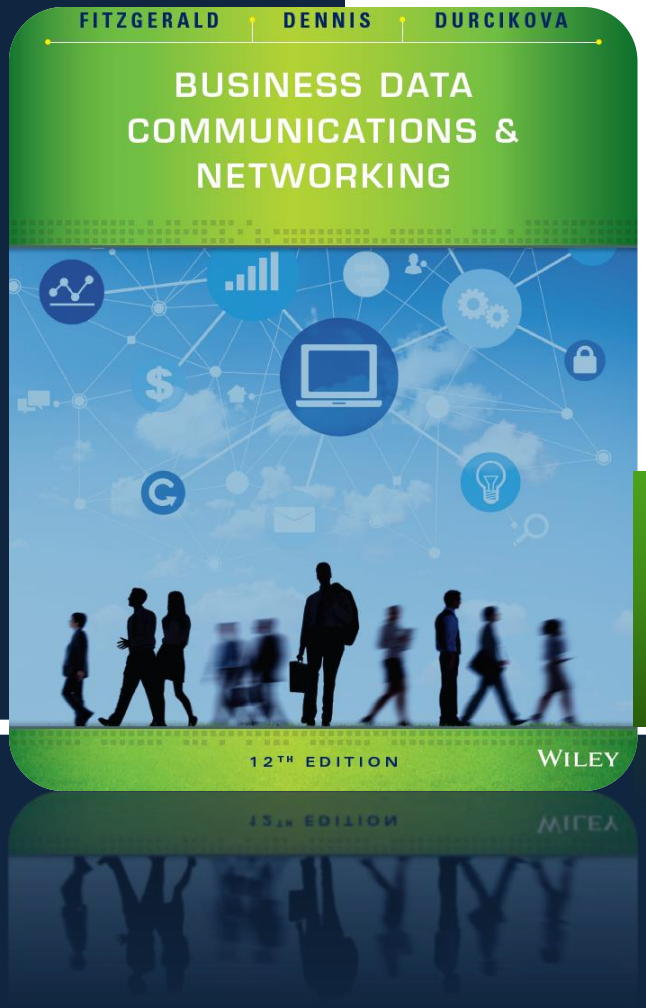

BUSINESS DATA COMMUNICATIONS & NETWORKING

Chapter 3
Physical Layer

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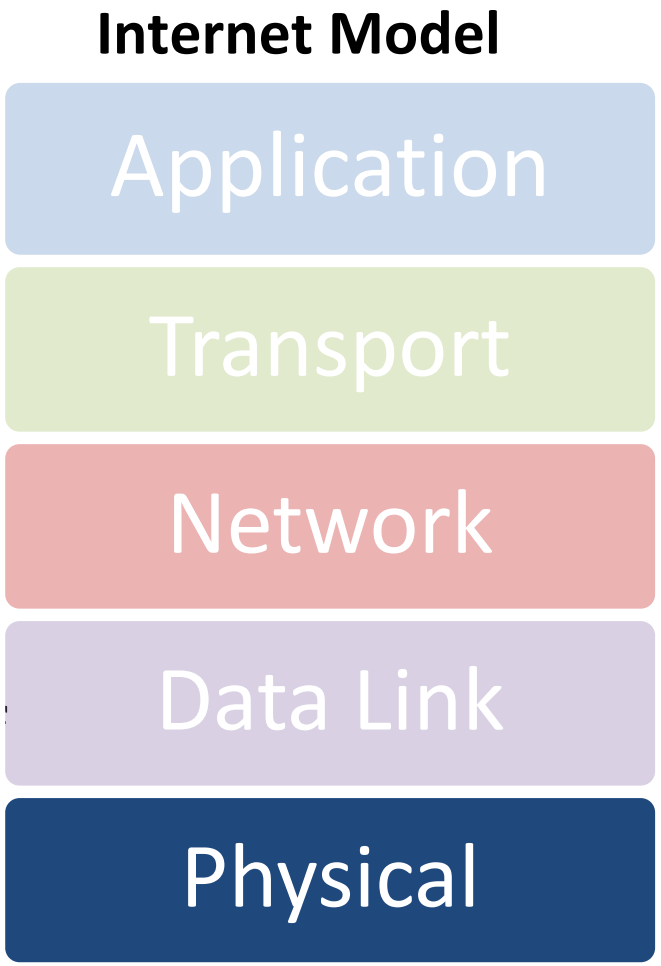
Outline

- Circuits and Data Flow
- Multiplexing
- Media
- Digital Transmission of Digital Data
- Analog Transmission of Digital Data
- Digital Transmission of Analog Data
- Implications for Management

Physical Layer

- Layer 1 in the Internet model
- Focus on transmission over circuits
- Types of Circuits
  - **Physical circuits** connect devices & include wires
  - **Logical circuits** refer to the transmission characteristics of the circuit



Circuits

- Circuit Configuration
  - **Point-to-Point** circuits include most wired connections today
  - **Multipoint** circuits are most commonly used in wireless today
- Shared circuits (multipoint) are less expensive

FIGURE 3-1
Point-to-point circuit

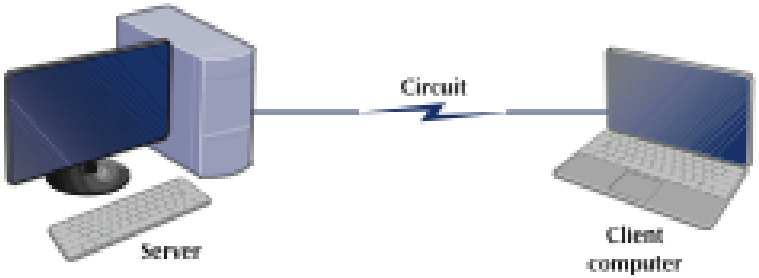
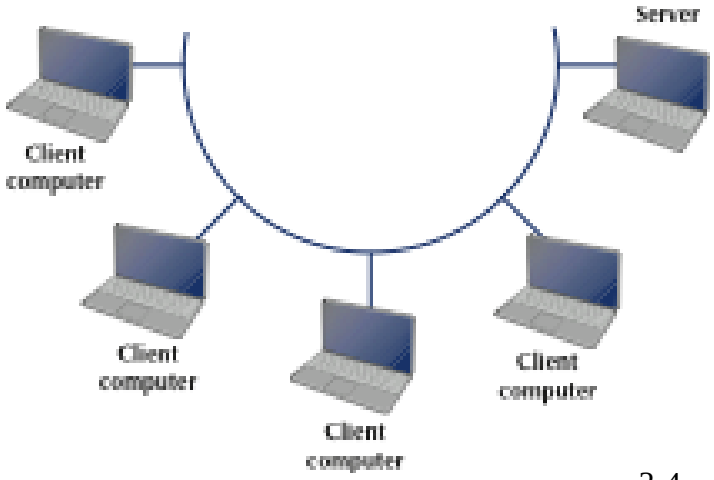
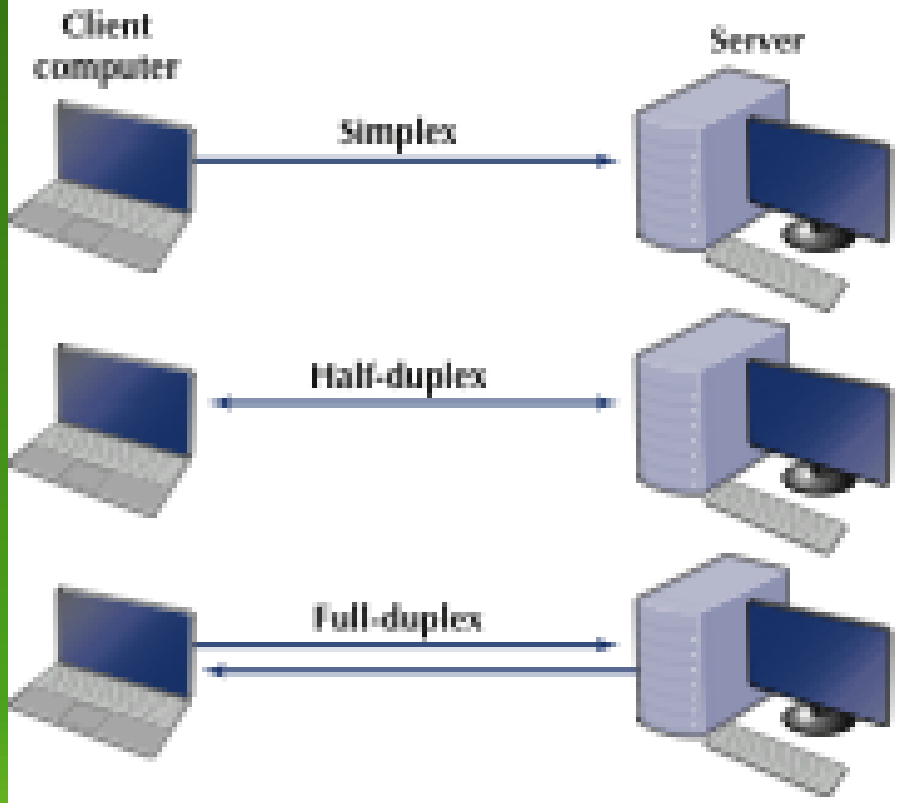


FIGURE 3-2
Multipoint circuit



Data Flow

FIGURE 3-3
Simplex, half-duplex, and full-duplex transmissions

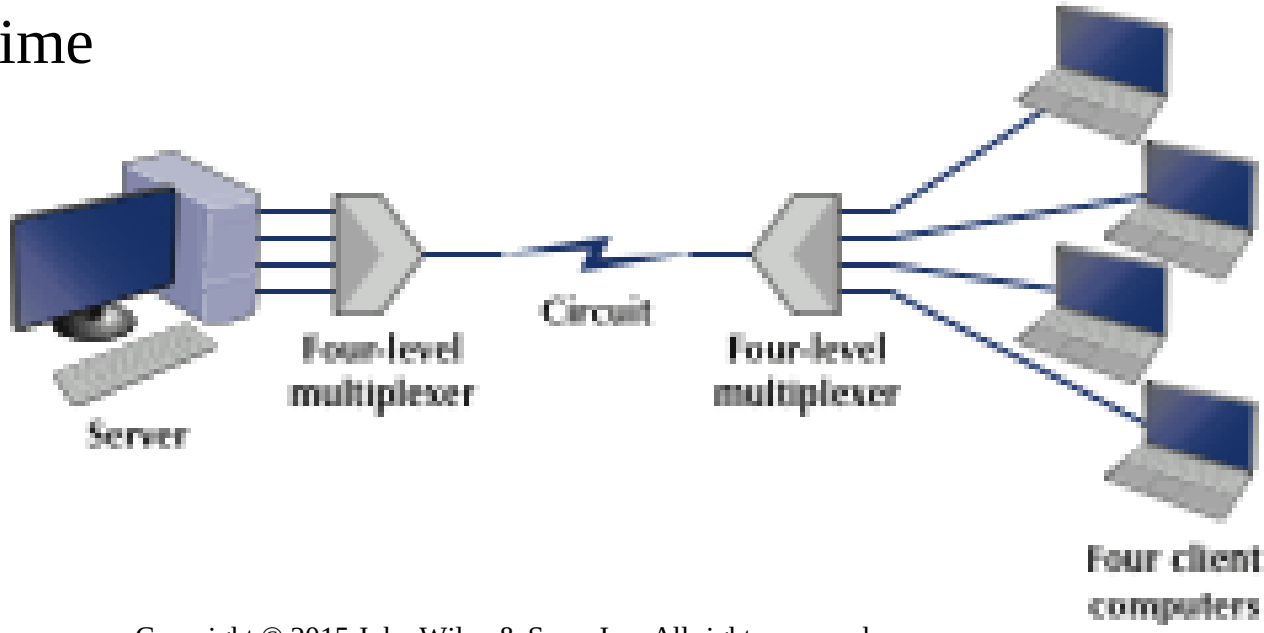


- Data flows in **one direction**
- Data flows **both directions**, but only **one at a time**
- Data flows simultaneously in **both directions**

Multiplexing

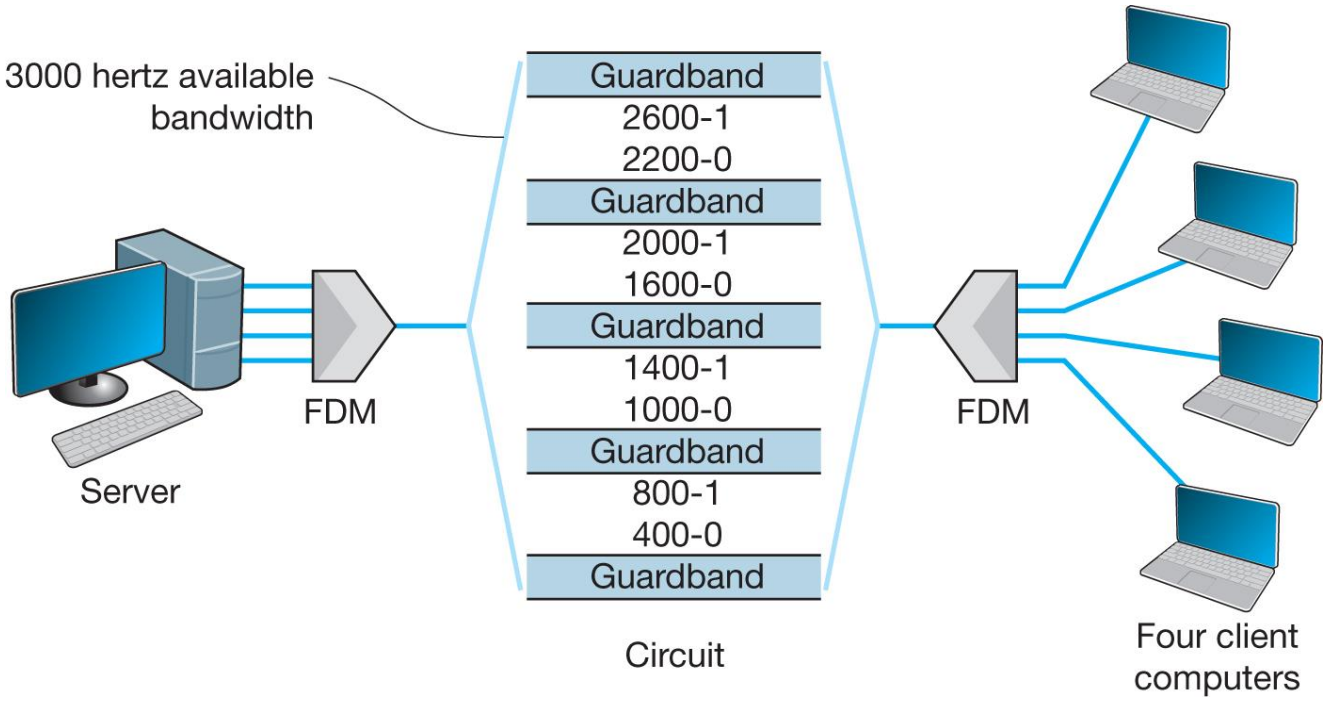
- Divide high-speed circuit into several slower (logical) circuits
- Main advantage is cost
- Categories of multiplexing
  - Frequency/Wavelength
  - Time

FIGURE 3-4
Multiplexed circuit



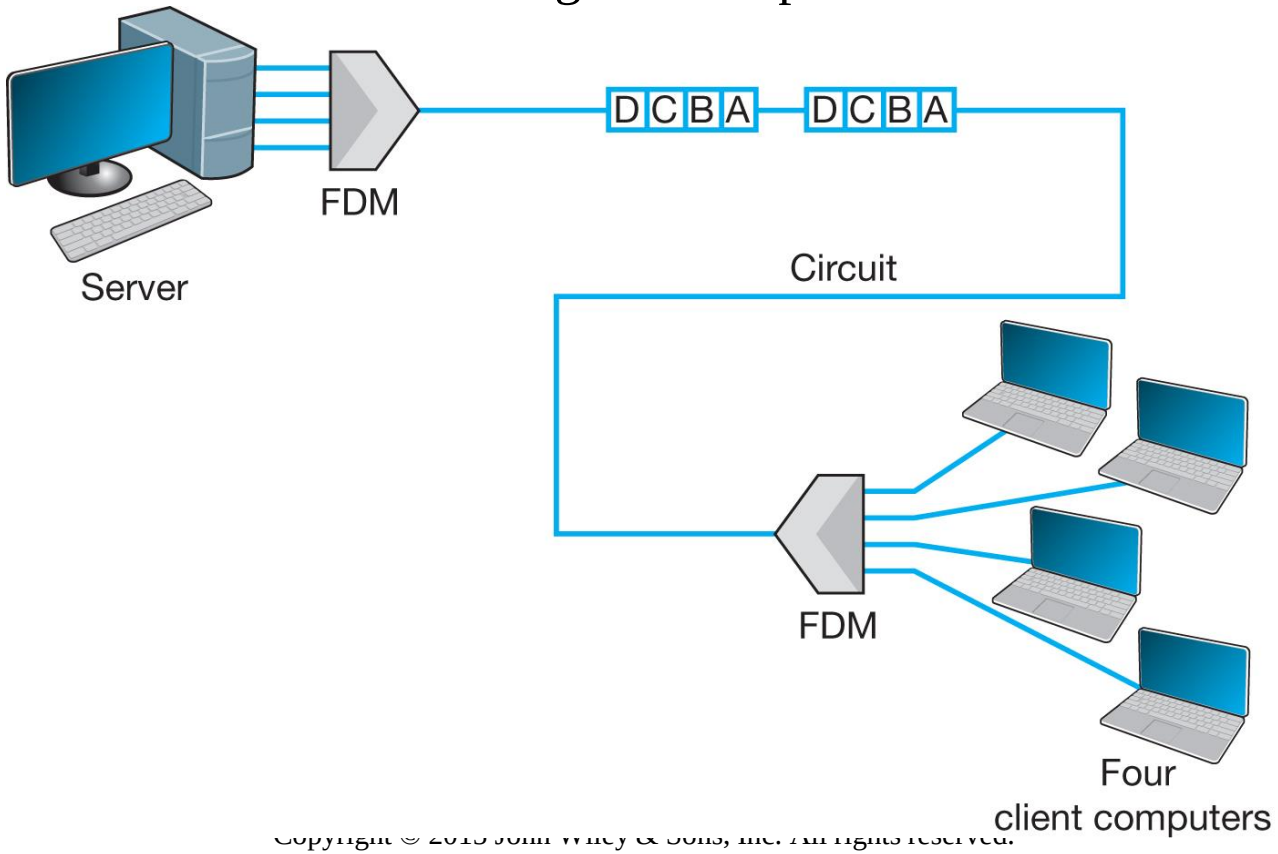
Multiplexing

- **Frequency Division Multiplexing (FDM)**
  - Creates "channels" from larger frequency band
  - **Guardbands** separate channels to prevent interference



Multiplexing

- **Wavelength Division Multiplexing (WDM)**
  - A variant of FDM used in fiber optic circuits
  - Makes use of multiple light wavelengths (colors) to divide circuit into channels
  - Dense WDM can divide circuit into more than 100 channels per fiber each transmitting at 10 Gbps



Multiplexing

- **Time Division Multiplexing (TDM)**
  - Circuit is divided by devices taking turns
  - In traditional TDM, all have equal turns
  - More efficient than FDM, but may have idle time slots
- **Statistical Time Division Multiplexing (STDM)**
  - A variation of TDM
  - Designed to reduce idle time slots by allocating slots based on statistical network usage
  - Disadvantages
    - Potential time delays when actual usage does not match statistically allocated time slots
    - Additional logical addressing requirements

Multiplexing

- **Inverse multiplexing**
  - Combines many low-speed circuits into one high-speed circuit
  - e.g., two T-1 lines multiplexed (creating a capacity of 2 x 1.544Mbps = 3.088 Mbps)

Media

- Physical matter used to carry voice or data transmissions
- **Guided media** – transmission flows along physical medium
- **Wireless (Radiated) media -** transmission flows through the air

Guided Media

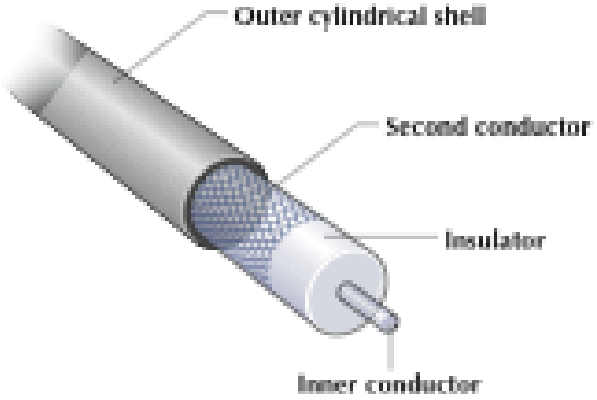
- Twisted-pair (TP) cable
  - Insulated pairs of wires bundled together
  - Wires twisted to reduce electromagnetic interference
  - Some times use additional shielding (STP)
  - Commonly used for telephones, LANs
  - Characteristics
    - Price – inexpensive
    - Distance – typically up to 100n
    - Use - Telephones, LANs

FIGURE 3-5
Category 5e twisted pair wire
Source: Courtesy of Belkin International, Inc.

Guided Media

- Coax cable
  - Has a single copper core, plus outer insulation, shielding, and inner insulation
  - Less prone to interference
  - Characteristics
    - Price - inexpensive (but more costly than TP)
    - Distance - up to 2 km (1.2 miles)
    - Use: Cable TV / Internet

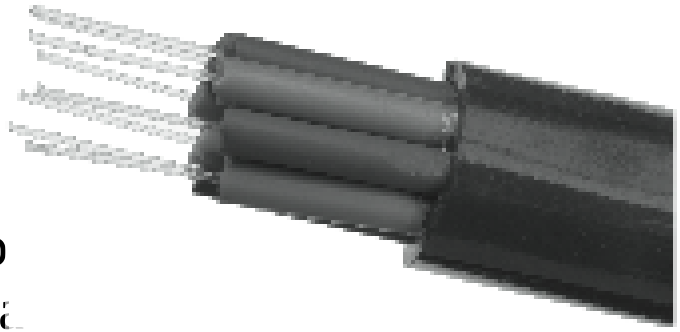
Source: Courtesy of Tim Kloske



Guided Media

- Fiber optic cable
  - Optical core made of glass or plastic
  - Data transmitted using light from lasers or LEDs
  - Resistant to interference and corrosion
  - Extremely fast data rates
  - Characteristics
    - Price: Expensive
    - Distance: 500m – 100km
    - Use: Trunk line / Backbone, lo distance circuits (e.g., undersea cables)

Source: © Hugh Threlfall/Alamy



Guided Media

- Fiber optics
  - Multimode (about 50 micron core)
  - Graded index multimode
  - Single mode (about 5 micron core)

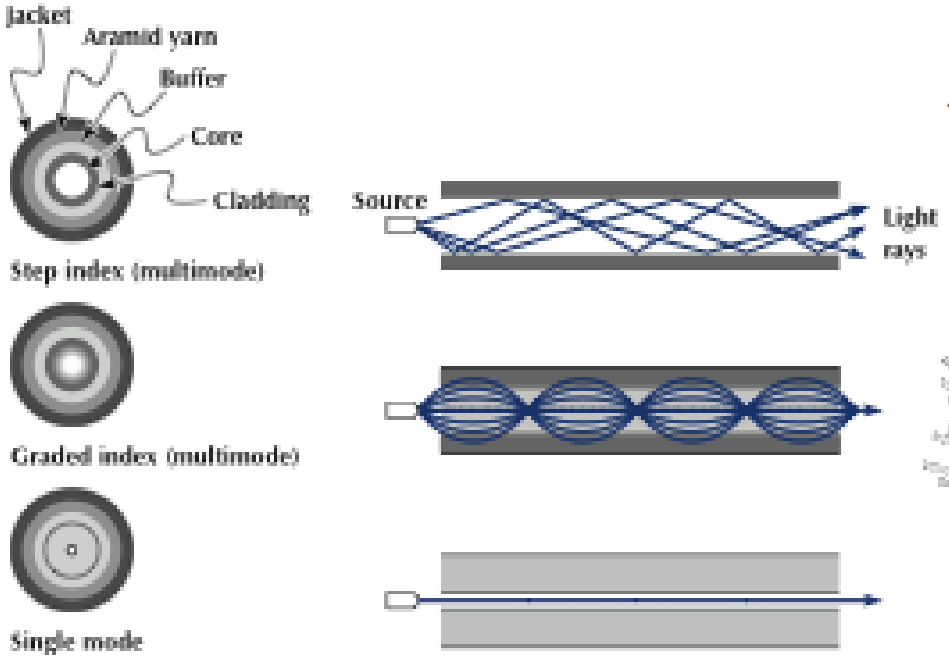
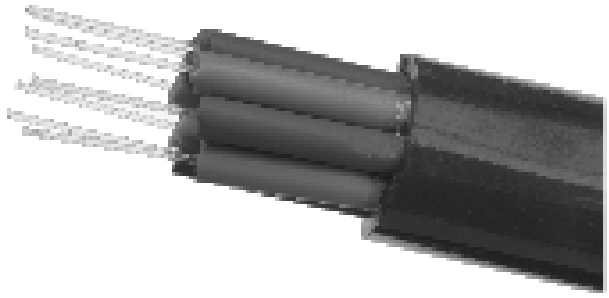


FIGURE 3-7 Fiber-optic cable

Source: © Hugh Threlfall/Alamy



Wireless Media

- Radio
  - Wireless transmission of electrical waves through air
  - Each device on network has a radio transceiver operating at a specific frequency range
  - Enables mobile network communication
  - Characteristics
    - Distance: depends on frequency and power
    - Use: Wireless LANs, cellular and cordless phones, baby monitors

Wireless Media

- Microwave
  - High-frequency radio communication
  - Requires line of sight which may require large antennas and towers
  - Affected by weather
  - Characteristics
    - Distance: ~60 km (due to curvature of earth
    - Use: Trunk line / Backbone, long distance
- Satellite
  - Special form of microwave communication
  - Long distance leads to propagation delays

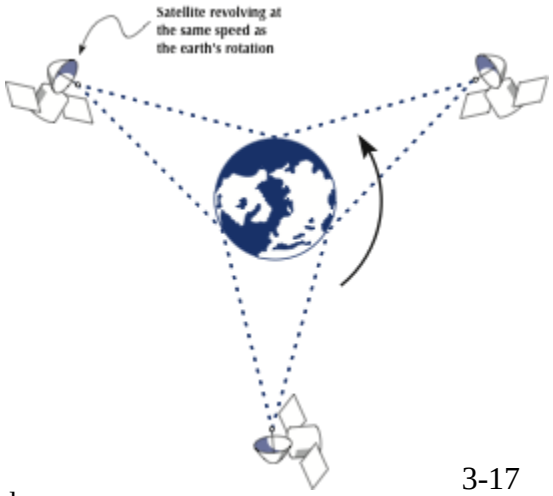
FIGURE 3-8

A microwave tower. The round antennas are microwave antennas and the straight antennas are cell phone antennas

Source: © Matej Pribelsky / iStockphoto

FIGURE 3-9

Satellites in operation

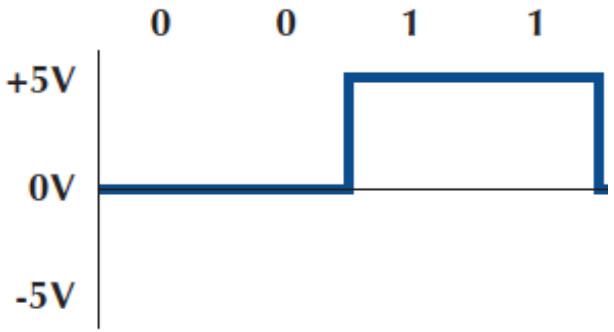


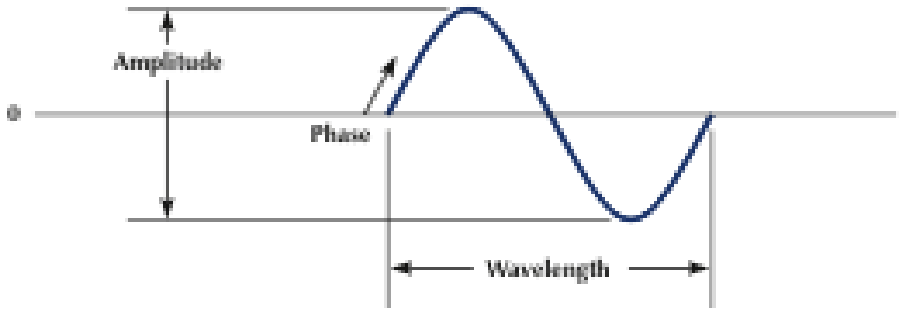
Media

- Factors to consider in media selection
  - Type of network
  - Cost
  - Transmission distance
  - Security
  - Error rates
  - Transmission speeds

Digital vs. Analog Data

- **Digital** transmission involves discrete binary values (i.e., 0 or 1)
- **Analog** transmission involves continuous waves





Digital Transmission of Digital Data

Total		2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
255		128	64	32	16	8	4	2	1

- Coding scheme needed to ensure sender and receiver understand messages (e.g., ASCII, Unicode, etc.)
- A character is represented by a group of bits

Standard or Lower ASCII characters and codes

Dec	Char	Dec	Char	Dec	Char	Dec	Char	Dec	Char	Dec	Char
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124	|
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o	127	_
48	0	64	@	80	P	96	`	112	p		

Character	ASCII
A	01000001
B	01000010
C	01000011
D	01000100
E	01000101
a	01100001
b	01100010
c	01100011
d	01100100
e	01100101
1	00110001
2	00110010
3	00110011
4	00110100
!	00100001
$	00100100

Digital Transmission of Digital Data

- Transmission modes
  1. **Parallel:** multiple bits transmitted simultaneously

Digital Transmission of Digital Data

- Transmission modes
  2. **Serial:** bits are transferred sequentially, one at a time

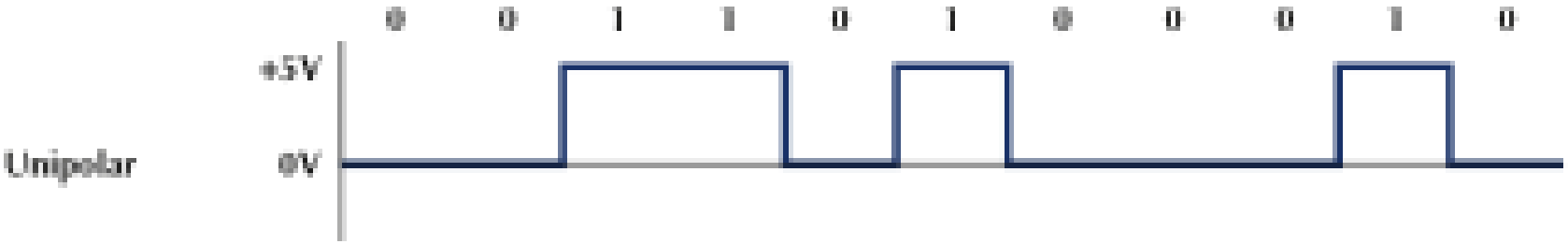
Digital Transmission of Digital Data

- Sender and receiver must agree upon:
  - **Set of symbols**
    - How bits are encoded as voltages or light pulses
    - e.g., +5V might be encodes as a “1”
  - **Symbol rate**
    - How often symbols are sent
    - e.g., with a symbol rate of 64 kilohertz (kHz), a symbol is sent every 1/64,000 of a second

Digital Transmission of Digital Data

- Five types of signaling techniques
  1. **Unipolar -** voltage is 0 or positive representing binary bits (in some circuits, 0 and negative voltage could be used)

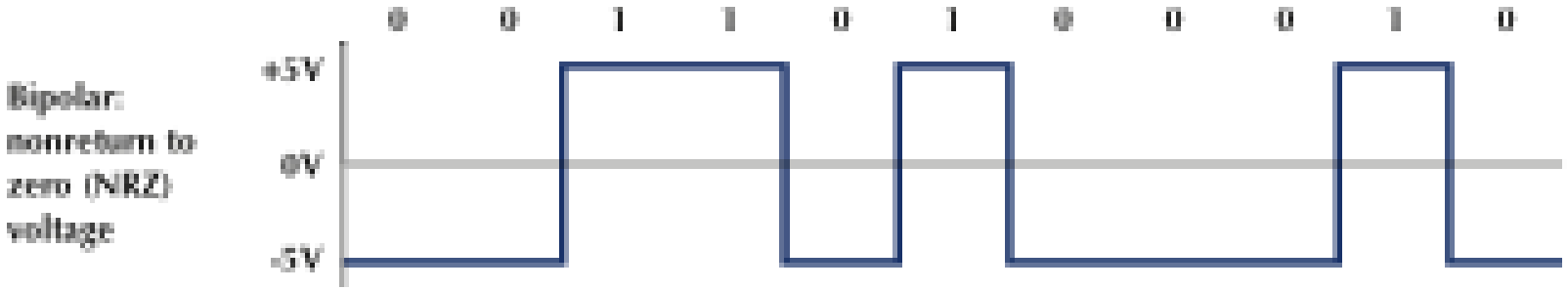
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  2. **Bipolar NRZ -** voltage is positive or negative, but not zero
     - Fewer errors than unipolar because signals are more distinct

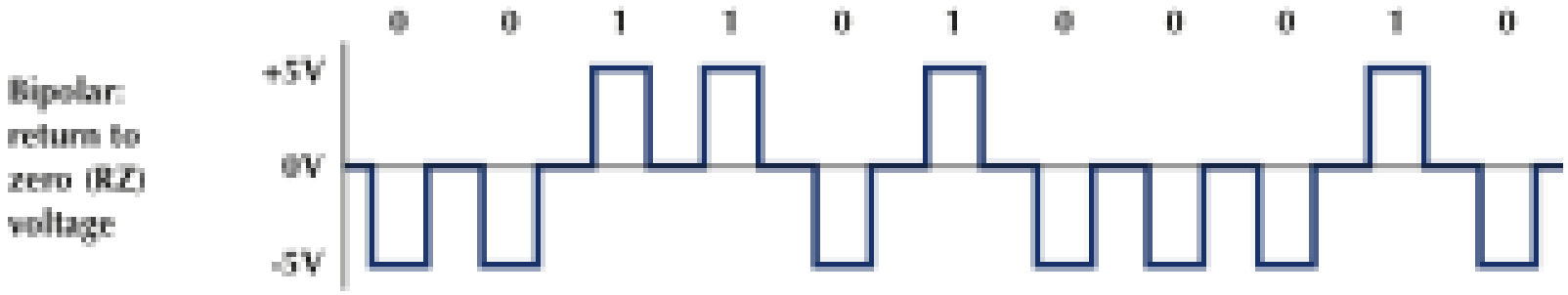
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  3. **Bipolar RZ -** voltage is positive or negative, returning to zero between each bit
     - Fewer synchronization errors than bipolar NRZ

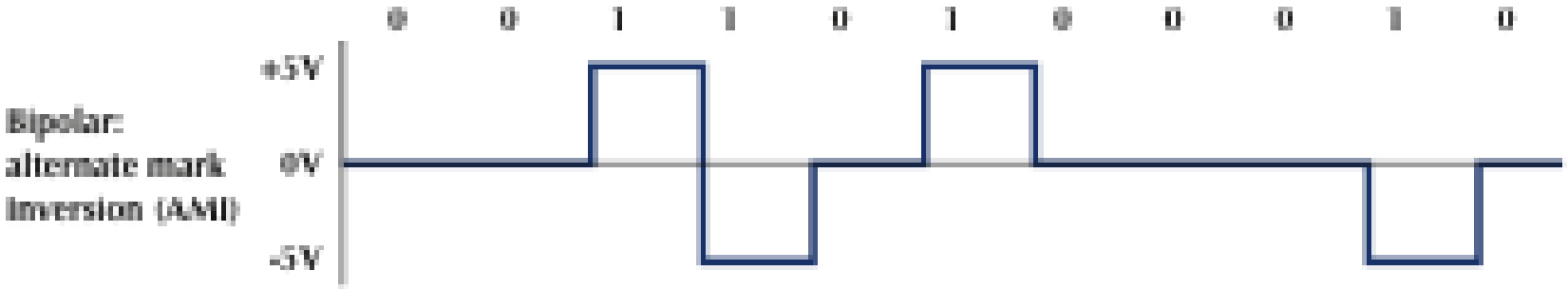
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  4. **Bipolar AMI -** voltage is 0, positive, or negative, returns to zero between each bit, and alternates between positive and negative voltage

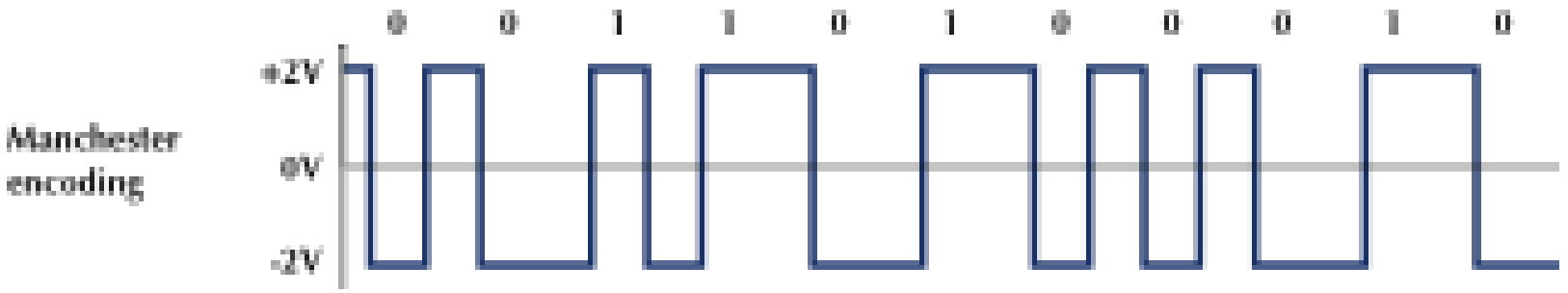
FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Digital Transmission of Digital Data

- Five types of signaling techniques
  5. **Manchester -** voltage is positive or negative and bits are indicated by a mid-bit transition

FIGURE 3-13
Unipolar, bipolar, and Manchester signals (digital)



Analog Transmission of Digital Data

- Telephone system built for analog data
  - Electrical signals mimic sound waves (i.e., voice)
  - Analog transmissions take on range of values (vs. discrete values of digital transmissions)
  - Need a **modem** (modulator/demodulator) to convert from analog to digital and vice versa

Analog Transmission of Digital Data

- Three characteristics of waves
  1. **Amplitude:** height of wave (decibels)
  2. **Frequency:** waves per second (hertz)
     - **Wavelength** is the inverse of frequency
  3. **Phase:** wave direction (degrees) or the point at which the wave begins

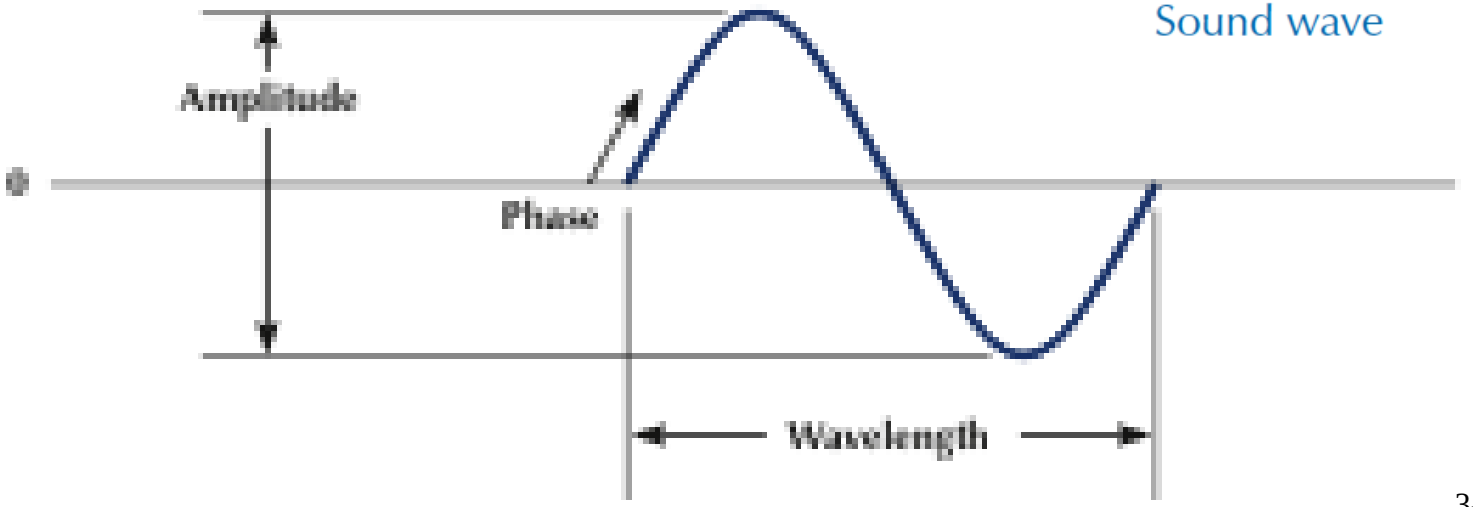


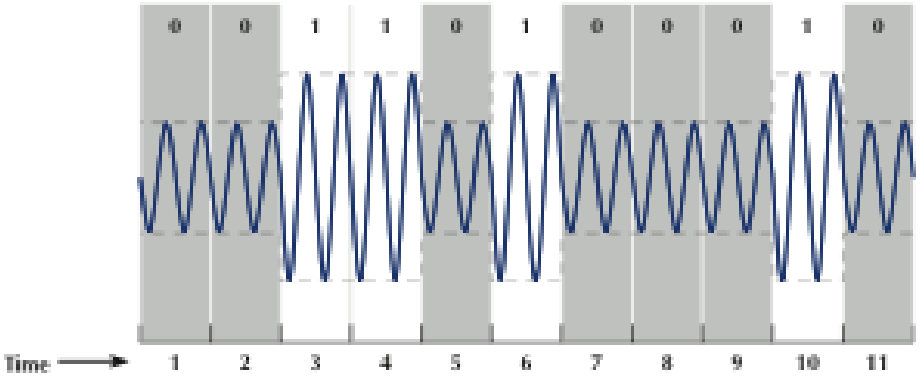
FIGURE 3-14
Sound wave

Analog Transmission of Digital Data

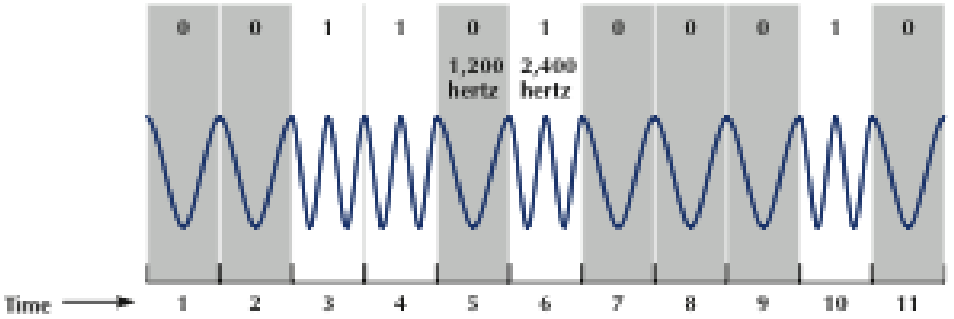
- **Carrier wave** is basic wave transmitted through a circuit
- **Modulation** is the modification of a carrier wave's fundamental characteristics in order to encode information
- Three ways to modulate a carrier wave:
  1. **Amplitude Modulation (AM)** or Amplitude Shift Keying (ASK)
  2. **Frequency Modulation (FM**) or Frequency Shift Keying (FSK)
  3. **Phase Modulation (PM)** or Phase Shift Keying (PSK)

Analog Transmission of Digital Data

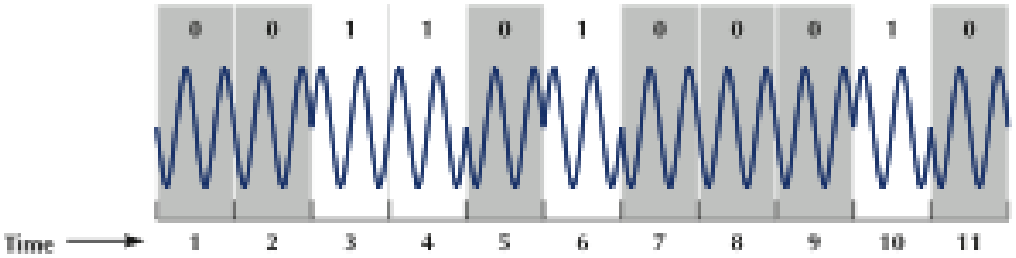
- Amplitude Modulation



- Frequency Modulation



- Phase Modulation



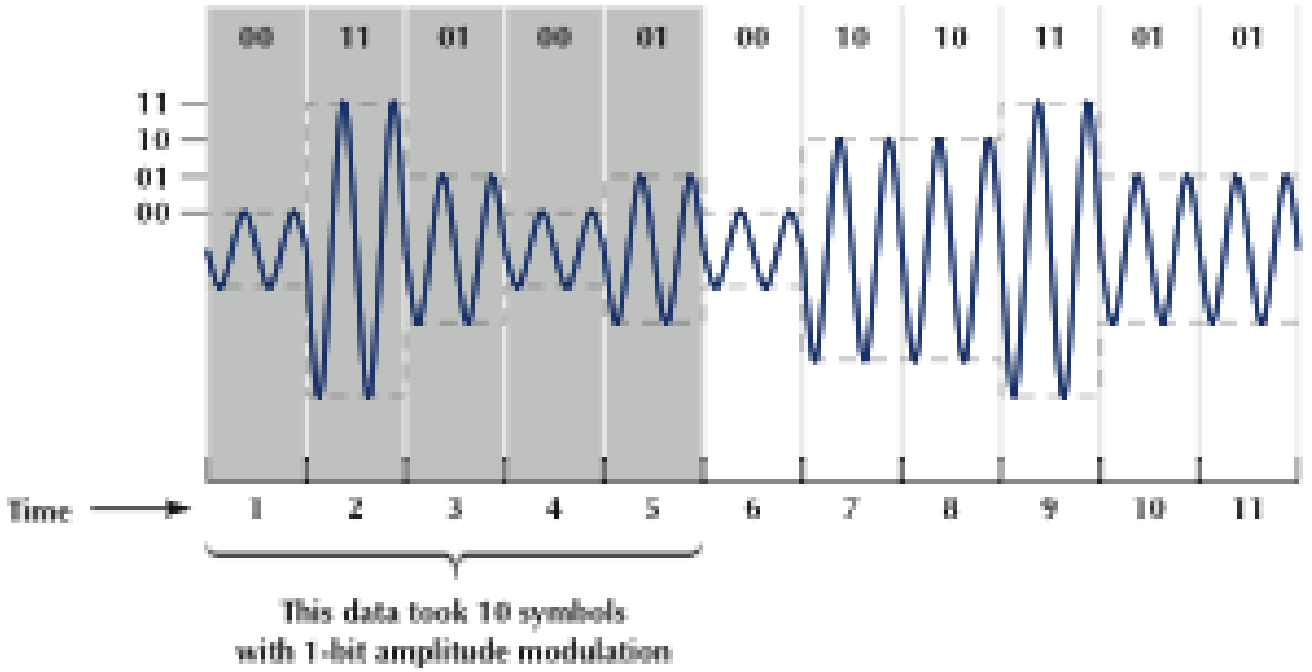
Analog Transmission of Digital Data

- **Symbol:** One or more modifications to a carrier wave used to encode data
- Can send 1 bit by defining two different symbols (e.g., amplitudes, frequencies, etc.)
- Can send multiple bits by defining more than two symbols
  - Need more complicated information coding schemes
  - 1 bit of information → 2 symbols
  - 2 bits of information → 4 symbols
  - 3 bits of information → 8 symbols
  - n bits of information → 2^n symbols

Analog Transmission of Digital Data

- Two-bit Amplitude Modulation
  - With 4 levels of amplitude defined as symbols, 2 bits can be transmitted per symbol

FIGURE 3-18
Two-bit amplitude modulation



Analog Transmission of Digital Data

- **Data rate (or bit rate)** is the number of bits transmitted per second
- **Symbol rate:** number of symbols transmitted per second

  Data rate = symbol rate × (# bits/symbol)

- Example

  Symbol rate = 16,000 symbols/sec

  #bits/symbol = 4 bits/symbol

  Data rate = 16,000 symbols/sec × 4 bits/symbol

  = 64,000 bits/sec = 64Kbps

Digital Transmission of Analog Data

- **Codecs (COde, DECode)** is a device or software that converts an analog signal (e.g., voice) into digital form and the reverse
- **Pulse-Code Modulation (PCM)** converts analog to digital by:
  1. Sampling the analog signal at regular intervals
  2. Measuring the amplitude of each sample
  3. Encoding (quantizing) the amplitude as binary data
- **Quantizing Error** is the difference between the original analog signal and the approximated, digital signal
- Reducing quantizing error can be done by:
  - Sampling more frequently
  - Using more levels of amplitude in encoding

Digital Transmission of Analog Data

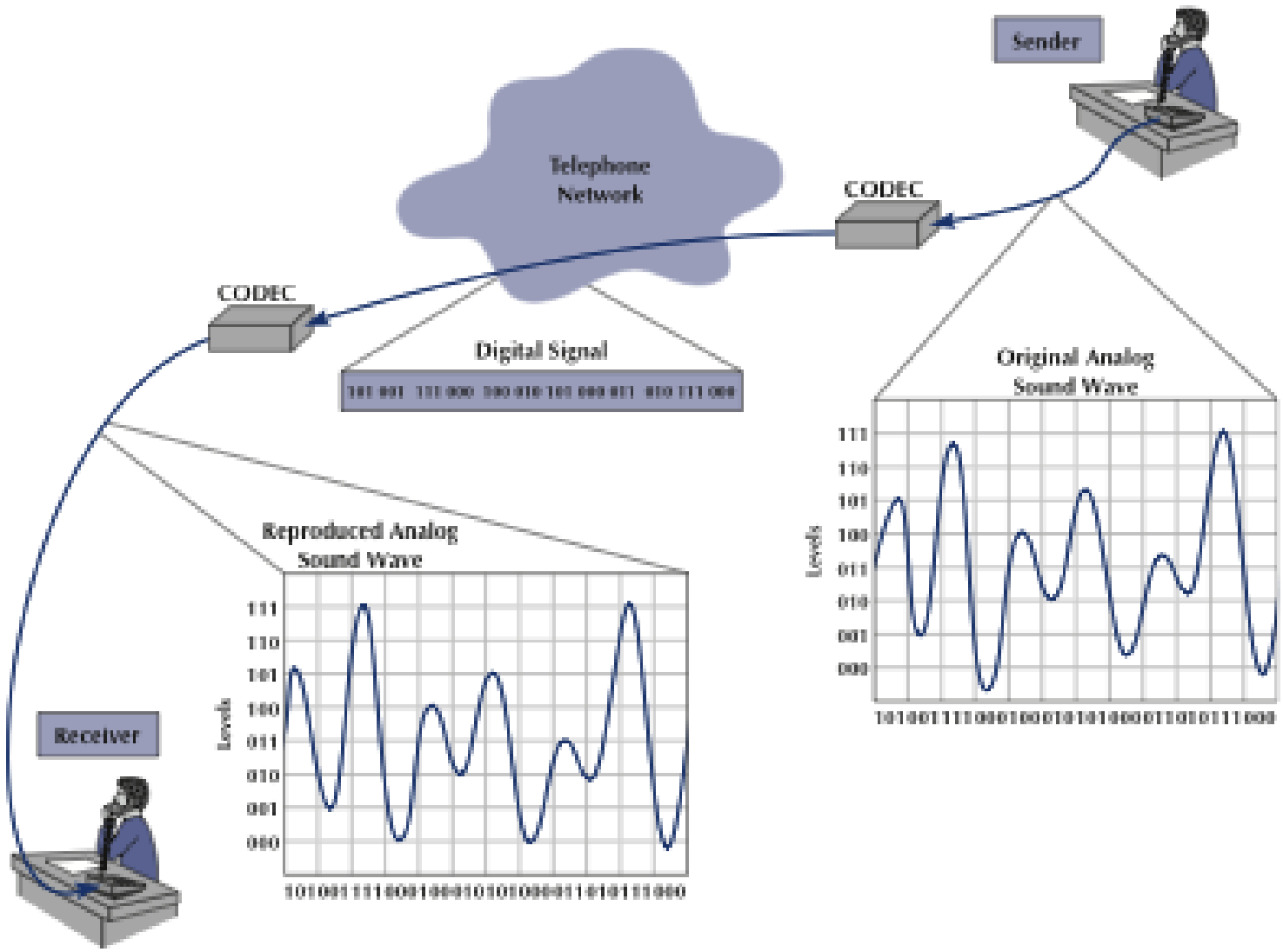


FIGURE 3-20 Pulse amplitude modulation (PAM)

Implications for Management

- Digital cabling tends to be least expensive and most reliable
- Data and voice networks continue to converge
- Wired networks remain more secure and reliable than wireless