS does not arrive within the specified timeout duration, S chooses a new back off value from a doubled Contention Window, counts down this back off value, and retransmits the RTS (similar to 802.11). Once the exchange of DATA/ACK packets are over, both S and R switch back to the omni directional mode.

To show the impact of deafness on DMAC, let us Assume that all nodes are idle and that one node x intends to transmit a data packet to y. DMAC requires y to beamform in the direction of x, and detect if the channel is idle for a DIFS duration. If the channel is found idle, x proceeds to the backoff phase and counts down the backoff counter while still beamformed towards y. Observe that while y is counting down its backoff counter, node z may intend to communicate with x. If z completes its own backoff before x and transmits an RTS to x, x would not receive the RTS. In the absence of a reply from x, z would repeatedly backoff and retransmits the RTS, until the dialog between x and y is over. Unproductive retransmissions are an outcome of deafness.

The MAC protocol proposed in[17] assumes that each node has the ability to simultaneously transmit on two channels, the control and data channels, with two antennas and their associated communication circuitry. The control channel needs lesser bandwidth as compared to the data channel and is used for transmitting control related signals to reserve the medium while the data channel is for transmitting the data and acknowledgments.

The control channel uses pulses for delivering information rather relying on bit based frames. The pulses in the control channel are single-frequency waves with random-length pauses. If a node is transmitting in the data channel but detects a pulse in the control channel, it aborts its transmissions. The directional antenna has received intensive research due to its variety of potential benefits for wireless communication systems. It is expected to provide significant improvements such as spatial reuse of the wireless channel, which allows nodes to communicate simultaneously without interference, and potentially establish links between nodes far away from each other, and the number of routing hops can be fewer than that of Omni-directional antennas.

IEEE 802.11s is an amendment draft of IEEE 802.11 for mesh networking. The main goal of this amendment is to provide the routing functionality between APs in a wireless distribution system. It defines a mandatory path selection protocol (Hybrid Wireless Mesh Protocol: HWMP) and a default metric (AirTime) to reflects the cost for each Wireless link at path discovery. This routing protocol is designed to support multiple interfaces (multiple wireless network devices). In this case, the PREQ used at the path discovery is broadcasted by all interfaces. In[16] authors have proposed a new improvement of HWMP protocol (Sector-HWMP) that take into account the using of directional antennas. This improvement is intended to reduce the routing overhead related to the use of multiple interfaces, and to take the advantage of directional antenna.

In order to evaluate the performance of our proposal, we have carried-out some simulation experiments in NS-3. In[11] authors proposed a CRDMAC (circular RTR DMAC) protocol, which uses new concept of receiver initiated mechanism to handle the deafness problem in directional MAC scheme. In this work the RTR message is used to handle deafness reactively, and proposed to alleviate the deafness problem in

WANETs using circular directional antennas. It is stated that the transmission time of circular messages will have no effect on the transmission time and will not delay data transmission, as the circular messages are sent after the data transmission. It is also claimed that the circular packets will not interfere with the neighbors by using sub channel which is better than CRCM.

Author in [18] has proposed a protocol to improve the throughput of mobile ad hoc networks without the aid of location information on the neighbor nodes, this protocol has been named as DUDMAC protocol. In this protocol ORTS and OCTS are used on the control channel as the source node does not know the exact location of the destination node. The use of omnidirectional transmissions on the control channel solves the deafness problem caused by the directional transmission on the data channel. However, this omnidirectional transmission reduces the spatial reuse and degrades the throughput of mobile ad hoc networks. Authors have proposed a tone DUDMAC (ToneDUDMAC) protocol to improve the spatial reuse by using an out-of-band tone that is uniquely assigned to each node using a static hash function of a node's unique identifier as in the case of the ToneDMAC protocol [18]. In [19] authors have proposed a new scheme using switched beam antenna used as tone antenna other beam as packet antenna. Each node with ATB-DMAC scheme uses following out-of-band tones to inform the neighbor nodes about its situation.

- Transmitter Direction Tone (TDT)
- Receiver Direction Tone (RDT)
- Other-direction Busy Tone (OBT)
- Same-direction Busy Tone (SBT)
- Desired Direction Tone (DDT)
- Collision Occurrence Tone (COT)
- RTS Collision Occurrence Tone (RCOT)

The method claims improved performance and signal to noise ratio for sustaining threshold value of communication and thus improving efficiency of network. In [20] authors have tried to justify their design comparing with traditional design of DMAC protocols, where traditional MAC protocols used in wireless ad hoc networks is Distributed Coordination Function IEEE 802.11 (DCF) has been taken as reference. In such protocols, nodes are allowed to access the channel without any base station and omni-directional antennas are used for packet transmission. The main problem in IEEE 802.11 DCF is the existence of silent area which leads to channel spatial reuse reduction and using directional antennas at the nodes can battle this problem. However, using directional antennas itself leads to other problems such as new hidden terminal and deafness problems. In [20] authors have proposed a new technique using multichannel MAC protocol based on CDMA as communication technology where CDMA codes and directional antennas are used to reserve the channels for prospective users. The control channel is used as common for all the users and nodes have to use this channel for RTS/CTS handshaking, whereas the other channels are used for data transmission for prospective nodes in the network depending upon the specific mode of communication. It is therefore well established that while using omnidirectional antenna in wireless ad hoc networks has few problems but have very low performance in terms of packet delivery and overall network performance whereas it directional antenna is used for such communicating protocols then performance is improved drastically. However, there are certain new problems like hidden terminal, exposed terminal and deafness, where researchers have to reach to tradeoff between them to optimize the performance with certain modifications in the protocol issues. It is also evident that using antenna beamforming techniques there are other advantages like improvement in SNR, which plays major role for performance improvement in the ad hoc networks.

Conclusion

This paper addresses deafness, an outcome of exploiting beam forming capabilities of directional antennas. A tone based directional MAC protocol has been used directional antennas in ad hoc networking has expected increasing attention. By transmitting towards a preferred direction, a node may be able to decrease wireless interference. Signal to Interference Ratio (SIR) may also recover if the receiver selectively beam forms in the direction of the Signal of Interest, thereby suppressing interferences that arrive from redundant directions. The protocol uses an explicit notification mechanism to indicate the end of a dialog. Notification is implemented by transmitting a carefully chosen tone for a suitable number of time slots. Nodes, waiting to transmit, use the tones to alleviate the impacts of deafness. Simulation results indicate that under multi-hop UDP traffic, Tone DMAC performs better than DMAC. When TCP traffic is used, the performance benefits are even greater.

References

[1] R. Roy Choudhury, X. Yang, N. H. Vaidya, and R. Ramanathan, “Using directional antennas for medium access control in ad hoc networks,” in Proceedings of ACM MOBICOM, September 2002.

[2] IEEE Std. 802-11. “IEEE Standard for Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification,” June 1997.

[3] C. Fullmer and J.J. Garcia-Luna-Aceves, “Floor Acquisition Multiple Access (FAMA) for packet radio networks,” Computer Communication Review, October 1995.

[4] R. Choudhury, X. Yang, R. Ramanathan, and N. Vaidya, “Using Directional Antennas for Medium Access Control in Ad Hoc Networks,” in ACM Mobicom, September 2002.

[5] T. Korakis, G. Jakllari, L. Tassiulas, “A MAC protocol for full exploitation of Directional Antennas in Ad-hoc Wireless Networks,” in ACM Mobihoc, June 2003.

[6] M. Takai, J. Martin, A. Ren, R. Bagrodia “Directional Virtual Carrier Sensing for Directional Antennas in Mobile Ad Hoc Networks,” in ACM MobiHoc, June 2002.

[7] R. Ramanathan, “On the performance of Ad Hoc Networks with Beamforming Antennas,” in ACM MobiHoc, October 2001.

[8] V. Bharghavan, S. Shenker, D. Demers, and L. Zhang, WACAW: a medium access protocol for wkless LANs,” Prwceedurgs of ACM SIGCOMM, August 1994.

[9] Aruna Jayasuriya, Sylvie Perreau, Arek Dadej, Steven Gordon, “hidden vs. exposed Terminal Problem in Ad Hoc Networks”.

[10] Anand Prabhu Subramanian, Samir R Das, “Addressing deafness and hidden terminal problem in directional antenna based wireless multi-hop networks”, Springers Wireless Network, Vol. 16, pp 1557–1567, 2010.

[11] Z.J. Haas and J. Deng, "Dual Busy Tone Multiple Access (DBTMA) performance evaluation," Proceedings of IEEE VTC, May 1999.

[12] A. Nasipuri, S. Ye, J. You, and R. Hiromoto, "A MAC protocol for mobile ad hoc networks using directional antennas," in Proceedings of IEEE Wireless Communication and Networking Conference, September 2000, vol. 3, pp. 1214–1219.

[13] M. Takai, J. Martin, R. Bagrodia, and A. Ren, "Directional virtual carrier sensing for directional antennas in mobile ad hoc networks," in Proceedings of ACM MobiHoc, June 2002, pp. 39–46.

[14] Yihu Li and Ahmed Safwat, "On Wireless Ad hoc Networks with Directional Antennas: Efficient Collision and Deafness Avoidance Mechanisms", EURASIP Journal on Wireless Communications and Networking, Vol. 2008, pp 1–14, 2008.

[15] Huang Lu, Jie Li, and Zhongping Dong, "CRDMAC: An Effective Circular RTR Directional MAC Protocol for Wireless Ad Hoc Networks", 2011 Seventh International Conference on Mobile Ad-hoc and Sensor Networks, pp 231–237, 2011.

[16] Jalel Ben-Othman, Lynda Mokdad, "On Improving the Performance of IEEE 802.11s based Wireless Mesh Networks Using Directional Antenna", 6th IEEE International Workshop on Performance and Management of Wireless and Mobile Networks P2MNET 2010, Denver, Colorado pp 785–790, 2010.

[17] Jun Peng, Liang Cheng, Biplab Sikdar, "A Wireless MAC Protocol With Collision Detection", IEEE Member IEEE TRANSACTIONS ON MOBILE COMPUTING pp 1–14, 2007.

[18] Jeong Woo Jwa, "Tone Dual-Channel MAC Protocol with Directional Antennas for Mobile Ad Hoc Networks" ETRI Journal, Volume 34, Number 1, pp 98–101, February 2012.

[19] Razgar Rahimi, Gholamreza Dadashzadeh, "Evaluation of auxiliary tone based MAC scheme for wireless ad hoc networks with directional antennas" 9th Multiconference on Systems, Signals and Devices, pp 1–4, 2012.

[20] Vahid Pourgolzari, Seyed Ali Ghorashi, "A CDMA Based MAC Protocol for Ad Hoc Networks with Directional Antennas", International Symposium on Computer Networks and Distributed Systems (CNDS), pp 73–77, February 23–24, 2011.