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Minimizing Interference in Multihop Wireless Networks in the Presence of Hidden Terminals

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Abstract— **Wireless communication sees an explosive growth in the number of customers in the past few decades, making large- scale wireless ad hoc network an important part of modern life. In such a large-scale wireless network, information are transmitted in a multi-hop fashion. However, due to the unreliability of links in severe environment, such a multi-hop path may not exist all the time, making delay a significant issue. Besides broadcasting is probably the most fundamental operation among all operations of wireless ad hoc networks. The broadcasting experiences problems like severe contention, collision, and congestion. Conventional wireless broadcast protocols rely heavily on the 802.11-based CSMA/CA model, which avoids interference and collision by conservative scheduling of transmissions. While CSMA/CA is amenable to multiple concurrent unicasts, it tends to degrade broadcast performance significantly. Moreover, the hidden terminal problem is known to degrade the throughput of wireless networks due to collisions. As a result, extensive research has been conducted to solve this problem such as Multiple Access Collision Avoidance (MACA). However, MACA-like protocols cannot solve this problem completely. In this paper, we propose a new protocol that improves the efficiency and scalability of broadcast service with a MAC/PHY layer that allows packet collisions. It resolves collision using symbol-level interference cancellation, and then combines the resolved symbols to restore the packet. Such a collision-tolerant mechanism significantly improves the transmission diversity and spatial reuse in wireless broadcast. It also helps in resolving collision caused due to hidden terminals.**

Keywords— **Optimal broadcast, wireless ad hoc and mesh networks, collision resolution, multipacket reception, self-interference cancellation, hidden terminal problem.**

I. INTRODUCTION

A wireless ad hoc network is a set of nodes which communicate with each other using radio transmissions [11]. Every node in the network has a *transmission range*, which is the maximum distance where the node's signal can be correctly received. In wireless networks, only nodes which are within the transmission range of each other can communicate directly[4]. Nodes which cannot reach each other directly must use intermediate nodes for routing their message. Ad hoc networks can operate without a centralized controller. The inherently distributed nature of the wireless nodes introduces many intriguing and challenging research problems that need to be tackled when designing applications on these networks. One fundamental operation in wireless networks is broadcast [7]. The objective of the broadcast operation is to deliver a message from a single source node to all the other nodes in the network. Typically, the area of a wireless ad hoc network is larger than the transmission range of any individual node [10].

The efficient broadcast support, whether in the form of theoretical analysis or practical protocol design, has mostly focused on the CSMA/CA MAC-layer scheduling model [18]. CSMA/CA has proven to be an effective distributed scheduling scheme, especially via the 802.11 family of MAC standards. The limitation of CSMA/CA, however, has not been examined carefully in case of network-wide broadcast [19]. While its fine-tuned sensing and scheduling reduces collision, CSMA/CA inevitably misses transmission opportunities, lowering channel usage and spatial reuse. This problem becomes acute, especially for network-wide broadcast with latency constraints [6]. Moreover, the hidden terminal problem is well-known in Wireless Local Area Networks (WLANs), which significantly degrade the network performance [3]. As shown by [2], the hidden terminal problem introduces severe packet loss due to collisions for 10% of the sender-receiver pairs. Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) designs a handshake mechanism called RTS/CTS [4] to mitigate both the hidden and the exposed terminal problems. However, RTS/CTS induces a rather high cost and introduces other problems like false blocking. Therefore, RTS/CTS is disabled by default in WLANs.

In this paper, we introduce a novel broadcast protocol, based on a MAC layer that adopts CSMA with collision resolution (CSMA/CR). With this protocol, collision of the same packets from different relays can be effectively resolved. With collision resolution, nodes can transmit packets immediately and independently after receiving them from the source .Only two time slots are required to deliver one packet over the entire network, due to the improved spatial reuse. Moreover, when links are unreliable, the decoded packets create transmit diversity for the common receiver, without consuming any additional channel time. This protocol also helps us to identify and resolve hidden terminals.

II. SURVEY AND ANALYSIS OF EXISTING SYSTEM

The most often method used to resolve collision and hidden terminal problem is the CSMA/CA protocol. Carrier Sense Multiple Access with Collision

Avoidance (CSMA/CA) in computer networking is a network multiple access method in which carrier sensing is used, but nodes attempt to avoid collisions by transmitting only when the channel is sensed to be idle. When they do transmit, nodes transmit their packet data in its entirety. It is particularly important for wireless networks, where the collision detection of the alternative Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is unreliable due to the hidden node problem. CSMA/CA is a protocol that operates in the Data Link Layer (Layer 2) of the OSI model. Collision avoidance is used to improve the performance of the CSMA method by attempting to divide the channel somewhat equally among all transmitting nodes within the collision domain.

1) *Carrier Sense:* Prior to transmitting, a node first listens to the shared medium (such as listening for wireless signals in a wireless network) to determine whether another node is transmitting or not. The hidden node problem means another node may be transmitting which goes undetected at this stage. Carrier sense multiple access (CSMA) is a probabilistic media access control (MAC) protocol in which a node verifies the absence of other traffic before transmitting on a shared transmission medium [16]. Carrier Sense means that a transmitter uses feedback from a receiver to determine whether another transmission is in progress before initiating a transmission. That is, it tries to detect the presence of a carrier wave from another station before attempting to transmit. If a carrier is sensed, the station waits for the transmission in progress to finish before initiating its own transmission [15]. In other words, CSMA is based on the principle "sense before transmit" or "listen before talk". Multiple access means that multiple stations send and receive on the medium. Transmissions by one node are generally received by all other stations connected to the medium [13].
2) *Collision avoidance*: If another node was heard, we wait for a period of time for the node to stop transmitting before listening again for a free communications channel.

   Request to Send/Clear to Send (RTS/CTS) may optionally be used at this point to mediate access to the shared medium. This goes some way to alleviating the problem of hidden nodes because, for instance, in a wireless network, the Access Point only issues a Clear to Send to one node at a time. However, wireless 802.11 implementations do not typically implement RTS/CTS for all transmissions [12].

   Transmission: If the medium was identified as being clear or the node received a CTS to explicitly indicate it can send, it sends the frame in its entirety. Unlike CSMA/CD, it is very challenging for a wireless node to listen at the same time as it transmits (its transmission will dwarf any attempt to listen). The node awaits receipt of an acknowledgement packet from the Access Point to indicate the packet was arrive after a timely manner, it assumes the packet collided with some other transmission, causing the node to enter a period of binary exponential back off prior to attempting to re-transmit [14].
3) *Solving Hidden terminal*: Problem CSMA/CA presents a simple scheme that solves the hidden terminal problem, does not need a base station, and is still a random access Aloha scheme – but with dynamic reservation. In Fig 1, A and C both want to send to B. A has already started the transmission, but is hidden for C and C also starts with its transmission, thereby causing a collision at B.

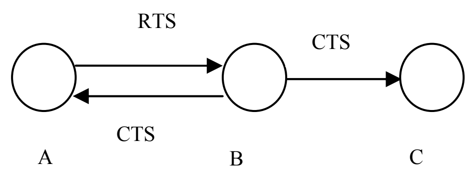

Fig. 1. Solving Hidden Node Problem

With CSMA/CA, A does not start its transmission at once, but sends a Request to Send (RTS) first. B receives the RTS that contains the name of sender and receiver, as well as the length of the future transmission. This RTS is not heard by C, but triggers an acknowledgement from B, called Clear to Send (CTS). The CTS again contains the names of sender (A) and receiver (B) of the user data, and the length of the future transmission. This CTS is now heard by C and the medium for future use by A is now reserved for the duration of the transmission. After receiving a CTS, C is not allowed to send anything for the duration indicated in the CTS toward B. A collision cannot occur at B during data transmission, and the hidden terminal problem is solved. Still, collisions can occur during the sending of an RTS. Both A and C could send an RTS that collides at B. RTS is very small compared to the data transmission, so the probability of a collision is much lower. B resolves this contention and acknowledges only one station in the CTS (if it was able to recover the RTS at all). No transmission is allowed without an appropriate CTS. This is one of the medium access schemes that is optionally used in the standard IEEE 802.11

. In CSMA/CA collision avoidance is used to improve the performance of CSMA by attempting to be less greedy on the channel [20]. If the channel is sensed busy before transmission then the transmission is deferred for a random interval. This reduces the probability of collisions on the channel. Conventional wireless broadcast protocols rely heavily on the 802.11 based Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). However Carrier Sense Multiple Access with Collision Avoidance protocol has got several drawbacks like

- Degrades performance in broadcast networks.
- It is amenable in unicast networks.
- It does not completely solve the exposed terminal problem.
- RTS/CTS mechanism causes overhead in transmission.
- CSMA/CA inevitably misses transmission opportunities.
- This method lowers channel usage and spatial reuse.
- It does not have access to the Channel Usage Information (CUI). CUI is the information about the nodes receiving and transmitting data nearby.

III. PROPOSED SYSTEM

The proposed protocol identifies the presence of hidden terminals. First of all, a topology control algorithm has to be developed where each node makes local decisions to construct its set of relative neighbours to which it can communicate directly. Further, a distributed code assignment algorithm has to be developed where the nodes use orthogonal CDMA codes for communication [17]. In this way, the degradation of performance caused due to collision can be avoided. Also, an algorithm has to be developed to detect collision. Collision resolution takes place using symbol-level interference cancellation [9]. Such a collision-tolerant mechanism can improves the transmission diversity and spatial reuse in wireless broadcast. In MAC layer a sensing and scheduling mechanism has to be introduced. The collision resolution mechanism has to be introduced in the PHY layer. The protocol is evaluated using symbol-level simulation, and its network-level performance can be validated via ns-2, in comparison with a typical CSMA/CA-based broadcast protocol.

The proposed protocol is a novel broadcast protocol which tries to resolve collision and the hidden terminal problem. It has got several advantages over CSMA/CA like:

- It identifies and solves collision caused due to hidden terminals.
- The degradation in performance due to collision is reduced.
- Collision resolution improves spatial reuse and transmit diversity without consuming any additional channel time.
- It increases the efficiency and scalability of broadcast service.

3.1 Identifying Hidden Terminals

A topology control algorithm has to be developed, where each node makes local decisions to construct its set of relative neighbours to which it can communicate directly. Using transitivity and relative neighbourhood, the algorithm should try to reduce the number of direct communication links as well as reduces interference [8]. Further, a distributed code assignment algorithm has to be developed where the nodes use orthogonal CDMA codes for communication. The code assignment is done by viewing the problem as a list colouring problem. The algorithm assigns codes in such a way that it eliminates direct and hidden terminal interference.

For topology control, a distributed algorithm is devised that uses the property of transitivity and relative neighborhood. This algorithm is referred to as RNB-DTC algorithm. It converts the induced network graph of the sensor network to a topologically condensed graph, thereby reducing the number of collisions. It reduces the number of edges in the topologically condensed graph.

Distributed Code Assignment Algorithm

For each node i, we denote Li as the list of codes $|Li| \leq 7$. NAC_i is the set of codes assigned to the 1- hop relative neighbors of node i. $Free_i$ is the set of free codes that are not assigned to any of its 1-hop relative neighbors. $AssignedCode_i$ is the code assigned to i for direct communication to its 1-hop relative neighbors. The control messages used are:

- broadcast (i, p,m) invoked by node i to broadcast a message m with power p.
- send (i, p,m, j) is invoked by node i to send a message m to node j with power p. This primitive is used to send unicast messages.
- receive (i,m, j) used by node i to receive message m from j.
- query code(i, j) sent by I to its relative neighbor j to determine the code assigned to j.
- reply(j,AssignedCodej): On receiving query message, j replies with its assigned code.

Algorithm executed by Node i:-

```
 Begin
  broadcast(i, P,RN(i)); NACi := ø;
  for each j E RN(i) send(i, p_j , query code(i, j), j);
  for each j E RN(i)
  begin
   receive(i, reply(j,AssignedCode_j), j);
   if AssignedCode_j 6= NULL then
    NAC_i := NAC_i U {AssignedCode_j};
   endif
  for each k E RN(j)
   begin /*Find codes assigned to 2-hop neighbors*/
    receive(i, reply(k,AssignedCode_k), j);
    if AssignedCode_k 6= NULL then
     NAC_i := NAC_i U {AssignedCode_k};
    endif
   end
   Free_i := L_i – NAC_i;
   Select a code C from the list of free codes, Free_i;
   AssignedCode_i := C;
   for each j E RN(i) send(i, pj,AssignedCode_i, j);
  end
```

On receiving query from Node i, Node j executes:

```
begin
 receive(j, query code(i, j), i);
 if j E RN(i) then
 for each k E RN(j)
  begin
   send(j, pk, query code(j, k), k);
   receive(j, reply(k,AssignedCode_k), k);
```

send(j, pi, reply(k,$AssignedCode_k$), i);
end
if code is assigned to j **then** $AssignedCode_j$:= code;
else $AssignedCode_j$:= NULL;
endif
send(j, pi, reply(j,$AssignedCode_j$), i);
end

3.2 Collision Detection

Once the hidden terminals are identified, the next step is to detect collision. By using the proposed algorithm the collision of the same packets from different relays can be effectively resolved. In this algorithm a preamble and a matched filter is used. A matched filter is an optimal linear correlator that maximizes the Signal to Noise Ratio (SNR) when correlating unknown signals with a known sequence.

Step 1: A transmitter attaches a known random sequence to the beginning of each packet as a preamble.
Step 2: The receiver then uses a matched filter to detect the exact arrival time of this preamble.
Step 3: Matched filter outputs a peak value whenever the packet preamble is detected, even if the preamble is hidden in a strong noise.
Step 4: It operates continuously, so that those preambles overlapping with other packets can still be identified.
Step 5: The number of preambles detected in a run indicates the number of overlapping packets at the receiver.
The peak output grows linearly with the number of bits in the preamble, and with the Received Signal Strength (RSS) of the packet. Therefore, the detection threshold is also a linear function of these two factors.

3.3 Collision Resolution

The technique used for collision resolution is Symbol level interference cancellation. Since a packet usually consists of thousands of symbols, the probability of two collided packets being aligned perfectly is close to 0. In practice, the higher layer operations at transmitters introduce further randomness, resulting in asynchronous arrivals. The natural offset between the two packets has to be identified by detecting their preambles. Within the offset region, no collision occurs. The clean symbols therein has to be decoded first, and then iteratively subtract such known symbols from the collided ones, thereby obtaining the desired symbol.

The steps involved are as follows:

Step 1: Decode clean symbols.

Step 2: Identify a collided symbol which results in a combination of a clean symbol and a collided one.

Step 3: Construct an image of the clean symbol.

Step 4: Subtract emulated image of clean symbol from collided one.

Step 5: Iterate process till end of packet.

3.4 Scheduling

The MAC layer of the proposed protocol adopts cognitive scheduling that exploits the collision-resolution feature, while avoiding irresolvable collisions. The principle of cognitive sensing is to decode the identity of the packet on the air, and accordingly, make the transmission decision. Each node will send data through the nearest cognitive sensing node [5]. Each cognitive sensing node will have to identify the best possible nearest node. Once the best possible nearest node is identified the data is transferred to it. This avoids collision and in turn the best possible nearest node sent the data to their respective destination. With the collision-resolution capability, each transmitter calls a SEND procedure to perform cognitive scheduling. Transmitters make scheduling decision following three rules:

Rule 1: Forward a packet immediately if the channel is idle.

Rule 2: If the channel is busy, and the packet on the air is exactly one of the packets in the transmit queue, then start transmission of the pending packet.

Rule 3: If the channel is busy, but a preamble cannot be detected, or the header field of the packet on the air cannot be decoded, or a different packet is on the air, then starts the back off procedure according to the 802.11.

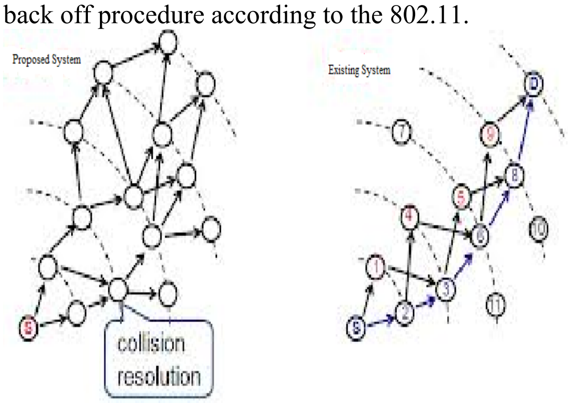

Fig 2. Comparison between Existing and Proposed System

In Fig 2, the existing and proposed system are shown. The existing system shows how it takes a random path in case of a collision occurrence. As already discussed this may have certain issues as choosing a random path is not feasible. The proposed system shows how the collision is resolved in it. The advantage is that using the collision resolution protocol the collision can be resolved in wireless mesh networks [1] and also in a random network.

IV. CONCLUSIONS

In this paper, we provide a way to resolve collision in multihop wireless network in the presence of hidden terminals.
The paper demonstrates the feasibility and advantages of a collision-resolution protocol for wireless broadcast. The protocol allows forwarders with the same outgoing packets to transmit roughly at the same time, and then employs physical-layer iterative decoding to resolve collisions at the receiver. By decoding multiple versions of a packet at once, it achieves transmit diversity and improves loss resilience without any retransmission. More importantly, with its collision-tolerant MAC, it significantly simplifies the CSMA

scheduling and improves its spatial reuse. A topology algorithm is implemented to identify and solve hidden terminal problem. The degradation in performance due to collision is reduced. The scalability and efficiency of broadcast service is also increased. The proposed protocol and CSMA/CA can be compared and the results can be analysed. The collision resolution protocol not only helps us to solve the interference and collision occurring in the wireless mesh network but also in a random network.

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