Wireless Communication Networks and Systems 1st Edition Beard Solutions Manual
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WIRELESS COMMUNICATION NETWORKS AND SYSTEMS

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SOLUTIONS MANUAL

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Chapter 2 Transmission Fundamentals

ANSWERS TO QUESTIONS

2.1 A continuous or analog signal is one in which the signal intensity varies in a smooth fashion over time while a discrete or digital signal is one in which the signal intensity maintains one of a finite number of constant levels for some period of time and then changes to another constant level.

2.2 Amplitude, frequency, and phase are three important characteristics of a periodic signal.

2.3 2π radians.

2.4 The relationship is $\lambda f = v$, where λ is the wavelength, f is the frequency, and v is the speed at which the signal is traveling.

2.5 The spectrum of a signal consists of the frequencies it contains; the bandwidth of a signal is the width of the spectrum.

2.6 Attenuation is the gradual weakening of a signal over distance.

2.7 The rate at which data can be transmitted over a given communication path, or channel, under given conditions, is referred to as the channel capacity.

2.8 Bandwidth, noise, and error rate affect channel capacity.

2.9 With guided media, the electromagnetic waves are guided along an enclosed physical path, whereas unguided media provide a means for transmitting electromagnetic waves through space, air, or water, but do not guide them.

2.10 Point-to-point microwave transmission has a high data rate and less attenuation than twisted pair or coaxial cable. It is affected by rainfall, however, especially above 10 GHz. It is also requires line of sight and is subject to interference from other microwave transmission, which can be intense in some places.

2.11 Direct broadcast transmission is a technique in which satellite video signals are transmitted directly to the home for continuous operation.

2.12 A satellite must use different uplink and downlink frequencies for continuous operation in order to avoid interference.

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2.13 Broadcast is omnidirectional, does not require dish shaped antennas, and the antennas do not have to be rigidly mounted in precise alignment.

2.14 Multiplexing is cost-effective because the higher the data rate, the more cost-effective the transmission facility.

2.15 Interference is avoided under frequency division multiplexing by the use of guard bands, which are unused portions of the frequency spectrum between subchannels.

2.16 A synchronous time division multiplexer interleaves bits from each signal and takes turns transmitting bits from each of the signals in a round-robin fashion.

ANSWERS TO PROBLEMS

2.1 Period = 1/1000 = 0.001 s = 1 ms.

2.2 **a.** sin $(2\pi ft - \pi)$ + sin $(2\pi ft + \pi)$ = 2 sin $(2\pi ft + \pi)$ or 2 sin $(2\pi ft - \pi)$ or - 2 sin $(2\pi ft)$
b. sin $(2\pi ft)$ + sin $(2\pi ft - \pi)$ = 0.

2.3

N	C		D		E		F		G		A		B		C
F	264		297		330		352		396		440		495		528
D		33		33		22		44		44		55		33	
W	1.25		1.11		1		0.93		0.83		0.75		0.67		0.63

N = note; F = frequency (Hz); D = frequency difference; W = wavelength (m)

2.4 $2 \sin(4\pi t + \pi)$; A = 2, f = 2, $\phi = \pi$

2.5 (1 + 0.1 cos 5t) cos 100t = cos 100t + 0.1 cos 5t cos 100t. From the trigonometric identity cos a cos b = (1/2)(cos(a + b) + cos(a – b)), this equation can be rewritten as the linear combination of three sinusoids:
cos 100t + 0.05 cos 105t + 0.05 cos 95t

2.6 We have $\cos^2 x = \cos x \cos x = (1/2)(\cos(2x) + \cos(0)) = (1/2)(\cos(2x) + 1)$. Then: $f(t) = (10 \cos t)^2 = 100 \cos^2 t = 50 + 50 \cos(2t)$. The period of cos(2t) is π and therefore the period of f(t) is π.

2.7 If $f_1(t)$ is periodic with period X, then $f_1(t) = f_1(t + X) = f_1(t + nX)$ where n is an integer and X is the smallest value such that $f_1(t) = f_1(t + X)$. Similarly, $f_2(t) = f_2(t + Y) = f_2(t + mY)$. We have $f(t) = f_1(t) + f_2(t)$. If f(t) is periodic with period Z, then $f(t) = f(t + Z)$. Therefore $f_1(t) + f_2(t) = f_1(t + Z) + f_2(t + Z)$. This last equation is satisfied if $f_1(t) = f_1(t$

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+ Z) and $f_2(t) = f_2(t + Z)$. This leads to the condition Z = nX = mY for some integers n and m. We can rewrite this last as (n/m) = (Y/X). We can therefore conclude that if the ratio (Y/X) is a rational number, then f(t) is periodic.

2.8 The signal would be a low-amplitude, rapidly changing waveform.

2.9 Using Shannon's equation: $C = B \log_2 (1 + SNR)$

We have W = 300 Hz $(SNR)_{dB} = 3$

Therefore, $SNR = 10^{0.3}$

$C = 300 \log_2 (1 + 10^{0.3}) = 300 \log_2 (2.995) = 474$ bps

2.10 Using Nyquist's equation: $C = 2B \log_2 M$

We have C = 9600 bps

a. $\log_2 M = 4$, because a signal element encodes a 4-bit word

Therefore, $C = 9600 = 2B \times 4$, and

B = 1200 Hz

b. $9600 = 2B \times 8$, and B = 600 Hz

2.11 Nyquist analyzed the theoretical capacity of a noiseless channel; therefore, in that case, the signaling rate is limited solely by channel bandwidth. Shannon addressed the question of what signaling rate can be achieved over a channel with a given bandwidth, a given signal power, and in the presence of noise.

2.12 **a.** Using Shannon's formula: $C = 3000 \log_2 (1+400000) = 56$ Kbps

b. Due to the fact there is a distortion level (as well as other potentially detrimental impacts to the rated capacity, the actual maximum will be somewhat degraded from the theoretical maximum. A discussion of these relevant impacts should be included and a qualitative value discussed.

2.13 $C = B \log_2 (1 + SNR)$

$20 \times 10^6 = 3 \times 10^6 \times \log_2(1 + SNR)$

log2(1 + SNR) = 6.67

1 + SNR = 102

SNR = 101

2.14 From Equation 2.1, we have $L_{dB} = 20 \log (4\pi d/\lambda) = 20 \log (4\pi df/v)$, where $\lambda f = v$ (see Question 2.4). If we double either d or f, we add a term 20 log(2), which is approximately 6 dB.

2.15

Decibels	1	2	3	4	5	6	7	8	9	10
Losses	0.8	0.63	0.5	0.4	0.32	0.25	0.2	0.16	0.125	0.1
Gains	1.25	1.6	2	2.5	3.2	4.0	5.0	6.3	8.0	10

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2.16 For a voltage ratio, we have

$$N_{dB} = 30 = 20 \log(V_2/V_1)$$
$$V_2/V_1 = 10^{30/20} = 10^{1.5} = 31.6$$

2.17 Power (dBW) = 10 log (Power/1W) = 10 log20 = 13 dBW

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Chapter 3 Communication Networks

ANSWERS TO QUESTIONS

3.1 Wide area networks (WANs) are used to connect stations over very large areas that may even be worldwide while local area networks (LANs) connect stations within a single building or cluster of buildings. Ordinarily, the network assets supporting a LAN belong to the organization using the LAN. For WANs, network assets of service providers are often used. LANs also generally support higher data rates than WANs.

3.2 It is advantageous to have more than one possible path through a network for each pair of stations to enhance reliability in case a particular path fails.

3.3 Telephone communications.

3.4 Static routing involves the use of a predefined route between any two end points, with possible backup routes to handle overflow. In alternate routing, multiple routes are defined between two end points and the choice can depend on time of day and traffic conditions.

3.5 This is a connection to another user set up by prior arrangement, and not requiring a call establishment protocol. It is equivalent to a leased line.

3.6 In the **datagram** approach, each packet is treated independently, with no reference to packets that have gone before. In the **virtual circuit** approach, a preplanned route is established before any packets are sent. Once the route is established, all the packets between a pair of communicating parties follow this same route through the network.

3.7 It is not efficient to use a circuit switched network for data since much of the time a typical terminal-to-host data communication line will be idle. Secondly, the connections provide for transactions at a constant data rate, which limits the utility of the network in interconnecting a variety of host computers and terminals.

3.8 If the video is having errors, there may be a high packet loss rate. If the video is pausing frequently for more buffering, the average data rate may be too low.

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ANSWERS TO PROBLEMS

3.1 a. Circuit Switching

Total= $C_1 + C_2 + C_3$ where

C_1 = Call Setup Time

C_2 = Message Delivery Time

C_3 = Call Teardown Time

C_1 = S = 0.2

C_2 = Propagation Delay + Transmission Time

= $N \times D + L/B$

= $4 \times 0.001 + 3000/9600 = 0.3165$

C_3 = T = 0.02

Total= 0.2 + 0.3165 + 0.02 = 0.5365 sec

Datagram Packet Switching

There are P – H = 1080 – 80 = 1000 data bits per packet. A message of 3000 bits requires three packets (3000 bits/1000 bits/packet = 3 packets).

Total= $D_1 + D_2 + D_3 + D_4$ where

D_1 = Time to Transmit and Deliver all packets through first hop

D_2 = Time to Deliver last packet across second hop

D_3 = Time to Deliver last packet across third hop

D_4 = Time to Deliver last packet across fourth hop

D_1 = $3 \times t + p$ where

t = transmission time for one packet

p = propagation delay for one hop

D_1 = $3 \times (P/B) + D$

= $3 \times (1080/9600) + 0.001$

= 0.3385

D_2 = $D_3 = D_4 = t + p$

= $(P/B) + D$

= $(1080/9600) + 0.001 = 0.1135$

T = 0.3385 + 0.1135 + 0.1135 + 0.1135

= 0.6790 sec

Virtual Circuit Packet Switching

T = $V_1 + V_2 + V_3$ where

V_1 = Call Setup Time

V_2 = Datagram Packet Switching Time

V_3 = Call Teardown Time

T = S + 0.6790 +T = 0.2 + 0.6790 + 0.02 = 0.8990 sec

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b. Circuit Switching vs. Diagram Packet Switching

T_c = End-to-End Delay, Circuit Switching

T_c = $S + N \times D + L/B + T$

T_d = End-to-End Delay, Datagram Packet Switching

N_p = Number of packets = $\left\lceil \frac{L}{P - H} \right\rceil$

T_d = $D_1 + (N - 1)D_2$

D_1 = Time to transmit and send all other packets from first hop

D_2 = Time to deliver last packet through N hops

D_1 = $(N_p - 1)(P/B)$

D_2 = $(P/B + D) \times N$

T_d = $(N_p - 1 + N)(P/B) + N \times D$

T_c = T_d

$S + L/B = (N_p + N - 1)(P/B)$

Circuit Switching vs. Virtual Circuit Packet Switching

T_V = End-to-End Delay, Virtual Circuit Packet Switching

T_V = $S + T_d + T$

$T_C = T_V$

$L/B = (N_p + N - 1)(P/B)$

Datagram vs. Virtual Circuit Packet Switching

$T_d = T_V$

T_d = $S + T_d + T$

Can never be true with S>0 or T>0

3.2 From Problem 3.1, we have

$$T_d = (N_p + N - 1)(P/B) + N \times D$$

For maximum efficiency, we assume that $N_p = L/(P - H)$ is an integer. Also, it is assumed that D = 0. Thus

$$T_d = (L/(P - H) + N - 1)(P/B)$$

To minimize as a function of P, take the derivative:

$0 = dT_d/(dP)$

$0 = (1/B)(L/(P - H) + N - 1) - (P/B)L/(P - H)^2$

$0 = L(P - H) + (N - 1)(P - H)^2 - LP$

$0 = -LH + (N - 1)(P - H)^2$

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$(P - H)^2 = LH/(N - 1)$

$P = H + \sqrt{\frac{LH}{N - 1}}$

3.3 From above, we have

$T_d = (N_p + N - 1)(P/B) + N \times D$

$T_c = S + N \times D + L/B + T$

$T_d < T_c$

$S + N \times D + L/B + T < (N_p + N - 1)(P/B) + N \times D$

$S + L/B + T < (N_p + N - 1)(P/B)$

$0.6825 < 0.1125*(2+N)$

$N > 4.067$

Since N is an integer and is greater than 4.067, $N \geq 5$.

3.4 Total times for datagram switching and virtual circuit switching now become

$T_{Dat} = T_D$ = processing time for datagram switching

T_{VC} = processing time for datagram switching

$T_d = (N_p + N - 1)(P/B + T_{Dat}) + N \times D$

$T_V = S + (N_p + N - 1)(P/B + T_{VC}) + N \times D + T$

$T_V < T_d$

$S + (N_p + N - 1)(P/B + T_{VC}) + N \times D + T < (N_p + N - 1)(P/B + T_{Dat}) + N \times D$

$S + (N_p + N - 1)(P/B + T_{VC}) + T < (N_p + N - 1)(P/B + T_{Dat})$

$0.2 + (3 + 4 - 1)(1080/9600 + 0.0035) + 0.02 < (3 + 4 - 1)(1080/9600 + T_{Dat})$

$0.916 < 6(0.1125 + T_{Dat})$

$T_{Dat} > 0.04017$ s

3.5 For what range numbers of packets would the end-to-end delay to transfer all of the packets be less for virtual circuit switching than the datagram approach?

Say X is the number of packets.

For virtual circuit switching, end-to-end delay is

$T_V = S + (X + N - 1)(P/B + T_{VC}) + N \times D + T$

For datagram switching it is

$T_d = (X + N - 1)(P/B + T_{Dat}) + N \times D$

For virtual circuit switching to take less time

$S + (X + N - 1)(P/B + T_{VC}) + N \times D + T < (X + N - 1)(P/B + T_{Dat}) + N \times D$

$S + (X + N - 1)(P/B + T_{VC}) + T < (X + N - 1)(P/B + T_{Dat})$

$0.2 + (1080/9600 + 0.003)(X+3) + 0.02 < (1080/9600 + 0.0145)(X + 3)$

$0.22 < (0.0115)(X + 3)$

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$X > 16.13$
Virtual circuit switching is better for 17 or more packets

For what range of sizes of the total message length does this correspond?

Note the following reordering and simplification of terms from above.

$S + (X + N - 1)(P/B + T_{VC}) + N \times D + T < (X + N - 1)(P/B + T_{Dat}) + N \times D$

$S + (X + N - 1)(P/B) + (X + N - 1)(T_{VC}) + N \times D + T$
$< (X + N - 1)(P/B) + (X + N - 1)(T_{Dat}) + N \times D$

$S + (X + N - 1)(T_{VC}) + T < (X + N - 1)(T_{Dat})$

$S + T < (X + N - 1)(T_{Dat} - T_{VC})$

$0.22 < (0.0115)(X + 3)$

$X > 16.13$

Transmission times (P/B) are the same for both approaches, so the terms cancel.

If we have a smaller packet size P_{last} for the 17th and last packet. The inequality becomes:

$S + (X - 1)(P/B) + (N)(P_{last}/B) + (X + N - 1)(T_{VC}) + N \times D + T$
$< (X - 1)(P/B) + (N)(P_{last}/B) + (X + N - 1)(T_{Dat}) + N \times D$

Again the P/B and P_{last}/B terms cancel and the dependence is only on the number of packets as above.

$S + (X + N - 1)(T_{VC}) + T < (X + N - 1)(T_{Dat})$

$X > 16.13$

Any message length which requires 17 packets makes the inequality favor virtual circuit switching. Hence, a message length of $16 \times (P - H)+1 = 16001$ bits creates 17 packets.

Answer: Message length $L \geq 16001$ bits

3.6 Each telephone makes 0.5 calls/hour at 6 minutes each. Thus a telephone occupies a circuit for 3 minutes per hour. Twenty telephones can share a circuit (although this 100% utilization implies long queuing delays). Since 10% of the calls are long distance, it takes 200 telephones to occupy a long distance (4 kHz) channel full time. The interoffice trunk has $10^6/(4 \times 10^3) = 250$ channels. With 200 telephones per channel, an end office can support $200 \times 250 = 50{,}000$ telephones.

3.7 The argument ignores the overhead of the initial circuit setup and the circuit teardown.

3.8 Yes. A large noise burst could create an undetected error in the packet. If such an error occurs and alters a destination address field or virtual circuit identifier field, the packet would be misdelivered.

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3.9 The number of hops is one less than the number of nodes visited.

- **a.** The fixed number of hops is 2.
- **b.** The furthest distance from a station is halfway around the loop. On average, a station will send data half this distance. For an N-node network, the average number of hops is (N/4) – 1.
- **c.** 1.

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