www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 3 March 2013 Page No. 580-587

An Efficient Scheme To Improve The Overlapped Transmission In Wireless Adhoc Network Using Carrier Sense Multiple Access

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Abstract— Wireless network refers to any type of computer network that is not connected by cables of any kind. Wireless network is divided into multiple types such as Wireless LAN, Wireless MAN, Cellular networks and Ad-hoc networks etc. In wireless ad-hoc networks, interference is one of the major impairments that reduce the performance of a network. To reduce this interference, we have been using a technique called Interference Cancellation(IC). Instead of this Interference Cancellation some of the techniques such as Multi User Detection (MUD), Multi Packet Reception (MPR) has been used in networks. However MPR is typically requires a very complicated hardware. As well as it is not suitable without knowing a interfering signals. Therefore we moved to Overlapped Transmission technique. In this overlapped transmission technique, a multiple transmission can occur in the same network. These techniques have much lower signal processing demand than the Multi Packet Reception. Overlapped Carrier Sense Multiple Access (OCSMA) protocol can be used to improve the performance of overlapped transmission technique. We develop a MAC protocol based on the IEEE 802.11 standard to support the overlapped transmission in networks. And we investigate the impact of overlapped transmission on the performance of Transmission Control Protocol in wireless ad-hoc MIMO networks using directional antennas.

Index Terms— Interference Cancellation(IC), Multi User Detection (MUD), Multi Packet Reception (MPR), Overlapped Carrier Sense Multiple Access (OCSMA)

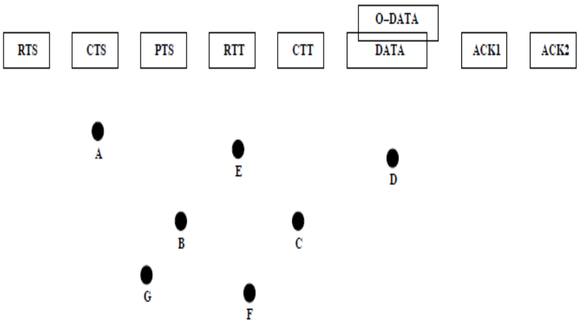
I. INTRODUCTION

The Performance of wireless ad hoc networks is typically limited by the need to use MAC protocols is to prevent transmissions from near by radios from interfering with each other. Thus, any technique that can improve spatial reuse and reduce contention among the radios has the potential to significantly improve the performance. Although multi-user detection (MUD) schemes have been investigated for many years (cf. [1]), multi-packet reception (MPR) techniques [2] have been drawing increasing interest from a cross-layer and military perspective over the last decade. Most of these works on MPR would require MUD schemes with high computational complexity, which may prevent MPR capabilities from being implemented in most military radios for many years to come. Thus, alternative approaches that can improve spatial reuse at lower complexity are desirable.

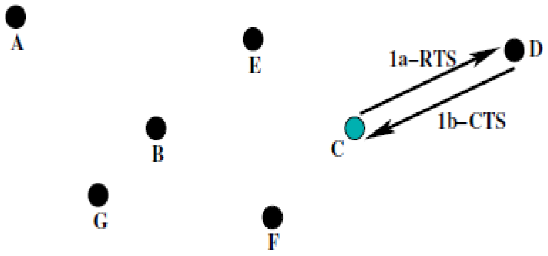
One way to increase spatial reuse without the complexity of MUD is to have radios use their knowledge of interfering packets to do a very simple form of interference cancellation. We call this approach *overlapped transmission*, as packets are allowed to overlap in the communication medium, and can still be recovered without full MUD. Several different overlapped transmission schemes have been proposed. To the best of our knowledge, we published the first work on such schemes in [10]. In [10] and its extensions [11], [12], the overlapped carrier-sense multiple access (OCSMA) protocol is proposed and evaluated. OCSMA coordinates packet transmissions so that packets are allowed to interfere if the nodes know the contents of the interfering packets and can remove the interference. Working independently, Zhang *et al.* proposed a closely related scheme called physical-layer network coding (PNC) [13] at approximately the same time. PNC relies on hard-decision demodulation and remodulation at a relay (in the terminology of cooperative communications, it is essentially a decode-and-forward scheme). In [14], analog network coding (ANC) is proposed. ANC is similar to PNC, except that soft demodulation and retransmission is used (similar to the amplify-and-forward scheme in cooperative communications).

In fact, one of the forms of ANC described in [14] is essentially the same as our overlapped transmission schemes described in [10], [11], [12]. Note that PNC and ANC are also derived from earlier work on wireless network coding [15],

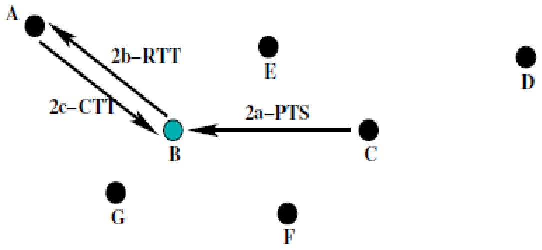
It is convenient to divide the previous papers on overlapped transmission and wireless network coding into two groups. One group focuses on problems that traditionally lie in the physical layer, such as how packets should be coded together, how packets can be recovered if they are allowed to combine in the air, the link performance of such schemes, and the performance improvement for some ideal network scenarios (typically consisting of 3-5 nodes). The other group considers the performance of such schemes in the context of a larger network [17], [10], [18], [11], [12]. This second group of papers have all identified a significant problem for overlapped transmission/wireless network-coding schemes: when the traffic is dominated by a small number of TCP flows, the performance gain will be severely limited. This is because TCP flow control results in nodes not having the appropriate packets to combine or overlap. We call this *packet starvation*.



(a) Ad hoc network



(b) Primary Handshaking



(c) Secondary Handshaking

In this paper, we investigate packet starvation for OCSMA with unidirectional TCP flows. In Section II, we provide an overview of the OCSMA protocol. In Section III, TCP causes packet starvation for the OCSMA protocol. In Section IV, we propose a new variant of the OCSMA protocol to address the packet starvation problem with TCP traffic. In Section V, we investigate the effects of the OCSMA protocols on fairness for network topologies with interacting TCP flows. We conclude the paper in Section VI.

II. OCSMA PROTOCOL OVERVIEW

We briefly review the OCSMA protocol [12]. The OCSMA protocol is based on the distributed coordinated function (DCF) mode of the IEEE 802.11 MAC protocol [20, Section 9.2]. Unless stated explicitly, the terminology used in the following sections corresponds with that in the IEEE 802.11 standard [20]. The OCSMA protocol can be summarized in four phases using the example network of Fig. 1(a): **1. Primary Handshaking** Consider the network in Fig. 1(a), where at some point of time, node C intends to forward a packet to D that it has received from B in an earlier transmission. C transmits a Request To Send (RTS) frame to D, and if D senses the medium to be free, it responds with a Clear To Send (CTS) frame, as shown in Fig. 1(b). Nodes C and D are called the *primary transmitter* and *primary receiver*, respectively. This is similar to the RTS/CTS exchange of the IEEE 802.11 MAC protocol [20].

2. Secondary Handshaking Upon receipt of the CTS, the primary transmitter sends a Prepare To Send (PTS) frame to the node from which it received the present data frame in an earlier transmission. Upon the transmission of PTS, the primary transmitter defers the transmission of the data frame until the completion of the secondary handshaking. After the completion of the RTS/CTS between C and D, C sends a PTS to B. The node receiving the PTS frame is called the *secondary receiver*. Upon receipt of the PTS, the secondary receiver ensures that there are no other transmissions occurring in its sensing range except for the primary transmission. If true, it identifies a suitable partner for secondary transmission. The secondary receiver sends a Request to Transmit (RTT) frame to the selected *secondary transmitter*. If the secondary transmitter finds the medium to be free and has a packet to transmit, it responds with a Clear to Transmit (CTT) frame. Transmission of the CTT implies that the secondary transmitter is capable of transmitting overlapped data without causing interference to any of the transmissions in its communication range. In the example network of Fig. 1(a), when B receives the PTS from C, it ensures that its Transmit Allocation matrix (TAX) is not set. TAX [12] consists of an array of Transmit Allocation Vectors (TAV), which are responsible for virtual carrier sensing. Similar to the NAV in IEEE 802.11, a TAV is set for each valid frame the node receives that is not addressed to it. The medium is considered busy if any of the TAVs are set. For more details on TAX implementation, refer to [12].

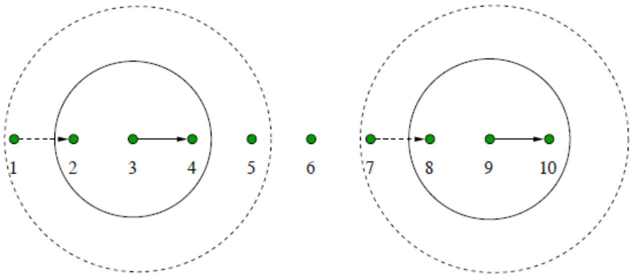


Fig. 2. Ten node linear network.

Based on the selection criteria for choosing a partner, assume node B chooses node A to send the RTT. If A senses the medium to be free, it responds with a CTT.

3. Primary and secondary transmissions Upon completion of the secondary handshaking, C starts the data transmission to D, as shown in Fig. 1(d). The secondary transmitter starts its overlapped transmission Δ0 seconds after the commencement of the primary transmission [12]. Fig. 1(d) also depicts B receiving an ODATA frame while using its knowledge of the packet being transmitted by C to cancel out the interference caused by that transmission.

4. Data Acknowledgments Upon the successful reception of DATA and ODATA frames, the primary and secondary transmitters sequentially transmit and give acks.

III. PACKET STARVATION IN TCP FLOWS

In this section, we investigate the interaction between TCP and OCSMA, and the effect that TCP has on the opportunities to perform overlapped transmission. The focus is on identifying factors that cause packet starvation and adjusting the parameters of the MAC and transport layers to alleviate this issue. We present simulation results from *ns2* [21] and study the interaction between the two layers. We compare and contrast the OCSMA protocol with the IEEE 802.11 protocol.

In all reported results, the effects of the additional overhead of the OCSMA protocol, including delay to acquire the DATA packet before the ODATA packet is transmitted, have been taken into account. In the following, we refer to a MAC service data unit (MSDU) as a frame, and a transport layer service unit (TSDU) as a packet.MAC layer acknowledgments are denoted by ACK, while those at the transport layer are denoted by *ack*. We also focus on a protocol model, in which a packet is received correctly if the intended receiver is within a radius of 250 m of the transmitter and there are no other transmissions within a radius of 550 m of the receiver. We first consider a ten-node linear network as depicted in Fig. 2. Node 1 is the source, and node 10 is the destination. The nodes are placed at regular intervals of 200 m. In Fig. 2, the transmission ranges of nodes 3 and 9 are denoted by solid circles, and their respective sensing ranges are denoted by dashed circles.

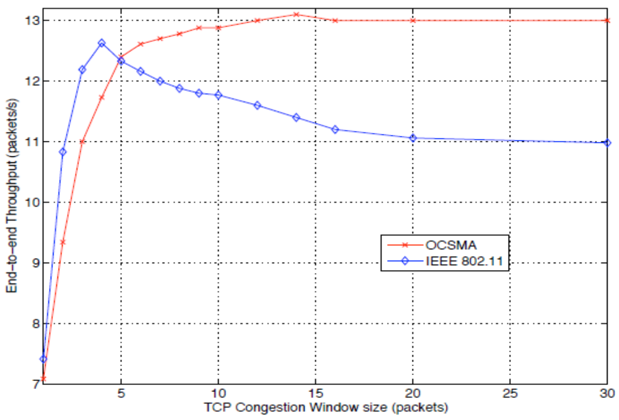


Fig. 3. End-to-end throughput comparison in a ten-node linear network with TCP traffic.

A.Impact of TCP Congestion Window Size

In this section, we evaluate the impact of the TCP congestion window (CW) size on the end-to-end throughput of the network. In ns2, the CW parameter represents the receiver advertised window size, and defines the maximum number of packets to be sent at every round-trip-time. TCP is designed to adjust the flow based on the CW size and the congestion in the network. Henceforth, unless otherwise stated, CW refers to the receiver's advertised CW.

We further investigate the behavior of OCSMA by analyzing the MAC-layer events1 across the network. The MAC-layer events under OCSMA are tabulated in Table II for several values of CW size. We begin by noting the effects of increasing the CW on the collision rate (COLL). The collision rate under OCSMA increases to over 8% for CW sizes of 8 and 16. In contrast, the collision rate of IEEE 802.11 is less than approximately 1% for CW sizes up to 20. The average rate of RTS frames received increases as the CW size increases, as does the reception rate of RTT frames (indicating that the opportunity to perform overlapped transmissions increases). However, the ratio of the reception of CTT to that of RTT is significantly lower than one, which indicates that the actual number of ODATA transmissions is significantly less than the potential number of overlapped transmissions.

IV. OCSMA WITH LOOK AHEAD CAPABILITY (OCSMA LA)

In the previous sections, we analyzed the impact of OCSMA on the performance of TCP flows in wireless networks. The simulation results suggest that although OCSMA provides significantly better end-to-end throughput than the IEEE 802.11 protocol, the full potential of overlapped transmissions is not realized. We attribute this to packet starvation and lack of interaction between the two layers. In this section, we modify the OCSMA protocol and incorporate the observations of the previous sections to address the issue of packet starvation. Motivated by the work in [25], we introduce the concept of *look-ahead*. Upon the completion of an overlapped transmission, both the primary and secondary receivers contend for the channel access. However, this design doesn't always guarantee the occurrence of an overlapped transmission. In networks with linear flows, the probability of an overlapped transmission can be increased by ensuring that the primary receiver of the current overlapped transmission *always* gets access to the channel before the secondary receiver. This is accomplished with the help of the look-ahead feature, as explained below.

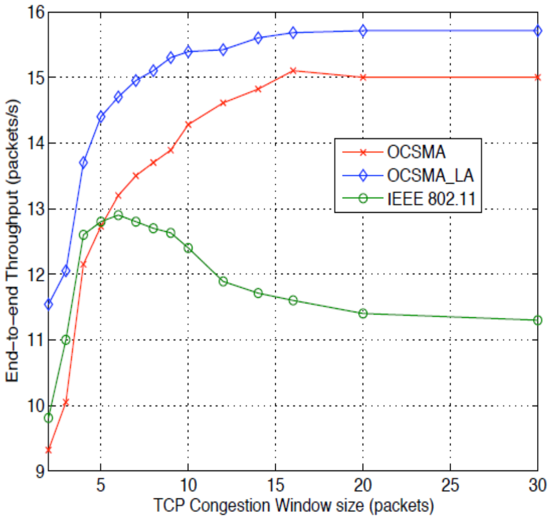
A. OCSMA with Look-ahead Protocol Description

OCSMA with look-ahead (OSCMA LA) is based on the OCSMA protocol, so here we highlight only the differences between the two protocols. We will use the example network of Fig. 7 to describe the design of the OCSMA LA protocol.

The differences between OCSMA and OCSMA LA are during the *acknowledgment* phase, as described below. The AKM frame, in addition to the Receiver Address (RA) field, contains the additional fields TA, NA and NFD.

The Transmitter Address (TA) field contains the address of the node transmitting the AKM frame. The Next Address (NA) field contains the address of the node for which the present node (the node transmitting the AKM) has a DATA frame, and the Next Frame Duration (NFD) contains the duration information of the DATA frame. Node 4 uses the contents of the first available DATA frame in its queue to fill the fields NA and NFD. If node 4 does not have a DATA frame in its queue and if the present frame is to be forwarded on by D, the present frame is used to generate the required information before sending it to the higher layers. (This requires the MAC to have access to the routing tables.) When the primary transmitter, node 3, receives the AKM, it resets its retry limits and performs backoff just like in the case of the reception of an ACK frame.When the next hop receiver, node 5, receives the AKM frame, it waits for a duration equal to the transmission of an ACK frame (to allow for node 2’s transmission of ACK to node 1), and transmits a CTS frame if the medium is free. Note that the information necessary for updating the fields RA and Duration of the CTS frame (refer to Fig. 8) are available through the TA and NFD fields of the AKM frame (refer to Fig. 8). When node 3 receives the CTS frame, it ensures that this frame is in response to either an RTS frame or an AKM frame. If this is true, it proceeds with the secondary handshaking phase of OCSMA.

Since the next hop receiver (node 5 in the present example) requests for the DATA frame even before the secondary and primary receivers have a chance to contend for the channel access, the secondary receiver, node 3, has a suitable frame for an overlapped transmission when node 4 transmits the DATA frame to node 5. Once an overlapped transmission occurs in the linear network, with high probability, the capability to perform overlapped transmission is retained until the DATA/ODATA frames reach the destination.



The probability of overlapped transmission remains high when the primary transmission is successful and the AKM is successfully received. For the protocol model used in this paper, this will be true as long as the collision rate is low. However, in more practical scenarios, fading may cause additional degradation to the performance increase from the look-ahead modification.

B. Simulation Results

We simulated the OCSMA LA protocol using ns2, and we compare its performance to OCSMA and IEEE 802.11 for the ten-node linear network of Fig. 2. The parameters used for the simulation are tabulated in Table I, except that the short and long retry limits are set to 20 and 10, respectively, and OCSMA LA utilizes delayed-*acks* with n = 2. The results in Fig. 9 compare the end-to-end throughput of the OCSMA DA(2), OCSMA LA, and IEEE 802.11 protocols as a function of the TCP CW size (also see Fig. 3). The end to- end throughput under IEEE 802.11 increases until the CW size equals 6, beyond which it decreases. The throughputs under OCSMA and

OCSMA LA increase with an increase in CW size, saturating for CW sizes greater than 16. For CW size greater than 20, OCSMA DA(2) provides a throughput gain of 31% to 34% over IEEE 802.11, while OCSMA LA provides a throughput gain of 39% to 41% over IEEE 802.11. The MAC-layer events under OCSMA LA are given in Table IV for three different values of the CW size. Note that under OCSMA LA, the number of CTS frames received can be greater than the number of RTS frames received. A CTS is transmitted either in response to an RTS or an AKM. For small CW sizes, the ratio CTS/RTS is very high. For instance, for CW size 2, CTS/RTS is 3.8, which indicates that the look ahead feature is often successful in scheduling transmissions by the next radio in the linear network.

V. FAIRNESS ISSUES AND MEDIUM CONTENTION

The interaction between TCP and the MAC is a major source of unfairness in multihop ad hoc networks. When different flows experience different congestion issues, the resources allocated to them may be different. Thus, an important consideration when proposing new MAC protocols is their impact on the fairness in the allocation of the channel among competing flows. In this section, we compare interflow contention issues for IEEE 802.11 and OCSMA LA5. Starvation is another major problem that is caused by the greediness of the MAC protocols and TCP. To evaluate these issues in the context of OCSMA LA, we consider the two network topologies illustrated in Figs. 11(a) and 11(b). Fig. 11(a) shows a network with three parallel flows each traversing through six nodes. The adjacent nodes in a flow are placed at a distance of 200 m, and the adjacent flows are separated by a distance of 400 m. Fig. 11(b) shows a network with two flows that intersect at a common node, with the adjacent nodes separated by a distance of 200 m. The results in Fig. 12 show the end-to-end throughput evolution for the network with three parallel TCP flows that is shown in Fig. 11(a). The throughput of each of the flows under the OCSMA LA and IEEE 802.11 MAC protocols is plotted for consecutive intervals of length 5 s.

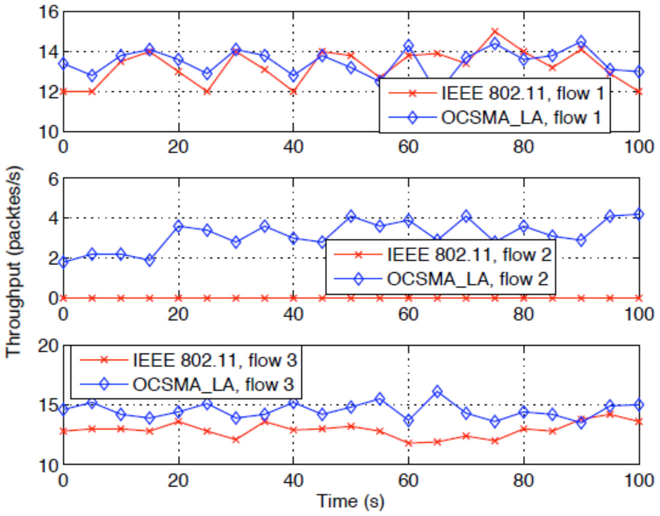


Fig. 12. Throughput comparison in a network with multiple flows.

VI. CONCLUSION

We investigated the impact of overlapped transmissions on the throughput of TCP traffic in multihop networks with linear flows. Through network simulations, we analyzed the interactions between the OCSMA and TCP protocols. We show that flow control in TCP limits the availability of packets for overlapped transmission, which greatly reduces the performance of the OCSMA protocol. This is the “packet starvation” problem that we then try to address. We first modify some key parameters at the MAC and transport layers but find that the full potential of OCSMA is still not realized because of lost opportunities for overlapped transmission. Thus, we modified the OCSMA protocol to provide a look-ahead feature that attempts to reserve the channel for the primary receiver to act as a transmitter after the completion of an overlapped transmission. The resulting protocol, OCSMA LA, reduces packet starvation and improves the end-to-end performance by up to 41% for TCP traffic and up to 126% for UDP traffic in a linear network. “Look ahead” and the other approaches considered in this paper can be applied to other overlapped transmission schemes, such as PNC, ANC, and COPE, to improve their performance with TCP flows. We also showed that the OCSMA protocols offers significantly better inter-flow fairness for some topologies that cause poor performance for TCP flows with the IEEE 802.11 MAC protocol.

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