Advanced computer Networks

- **What is a network**
- A computer network, often simply called a *network*, is a collection of computers and devices that are interconnected by communication channels.
- These channels allow for the efficient sharing of resources, services, and information among it

Interconnection models

- An interconnection model is a standard that is used to connect sources and targets in a network, and there are some well-known models in the IT industry such as the open systems interconnection model (OSI), Department of Defense (DoD), TCP/IP protocol suite, and Fibre Channel. Each model has its advantages and disadvantages. Its model is applied where it has the maximum benefit in terms of performance, reliability, availability, cost benefits, and so on.

- All the network components are categorized into five groups:
- End devices: An end device is a computer system which has a final purpose like desktop computers, printers, storage, or servers.
- Network interface: It is an interface between the media and end devices which can interact with other network interfaces and understands an interconnection model.
- Connector: This is the physical element at the end of the media which allows a connection to the network interface.

- Media: This is the physical path that is used to transmit an electrical or optical signal. It might be wired or wireless, copper, or a fiber optic cable.
- Network devices: These are used to interconnect multiple end devices as a single point of interconnection, route communication through different networks, or for providing network security. Examples of network devices are switches, routers, firewalls, and directors.

- 1.1 What Is the Internet?
- what is the Internet? There are a couple of ways to answer this question.
- First, we can describe the nuts and bolts of the Internet, that is, the basic hardware and software components that make up the Internet.
- Second, we can describe the Internet in terms of a networking infrastructure that provides services to distributed applications
- a global computer network providing a variety of information and communication facilities, consisting of interconnected networks using standardized communication protocols.

1.1 A Nuts-and-Bolts Description

- The Internet is a computer network that interconnects hundreds of millions of computing devices throughout the world.
- these computing devices were primarily traditional desktop PCs, Linux workstations, and so-called servers that store and transmit information such as Web pages and e-mail messages. Increasingly, however, non traditional Internet end systems such as laptops, smartphones, tablets, TVs, gaming consoles, Web cams, are being connected to the Internet.
- In Internet, all of these devices are called hosts or end systems

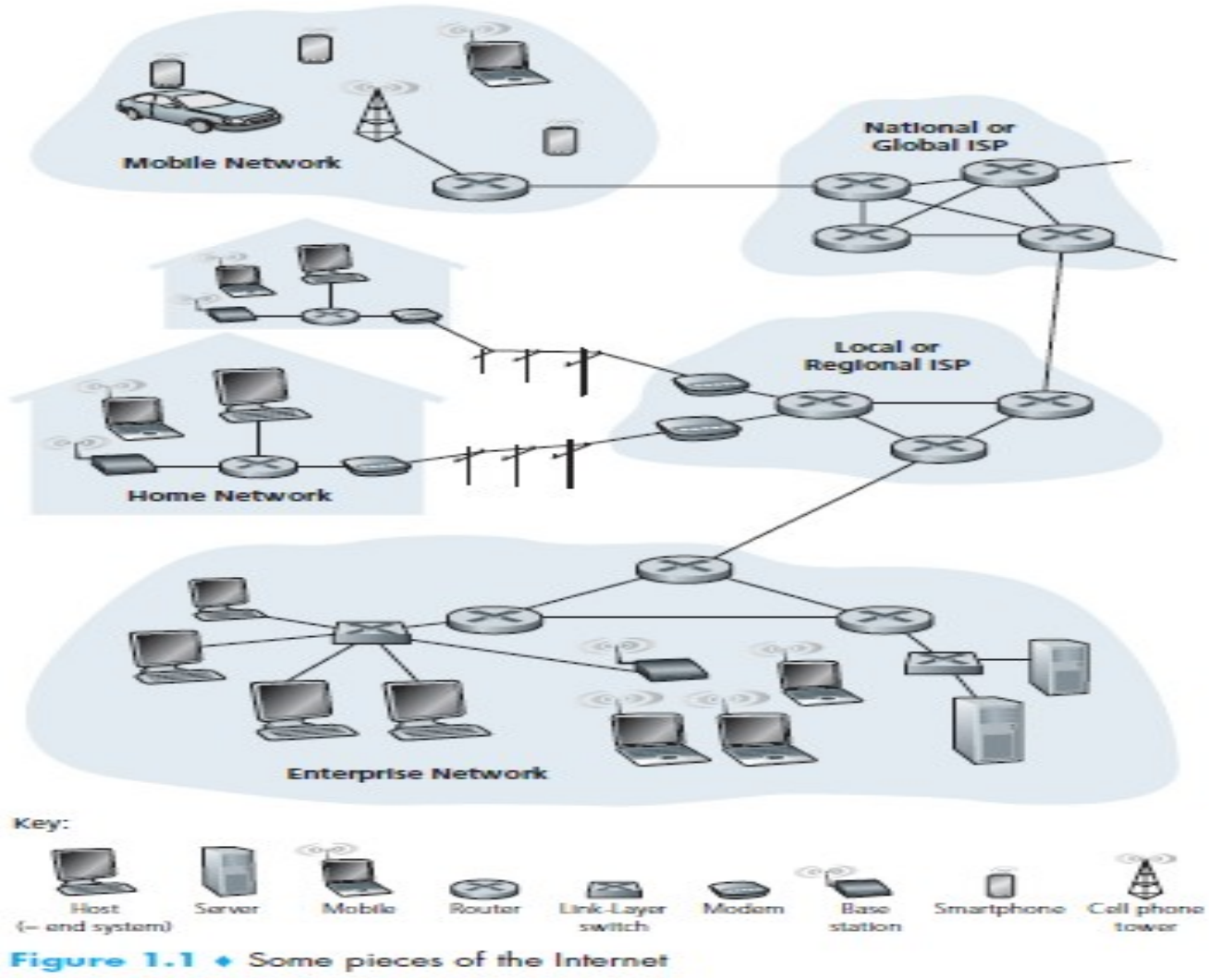

Figure 1.1 ♦ Some pieces of the Internet

- End systems are connected together by a network of communication links and packet switches.
- there are many types of communication links, which are made up of different types of physical media, including coaxial cable, copper wire, optical fiber,.
- Different links can transmit data at different rates, with the transmission rate of a link measured in bits/second.
- When one end system has data to send to another end system, the sending end system segments the data and adds header bytes to each segment.

- End systems access the Internet through Internet Service Providers (ISPs), including residential ISPs such as local cable or telephone companies; corporate ISPs; university ISPs; and ISPs that provide WiFi access in airports, hotels, coffee shops, and other public places.
- The Transmission Control Protocol (TCP) and the Internet Protocol (IP) are two of the most important protocols in the Internet.

- A protocol defines the format and the order of messages exchanged between two or more communicating entities,

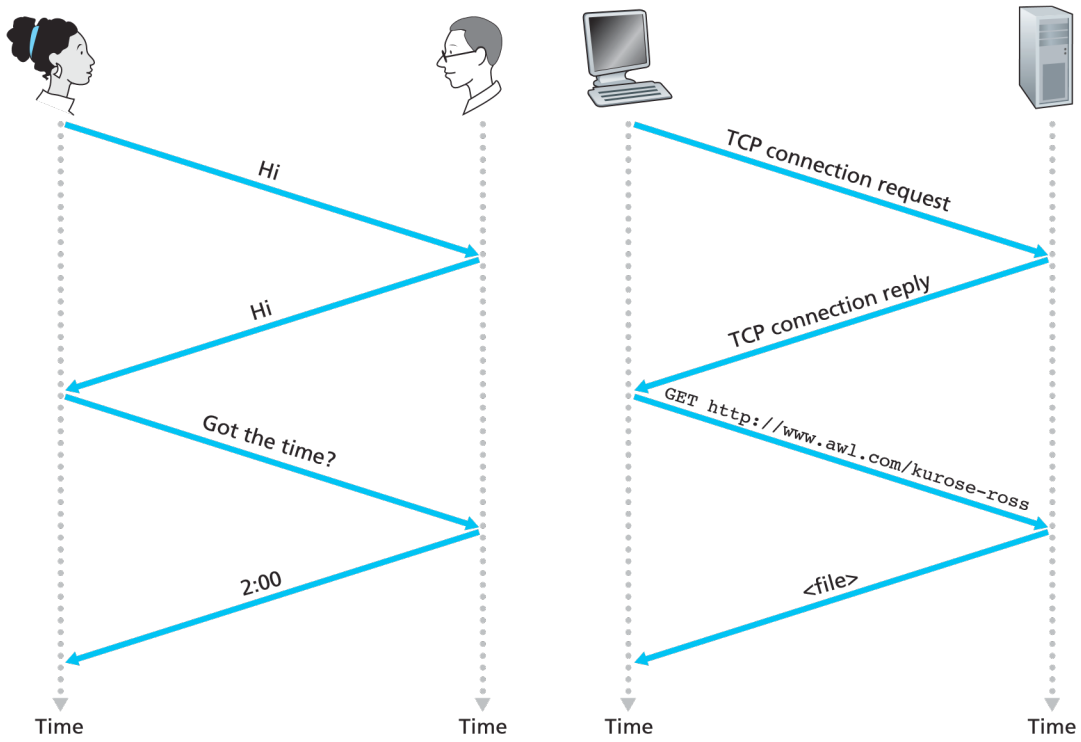

Figure 1.2 A human protocol and a computer network protocol

1.2 The Network Edge

- Recall from the previous section that in computer networking jargon, the computers and other devices connected to the Internet are often referred to as end systems.
- They are referred to as end systems because they sit at the edge of the Internet, as shown in Figure 1.3
- The Internet's end systems include desktop computers (e.g., desktop PCs, Macs, and Linux boxes), servers (e.g., Web and e-mail servers), and mobile computers (e.g., laptops, smartphones, and tablets)

- End systems are also referred to as *hosts* because they host (that is, run) application programs such as a Web browser program, a Web server program, an e-mail client program, or an e-mail server program
- Hosts are sometimes further divided into two categories: **clients** and **servers**.

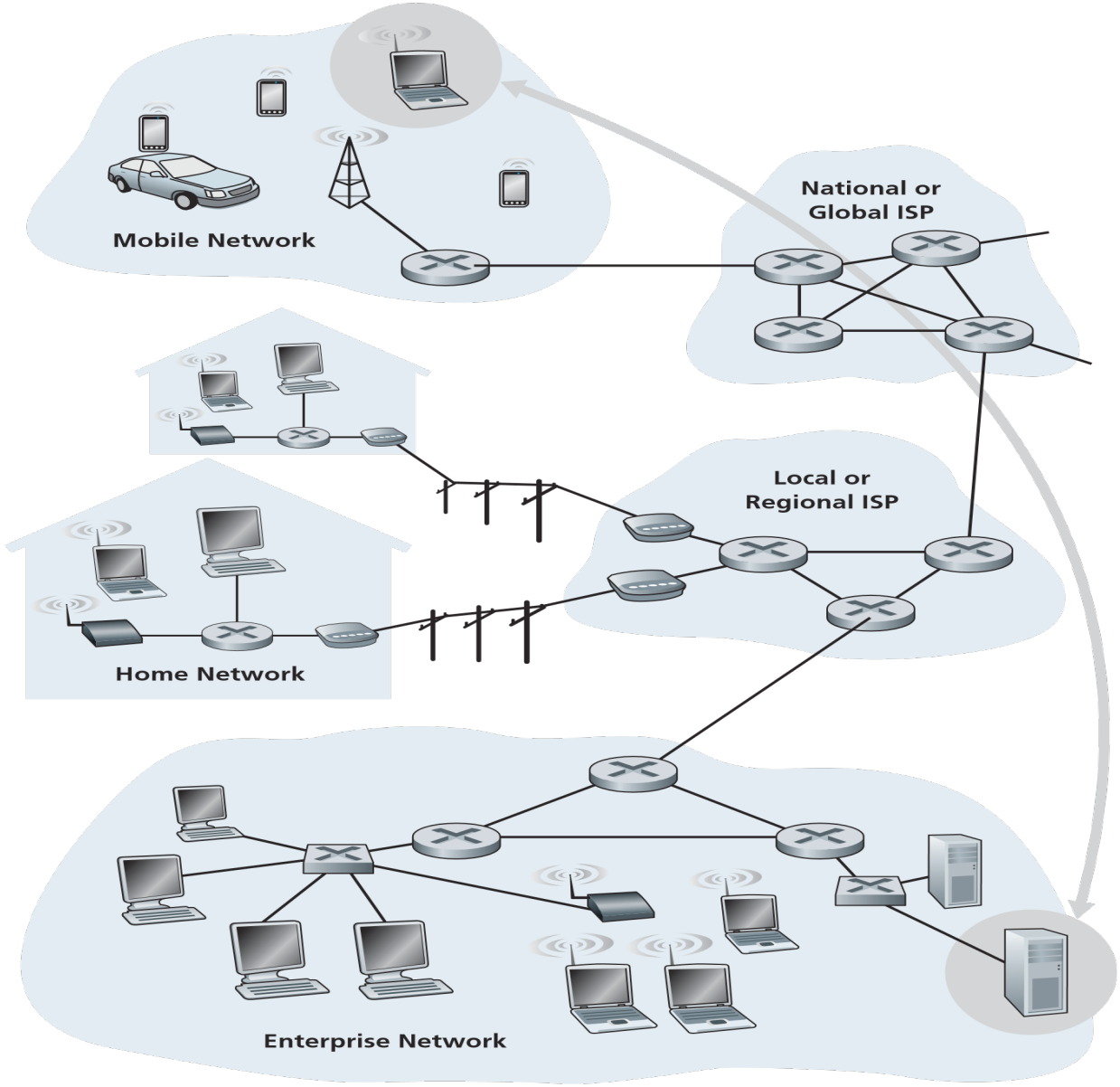

Figure 1.3 ♦ End-system interaction

1.2.1 Access Networks

- Having considered the applications and end systems at the “edge of the network,” let’s next consider the access network—the network that physically connects an end system to the first router (also known as the “edge router”) on a path from the end system to any other distant end system. Figure 1.4 shows several types of access

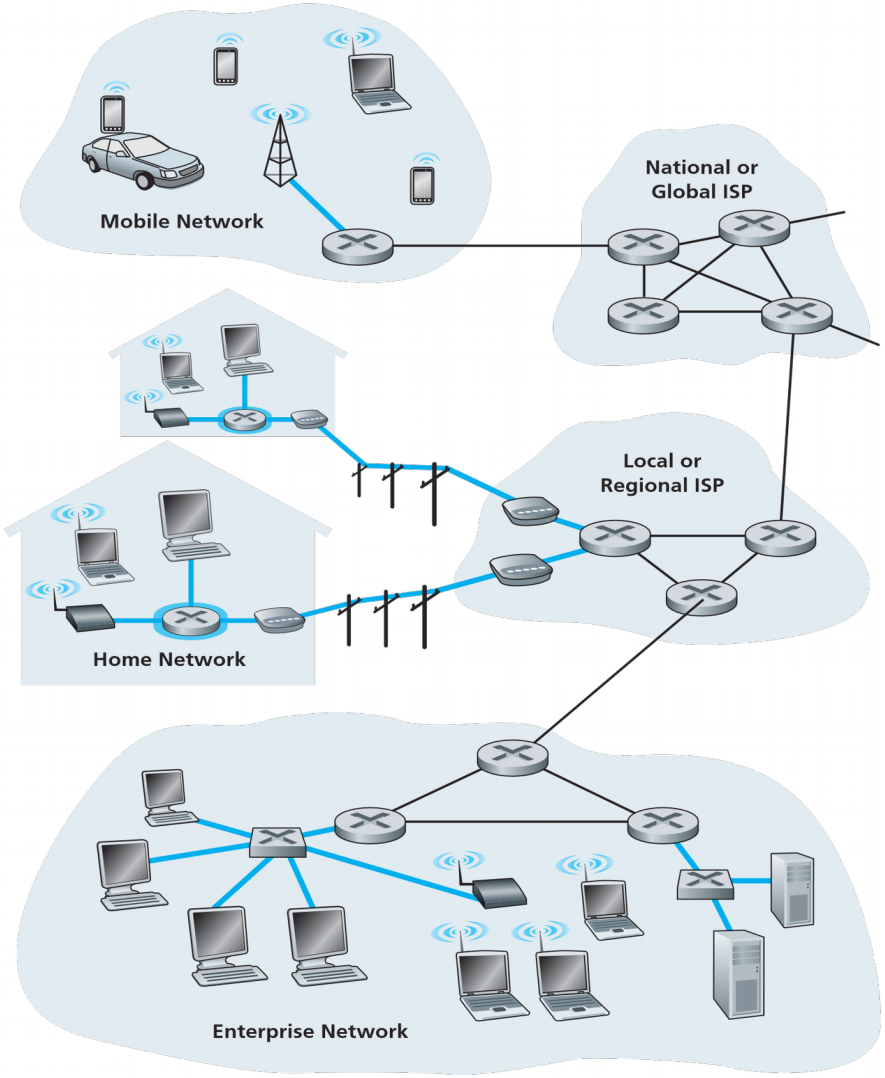

Figure 1.4 ♦ Access networks

- Home Access: DSL, Cable, FTTH, Dial-Up.
- Today, the two types of broadband residential access are **digital subscriber line (DSL)** and cable. A residence typically obtains DSL Internet access from the same local telephone company (telco) that provides its wired local phone access

- As shown in Figure 1.5, each customer's DSL modem uses the existing telephone line (twistedpair copper wire,) to exchange data with a digital subscriber line access multiplexer (DSLAM) located in the telco's local central office (CO).
- The residential telephone line carries both data and traditional telephone signals simultaneously.

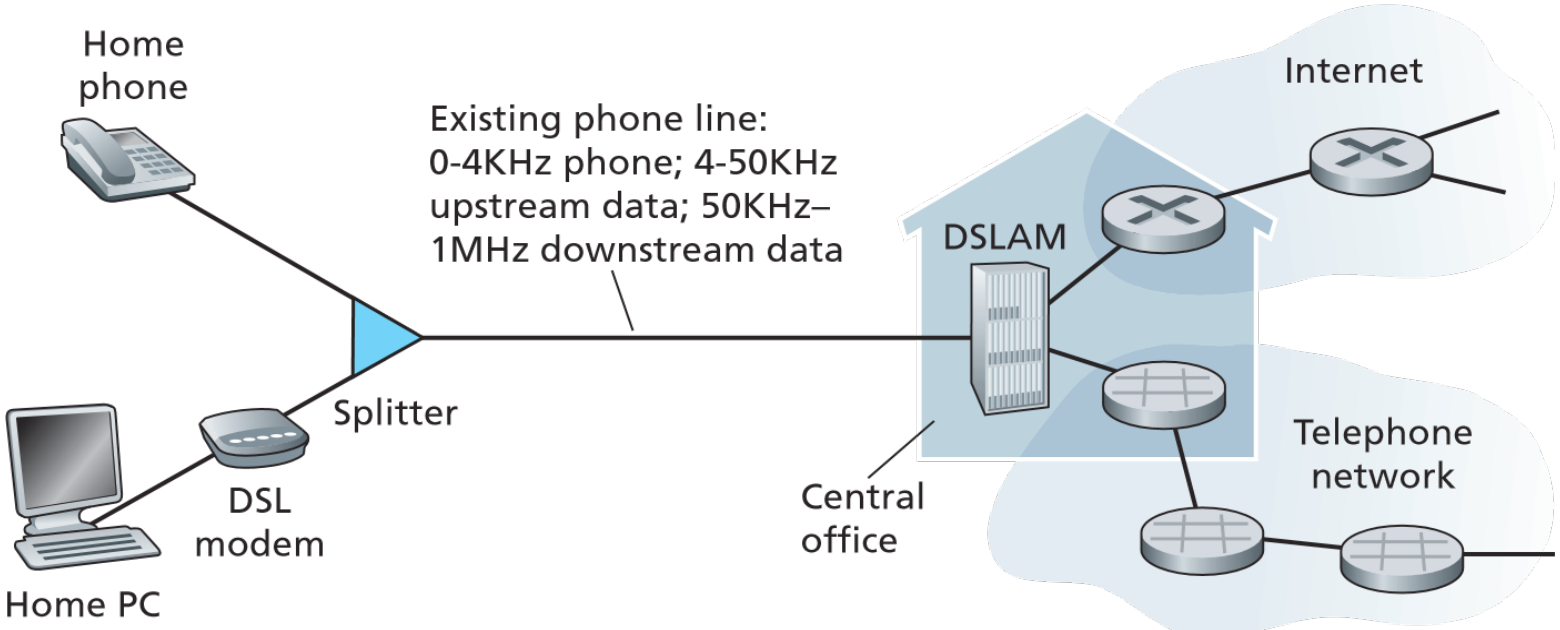

Figure 1.5 ♦ DSL Internet access

- While DSL makes use of the telco's existing local telephone infrastructure,
- **cable Internet access** makes use of the cable television company's existing cable television infrastructure.
- A residence obtains cable Internet access from the same company that provides its cable television.

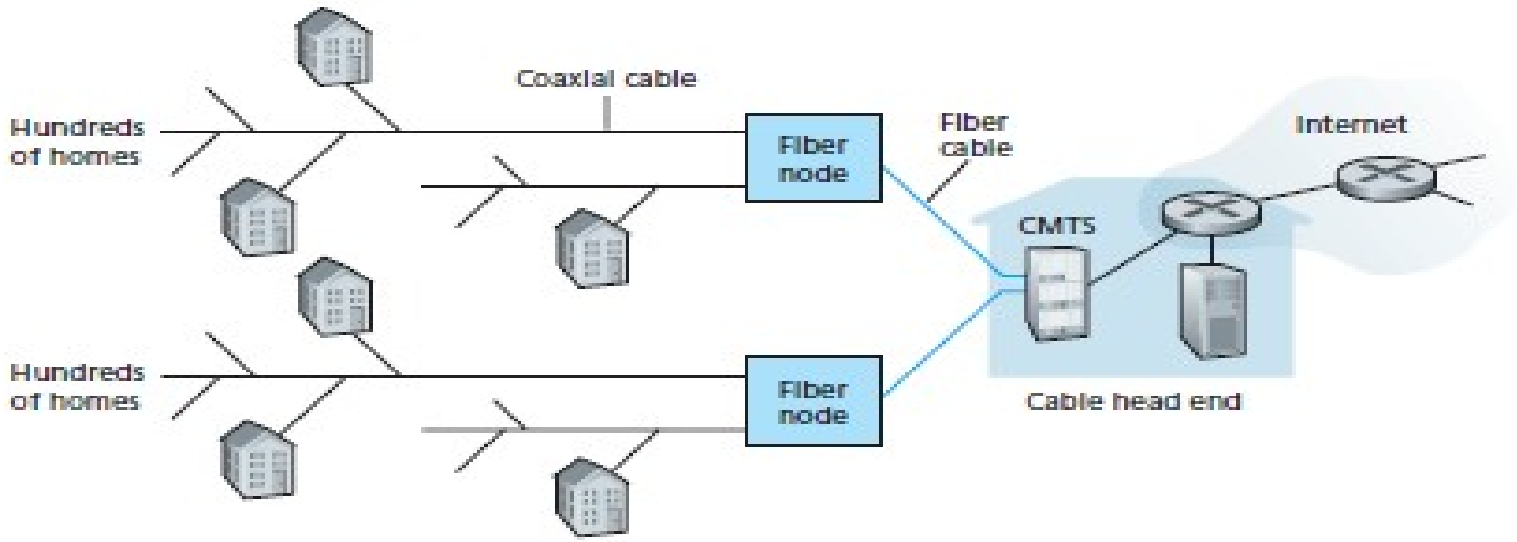

Figure 1.6 ♦ A hybrid fiber-coaxial access network

- FTTH concept is simple— provide an optical fiber path from the CO directly to the home.
- There are several competing technologies for optical distribution from the CO to the homes.
- The simplest optical distribution network is called direct fiber, with one fiber leaving the CO for each home.

- More commonly, each fiber leaving the central office is actually shared by many homes; it is not until the fiber gets relatively close to the homes that it is split into individual customer-specific fibers.
- There are two competing optical-distribution network architectures that perform this splitting: active optical networks (AONs) and passive optical networks (PONs). AON is essentially switched Ethernet,
- Here, we briefly discuss PON, which is used in Verizon's FIOS service. Figure 1.7 shows FTTH using the PON distribution architecture.

- Each home has an optical network terminator (ONT), which is connected by dedicated optical fiber to a neighbourhood splitter.
- The splitter combines a number of homes (typically less than 100) onto a single, shared optical fiber, which connects to an optical line terminator (OLT) in the telco's CO.
- The OLT, providing conversion between optical and electrical signals, connects to the Internet via a telco router

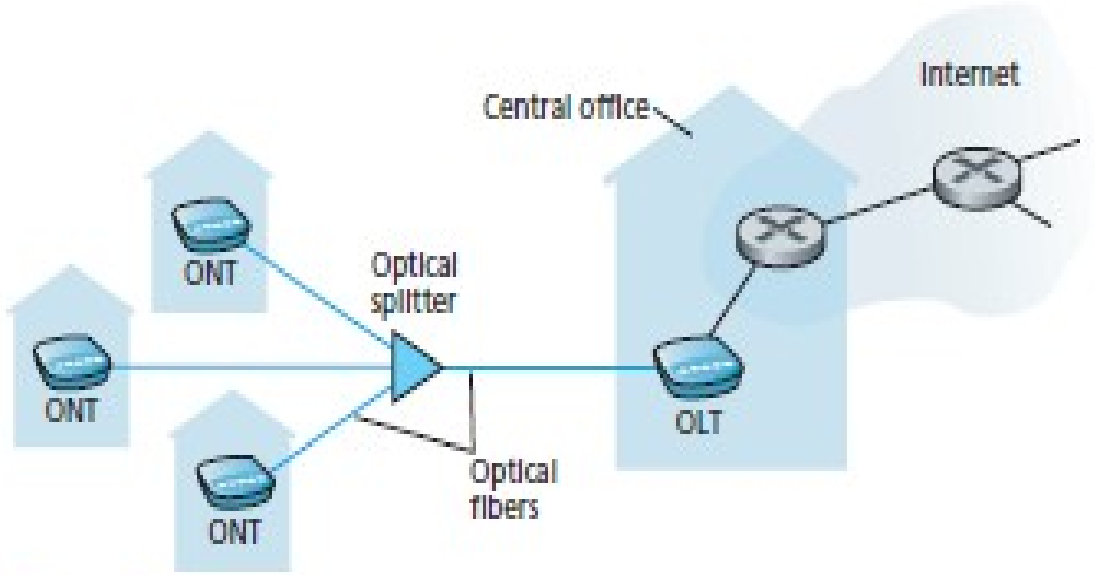

Figure 1.7 ♦ FTTH Internet access

- **Access in the Enterprise (and the Home): Ethernet and WiFi**

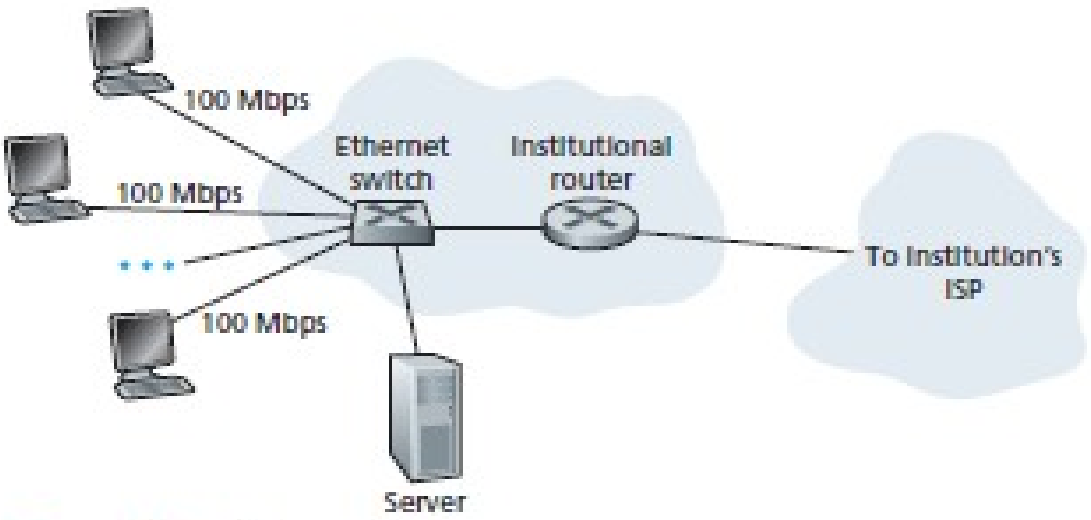

Figure 1.8 ♦ Ethernet Internet access

- On corporate and university campuses, and increasingly in home settings, a local area network (LAN) is used to connect an end system to the edge router.
- Although there are many types of LAN technologies, Ethernet is by far the most prevalent access technology in corporate, university, and home networks.
- As shown in Figure 1.8, Ethernet users use twisted-pair copper wire to connect to an Ethernet switch, a

- The Ethernet switch, or a network of such interconnected switches, is then in turn connected into the larger Internet. With Ethernet access, users typically have 100 Mbps access to the Ethernet switch, whereas servers may have 1 Gbps or even 10 Gbps access.
- Increasingly, however, people are accessing the Internet wirelessly from laptops, smartphones, tablets, and other devices

- In a wireless LAN setting, wireless users transmit/receive packets to/from an access point that is connected into the enterprise's network (most likely including wired Ethernet), which in turn is connected to the wired Internet. A wireless LAN user must typically be within a few tens of meters of the access point
- Wireless LAN access based on IEEE 802.11 technology, more colloquially known as WiFi, is now just about everywhere—universities, business offices, cafes, airports, homes, and even in airplanes.

1.2.2 Physical Media

- In the previous subsection, we gave an overview of some of the most important network access technologies in the Internet
- In this subsection we provide a brief overview of these and other transmission media that are commonly used in the Internet.
- Examples of physical media include twisted-pair copper wire, coaxial cable, multimode fiber-optic cable

- Physical media fall into two categories: **guided media** and **unguided media**.
- With guided media, the waves are guided along a solid medium, such as a fiber-optic cable, a twisted-pair copper wire, or a coaxial cable.
- With unguided media, the waves propagate in the atmosphere and in outer space, such as in a wireless LAN or a digital satellite channel.

Twisted-Pair Copper Wire

- The least expensive and most commonly used guided transmission medium is twisted-pair copper wire.
- type of cable that consists of two independently wires twisted around one another. The use of two wires twisted together helps to reduce crosstalk. While twisted-pair cable is used by older telephone networks and is the least expensive type of local-area network (LAN) cable, most networks contain some twisted-pair cabling at some point along the network. Other types of cables used for LANs include coaxial cables and fiber optic cables.

- **Unshielded twisted pair (UTP)** is commonly used for computer networks within a building, that is, for LANs. Data rates for LANs using twisted pair today range from 10 Mbps. The data rates that can be achieved depend on the thickness of the wire and the distance between transmitter and receiver.

	Cable Type	Maximum Data Transmission Speed
Category 3	UTP	10 Mbps
Category 5	UTP	10/100 Mbps
Category 5 e	UTP	1000 Mbps
Category 6	UTP or STP	1000 Mbps

All of these wiring types are often referred to as UTP (Unshielded Twisted Pair), to contrast them with the bulky, expensive, shielded twisted pair cables IBM introduced in the early 1980s, but which have not proven popular outside of IBM installations. Twisted pair cabling is illustrated in Fig.2.

Fig.2: (a) Category 3 UTP. (b) Category 5 UTP.

Coaxial Cable

- A type of wire that consists of a center wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference.
- Coaxial cabling is the primary type of cabling used by the cable television industry and is also widely used for computer networks, such as Ethernet. Although more expensive than standard telephone wire, it is much less susceptible to interference and can carry much more data.

- Coaxial cable can be used as a guided **shared medium**.
- Specifically, a number of end systems can be connected directly to the cable, with each of the end systems receiving whatever is sent by the other end systems

A coaxial cable consists of a stiff copper wire as the core, surrounded by an insulating material. The insulator is encased by a cylindrical conductor, often as a closely-woven braided mesh. The outer conductor is covered in a protective plastic sheath. A cutaway view of a coaxial cable is shown in Fig.1.

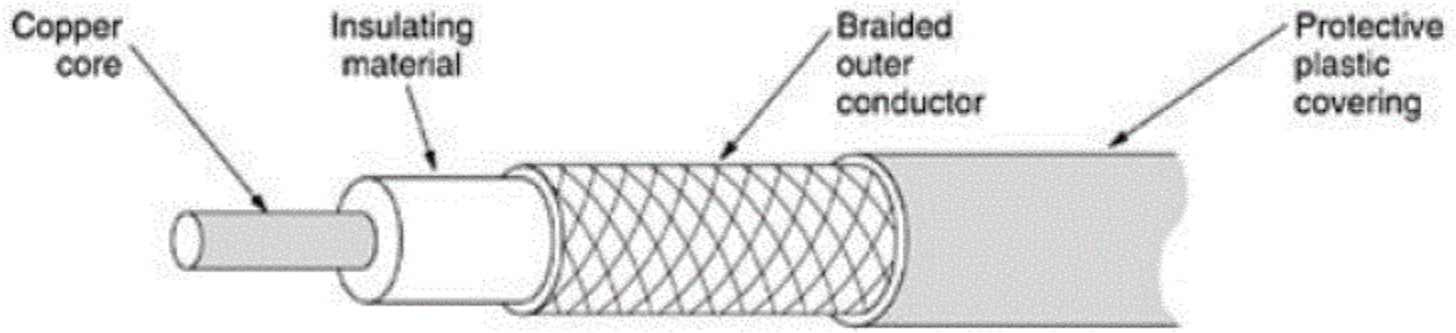

Fig.1: A coaxial cable.

- **Fiber Optics**
- An optical fiber is a thin, flexible medium that conducts pulses of light, with each pulse representing a bit. A single optical fiber can support tremendous bit rates, up to tens or even hundreds of gigabits per second

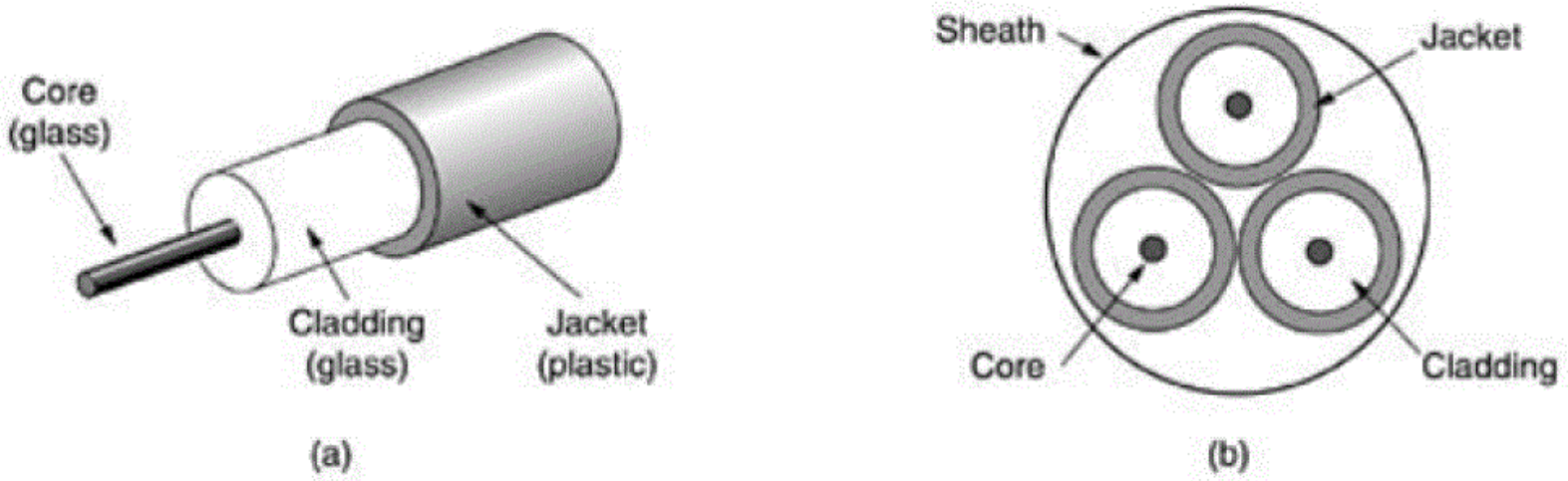

Fig.3.1: (a) Side view of a single fiber. (b) End view of a sheath with three fibers.

- Network Core
- Packet Switching
- In a network application, end systems exchange **messages** with each other.
- Messages can contain anything the application designer wants.
- Messages may perform a control function (for example, the “Hi” messages in our handshaking example in Figure 1.2) or can contain data, such as an email message, a JPEG image, or an MP3 audio file

- To send a message from a source end system to a destination end system, the source breaks long messages into smaller chunks of data known as **packets**.
- Between source and destination, each packet travels through communication links and **packet switches** (for which there are two predominant types, **routers** and **linklayer switches**).
- Packets are transmitted over each communication link at a rate equal to the *full* transmission rate of the link. So, if a source end system or a packet switch is sending a packet of *L* bits over a link with transmission rate *R* bits/sec, then the time to transmit the packet is *L/R* seconds.

Store-and-Forward Transmission

- Most packet switches use **store-and-forward transmission** at the inputs to the links. Store-and-forward transmission means that the packet switch must receive the entire packet before it can begin to transmit the first bit of the packet onto the outbound link
- To explore store-and-forward transmission in more detail, consider a simple network consisting of two end systems connected by a single router, as shown in Figure 1.11

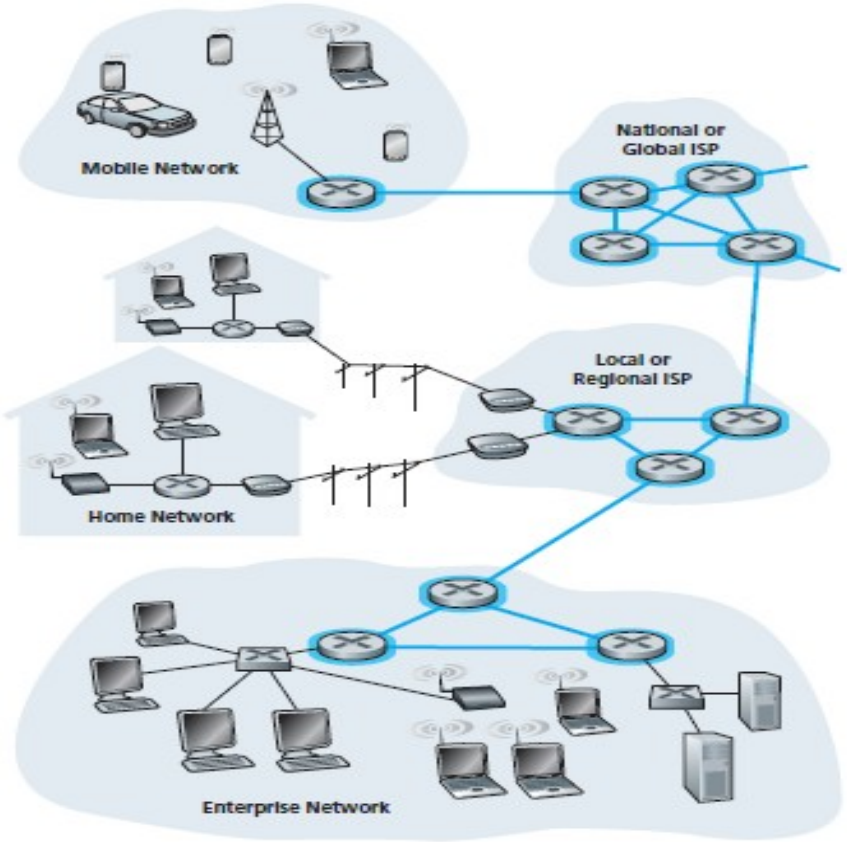

Figure 1.10 ♦ The network core

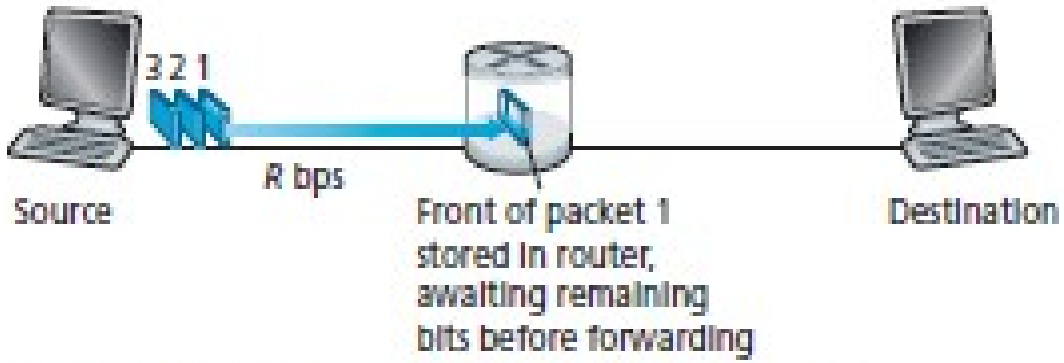

Figure 1.11 ♦ Store-and-forward packet switching