

Computer Networks

-Physical layer-

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W10 short test (1)

- What are the two main types of channel allocation involving the MAC sublayer, and what is the difference between them?
 - Static channel allocation: the bandwidth is divided into N equal-sized portions for N users (e.g., chop up the channels capacity using multiplexing). Dynamic channel allocation: channels are allocated dynamically based on usage, no permanent allocation scheme.
- What is the main idea behind CSMA?
 - In Carrier Sense Multiple Access protocols, when the state of the channel can be sensed, stations can avoid starting a transmission while another station is transmitting.

W10 short test (2)

- How switches work (in the context of switched Ethernet)?
 - A switch contains a high-speed backplane that connects all of the ports. Switches only output frames to the ports for which those frames are destined: when a switch port receives an Ethernet frame from a station, the switch checks the Ethernet addresses to see which port the frame is destined for.
- The user-generated data is passed to the transport layer where a header is added. The resulting unit is passed to the network layer. 2. This layer adds its own header to form a (network layer) packet . 3. This goes to the data link layer that adds its own header and checksum, and the resulting frame is given to the physical layer.
- Match the devices with the layers!
 - Data link layer - Switch, Network layer - Router, Physical layer - Repeater

W10 short test (3)

- What are VLANs?
 - Virtual LANs that are configured logically rather than physically. In a VLAN, users are grouped to reflect the organizational structure rather than the physical layout of a building(s). Configuration tables have to be set up in the bridges to tell which VLANS are accessible via certain ports.
- In the IEEE 802.1Q standard, which field specifies the VLAN the frame belongs to?
 - VLAN identifier.

W10 recap (1)

- Access networks connect subscribers to service providers, and a WAN spans a large geographical area
- When distances are large, network designers must rely on the existing telecommunication facilities
- Three major components in the telephone system: local loops, trunks, and switching offices
- Although limited, telephone modems send digital data between computers over the narrow channel the telephone network uses for voice call
- Early DSL technologies over the PSTN were slow, but modern broadband services such as ADSL are high bandwidth
 - involves an ADSL modem, splitters, codec, DSLAM
- Common to use variations of FTTX, because the speed of last-mile networks is often constrained by the copper cables used in conventional telephone networks

W10 recap (2)

- SONET and SDH are standards used to transmit data over large distances with fiber optics
- Many people nowadays get their television, telephone, and Internet service "over cable"
- A system with fiber for the long-hauls and coaxial cable to the houses is an HFC (Hybrid Fiber Coax), where a single fiber node can feed multiple coaxial cables
 - uses the DOCSIS standards, where a dedicated cable modem is needed (often combined with a wireless access point)
- Same trend with cable and telephone networks: moving fiber closer to the subscriber home, and all access network technologies now use fiber in the backbone
- Although they differ on the last-mile access technology, comparable services and prices
 - fiber and ADSL providers tend to deliver more consistent bandwidth

W10 recap (3)

- IPsec is a network protocol suite that authenticates and encrypts the packets of data sent over a network
 - the connection in IPsec between two endpoints having a security identifier is a SA
 - in transport mode, the IPsec header is inserted after the IP header
 - in tunnel mode, the entire IP packet is encapsulated in the body of a new IP packet
- VPNs are usually built over the Internet, but without giving up most of the security advantages of a real private network
 - if IPsec is used for tunneling, it is possible to aggregate all traffic between any two pairs of offices onto a single authenticated and encrypted SA
 - as the SAs have been established, a packet traveling along a VPN tunnel is just an ordinary packet

Agenda

- Guided Transmission Media
- Wireless transmission
- Digital modulation
- Multiplexing
- Summary

Guided transmission media in the physical layer

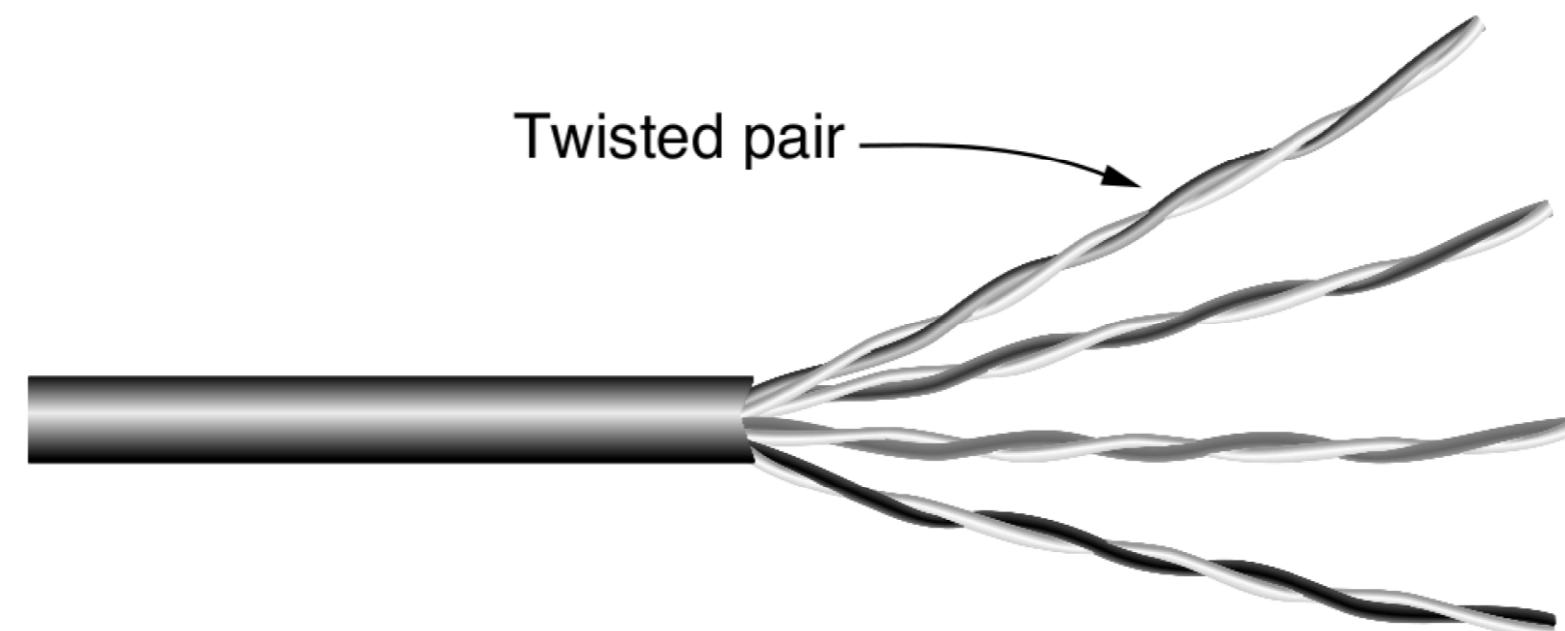
- The physical layer defines the electrical, timing, and other interfaces by which bits are sent as signals over channels
- The properties of different kinds of physical channels determine the performance (e.g., error rate, latency, etc.)
- **Full-duplex** vs. **half-duplex** vs. **simplex** links
- Transmission media that rely on a physical cable/wire are often called **guided transmission media**
 - each type has its own set of trade-offs: frequency, bandwidth, delay, cost, maintenance
 - bandwidth is a measure of the carrying capacity of a medium, measured in Hz (Hertz)

Persistent Storage

- Consists of magnetic or solid-state storage
- Common way to transport data
 - write to persistent storage
 - physically transport the tape or disks to the destination machine
 - read data back again
- Cost effective for applications where a high data rate or cost per bit transported is the key factor
- For moving very large amounts of data, this is often the best solution
- The "bandwidth" of persistent storage is excellent, but the delay is poor: slow transmission time

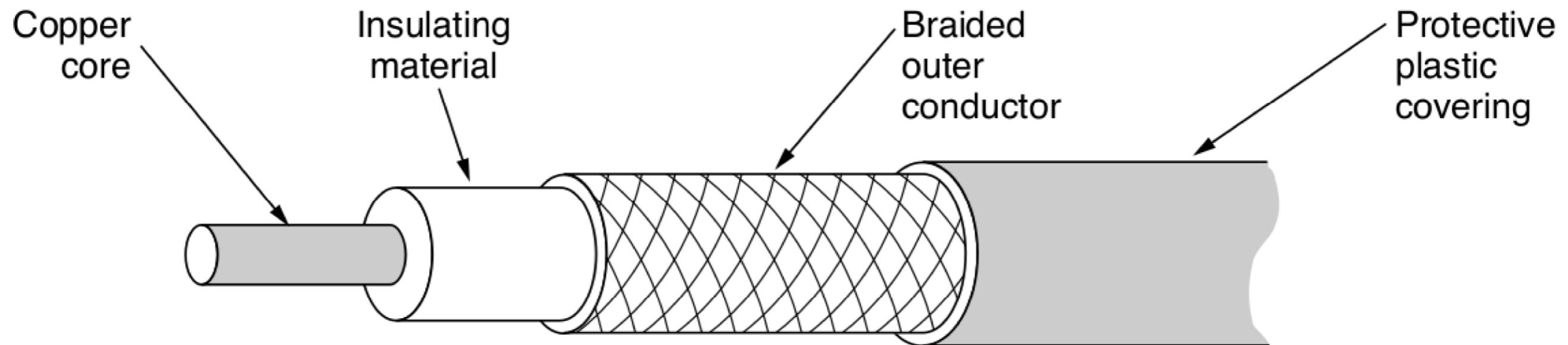
Twisted pairs

- A **twisted pair** consists of two insulated copper wires twisted together, where the signal is usually carried as the difference in voltage between the two wires
 - low cost: telephone system, ADSL
 - Category 5e (Cat 5e) consists of four pairs of two insulated wires twisted together in an outside plastic sheath
- Bandwidth depends on the thickness of the wire and the distance traveled
 - Category 3, 5, 6, 7, 8, UTP (Unshielded Twisted Pair) up to 6



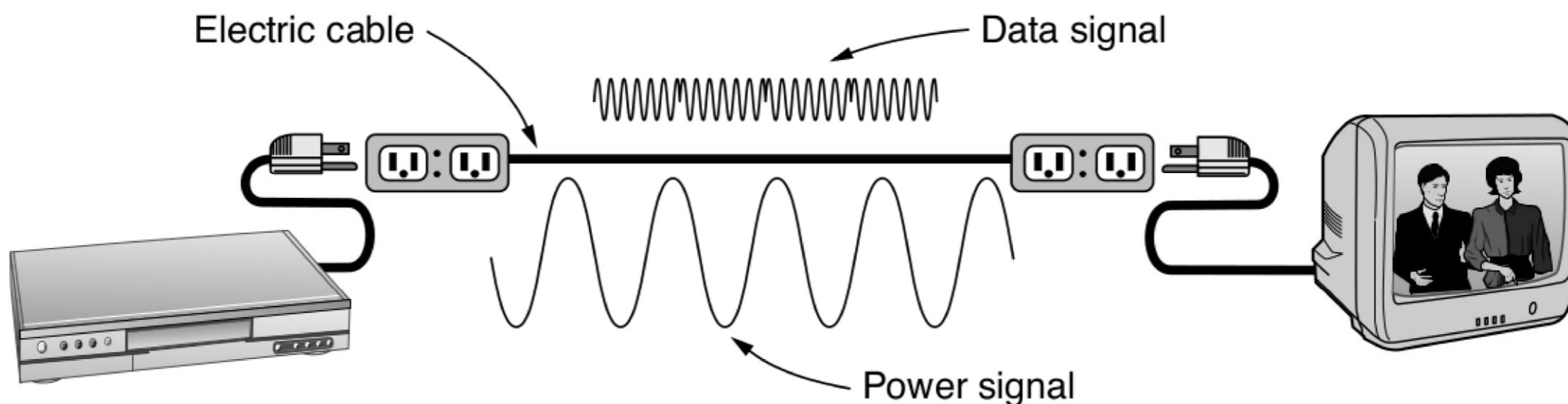
Coaxial Cable

- **Coaxial cable** (coax) has better shielding and greater bandwidth than unshielded twisted pairs
 - it can span longer distances at higher speeds



Power lines

- Electrical power lines are a common kind of wiring: deliver electrical power to houses, and within houses distribute power to outlets
 - convenient for networking: plug TV and receiver into the wall, so one receives power and data over the electrical wiring
 - high frequency signals are needed for high-rate data communication

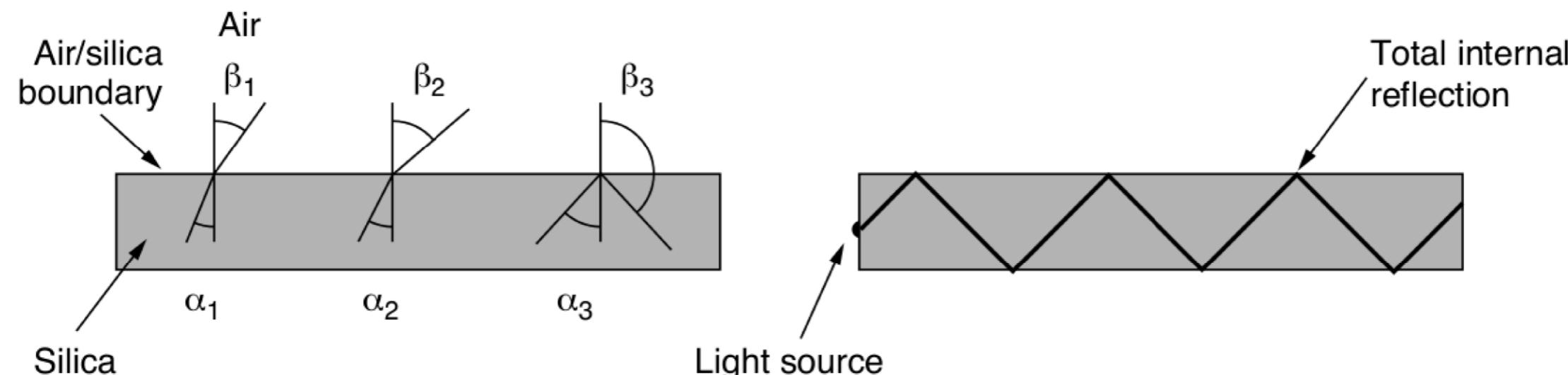


Fiber optics (1)

- In theory, allows for an enormous bandwidth but the cost to install fiber over the last mile to reach consumers and bypass the low bandwidth of wires is huge
- Used for long-haul transmission in network backbones, high-speed LANs, and high-speed Internet access (FTTH)
- Three key components: light source, transmission medium, detector
 - a pulse of light indicated a 1 bit, the absence of light refers to a 0 bit
 - the transmission medium is an ultra-thin fiber of glass
 - the detector generates an electrical pulse when light falls on it
- Simple transmission system: light source to one end, detector to the other
 - simplex transmission system that accepts an electrical signal, converts and transmits it by light pulses, then reconverts the output to an electrical signal at the receiving end

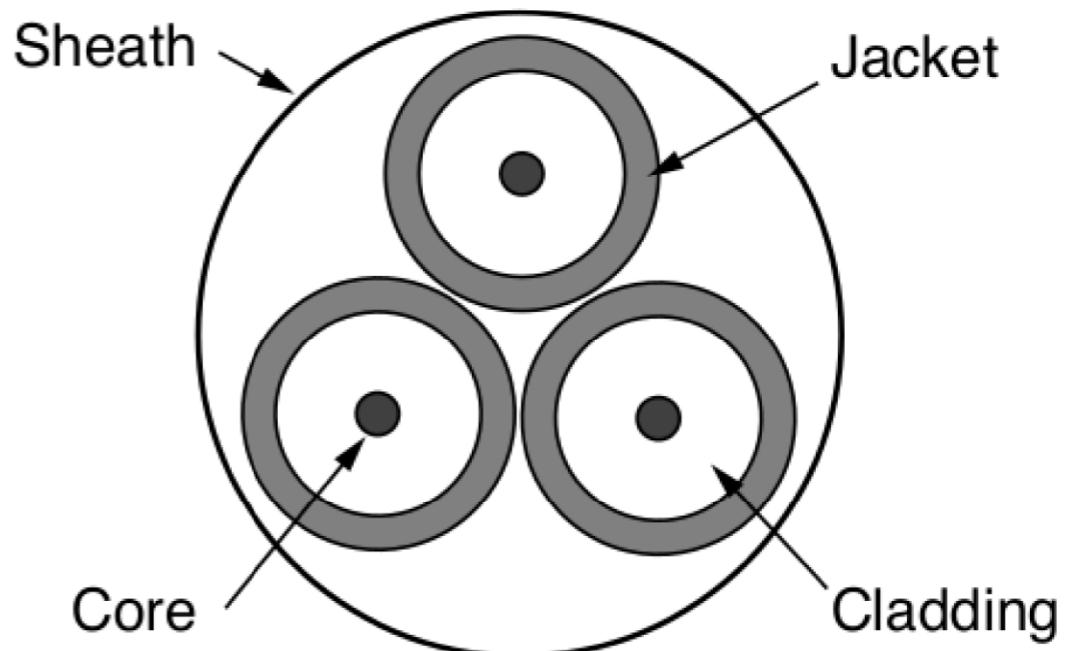
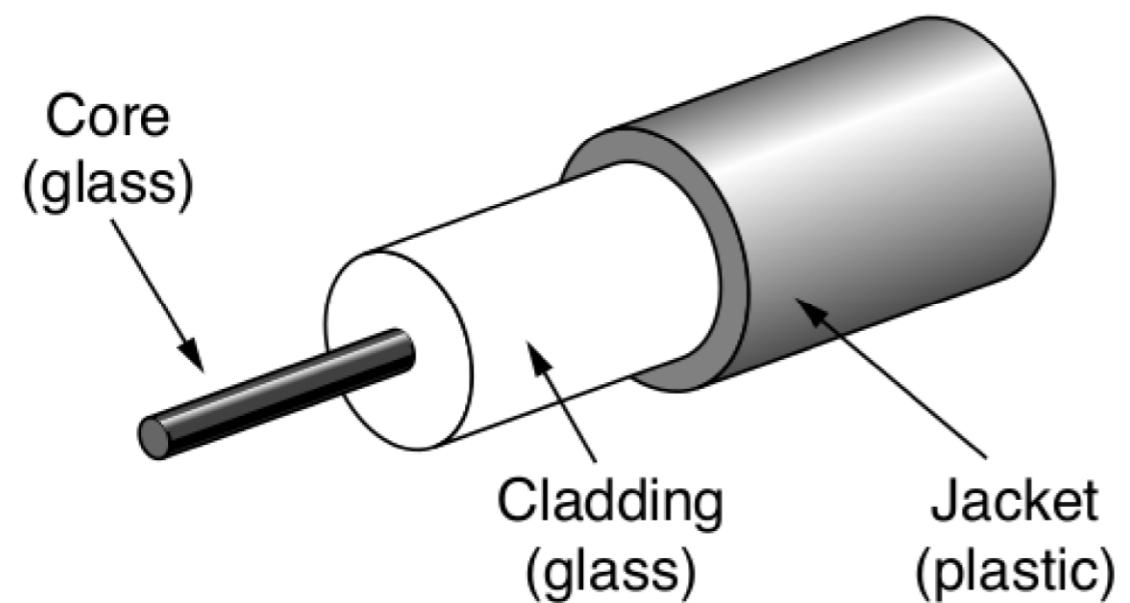
Fiber optics (2)

- When a light ray passes from glass to air, it is bent at the silica/air boundary (refraction)
 - a ray incident at or above the "critical angle" is trapped inside the fiber
 - many different rays will be bouncing around at different angles: **multimode fiber**
 - if the fiber's diameter is reduced to a few wavelengths of light, the fiber acts like a waveguide and the light can propagate in a straight line, yielding **single-mode fiber** (100 Gbps for 100km)



Fiber optics (3)

- Similar to coaxial without the braid, multimode fibers have a core around $d = 50$ microns, single-mode cores are 8-10 microns
- Typically grouped in bundles, protected by an outer sheath



Fiber optics (4)

- Can terminate in connectors: plugged into fiber sockets
 - easy to reconfigure systems, but around 10-20% of light loss
- Spliced mechanically: lay two cut ends next to each other in a sleeve
 - fast to do, results in around 10% of light loss
- Fuse (melt) two pieces together
 - fusion splices are harder to do, but small amount of light loss
- Two kind of light sources: LEDs and semiconductor lasers

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multi-mode	Multi-mode or single-mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

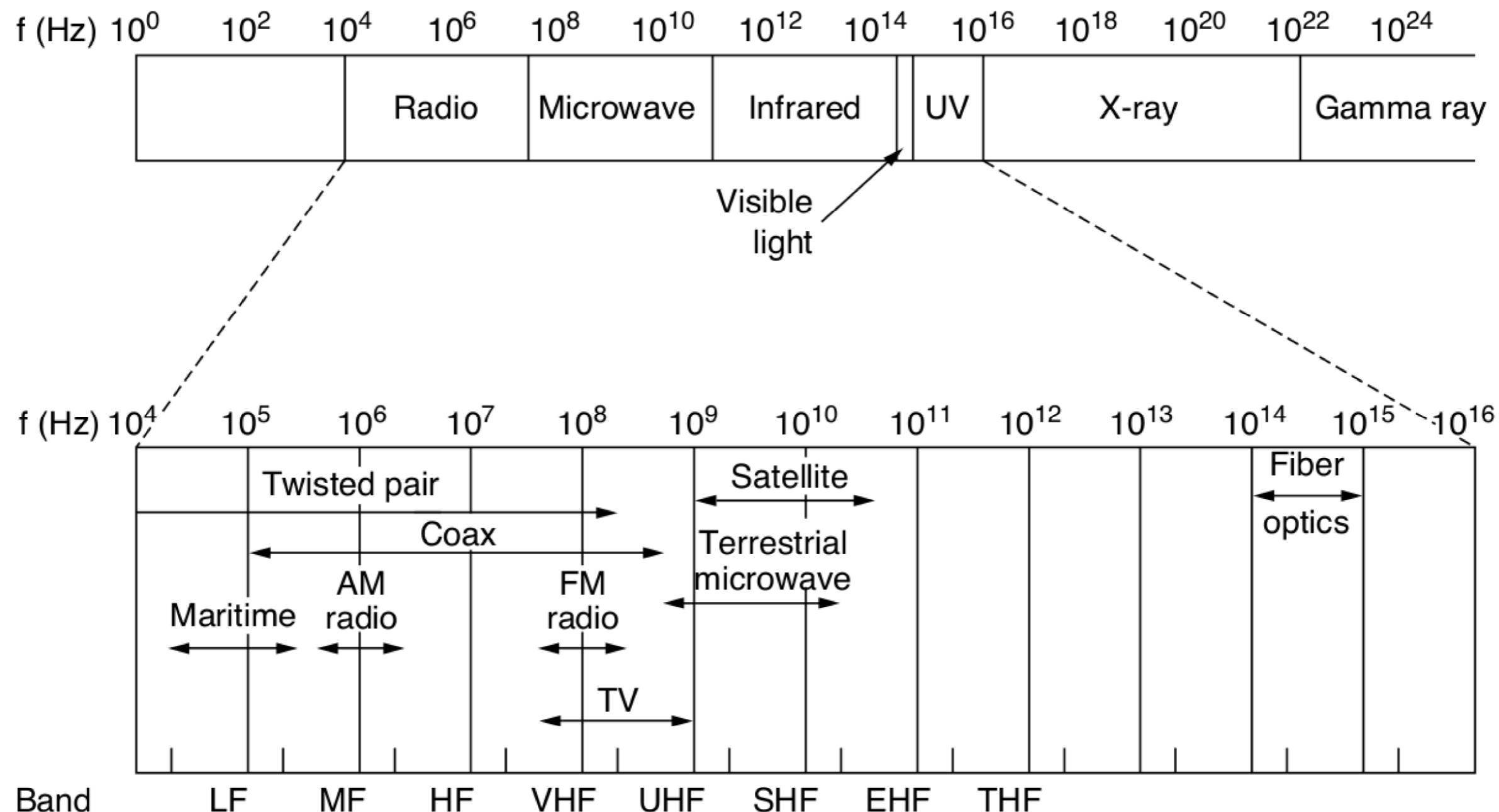
Fiber optics vs Copper wire

- Fiber can handle much higher bandwidths than copper, and repeaters are needed only about every 50kms (copper needs it at about every 5km)
- Fiber is not affected by power surges, electromagnetic interference, power failures, corrosive chemicals in the air
- Fiber is thin and lightweight: useful in situations when there are space or weight restrictions
 - for new routes, fiber has much lower installation cost
- On the downside, not all engineers have the skills to install/manage fiber
- Fiber can be damaged easily if bent too much
- Since fiber is unidirectional, it requires either two fibers or two frequency bands on one fiber
- Fiber interfaces cost more than electrical

The electromagnetic spectrum (1)

- When electrons move, they create electromagnetic waves that can propagate through space
 - the number of oscillations per second of a wave is called its **frequency** (Hz)
 - the distance between two consecutive maxima or minima is called the **wavelength** (λ)
- When an antenna is attached to an electrical circuit, the waves can be broadcast and received by a receiver
- The amount of information a signal such as an electromagnetic wave can carry depends on the received power and is proportional to its bandwidth

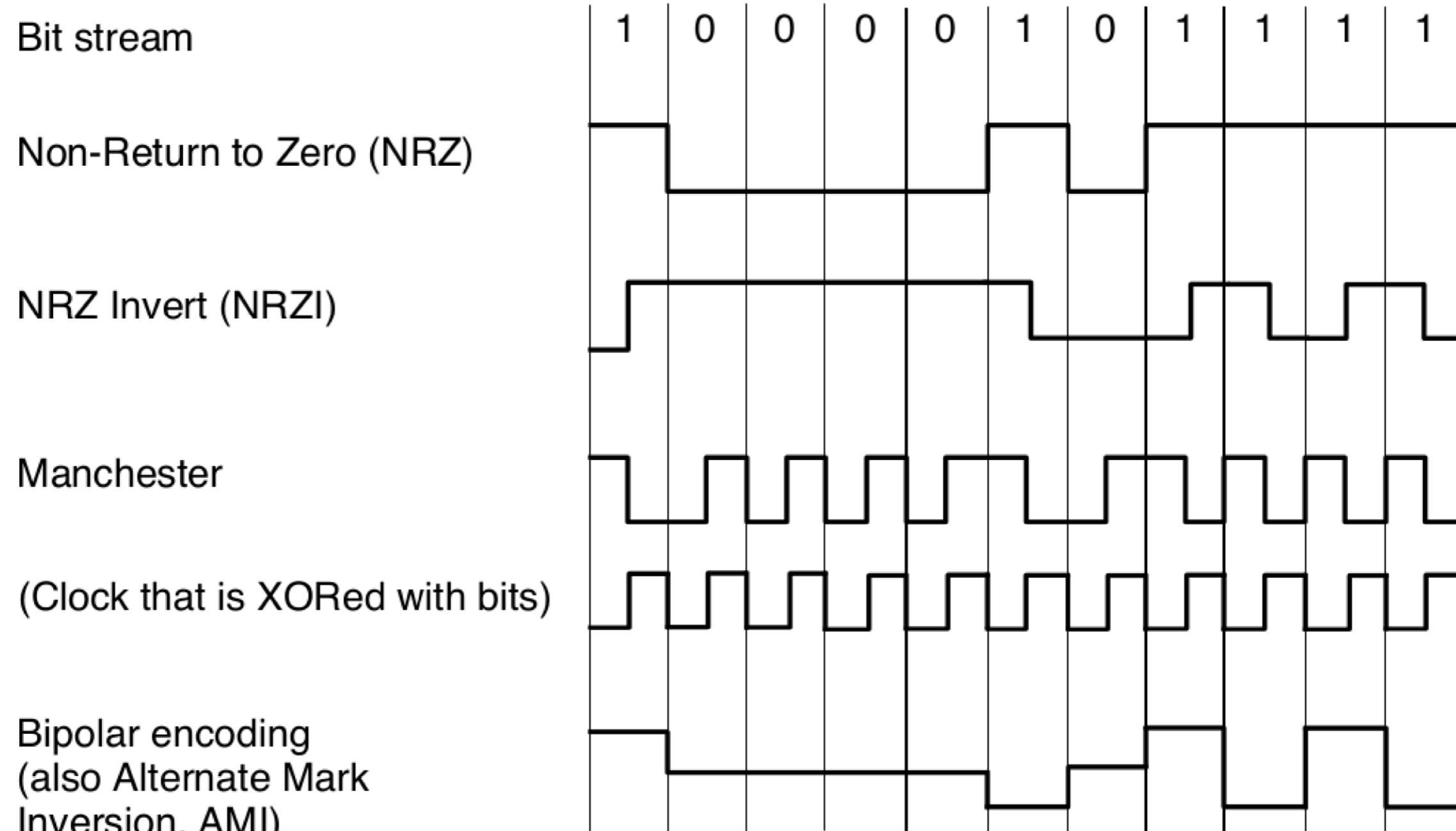
The electromagnetic spectrum (2)



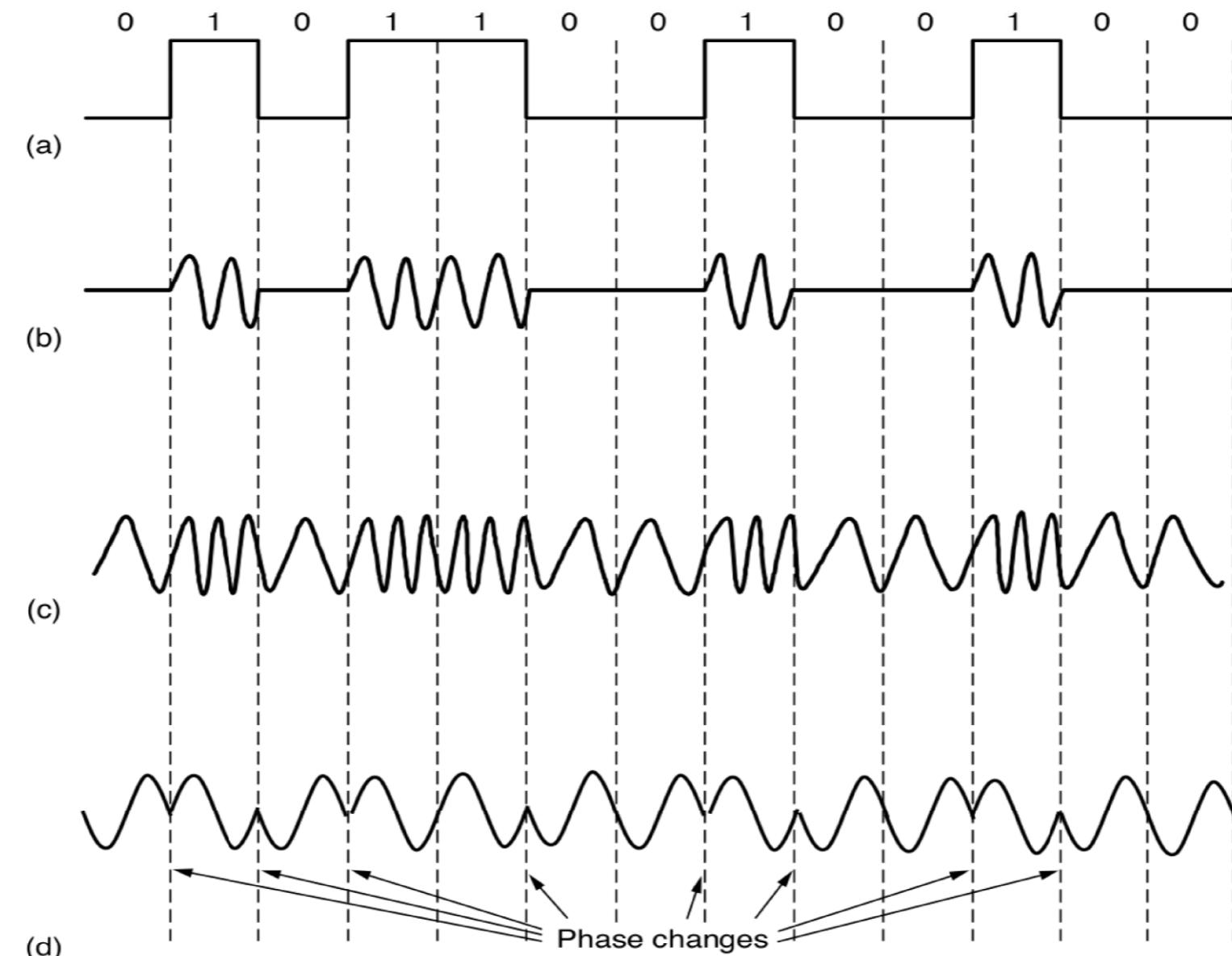
Modulation, transmission, multiplexing

- Wires and wireless channels carry analog signals (varying voltage, light or sound intensity)
- To send digital information, analog signals must be represented in bits
 - the process of converting between bits and signals that represent them is called **digital modulation**
- In **baseband transmission**, the signal occupies frequencies from zero up to a maximum that depends on the signaling rate
 - common for wires
- Schemes which regulate the amplitude, phase, or frequency of a carrier signal to convey bits are called **passband transmission** schemes
 - common for wireless and optical channels for which signals must reside in a given frequency band
- When channels are shared by multiple signals it is called **multiplexing**

Line codes for baseband transmission



Passband transmission



(a) A binary signal. (b) Amplitude shift keying. (c) Frequency shift keying. (d) Phase shift keying.

Multiplexing schemes

- Multiplexing schemes have been developed to share lines among many signals
- Three main (basic) ways to multiplex: time, frequency, code
- **FDM** (Frequency Division Multiplexing) divides the spectrum into frequency bands, with each user having exclusive possession of some band in which to send a signal
- In **TDM** (Time Division Multiplexing), the users take turns, each one periodically getting the entire bandwidth for a certain time
- **CDM** (Code Division Multiplexing) a narrowband signal is spread out over a wider frequency band that allows different users to share the same frequency band

W11 Summary (1)

- The physical layer defines the electrical, timing, and other interfaces by which bits are sent as signals over channels
- Full-duplex vs. half-duplex vs. simplex links
- Transmission media that rely on a physical cable/wire are often called guided transmission media
 - each type has its own set of trade-offs: frequency, bandwidth, delay, cost, maintenance
- Twisted pair has a low cost, and bandwidth depends on the thickness of the wire and the distance traveled
 - Cat 5e, Cat 7e, etc.
- Coaxial cable has better shielding and greater bandwidth than UTP
- Electrical power lines are a common kind of wiring: deliver electrical power to houses, and within houses distributed power to outlets

W11 Summary (2)

- Fiber optics has a huge bandwidth, and used for long-haul transmission in network backbones, high-speed LANs, and high-speed Internet access
 - three key components: light source, transmission medium, detector
 - multimode vs single-mode fiber, with two kinds of light sources
 - connectors, splicing, fusing
 - can handle much higher bandwidths than copper, and not affected by as many environmental issues
 - thin and lightweight, but can be damaged easily
 - unidirectional and the interfaces cost more than electrical
- For all kinds of wireless transmissions: when an antenna is attached to an electrical circuit, the waves can be broadcast and received by a receiver
- The amount of information a signal such as an electromagnetic wave can carry depends on the received power and is proportional to its bandwidth
 - different bands in the electromagnetic spectrum

W11 Summary (3)

- The process of converting between bits and signals that represent them is called digital modulation
- In baseband transmission, the signal occupies frequencies from zero up to a maximum that depends on the signaling rate
 - NRZ, NRZI, Manchester, Bipolar
- Schemes which regulate the amplitude, phase, or frequency of a carrier signal to convey bits are called passband transmission schemes
 - ASK, FSK, PSK
- When channels are shared by multiple signals it is called multiplexing
 - FDM, TDM, CDM