University of Science and Technology

Faculty of Computer Science and Information Technology

ICT Department

Wireless Networks: Lecture (1)

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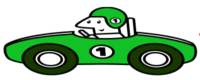
Introduction to Wireless Networks

Over the past five years, the world has become increasingly mobile. As a result, traditional ways of networking the world have proven inadequate to meet the challenges posed by our new collective lifestyle. If users must be connected to a network by physical cables, their movement is dramatically reduced. Wireless connectivity, however, poses no such restriction and allows a great deal more free movement on the part of the network user.

Wireless telephony has been successful because it enables people to connect with each other regardless of location. New technologies targeted at computer networks promise to do the same for Internet connectivity. The most successful wireless networking technology this far has been 802.11.

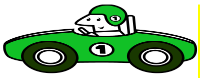


Why Wireless?

Wireless networks share several important advantages, no matter how the protocols are designed, or even what type of data they carry.

The most obvious advantage of wireless networking is *mobility*. Wireless network users can connect to existing networks and are then allowed to roam freely.

Wireless networks typically have a great deal of *flexibility*, which can translate into rapid deployment. Wireless networks use a number of base stations to connect users to an existing network. The infrastructure side of a wireless network, however, is qualitatively the same whether you are connecting one user or a million users. To offer service in a given area, you need base stations and antennas in place. Once that infrastructure is built, however, adding a user to a wireless network is mostly a matter of authorization. With the infrastructure built, it must be configured to recognize and offer services to the new users, but authorization does not require more infrastructures.

 What Transmission Media is used in Wireless Networks?

Like all networks, wireless networks transmit data over a network medium. The medium is a form of electromagnetic radiation. To be well-suited for use on mobile networks, the medium must be able to cover a wide area so clients can move throughout a coverage area.

The two media that have seen the widest use in local-area applications are infrared light and radio waves.

However, infrared light has limitations; it is easily blocked by walls, partitions, and other office construction. Radio waves can penetrate most office obstructions and offer a wider coverage range. It is no surprise that most, if not all, 802.11 products on the market use the radio wave physical layer

Figure 6.1 shows the setting in which we'll consider the topics of wireless data communication and mobility. We'll begin by keeping our discussion general enough to cover a wide range of networks, including both wireless LANs such as IEEE 802.11 and cellular networks such as a 3G network.

We can identify the following elements in a wireless network:

• ***Wireless hosts***. As in the case of wired networks, hosts are the end-system devices that run applications. A **wireless host** might be a laptop, palmtop, smartphone, or desktop computer. The hosts themselves may or may not be mobile.

Wireless links. A host connects to a **base station** (defined below) or to another wireless host through a **wireless communication link**. **Different wireless link technologies have different transmission rates and can transmit over different distances.**

Figure 6.2 shows two key characteristics (coverage area and link rate) of the more popular wireless network standards.

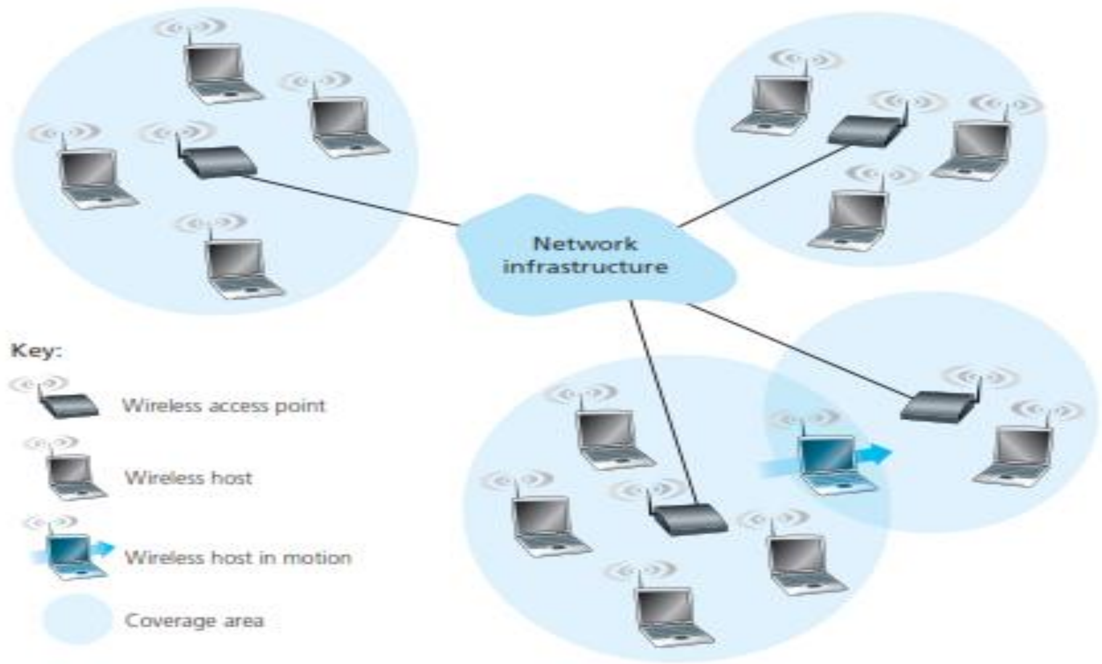


Figure 6.1 ♦ Elements of a wireless network

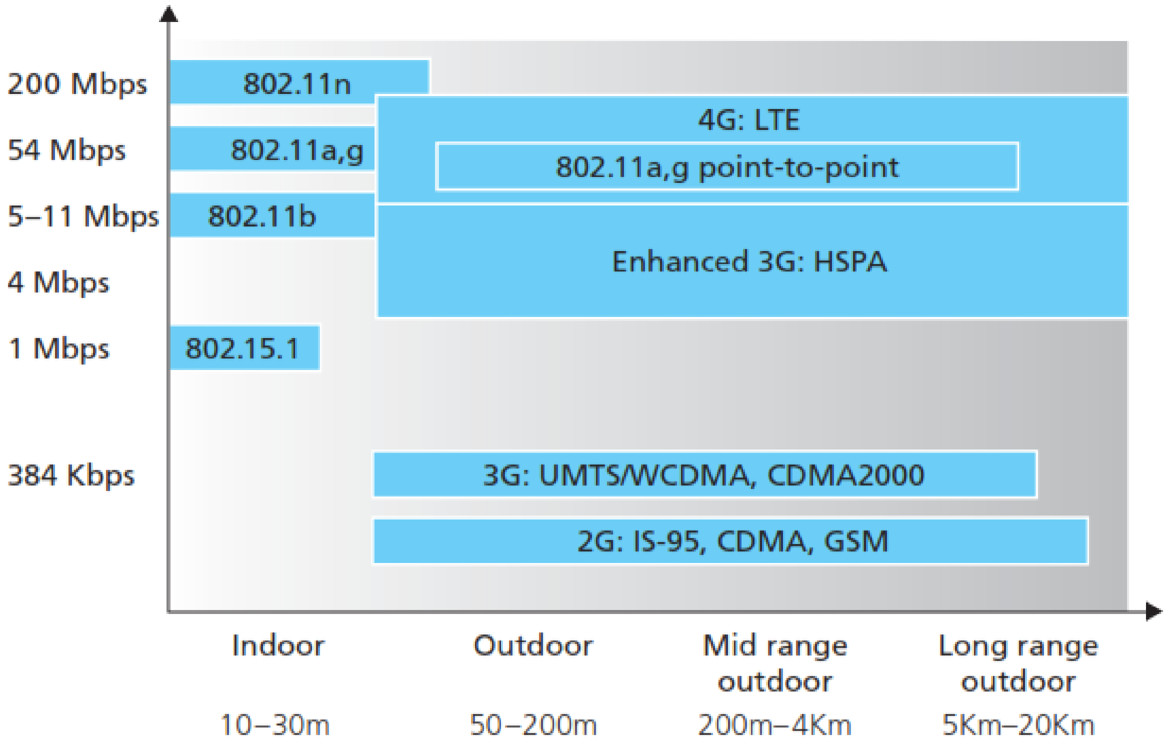
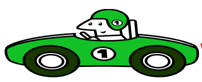


Figure 6.2 ♦ Link characteristics of selected wireless network standards

- *Base station*. The **base station** is a key part of the wireless network infrastructure. Unlike the wireless host and wireless link, a base station has no obvious counterpart in a wired network. **Abase station is responsible for sending and receiving data (e.g., packets) to and from a wireless host that is associated with that base station**.

A base station will often be responsible for coordinating the transmission of multiple wireless hosts with which it is associated.



What do we mean by a wireless host is "associated" with a base station?

We mean that:

(1) The host is within the wireless communication distance of the base station, and

(2) The host uses that base station to relay data between it (the host) and the larger network.

Cell towers in cellular networks and **access points** in 802.11 wireless LANs are examples of base stations.

What is Infrastructure mode and Infrastructure less mode?

Hosts associated with a base station are often referred to as operating in **infrastructure mode**, since all traditional network **services (e.g., address assignment and routing) are provided by the network to which a host is connected via the base station**.

In **adhoc networks**, wireless hosts have no such infrastructure with which to connect. In the absence **of such infrastructure, the hosts themselves must provide for services such as routing, address assignment,** DNS-like name translation.

What is handoff?

When a mobile host moves beyond the range of one base station and into the range of another, it will change its point of attachment into the new network (i.e., change the base station with which it is associated) a process referred to as **handoff**.

Such mobility raises many challenging questions.

If a host can move, how does one find the mobile host's current location in the network so that data can be forwarded to that mobile host?

How is addressing performed, given that a host can be in one of many possible locations?

If the host moves *during* a TCP connection or phone call, how is data routed so that the connection continues uninterrupted?

Wireless Network Classification

At the highest level we can classify wireless networks according to two criteria: *(i)* whether a packet in the wireless network crosses exactly *one wireless hop or multiple wireless hops*, and *(ii)* whether there is *infrastructure* such as a base station in the network:

• *Single-hop, infrastructure-based*. These networks have a base station that is connected to a larger wired network (e.g., the Internet). Furthermore, all communication is between this base station and a wireless host over a single wireless hop. **The 802.11 networks you use in the classroom, café, or library; and the 3G cellular data networks that we will learn about shortly all fall in this category.**

• *Single-hop, infrastructure-less*. In these networks, there is no base station that is connected to a wireless network. However, as we will see, one of the nodes in this single-hop network may ***coordinate the transmissions of the other nodes***.

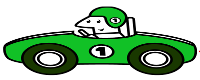
Bluetooth networks and 802.11 networks in ad hoc mode are single-hop, infrastructure-less networks.

• *Multi-hop, infrastructure-based*. In these networks, a base station is present that is **wired to the larger network**. However, **some wireless nodes may have to relay their communication through other wireless nodes in order** to communicate via the base station. Some wireless sensor networks and so-called **wireless mesh networks** fall in this category.

• *Multi-hop, infrastructure-less.* There is no base station in these networks, and nodes may have to **relay messages among several other nodes in order to reach a destination**. Nodes may also be mobile, with connectivity changing among nodes—a class of networks known as **mobile ad hoc networks (MANETs)**.

If the mobile nodes are vehicles, the network is a **vehicular ad hoc network (VANET)**. As you might imagine, the development of protocols for such networks is challenging and is the subject of much ongoing research.

Wireless and Mobile Networks



What are the Differences between Wired and Wireless Networks?

We have to focus our attention on the link layer when we looking for important differences between wired and wireless networks.

The most important differences between a wired link and a wireless link are:

1- Decreasing signal strength in wireless networks. Electromagnetic radiation decreases as it passes through matter (e.g., a radio signal passing through a wall). Even in free space, the signal will disperse, resulting in decreased signal strength (sometimes referred to as **path loss**) as the distance between sender and receiver increases.

2- **Signal *Interference with other sources***. Radio sources transmitting in the same frequency band will interfere with each other. For example, 2.4 GHz wireless phones and 802.11b wireless LANs transmit in the same frequency band. **In addition to interference from transmitting sources, electromagnetic noise within the environment (e.g., a nearby motor, a microwave) can result in interference**.

3- Multipath propagation of Signals

Multipath propagation occurs when portions of the electromagnetic wave reflect off objects and the ground, taking paths of different lengths between a sender and receiver. Moving objects between the sender and receiver can cause multipath propagation to change over time.

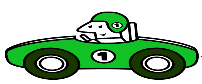
Bit Error

Due to the above differences it is clear that bit errors will be more common in wireless links than in wired links. For this reason, it is perhaps not surprising that wireless link protocols employ error detection codes, and link-level reliable data-transfer protocols that retransmit corrupted frames.

The receiving host receives an electromagnetic signal that is a combination of a *degraded form of the original signal transmitted* by the sender and *background noise in the environment*.

What is SNR?

The signal-to-noise ratio (SNR) is a relative measure of the strength of the received signal (i.e., the information being transmitted) and this noise.



What is Bit Error Rate (BER)?

The bit error rate (BER) is the probability that a transmitted bit is

received in error at the receiver.

Wireless links has a higher bit error rates than wired links.

Hidden Terminal and Fading Problems

Suppose that Station A is transmitting to Station B. Suppose also that Station C is transmitting to Station B. With the so called **hidden terminal problem**, physical obstructions in the environment (for example, a mountain or a building) may prevent A and C from hearing each other's transmissions, even though A's and C's transmissions are indeed interfering or collide at the destination, B. **This is shown in Figure 6.4(a).**

A second scenario that results in undetectable collisions at the receiver results from the **fading (loss)** of a signal's strength as it propagates through the wireless medium. **Figure 6.4(b) illustrates the case where A and C are placed such that their signals are NOT strong enough to detect each other's transmissions, but their signals *are* strong enough to interfere with each other at station B**.

So What?

The **hidden terminal problem** and **fading** make multiple access in a wireless network considerably more complex than in a wired network.

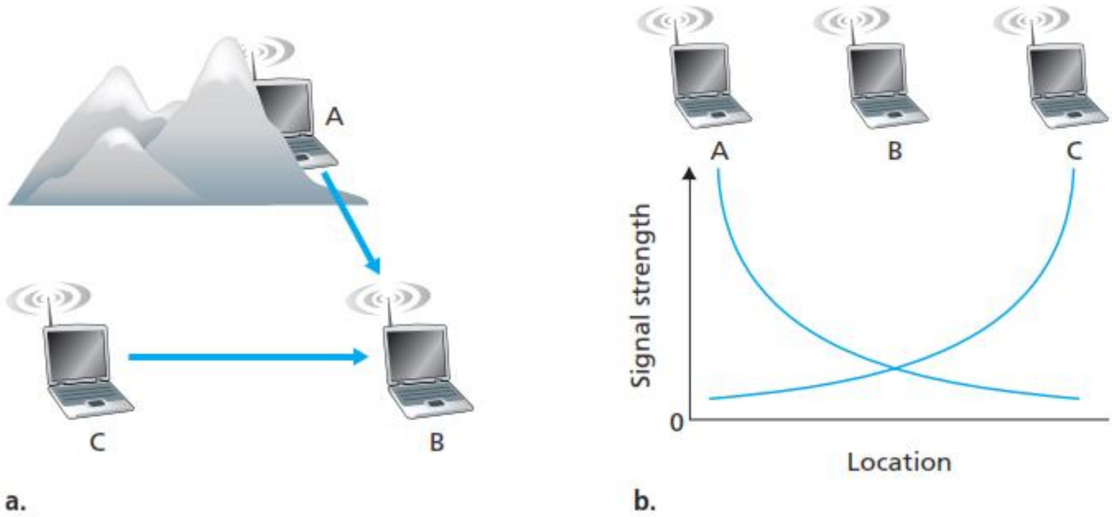


Figure 6.4 ♦ Hidden terminal problem caused by obstacle (a) and fading (b)

The question now is

If in a shared medium, multiple hosts send signals to a receiver, how can we be sure that these signals do interfere at the receiver?

The answer is: we need a protocol to manage this.

CDMA

Code Division Multiple Access (CDMA) protocol belongs to the family of channel partitioning protocols. It is common in wireless LAN and cellular technologies. Because CDMA is so important **in the wireless world, we'll take a quick look at CDMA now**.

In a CDMA protocol, each bit being sent is encoded by multiplying the bit by a signal (the code) that changes at a much faster rate (known as the **chipping rate**) than the original sequence of data bits.

How CDMA perform encoding and decoding?

1- Suppose that the rate at which original data bits reach the CDMA encoder defines the unit of time; that is, each original data bit to be transmitted requires a one-bit slot time.

2- Let d_i be the value of the data bit for the *i*th bit slot. (For mathematical convenience, we represent a data bit with a 0 value as –1.)

Each bit slot is further subdivided into *M* mini-slots; (in Figure 6.5, *M* = 8, although in practice *M* is much larger).

3- The CDMA code used by the sender consists of a sequence of *M* values, c_m , *m* = 1, . . . , *M*, each taking a +1 or –1 value. (In the example in Figure 6.5, the *M*-bit CDMA code being used by the sender is (1, 1, 1, –1, 1, –1, –1, –1)).

4- To encode the the *i*th data bit, d_i the output of the CDMA encoder, $Z_{i,m}$ is:

$$Z_{i,m} = d_i \cdot c_m \qquad (6.1)$$

5- The receiver would receive the encoded bits, $Z_{i,m}$, and recover the original data bit, d_i , by computing

$$d_i = \frac{1}{M}\sum_{m=1}^{M} Z_{i,m} \cdot c_m \qquad (6.2)$$

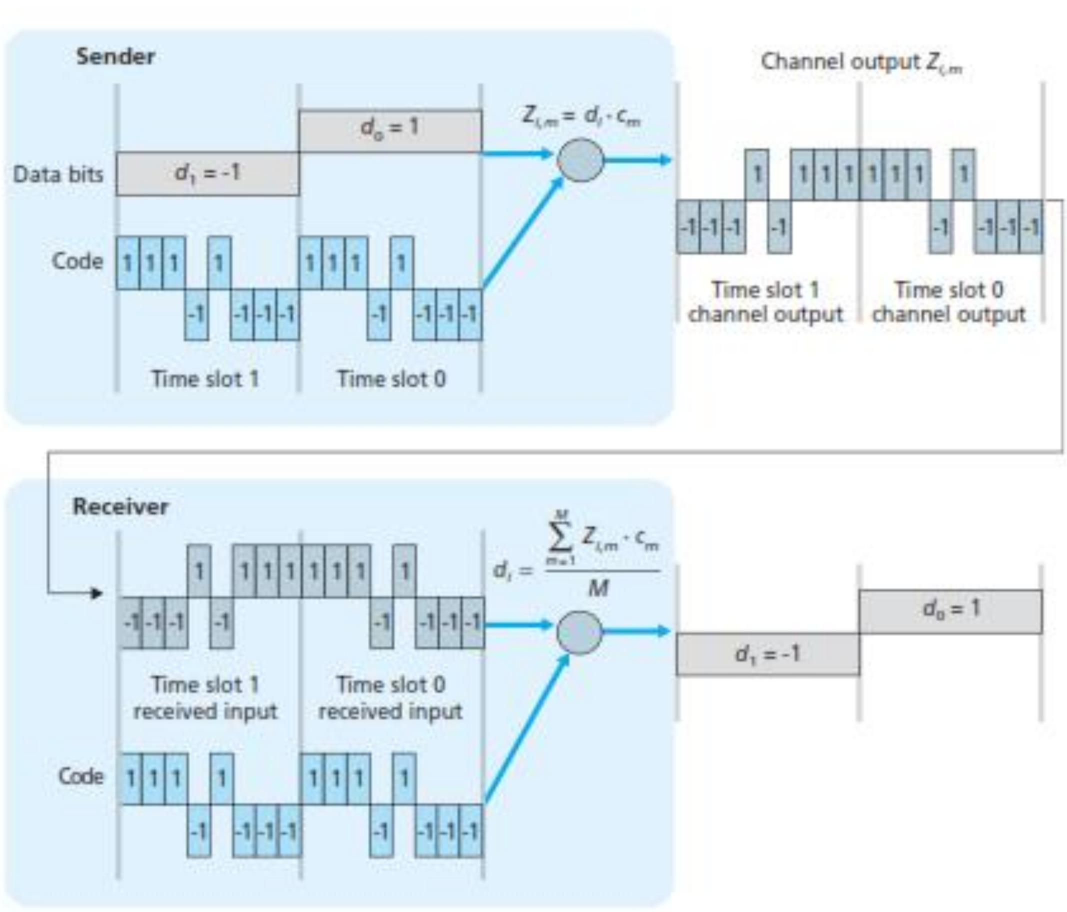


Figure 6.5 ♦ A simple CDMA example: sender encoding, receiver decoding

CDMA must work in the presence of interfering senders that are encoding and transmitting their data using a different assigned code.

But how can a CDMA receiver recover a sender's original data bits when those data bits are being tangled with bits being transmitted by other senders?

CDMA works under the assumption that the interfering transmitted bit signals are additive. This means, for example, that if three senders send a 1 value, and a fourth sender sends a –1 value during the same mini-slot, then the received signal at all receivers during that mini-slot is a 2 (since 1+ 1+ 1- 1 = 2).

In the presence of multiple senders, sender s computes its encoded transmissions, $Z^s i,m$, in exactly the same manner as in Equation 6.1. The value received at a receiver during the *m*th mini-slot of the *i*th bit slot, however, is now the *sum* of the transmitted bits from all *N* senders during that mini-slot:

$$Z^{*}_{i,m} = \sum_{s=1}^{N} Z^{s}_{i,m}$$

Amazingly, if the senders' codes are chosen carefully, each receiver can recover the data sent by a given sender out of the aggregate signal simply by using the sender's code in exactly the same manner as in Equation 6.2:

$$d_i = \frac{1}{M}\sum_{m=1}^{M} Z^{*}_{i,m} \cdot c_m \qquad (6.3)$$

Example

Figure 6.6, shows a two-sender CDMA example. The *M*-bit CDMA code being used by the upper sender is (1, 1, 1, –1, 1, –1, –1, –1), while the CDMA code being used by the lower sender is (1, –1, 1, 1, 1, –1, 1, 1). Figure 6.6 illustrates a receiver recovering the original data bits from the upper sender.

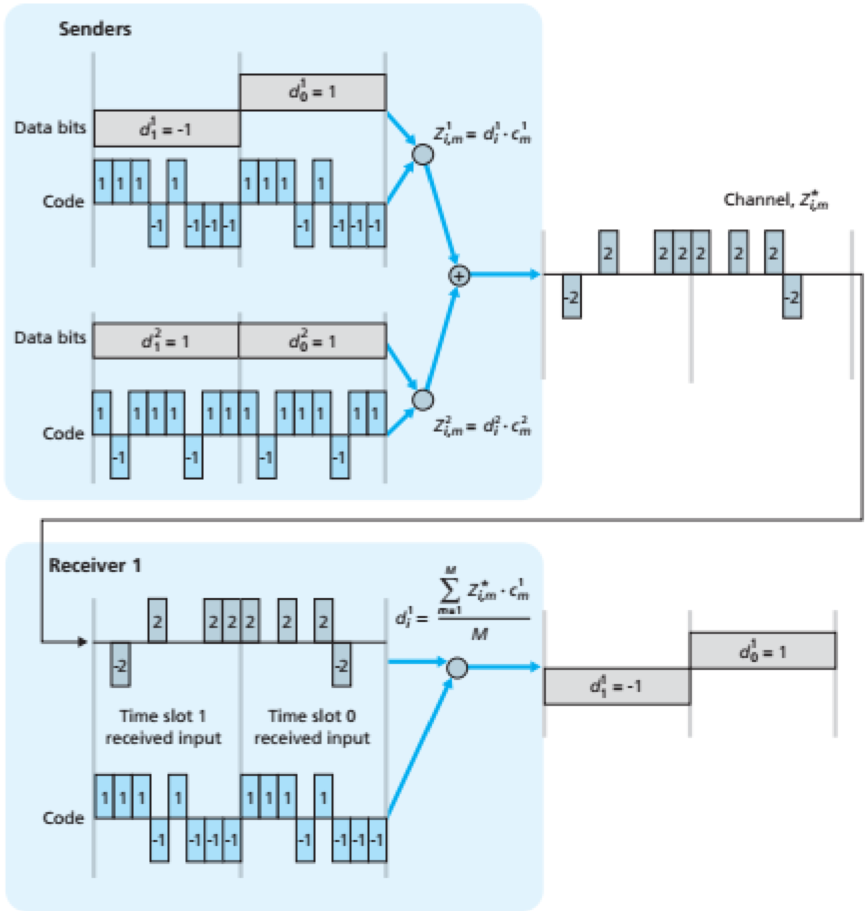


Figure 6.6 ♦ A two-sender CDMA example