# Optimizing the Redundancy in Wireless Networks Using Chorus

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Abstract: A wireless network sees an explosive growth in past few decades, making adhoc networks as a part of life. In large scale wireless networks information is transmitted in multihop fashion. Multihop may be exist all the time due unavailibity of links which causes delay, a significant issue. Broadcasting is fundamental operation in wireless networks which experiences problems like congestion, collision and contention. Conventional wireless network broadcasting protocols heavily depend on 802.11 based CSMA/CA models, which avoids collisions and interferences by preservative scheduling of transmissions. While CSMA/CA is ready to transmit data in unidirectional which degrades the performance of broadcasting significantly in large scale networks. Hidden terminal problems also degrade the throughput of wireless networks due to collisions. However carrier senses multiple access collision avoidance cannot solve the problem completely. So, in this paper we propose novel broadcast protocol called chorus which improves the efficiency and scalability of broadcast service. Chorus resolves collisions by symbol level self interference and combine the resolved symbol to restore the normal packet. Such a collision tolerant mechanism significantly improves transmission diversity and spatial reuse in wireless networks. Cognitive sensing and scheduling in chorus MAC layer adds advantage in broadcasting the information. Collision resolution mechanism is evaluated in ns2 and network level performance is compared with CSMA/CA based protocol.

**Keywords:** wireless networks, optimal broadcasting, wireless adhoc networks, mesh networks, collision resolution, self interference cancellation, hidden terminal problems

## 1. Introduction

In multihop wireless networks broadcasting is the fundamental operation for many communication protocol, such as route discovery and information propagation [2].In wireless networks there are many number of nodes and information is transmitted in multihop fashion through intermediate nodes. Nodes within the range can communicate directly and nodes which are out of nodes transmitting range use intermediate for communication. An efficient protocol needs to deliver packet to all nodes within the region with high packet delivery ratio (PDR) and with less delay. In lossy and large scale networks to improve PDR, multiple intermediate nodes can forward and retransmit each packet which creates transmit diversity. In order to reduce delay and channel usage number of transmissions are kept low, since unnecessary transmissions waste channel time and slows PDR to edge of network.

The efficient broadcast support, has mostly focused on CSMA/CA when taken in theoretical or practical design[1].CSMA/CA has proved to be efficient scheduling scheme in 802.11 family of MAC standards, but in network wide broadcast CSMA/CA are not focused carefully. While fine tuned sensing and scheduling reduces collisions but this will become problem in large scale networks. CSMA/CA inevitably misses transmission opportunities which lower channel usage and spatial reuse. Hidden terminal problem is well known which degrades the broadcast performance. More than 10% of packet loss is due to hidden problem collisions in sender receiver pair. CSMA/CA assign RTS/CTS to avoid this problem, but this induce high cost and there is a problem of false blocking.

## 2. Survey and Analysis of Existing System

#### 2.1 CSMA/CA for Efficient Broadcast

Figure.1.a. illustrates a typical scenario where CSMA/CA limits broadcast efficiency. In CSMA/CA, to deliver a packet from source S to other nodes at least three time slots are required. Nodes A and B cannot transmit simultaneously though they have to forward the same packet. In a lossy network, suppose if node D had already received packet, while node C and E waits for retransmission from A and B. In an optical scheduling protocol, A and B are allowed to transmit the packets concurrently, without considering collisions at node D, But in CSMA/CA it is not possible, as one of nodes will back off immediately by sensing others activity.

In chorus Figure.1.b. Now node A and B can transmit data packets independently and immediately after receiving from the source. Node D exploits collision resolution to decode the two collided packets from A and B. So, only two time slots are required to transmit data packet for entire network, due to improved spatial reuse. Whenever links are not available, the two decoded packets create transmit diversity for common receiver D, without consuming any additional time.



Figure 1: Broadcast with traditional CSMA/CA in comparison with CSMA/CR in 802.11

#### **2.2 Evaluation Approaches**

To verify the feasibility of collision resolution, we design and implement CSMA/CR PHY layer on GNU Radio software platform. The component in our design includes packet-offset identification, channel parameter estimation and sample level signal modeling and cancellation which are discussed later.

Due to limitations in software platforms, CSMA/CR MAC and Broadcasting protocols cannot be implemented directly. So an analytical model is developed with closed-form characteristics of CSMA/CR's packet error rate (PER) and bit error rate (BER). We will modify the ns-2 PHY layer with this reception model and we will implement the Chorus protocol.

The Chorus protocol is compared with typical CSMA/CA protocol, In a large set of randomly chosen topologies, Chorus shows better performance improvement in packet delivery ratio (PDR) and latency. The performance gain is not effected by network size, link quality and source rate, which is observed in both single and multi-source broadcasting. To understand the performance of Chorus, we rigorously analyze its network-level performance in terms of latency and throughput.

## 2.3 Broadcasting in multihop mesh networks

Efficient broadcasting in multihop mesh networks is studied extensively from both theoretical and practical perspectives. From the theoretical perspective it is well known that scheduling minimum latency broadcasting is NP-hard, either in unit disk graph or in a general undirected graph.

CSMA/CR follows zigzag protocol, which exploits the signal processing to solve hidden terminal problem. Zigzag protocol will extracts symbols from collided packets by identifying repeated collision of two hidden terminals. It treats two collided packets as a sum of two packets. The two original data packets are recovered from two known sums, which is similar to solving linear equation. CSMA/CR is similar to zigzag which aims to resolve packets from collision with sample level estimation and cancellation. CSMA/CR will improves broadcasting and relaying efficiently in wireless networks, where it exploits spatial reuse and transmit diversity using Mac layer cognitive sensing, network relay selection and scheduling.

## 2.4 CSMA/CA Protocol

Access with Carriers Sense Multiple Collision Avoidance (CSMA/CA): It method is а in which carrier sensing is used in computer networking, but intermediate nodes transmits only when the channel is sensed to be "idle" to avoid collisions. In wireless networks it is important, where the collision detection is unreliable due to the hidden node problem in CSMA/CD. CSMA/CA is a protocol that is implemented in the Data Link Layer (Layer 2) of the OSI model.

Collision avoidance attempts to divide the channel equally among all transmitting nodes by improving the performance of the CSMA method by within the collision domain.

- 1)**Carrier Sense**: In carrier sense method, first a node listens to the shared medium before transmitting a message to determine whether another node is transmitting or not. The hidden node problem means another node may be transmitting the data which goes undetected [9].
- 2)**Collision Avoidance**: While transmitting data, if another node was heard, it will wait for some time for the node to stop transmitting before listening again for a next transmission.
- 3) **Request to Send/Clear to Send** (RTS/CTS): This may be used at some point optionally in shared medium. This will resolves the problem of hidden nodes because, for example, the Access Point only issues a *Clear to send* to one node at a time, in a wireless network. However, in wireless 802.11 implementations do not implement RTS/CTS for all transmissions; RTS/CTS were not used for small packets or they may turn off it completely [5].
- 4) **Transmission**: While transmission if the medium was identified as being clear *or* the node received CTS to explicitly indicate that it can send the frame in its entirety. Unlike in CSMA/CD, it is very difficult for a wireless node simultaneously to listen as it transmits. Continuing the wireless example, the node awaits for an acknowledgement packet from the receiver to indicate the packet was received and check-summed correctly. If such acknowledgement was not received after a regular interval of time, it will assumes the packet collided with some other packet during transmission, making the node to enter a period of binary exponential back-off before attempting to re-transmit[13].

However Carrier sense multiple access with collision avoidance have several drawbacks like:

- Performance in broadcast service is degraded.
- Hidden terminal problems are not solved.
- RTS/CTS cause overhead in transmissions.
- This method lowers channel usage and spatial reuse.

# 3. Proposed System

The proposed protocol is a novel broadcast protocol which resolves collision resolution and hidden terminal problems. Chorus has got several advantages over CSMA/CA like:

- It identifies and solves collisions due to hidden terminal problems.
- Performance degradation due to collision is reduced.
- Improves spatial reuse and diversity without consuming additional time slots.
- It increases scalability and efficiency in broadcasting.

#### 3.1 Collision Resolution: The PHY design

We introduce a physical layer collision resolution in Chorus. When two packets collision occurs, then they have to detect, decode and combine to achieve diversity gain.

#### **3.2 Detecting collided packets:**

In Chorus, when data is transmitted, a transmitter attaches a known random sequence called preamble at the beginning of each packet. At the receiver, a matched filter is used to detect the exact time arrival of this preamble. A matched filter is an optimal correlator that maximizes SNR when correlated with unknown sequence with known sequence [5]. When preamble is detected it outputs a peak value, even if preamble is hidden in strong noise. Matched filter is operated continuously so that preambles overlapping with other packets can be identified.

#### 3.3 Iterative collision resolution:

When a packet is transmitted, a packet usually consists of thousands of symbols, the probability of two collided packet being align is perfectly zero. At transmitters, further randomness is introduced which results in asynchronous arrivals. We will identify natural offset by detecting their preamble between two collided packets. Collisions will not occur within the offset region. We first decode clean symbols and then iteratively subtract known symbols from collided packets so that desired symbols are obtained.

For example, Figure 2 shows collisions of two packets, one is head packet P1 and other is tail packet P2 from different transmitters. First we decode two clean symbols A and B in head packet P1. Symbol C is corrupted as it collides with A' in tail packet P2, which results in combined symbol S. The symbols A and A' carry same bits which are used to recover bit C, but their analog forms are different because of channel distortion. An image of A' is reconstructed by emulating the channel distortion with the known bits of A. The amplitude attenuation, frequency offset, phase shift and timing offset can be estimated accurately by using standard communication technique [4].



Figure 2: Iteratively decoding two collided packets

After reconstructing, we will subtract the image A' from symbol s, and obtains a decision symbol C. The channel estimation is used for normalization of decision symbol for P1, and slicer decides if bit is 1 or 0. For BPSK, if normalized value is negative real part then slicer outputs 0 and vice versa. The decoded bit C is used to reconstruct C" and decode E. This iteration process continues till the end of packet is reached. An iterative decoding process proceeds in forward direction, Chorus can works in backward direction, starting from clean symbol in P2, to its beginning and obtains different estimation of packets [4].

#### **3.4 Packet Combination to Improve Diversity**

Packets P1 and P2 have different strengths and their decoding confidence also differs. The decoding confidence is denoted by magnitude of decision symbol. The bit with highest threshold can produce correct bits, since it is equivalent to higher SNR. The decoding confidence can be increased by combining two decision symbols which carry same bits (e.g.: A and A'), While noise within the two symbols is not combined coherently.

#### 3.5 CSMA/CR: The MAC Design

Now we introduce Mac layer of CSMA/CR and extend 802.11 CSMA protocol, but integrate with collision resolution PHY. Chorus physical layer must be integrated with MAC layer to reduce irresolvable collisions which occurs when packets with different data collides.

#### 3.6 MAC Layer Cognitive Sensing and Scheduling

Chorus' MAC layer maintains carrier sensing and backoff in 802.11 based CSMA protocol, but adopts cognitive sensing which exploits collision resolution to avoid unresolvable collisions. The basic principle of cognitive sensing is to detect the identity of packet which is on air and make transmission decision according to it. At the end, chorus will add new header field to 802.11 packets.

## 3.7 Chorus packet format

The broadcast packet in chorus is illustrated in Figure.3, First, at the beginning a known random sequence is attached to make easy packet detection and offset identification. Next, a Chorus header packet is added, that informs packet identity of the receiver, which includes packet sequence number and broadcast source ID. A 16-bit Cyclic Redundant check (CRC) is added to header packet[5]. If CRC fails, packet id discarded as it provides wrong information.



Figure 3: Frame packet in CSMA/CR

When header of two packets collides, Chorus will follow iterative decoding process assuming that packets will have

same identity. When decoding process is completed, it will perform CRC checking over header of each packet to make sure that they are identical. If decoding process failure occurs both packets will be discarded.

#### 3.8 Scheduling of sensing and transmission

With collision resolution protocol, a SEND procedure is called by each transmitter to perform cognitive sensing as shown in figure.4, Transmitters perform scheduling decision following certain rules:

- R1. If the channel is idle forward a packet immediately.
- R2. If the channel is busy, and packets which are transmitted on air is same as in transmit queue, then start transmitting pending packet.
- R3.If channel is busy and if preamble cannot be decoded then start backoff procedure according to 802.11.

Rule R1 is typically CSMA protocol. Rule R2 is similar to Chorus's CSMA/CR. The principle of Chorus is overlapping packets carrying same data cannot cause collisions. By collision resolution, a sender node such as B in fig: can forward its pending packet if it has same identity as that of one on air. Whenever channel is busy CSMA/CA transmitters will do backoff.



Figure1: MAC layer control flow in CSMA/CR

Rule R3 will ensures friendliness to traffic and is used for multisource broadcast and exist with CSMA/CA based Unicast traffic. Chorus starts 802.11 backoff to prevent unresolvable collisions if it senses that channel is occupied by alien traffic. Chorus will backoff packets, if the identity of packet on air is not detected so that interference is reduced.

If any neighbor overhears this packet, FORWARD procedure is followed to forward that packet once. Collision resolution is performed by overlapping packets before continuing to packet relaying by receivers. In order to resolve unresolvable collisions, a receiver flushes those pending packets with sequence numbers. In continuous broadcasting, the source distributes batch of packets, in such case Chorus controls source rate to prevent to avoid collision and congestion between packets

4. Results

#### 4.1 Packet Delivery Ratio



Figure 5: Comparison Graph Of PDR for Chorus & CSMA



Figure 6: Comparison Graph for DELAY of Chorus & CSMA Throughput



Figure 7: Comparison Graph of THROUPUT for Chorus & Csma

# 5. Conclusion

In this paper, we provide solution to resolve collision in wireless networks in presence of hidden terminals. The advantages and feasibility for wireless broadcast is demonstrated. Here chorus protocol will allows nodes to forward continuously at same time with same data packets. Physical-layer iterative decoding was employed to resolve collisions at receiver. Transmit diversity and spatial usage is improved. Delay, PDR and throughput are improved.

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