Chapter (5)
Lecture (1)
Link Layer

The network layer provides a communication service between *any* two network hosts. Between the two hosts, datagrams travel over a series of communication links, some wired and some wireless, starting at the source host, passing through a series of packet switches (switches and routers) and ending at the destination host.

The questions now are:

1- How packets are sent across the *individual links* that make up the end-to-end communication path?

2- How is the network-layer datagrams encapsulated in the link-layer frames for transmission over a single link?

3- Are different link-layer protocols used in the different links along the communication path?

4- How are transmission conflicts in broadcast links resolved?

5- Is there addressing at the link layer and, if so, how does the link-layer addressing operate with the network-layer addressing we learned in network layer?

6- And what exactly is the difference between a switch and a router?

We'll answer these and other important questions in this chapter.

5.1 Introduction to the Link Layer

Let's begin with some important terminology;

Node: A node is any device that runs a link-layer (i.e., layer 2) protocol. Nodes include hosts, routers, switches, and WiFi access points.

Link: A link is a communication channels that connect adjacent nodes along the communication path.

Example to Understand Links

In order for a datagram to be transferred from source host to destination host, it must be moved over each of the *individual links* in the end-to-end path. As an example, in the company network shown at the bottom of Figure 5.1

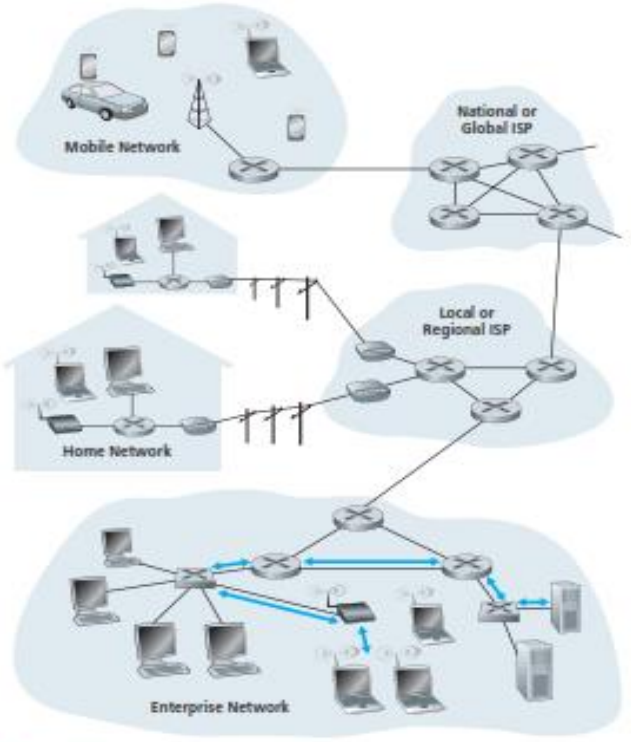

Figure 5.1 ♦ Six link-layer hops between wireless host and server

Consider sending a datagram from one of the wireless hosts to one of the servers. This Datagram will actually pass through six links:

- a WiFi link between sending host and WiFi access point,
- an Ethernet link between the access point and a link-layer switch;
- a link between the link-layer switch and the router,
- a link between the two routers;
- an Ethernet link between the router and a link-layer switch; and finally
- an Ethernet link between the switch and the server.

Each Link moves the datagram from one node to the adjacent node. Each transportation mode is defined by a Link-Layer Protocol (limousine, plane, and train)**, and the travel agent is a Routing Protocol (**Taxi Company, Airlines Company, Train Company**).**

Link Layer Frame

Over a given link, a transmitting node encapsulates the datagram in a link-layer frame and transmits the frame into the link.

5.1.1 The Services Provided by the Link Layer

Although the basic service of any link layer is to move a datagram from one node to an adjacent node over a single communication link, the details of the provided service can vary from one link-layer protocol to another.

Possible services that can be offered by a link-layer protocol include:

• ***Framing***. Almost all link-layer protocols encapsulate each network-layer datagram within a link-layer frame before transmission over the link. A frame consists of a data field, in which the network-layer datagram is inserted, and a number of header fields. The structure of the frame is specified by the link-layer protocol.

• ***Link access***.
A medium access control (MAC) protocol specifies the rules by which a frame is transmitted onto the link.

1- For point-to-point links that have a single sender at one end of the link and a single receiver at the other end of the link, the MAC protocol is simple; the sender can send a frame whenever the link is idle.
2- The more interesting case is when multiple nodes share a single broadcast link—the so-called multiple access problem. Here, the MAC protocol serves to coordinate the frame transmissions of the many nodes.

• ***Reliable delivery***. When a link-layer protocol provides reliable delivery service, it guarantees to move each network-layer datagram across the link without error.

• ***Error detection and correction***.
The link-layer hardware in a receiving node can incorrectly decide that a bit in a frame is zero when it was transmitted as a one, and vice versa. Such bit errors are introduced **by signal attenuation and electromagnetic noise.**
Because there is no need to forward a datagram that has an error, many link-layer protocols provide a mechanism to detect such bit errors.

5.1.2 Where Is the Link Layer Implemented?

Figure 5.2 shows typical host architecture. For the most part, the link layer is implemented in a **network adapter**, also sometimes known as a **network interface card (NIC)**.

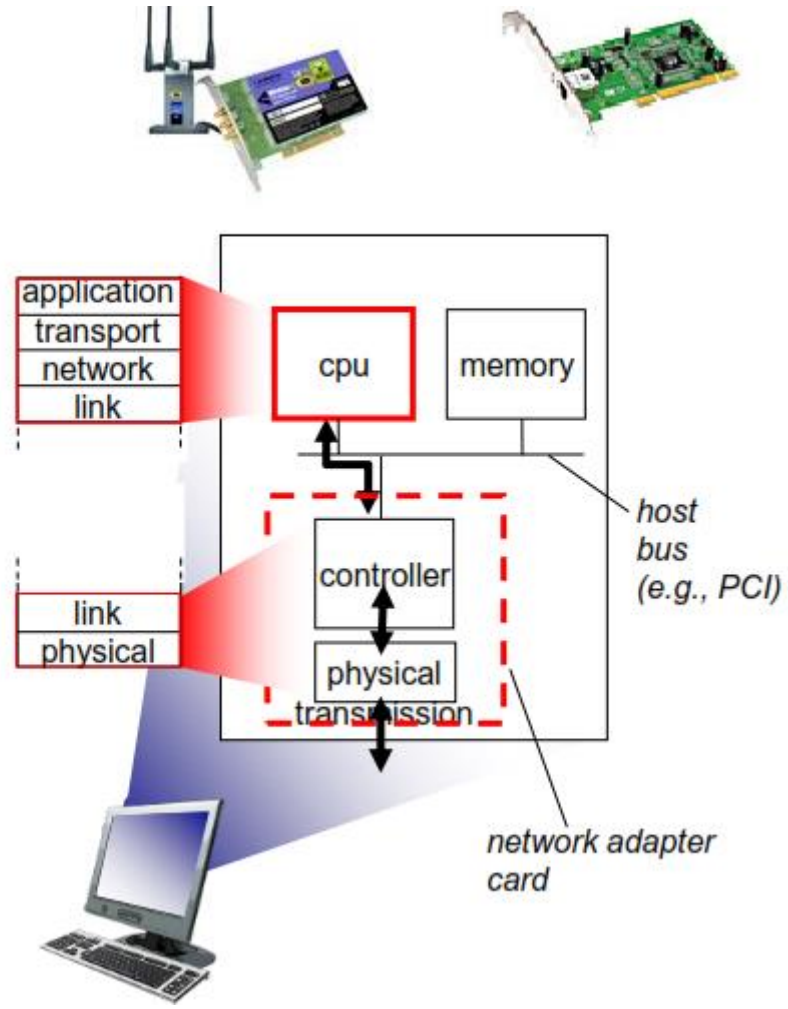

Figure (5.2)

Network Adapter Components

1- Hardware (Controller)

At the heart of the network adapter is **the link-layer controller**, usually a single, **special-purpose chip that implements many of the link-layer services (framing, link access, error detection, and so on).**

Thus, much of a link-layer controller's functionality is implemented in hardware. For example, Intel's 8254x controller implements the Ethernet protocols; the Atheros AR5006 controller implements the 802.11 WiFi protocols.

Until the late 1990s, most network adapters were physically separate cards (such as a PCMCIA card or a plug-in card fitting into a PC's PCI card slot) *but increasingly, network adapters are being integrated onto the host's motherboard—a so-called LAN-on-motherboard configuration*.

What Does the Controller Do?

On the sending side, the controller:

1- **takes a datagram that has been created and** stored in host memory by the higher layers of the protocol stack,
2- **encapsulates the datagram in a link-layer frame** (filling in the frame's various fields), and then
3- **transmits the frame into the communication link**, following **the link-access protocol**.

On the receiving side, a controller

1- **receives the entire frame**, **and**
2- **extracts the network-layer datagram.**

If the ***link layer performs error detection***, then it is the sending controller
4- **that sets the error-detection bits in the frame header** and it is the receiving controller **that**
3- performs error detection.

2- Software

Is there Software in the Data Link Layer?

The software components of the link layer **implement higher-level link layer functionality** such **as**

1- assembling link-layer addressing information and
2- activating the controller hardware.

On the receiving side, link-layer software

1- **responds to controller interrupts** (e.g., due to the receipt of one or more frames),
2- **handling error conditions and**
3- **passing a datagram up to the network layer**.

Thus, the link layer is a combination of hardware and software—the place in the protocol stack where software meets hardware.

5.2 Error-Detection and -Correction Techniques

Detecting and correcting the corruption of bits in a link-layer frame sent from one node to another physically connected neighboring node—**are two services often provided by the link layer.**
Figure 5.3 illustrates the setting for our study.

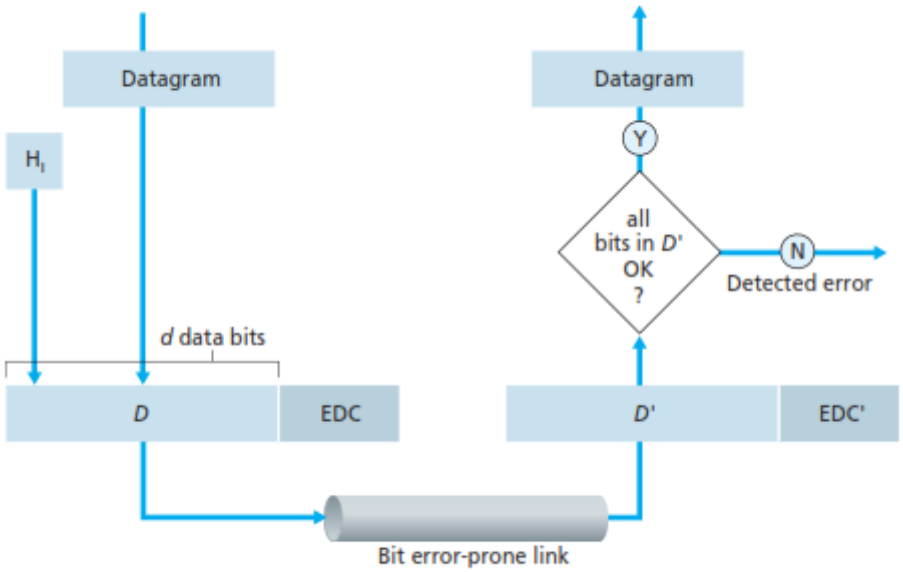

Figure 5.3 ♦ Error-detection and -correction scenario

At the sending node, data, *D*, to be protected against bit errors is added to error-detection and -correction bits (*EDC*). Typically, the data to be protected includes not only the datagram passed down from the network layer for transmission across the link, **but also link-level addressing information, sequence numbers, and other fields in the link frame header**.
Both *D* and *EDC* are sent to the receiving node in a link-level frame.
At the receiving node, a sequence of bits, *D*' and *EDC*' is received. Note that *D*' and *EDC*' may differ from the original *D* and *EDC* as a result of in-transit bit flips.

The receiver's challenge is to determine whether or not *D*' is the same as the original *D*, given that it has only received *D*' and *EDC*'.
Error-detection and -correction techniques allow the receiver to sometimes, *but not always*, detect that bit errors have occurred. Even with the use of error-detection bits there still may be **undetected bit errors**; that is, the receiver may be unaware that the received information contains bit errors.
As a consequence, the receiver might deliver a corrupted datagram to the network layer, or be unaware that the contents of a field in the frame's header have been corrupted.

Thus

- Error detection not 100% reliable!

• Link Layer protocol may miss some errors, but rarely
• Larger EDC field yields better detection and correction

We thus want to choose an error-detection scheme that keeps the probability of such occurrences small.