ECE 5325/6325: Wireless Communication Systems
Lecture Notes, Spring 2013

Lecture 22

Today: (1) Presentation Day Schedule

1 CSMA-CA

1.1 Carrier Sensing

One more simple idea in packet radio is *carrier sensing*. Carrier sensing refers to a transceiver's use of its receiver to sense whether or not there is currently another packet being transmitted on the channel, *i.e.*, "if the channel is busy", before transmitting its own packet. If it detects transmission, it will wait until the transmission is completed, until starting its own transmission. This is called "carrier sense multiple access" (CSMA).

A minor modification of CSMA is called CSMA-collision avoidance, or CSMA-CA. This means that, when a CSMA transceiver detects the channel to be busy, rather than just waiting for the other transmission to be completed, it *also* waits a random time interval before trying to retransmit.

1.2 Hidden Terminal Problem

What is a problem of relying on one terminal to know when the channel is busy? Since signal power is spatially varying, one terminal may be transmitting to the server successfully, even while a second terminal at a third location is not able to hear that the channel is busy, as shown in Figure 1.

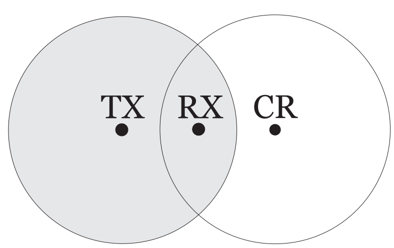

Figure 1: Terminal TX is transmitting to server RX. Terminal CR cannot hear TX's signal, so even if it uses carrier sensing, when it has data to send, it would transmit and cause interference at terminal CR.

The hidden terminal problem is ubiquitous in packet radio networks. This makes carrier sensing systems less useful than you would otherwise imagine.

1.3 802.11 DCF

Our 802.11 networks operate using a basic CSMA-CA protocol which is named the "distributed control function" (DCF). They use CSMA-CA, and when a collision occurs, for collision avoidance, a terminal waits a random amount of time in a procedure called exponential backoff.

This material supplements and draws heavily from [1].

The job of a terminal's transmitter is to send its packets. When it has a packet to send, it:

1. Listens to the channel for a duration of DIFS (a constant time window called the distributed interframe space).

2. After the channel is sensed to be free for a duration of DIFS (by the receiver), the transmitter picks a random *backoff delay* X, which is an integer, picked as follows. X is chosen randomly and uniformly from the range 0 to $2^i CW_{min} - 1$ for some integer i called the backoff stage and some minimum window length CW_{min}. This backoff stage i is initially set to zero. So initially, when a collision occurs, the transmitter picks this random integer X between 0 and $CW_{min} - 1$.

3. If $X = 0$, the terminal immediately transmits.

4. If not, it continues sensing. After σ period of time (called the slot time) with the channel unoccupied, the receiver decrements X by one. Note that if the receiver hears another terminal transmit, it waits a period DIFS after the end of the transmission, and then waits σ and decrements X by one.

5. The terminal goes back to step 3.

After the transmitter sends its packet, its receiver checks for the ACK from the access point within ACK_Timeout (another constant period of time):

1. *If it does not receive the ACK within the specified time window*, it assumes that the packet collided and was lost. In this case, it increments the backoff stage i (up to a maximum of m), and starts the procedure to transmit the packet again.

2. *If it does receive the ACK*, it resets the backoff stage i to zero, and then starts the procedure to transmit the next packet (assuming there is another one).

Because there are so many acronyms, here is a table of the most important:

- ACK: positive acknowledgement
- CSMA/CA: carrier sense multiple access with collision avoidance
- DCF: distributed coordination function: the algorithm in 802.11 which is the main subject of this paper

- DIFS: distributed interframe space: how long a terminal measures the channel before determining it is idle
- MAC: medium access control
- SIFS: short inter-frame space: delay between end of reception and transmission of ACK

Notation:

- σ: slot time size (time needed for any terminal to detect a transmission)
- CW_{min}: minimum size of the contention window
- n: number of "contending terminals", *i.e.*, those offering packet traffic to the network.
- i: backoff stage, in the range $\{0, \ldots, m\}$
- m: maximum backoff stage ($CW_{max} = 2^m W$)

1.4 In-Class DCF Demo

This activity recreates a few milliseconds in the life of a 802.11 network running the DCF. For our exercise, let:

- $W = 4$, $m = 2$. Thus the maximum contention window is length 16.
- Let $\sigma = 1$, DIFS = 3, SIFS = 1.
- packet duration $P = 20$, ACK duration = 3.
- $n = 3$: terminals A, B, and C. All terminals can hear the access point. First assume that all terminals can hear each other, then assume that terminal A cannot hear terminal C, and vice versa.
- $ACK_{Timeout} = 24$.

Each person will "act out" a terminal TX or RX, or access point TX or RX. Other "actors" include the random number generator (the person who selects random numbers from 0 to $2^i CW_{min} - 1$), and the "time counter" who moves time to the next multiple of σ when the actors are ready.

The exercise starts by the random number generator presenting a random number in $\{0, \ldots, CW_{min}\}$ to each of the terminal transmitters to use as their backoff counter. Terminals are all in backoff stage 0 at the start.

Each terminal comprises a transmitter and receiver. The transmitter's job is to decrement the backoff counter whenever the receiver allows it to do so, and then transmit a packet whenever the backoff counter hits zero. The receiver's job is to sense the channel (and thus stop the backoff counter from whenever a packet is transmitted until DIFS after the ACK is finished). After transmitting a packet, or a collision, the transmitter requests a random number (ask the random number generator to pick a number out of a hat according to the backoff stage). The receiver's job is also to make sure that an ACK is received within $ACK_{Timeout}$ of the start of the transmitter sending a packet. If it is not, increment the backoff stage (up to the maximum stage m) and tell the transmitter to request a new random number for the backoff counter.

The access point receiver's job is to listen for each packet; then SIFS after the end of a packet, the access point transmitter sends an ACK. Unless, of course, two packets were transmitted at the same time, in which case, neither packet is received and an ACK is not transmitted.

Whenever your terminal or access point transmits a packet, the transmitter actor will hold up card letting the other players know that he or she is occupying the medium. For the hidden terminal simulation, terminal A should ignore terminal C, and vice versa.

Important questions:

1. How efficient is the 802.11 DCF when there is no hidden terminal problem? The paper eventually shows that a utilization rate of just above 80% is possible in this case.

2. How significant is the hidden node problem in the 802.11 DCF?

References

[1] G. Bianchi. Performance analysis of the IEEE 802.11 distributed coordination function. *IEEE Journal on Selected Areas in Communications*, 18(3):535–547, 2000.