# Wireless and Mobile Networks

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## 1 Consider the single-sender CDMA example in figure 7.5. What would be the sender's output (for the two data bits shown) if the sender's CDMA code were (1, -1, 1, -1, 1, -1, 1, -1)?

(-1, 1, -1, 1, -1, 1, -1, 1)
(1, -1, 1, -1, 1, -1, 1, -1)

## 2 Consider sender 2 in figure 7.6. What is the sender's output to the channel (before it is added to the signal from sender 1), $Z_{i,m}^2$?

(1, -1, 1, 1, 1, -1, 1, 1)
(1, -1, 1, 1, 1, -1, 1, 1)

## 3 Suppose that the receiver in figure 7.6 wanted to receive the data being sent by sender 2. Show (by calculation) that the receiver is indeed able to recover sender 2's data from the aggregate channel signal by using sender 2's code.

First, an intuitive explanation. The data the receiver receives is:
(0, -2, 0, 2, 0, 0, 2, 2)
(2, 0, 2, 0, 2, -2, 0, 0)

At first glance, the 0 bits are ambiguous, because although it is clear that one sender encoded 1 and the other -1, it is not clear which sent which. The

bits that are either 2 or -2 mean that both senders encoded either 1 or -1, respectively. Letting X be the ambiguous bits, the senders sent the following:
(X, -1, X, 1, X, X, 1, 1)
(1, X, 1, X, 1, -1, X, X)

Based on sender 2's code, (1, -1, 1, 1, 1, -1, 1, 1), which is known to the receiver, the only possible input that matches the received output is
(1, -1, 1, 1, 1, -1, 1, 1)
(1, -1, 1, 1, 1, -1, 1, 1),
so the receiver knows that sender 2 sent (1, 1). The actual calculation is as follows:
$d_0^2 = \frac{0*1+-2*-1+0*1+2*1+0*1+0*-1+2*1+2*1}{8} = 1$
$d_1^2 = \frac{2*1+0*-1+2*1+0*1+2*1+-2*-1+0*1+0*1}{8} = 1$

# 4 For the two-sender, two-receiver example, give an example of two CDMA codes containing 1 and -1 values that do not allow the two receivers to extract the original transmitted bits from the two CDMA senders.

A trivial example is two senders using the same CDMA code. If they encode opposite bits, the result will be a string of zeros and it will be impossible to tell which sent which. Another simple example is using opposite codes. Whenever they encode the same bits, the results will again be ambiguous.

# 5 Suppose there are two ISPs providing WiFi access in a particular cafe, with each ISP operating its own AP and having its own IP address block.

## 5.1 Further suppose that by accident, each ISP has configured its AP to operate over channel 11. Will the 802.11 protocol completely break down in this situation? Discuss what happens when two stations, each associated with a different ISP, attempt to transmit at the same time.

The protocol will not break down, but the channel will be more congested than it needs to be since they will have to share the 22 Mbps allowed by 802.11. Simultaneous transmissions will result in collisions, which will cause both stations to choose backoff values and wait until the channel is clear, just as they would if the traffic was coming from another station associated with the same ISP.

### 5.2 Now suppose that one AP operates over channel 1 and the other over channel 11. How do your answers change?

Since they are more than four channels apart, there is no bandwidth overlap and there will be no collisions between frames to and from the different APs.

## 6 In step 4 of the CSMA/CA protocol, a station that successfully transmits a frame begins the CSMA/CA protocol for a second frame at step 2, rather than at step 1. What rationale might the designers of CSMA/CA have had in mind by having such a station not transmit the second frame immediately (if the channel is sensed idle)?

This prevents a single station from monopolizing the channel. Having the station choose a random backoff value puts it on equal footing with other stations that might be waiting to transmit, which have also chosen random backoff values.

## 7 Suppose an 802.11b station is configured to always reserve the channel with the RTS/CTS sequence. Suppose this station suddenly wants to transmit 1,000 bytes of data, and all other stations are idle at this time. As a function of SIFS and DIFS, and ignoring propagation delay and assuming no bit errors, calculate the time required to transmit the frame and receive the acknowledgement.

The size of the header of each frame is 32 bytes, and RTS, CTS, and ACK frames have no additional data. Since 802.11 allows up to 11 Mbps, the total transmission delay will be $(32 * 4 + 1000) * 8/(11 * 10^6) = .00082$ seconds. The total time to transmit the frame and receive the acknowledgement is:

$DIFS + RTS + SIFS + CTS + SIFS + DATA + SIFS + ACK$
$= DIFS + 3 * SIFS + d_{trans}(RTS + CTS + DATA + ACK)$
$= DIFS + 3 * SIFS + .82$ milliseconds

# 8 Consider the scenario shown in figure 7.34, in which there are four wireless nodes, A, B, C, and D, and the characteristics of the system are as follows.

## 8.1 Suppose that an omniscient controller can command each node to do whatever the controller wishes. Given this omniscient controller, what is the maximum rate at which a data message can be transferred from C to A given that there are no other messages between any other source/destination pairs?

0.5 messages/slot, since it takes two slots to send a single message

## 8.2 Suppose now that A sends messages to B, and D sends messages to C. What is the combined maximum rate at which data messages can flow from A to B and from D to C?

2 messages/slot, since A and D can safely transmit simultaneously

## 8.3 Suppose now that A sends messages to B, and C sends messages to D. What is the combined maximum rate at which data messages can flow from A to B and from C to D?

1 message/slot, since A and C cannot safely transmit simultaneously (the messages arriving at B will be corrupted.)

## 8.4 Suppose now that the wireless links are replaced by wired links. Repeat the previous questions.

1. 0.5 messages/slot
2. 2 messages/slot
3. 2 messages/slot

### 8.5 Now suppose we are again in the wireless scenario, and that for every data message sent from source to destination, the destination will send an ACK message back to the source. Also suppose that each ACK message takes up one slot. Repeat the previous questions.

1. 0.25 messages/slot
2. 0.67 message/slot (since A and D can send messages simultaneously, but B and C must ACK separately)
3. 0.67 messages/slot (since D can send ACK to C at the same time as A sends message to B)

# 9 Describe the format of the 802.15.1 Bluetooth frame. Is there anything in the frame format that inherently limits the number of active nodes in an 802.15.1 network to eight active nodes?

A bluetooth frame has three sections: a 72 or 68 bit access code, a 54 bit header, and the payload. The header has six fields: the destination address, the packet type, a flow bit, an acknowledgement bit, the sequence number, and a header error check. The destination address is only three bits, allowing eight possible addresses. This is what limits the number of active nodes to eight.

# 10 Consider the following idealized LTE scenario.

### 10.1 What is the maximum rate at which the base station can send to the nodes, assuming it can send to any node it chooses during each time slot? Is your solution fair? Explain and define what you mean by "fair."

The maximum rate the base station can achieve is 10 Mbps if it transmits exclusively to node A. Clearly, this is unfair to nodes B, C, and D, since they receive no data. This is true whether "fair" is defined as receiving equal numbers of frames, a number of frames proportional to the maximum rate at which the base station can send them, or something in between.

## 10.2 If there is a fairness requirement that each node must receive an equal amount of data during each one second interval, what is the average transmission rate by the base station (to all nodes) during the downstream sub-frame? Explain.

Let X be the total number of available slots and a, b, c, and d be the fraction of those slots transmitting to nodes A, B, C, and D, respectively. In order to make sure they each receive an equal amount of data, $\frac{aX}{10} = \frac{bX}{5} = \frac{cX}{2.5} = \frac{dX}{1}$, which implies $a = 2b = 4c = 10d$. This means that the base station uses 1/17 of the available slots to transmit to A, 2/17 to transmit to B, 4/17 to transmit to C, and 10/17 to transmit to D, giving an average transmission rate of $1/17 * 10 + 2/17 * 5 + 4/17 * 2.5 + 10/17 * 1 = 2.35$ Mbps.

## 10.3 Suppose that the fairness criterion is that any node can receive at most twice as much data as any other node during the sub-frame. What is the average transmission rate by the base station during the sub-frame? Explain.

Using the same notation as in the previous problem, the amount each node receives is $\frac{aX}{10}$, $\frac{bX}{5}$, $\frac{cX}{2.5}$, and $\frac{dX}{1}$.

The relevant constraints are:
$a + b + c + d = 1$, $a, b, c, d \geq 0$
$5b \leq 2 * 10a$, $2.5c \leq 2 * 10a$, $d \leq 2 * 10a$
$10a \leq 2 * 5b$, $2.5c \leq 2 * 5b$, $d \leq 2 * 5b$
$10a \leq 2 * 2.5c$, $5b \leq 2 * 2.5c$, $d \leq 2 * 2.5c$
$10a \leq 2 * d$, $5b \leq 2 * d$, $2.5c \leq 2 * d$

Using a linear optimization solver, the optimum values of (a, b, c, d) in order to maximize $z = 10a + 5b + 2.5c + d$ are (0.1, 0.2, 0.2, 0.5), which give an average transmission rate of $0.1 * 10 + 0.2 * 5 + 0.2 * 2.5 + 0.5 = 3$ Mbps.

## 11 In section 7.5, one proposed solution that allowed mobile users to maintain their IP addresses as they moved among foreign networks was to have a foreign network advertise a highly specific route to the mobile user and use the existing routing infrastructure to propagate this information throughout the network. We identified scalability as one concern. Suppose that when a mobile user moves from one network to another, the new foreign network advertises a specific route to the mobile user, and the old foreign network withdraws its route. Consider how routing information propagates in a distance-vector algorithm.

### 11.1 Will other routers be able to route datagrams immediately to the new foreign network as soon as the foreign network begins advertising its route?

Distance-vector routing spreads routing information by having each node inform its neighbors of its distance to each other node in the network. The neighbors then compare their own distances to that node with the neighbor's distance plus the distance to that neighbor. The effect is that information spreads slowly, one node at a time. The time it takes other routers in the network to be informed of the new route will be proportional to their distance from the new location.

### 11.2 Is it possible for different routers to believe that different foreign networks contain the mobile user?

Yes. As the distance values are being updated throughout the network, different routers could implicitly believe that the mobile user is at the end of completely different routes.

### 11.3 Discuss the timescale over which other routers in the network will eventually learn the path to the mobile user.

Routers closest to the mobile user's new location will learn of the new path first, and routers closest to the user's old location will learn that the old path has been withdrawn first. Routers in between will receive the new pieces of information at times proportional to their distance from the new and old locations.

## 12 Suppose the correspondent in figure 7.23 were mobile. Sketch the additional network-layer infrastructure that would be needed to route the datagram from the original mobile user to the (now mobile) correspondent. Show the structure of the datagram(s) between the original mobile user and the (now mobile) correspondent.

If the correspondent as well as the original user were mobile, the relevant network-layer infrastructure would be symmetrical, with both users having a home network and agent as well as a foreign network and agent. Both would have permanent addresses as well as care-of addresses, which would be invisible to the other. Each user would send datagrams to the permanent address of the other, and each user's home agent would encapsulate those datagrams within new datagrams addressed to the care-of address in the foreign network.

## 13 In mobile IP, what effect will mobility have on end-to-end delays of datagrams between the source and destination?

The end-to-end delay is proportional to the routing distance between the correspondant and the home network plus the distance between the home network and the moble user's current foreign network. Mobility will always increase the delay, and the delay depends on the distance between the home and foreign networks of the mobile user.

# 14 Consider the chaining example discussed at the end of section 7.7.2. Suppose a mobile user visits foreign networks A, B, and C, and that a correspondent begins a connection to the mobile user when it is resident in foreign network A.

## 14.1 List the sequence of messages between the foreign agents, and between foreign agents and the home agent as the mobile user moves from network A to network B to network C.

Indirect routing, mobile user is registered in foreign network A.
1. As the mobile user moves into network B, it registers with B's foreign agent.
2. B's foreign agent informs the user's home agent of the user's new COA.
3. The home agent routes all of the user's arriving datagrams to the COA in network B.
4. As the user moves into network C, it registers with C's foreign agent.
5. C's foreign agent informs the user's home agent of the user's new COA.
6. The home agent routes all of the user's arriving datagrams to the COA in network C.

## 14.2 Suppose chaining is not performed, and the correspondent (as well as the home agent) must be explicitly notified of the changes in the mobile user's care-of address. List the sequence of messages that would need to be exchanged in this second scenario.

Direct routing, mobile user is registered in foreign network A, and the correspondent has queried the user's home agent and discovered the user's COA. A's foreign agent is the user's anchor foreign agent.
1. As the mobile user moves into network B, it registers with B's foreign agent.
2. B's foreign agent informs the user's home agent of the user's new COA.
3. B's foreign agent informs the anchor foreign agent (A's foreign agent) of the user's new COA, which it uses to forward arriving datagrams.
4. When the user moves into network C, it registers with C's foreign agent.
5. C's foreign agent informs the user's home agent as well as the anchor foreign agent of the user's new COA.

## 15 Consider two mobile nodes in a foreign network having a foreign agent. Is it possible for the two mobile nodes to use the same care-of address in mobile IP? Explain your answer.

Yes. Care-of addresses are frequently associated with the foreign agent, so two visiting nodes registered to the same foreign agent will have the same COA. Once the foreign agent decapsulates the datagram, it will know which visiting node to route it to.

## 16 In our discussion of how the VLR updated the HLR with information about the mobile's current location, what are the advantages and disadvantages of providing the MSRN as opposed to the address of the VLR to the HLR?

In both cases the home MSC will eventually need to obtain the MSRN in order to route incoming calls. If the VLR only provides its own address to the HLR, the home MSC will have to query the VLR to get the MSRN. This will add a small delay to the routing of incoming calls. The advantage of simply sending the address of the VLR to the HLR is that it can be done as soon as the mobile enters the visted network. The MSRN is not assigned until after an exchange of signaling messages between the mobile and the VLR, and it changes more frequently than the VLR address does.