Chapter 11

Data Networks

11.1 Problems

Problem 11.1 (Asynchronous byte transmission) *A 1 MB data file must be transmitted to another computer using asynchronous data transmission described in Example 15.2. How many bits are transmitted over the channel?*

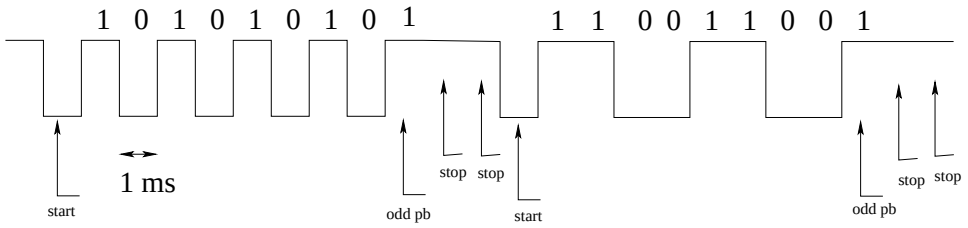
(ans: Each byte is enclosed within a character that includes a start byte, a parity bit, and at least one stop bit. Using one stop bit, each character contains 11 bits per 8-bit byte. Hence, with 1 MB equally 8×2^{20} *bits, the total number of bits equals*

$$(8+3) \times 2^{20} = 11 \; Mb$$

)

Problem 11.2 (Asynchronous data characters) *Construct two serial data characters to transmit bytes* 10101010 *and* 11001100*. Assume each character is transmitted in a separate character waveforms each using a start bit, odd parity, and two stop bits. Sketch the two character waveforms of the data and label the character elements. Assume a transmission rate of 1,000 baud (bps), the idle channel level is 5V, and a logic 1 is 5V and logic 0 is 0V.*

(ans:



)

Problem 11.3 (Probing the Internet with Tracert) *This problem asks you to estimate the speed of data transmission over the Internet from data produced by tracert.*

1. *Find four web addresses, each one from a different continent. University web pages are good addresses to use for this problem.*
2. *Find a distance calculator on the web that determines the distance (in km) from your present location to the city hosting the Web address.*
3. *Tracert reports three round-trip travel times to each node on the way to the destination. Use the minimum of these three values for only the destination as the time that the data packet took to travel the round trip distance between your location and the destination.*
4. *Compute the data travel speed by dividing the round-trip distance by the round-trip travel time.*
5. *Compare your results to the speed of light c.*

(ans:
From Yale (New Haven CT) to MIT (Cambridge MA):

```
tracert www.mit.edu >foo.txt

Tracing route to e7086.b.akamaiedge.net [23.45.38.151] over a maximum of 30 hops:
  1     2 ms    <1 ms    <1 ms  anger.net.yale.edu [130.132.20.1]
  2    <1 ms    <1 ms    <1 ms  10.1.2.113
  3     1 ms     1 ms     1 ms  comcast-asr.net.yale.internal [10.1.4.10]
  4     9 ms    10 ms     7 ms  ge-0-3-0-0-3625-sur01.westhaven.ct.hartford.comcast.net [107.1.76.205]
  5    10 ms     7 ms     7 ms  te-0-5-0-6-ar01.chartford.ct.hartford.comcast.net [68.85.106.221]
  6     7 ms     7 ms     7 ms  pos-1-5-0-0-ar01.needham.ma.boston.comcast.net [68.85.162.73]
  7    10 ms    11 ms    11 ms  he-2-5-0-0-cr01.newyork.ny.ibone.comcast.net [68.86.94.201]
  8     8 ms     8 ms     8 ms  68.86.85.190
  9     9 ms    12 ms     8 ms  as20940-3-c.111eighthave.ny.ibone.comcast.net [75.149.231.86]
 10     9 ms     9 ms     9 ms  a23-45-38-151.deploy.static.akamaitechnologies.com [23.45.38.151]
Trace complete.
```

From Yale (New Haven CT) to Oxford (Cambridge, UK):

```
tracert www.oxford.ac.uk >foo.txt

Tracing route to www.oxford.ac.uk [163.1.0.90]
over a maximum of 30 hops:
  1    <1 ms    <1 ms    <1 ms  anger.net.yale.edu [130.132.20.1]
  2    <1 ms    <1 ms    <1 ms  10.1.2.113
  3     1 ms    <1 ms    <1 ms  att-asr.net.yale.internal [10.1.4.6]
  4     1 ms     1 ms     1 ms  10.1.3.102
  5     *        *        *     Request timed out.
  6     5 ms     5 ms     5 ms  enrt043h-te-0-3-0-3-dwdm-1533-46.net.cen.ct.gov [67.218.83.254]
  7     5 ms     5 ms     5 ms  enrt043c-bundle-ether10.net.cen.ct.gov [67.218.83.2]
  8     5 ms     5 ms     5 ms  enrt078c-9k-bundle-ether20.net.cen.ct.gov [67.218.83.6]
  9     5 ms     5 ms     4 ms  nox300gw1-peer-nox-yale-207-210-143-90.nox.org [207.210.143.90]
 10     5 ms     5 ms     5 ms  nox300gw1-vl-706-nox-yale.nox.org [207.210.143.89]
 11     9 ms     9 ms     9 ms  nox300gw1-peer-nox-internet2-192-5-89-222.nox.org [192.5.89.222]
 12    84 ms    84 ms    84 ms  198.71.45.237
 13    96 ms    96 ms    96 ms  ae3.mx1.ams.nl.geant.net [62.40.98.115]
 14    92 ms    92 ms    91 ms  ae2.mx1.lon.uk.geant.net [62.40.98.80]
 15   108 ms    91 ms    92 ms  janet-gw.mx1.lon.uk.geant.net [62.40.124.198]
 16    92 ms    92 ms   125 ms  ae29.londpg-sbr1.ja.net [146.97.33.2]
 17    93 ms    93 ms    93 ms  ae21.read-rbr3.ja.net [146.97.37.206]
 18    93 ms    93 ms    93 ms  ae1.read-rbr2.ja.net [193.63.108.129]
 19   106 ms   106 ms   106 ms  ae2.oxfo-rbr2.ja.net [193.63.108.134]
 20    94 ms    94 ms    94 ms  Oxford-University-1.ja.net [193.63.109.110]
 21    94 ms    94 ms    94 ms  coucs2b.backbone.ox.ac.uk [192.76.21.2]
 22    94 ms   106 ms    94 ms  www.oxford.ox.ac.uk [163.1.0.90]
Trace complete
```

From Yale (New Haven CT) to University of Tokyo (Tokyo, Japan):

```
tracert www.u-tokyo.ac.jp >foo.txt

Tracing route to www.u-tokyo.ac.jp [59.106.161.27]
over a maximum of 30 hops:
  1    <1 ms    <1 ms    <1 ms  anger.net.yale.edu [130.132.20.1]
  2    <1 ms    <1 ms    <1 ms  10.1.2.113
  3     1 ms    <1 ms     1 ms  att-asr.net.yale.internal [10.1.4.6]
  4     1 ms     1 ms     1 ms  12.249.64.89
  5     5 ms     6 ms     7 ms  cr81.chsct.ip.att.net [12.122.105.66]
```

```
  6     6 ms     7 ms     7 ms  cr2.n54ny.ip.att.net [12.122.156.18]
  7     6 ms     7 ms     7 ms  igs3.n54ny.ip.att.net [12.122.115.89]
  8     4 ms     4 ms     5 ms  ae-15.r05.nycmny01.us.bb.gin.ntt.net [129.250.9.205]
  9     4 ms    21 ms     4 ms  ae-1.r22.nycmny01.us.bb.gin.ntt.net [129.250.4.172]
 10    83 ms    80 ms    82 ms  ae-4.r21.sttlwa01.us.bb.gin.ntt.net [129.250.2.51]
 11   188 ms   208 ms   216 ms  ae-2.r22.sttlwa01.us.bb.gin.ntt.net [129.250.6.142]
 12   172 ms   173 ms   171 ms  ae-7.r21.osakjp02.jp.bb.gin.ntt.net [129.250.3.86]
 13   187 ms   175 ms   172 ms  ae-5.r22.osakjp02.jp.bb.gin.ntt.net [129.250.6.192]
 14   169 ms   171 ms   169 ms  ae-7.r25.tokyjp05.jp.bb.gin.ntt.net [129.250.3.223]
 15   181 ms   169 ms   169 ms  ae-4.a21.tokyjp01.jp.ra.gin.ntt.net [61.213.162.166]
 16   178 ms   193 ms   180 ms  xe-4-0-3.a21.tokyjp01.jp.ra.gin.ntt.net [61.120.145.170]
 17     *        *        *     Request timed out.
 18     *        *        *     Request timed out.
 19     *        *        *     Request timed out.
 20   183 ms   183 ms   185 ms  59.106.85.27
 21   173 ms   173 ms   173 ms  IP-59-106-161-2.adm.u-tokyo.ac.jp [59.106.161.2]
 22   181 ms   190 ms   181 ms  59.106.161.27
Trace complete.
```

From Yale (New Haven CT) to University of South Africa (Pretoria, South Africa): (Node 18 is "za" in South Africa, so we use its values.)

```
tracert www.unisa.ac.za >foo.txt

Tracing route to www.unisa.ac.za [163.200.81.116]
over a maximum of 30 hops:
  1    <1 ms     1 ms    <1 ms  anger.net.yale.edu [130.132.20.1]
  2    <1 ms    <1 ms    <1 ms  10.1.1.113
  3     1 ms    <1 ms    <1 ms  qwest-asr.net.yale.internal [10.1.4.5]
  4     1 ms     1 ms     1 ms  10.1.3.102
  5     *        *        *     Request timed out.
  6     5 ms     5 ms     5 ms  enrt043h-te-0-3-0-3-dwdm-1533-46.net.cen.ct.gov [67.218.83.254]
  7     5 ms     5 ms     5 ms  enrt043c-bundle-ether10.net.cen.ct.gov [67.218.83.2]
  8     5 ms     5 ms     5 ms  enrt078c-9k-bundle-ether20.net.cen.ct.gov [67.218.83.6]
  9     5 ms     4 ms     4 ms  nox300gw1-peer-nox-yale-207-210-143-90.nox.org [207.210.143.90]
 10     5 ms     5 ms     5 ms  nox300gw1-vl-706-nox-yale.nox.org [207.210.143.89]
 11     9 ms     9 ms     9 ms  nox300gw1-peer-nox-internet2-192-5-89-222.nox.org [192.5.89.222]
 12   108 ms   108 ms   108 ms  198.71.45.237
 13   109 ms   118 ms   109 ms  ae3.mx1.ams.nl.geant.net [62.40.98.115]
 14    96 ms    96 ms    96 ms  ubuntunet-gw.mx1.ams.nl.geant.net [62.40.125.22]
 15   301 ms   300 ms   301 ms  te-1-4-2018-mtz1-pe1.ubuntunet.net [196.32.209.117]
 16   310 ms   305 ms   309 ms  mtz1pe1-x001-700-mtzub1-vl700.net.tenet.ac.za.6.232.155.in-addr.arpa [155.232.6.86]
 17   318 ms   317 ms   320 ms  unknown.uni.net.za [155.232.6.29]
 18   327 ms   327 ms   327 ms  pta1pe1-t94-pta1p1-t01200.net.tenet.ac.za [155.232.6.138]
 19     *        *        *     Request timed out.
 20     *        *        *     Request timed out.
 21     *        *        *     Request timed out.
 22     *        *        *     Request timed out.
 23     *        *        *     Request timed out.
 24     *        *        *     Request timed out.
 25     *        *        *     Request timed out.
 26     *        *        *     Request timed out.
 27     *        *        *     Request timed out.
 28     *        *        *     Request timed out.
 29     *        *        *     Request timed out.
 30     *        *        *     Request timed out.
Trace complete.
```

Distance was found using distance calculator, such as `www.infoplease.com`*. Speed of light is* $c = 3 \times 10^8$ *m/s.*

Destination	*D from Yale*	T_{min}	*Data speed* ($c_d = 2D/T_{min}$)	c_d/c
MIT	*139 km*	*9 ms*	3.1×10^7 *m/s*	*0.10*
Oxford	*5,465 km*	*94 ms*	1.2×10^8 *m/s*	*0.40*
U. of Tokyo	*10,852 km*	*181 ms*	1.2×10^8 *m/s*	*0.40*
U. of South Africa	*12,813 km*	*327 ms*	7.8×10^7 *m/s*	*0.26*

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Problem 11.4 (Maximum delay for a wired-line telephone call) *Assume an electrical signal travels along a wire at the speed of light. What is the minimum travel delay that occurs for a telephone waveform from NYC to LA (distance = 4,000 km)? What is the minimum delay between any two cities on Earth assuming signals travel along the Earth's surface?*

(ans: From NYC to LA

$$t_d = \frac{D}{c} = \frac{4 \times 10^6 \; m}{300 \times 10^6 \; m/s} = 0.0133 \; s = 13.3 \; ms$$

In a telephone conversation the round-trip delay is relevant:

$$t_{rt} = 2t_d = 26.6 \; ms$$

The circumference of the Earth is 40×10^6 *m. Hence, distance between any two cities* $d < 20 \times 10^6$ *m.*

$$t_{min} = \frac{d}{c} = \frac{20 \times 10^6 \; m}{300 \times 10^6 \; m/s} = 0.0667 \; s = 66.7 \; ms$$

In a telephone conversation the round-trip delay is relevant:

$$t_{rt} = 2t_{min} = 133.3 \; ms$$

)

Problem 11.5 (Delay for a geostationary satellite telephone call) *Assume an electrical signal travels along a wire at the speed of light. What is the minimum travel delay that occurs for a telephone waveform travelling to and from a geostationary satellite that is orbiting at an altitude of 36,000 km?*

(ans: Round-trip from earth to satellite

$$t_d = \frac{2D}{c} = \frac{2 \times 36 \times 10^6 \; m}{300 \times 10^6 \; m/s} = 0.240 \; s = 240 \; ms$$

In a telephone conversation the round-trip delay is relevant:

$$t_{rt} = 2t_d = 480 \; ms$$

This large delay made satellite telephone conversations difficult.
)

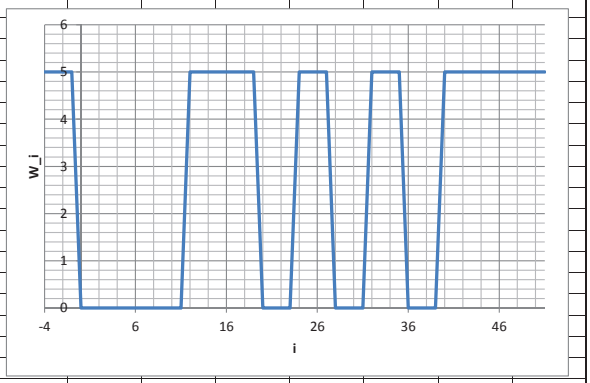
11.2 Excel Projects

Project 11.1 (Asynchronous data packet character design) *Let sampling period $T_s = T_b/4$. Design the data packet that transmit the ASCII number 5. Show T_b idle channel before and after packet. The packet contains a start bit, 8 data bits, 1 even parity bit, and 2 stop bits.*

(ans:

	A	B	C	D	E	F	G	H	I	J	K
1	i	Wi									
2	-4	5	idle								
3	-3	5									
4	-2	5									
5	-1	5									
6	0	0	start								
7	1	0									
8	2	0									
9	3	0									
10	4	0	0								
11	5	0									
12	6	0									
13	7	0									
14	8	0	0								
15	9	0									
16	10	0									
17	11	0									
18	12	5	1								
19	13	5									
20	14	5									
21	15	5									
22	16	5	1								
23	17	5									
24	18	5									
25	19	5									
26	20	0	0								
27	21	0									
28	22	0									
29	23	0									
30	24	5	1								
31	25	5									
32	26	5									
33	27	5									
34	28	0	0								
35	29	0									
36	30	0									
37	31	0									
38	32	5	1								
39	33	5									
40	34	5									
41	35	5									
42	36	0	EPB=0								
43	37	0									
44	38	0									
45	39	0									
46	40	5	Stop 1								
47	41	5									
48	42	5									
49	43	5									
50	44	5	Stop 2								
51	45	5									
52	46	5									
53	47	5									
54	48	5	idle								
55	49	5									
56	50	5									
57	51	5									

Total T_b = 14 (idle, start, 8 bits, pb, 2 stop, idle). $T_{i=4Tb}$ from -4 to 13*4 -1 = 51. Idle channel = 5V. Data "1" = 5V. ASCII 5 = h35 = b0011 0101. Even parity bit = 0.



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Project 11.2 (Data packet collision simulation) *Using Example 13.55 as a guide determine the Prob[error] for $T_p = 1$ ms containing a 10-bit packet with data interval equal to $T_d = 10$ ms and time resolution of 0.5 ms for three users.*

(ans:

	A	B	C	D	E	F	G	H	I	J
1	P1 start=	3.40								
2	P1 end=	4.40			duration (ms)=	1				
3	P2 start=	2.90			P1/P2 collision?	1				
4	P2 end=	3.90			P1/P3 collision?	0				
5	P3 start=	8.90			P2/P3 collision?	0				
6	P3 end =	9.90								
7										
8	**time (ms)**	**P1**	**P2**	**P3**	**P1 * P2**	**P1 * P3**	**P2 * P3**		transmits=	330
9	0.0	0	0	0	0	0	0		collisions=	46
10	0.5	0	0	0	0	0	0		collsion prob=	0.14
11	1.0	0	0	0	0	0	0		total data transmitted=	2840
12	1.5	0	0	0	0	0	0		data/transmit=	8.61
13	2.0	0	0	0	0	0	0			
14	2.5	0	0	0	0	0	0			
15	3.0	0	1	0	0	0	0		Transmit	
16	3.5	1	1	0	1	0	0			
17	4.0	1	0	0	0	0	0			
18	4.5	0	0	0	0	0	0			
19	5.0	0	0	0	0	0	0			
20	5.5	0	0	0	0	0	0			
21	6.0	0	0	0	0	0	0			
22	6.5	0	0	0	0	0	0			
23	7.0	0	0	0	0	0	0			
24	7.5	0	0	0	0	0	0		RESET	
25	8.0	0	0	0	0	0	0			
26	8.5	0	0	0	0	0	0			
27	9.0	0	0	1	0	0	0			
28	9.5	0	0	1	0	0	0			
29	10.0	0	0	0	0	0	0			

	A	B	C	D	E	F	G	H	I	J
1	P1 start=	=FLOOR(10*(10-$F$2)*RAND(),1)/10								
2	P1 end=	=B1+F2			duration (ms)=	1				
3	P2 start=	=FLOOR(10*(10-$F$2)*RAND(),1)/10			P1/P2 collision?	=IF(SUM(E9:E29)>0,1,0)				
4	P2 end=	=B3+F2			P1/P3 collision?	=IF(SUM(F9:F29)>0,1,0)				
5	P3 start=	=FLOOR(10*(10-$F$2)*RAND(),1)/10			P2/P3 collision?	=IF(SUM(G9:G29)>0,1,0)				
6	P3 end =	=B5+F2								
7										
8	time (ms)	P1	P2	P3	P1 * P2	P1 * P3	P2 * P3		transmits=	330
9	0	=IF(AND(A9>=$B$1,A9<$B$2),1,0)	=IF(AND(A9>=$B$3,A9<$B$4),1,0)	=IF(AND(A9>=$B$5,A9<$B$6),1,0)	=B9*C9	=B9*D9	=C9*D9		collisions=	46
10	=A9+0.5	=IF(AND(A10>=$B$1,A10<$B$2),1,0)	=IF(AND(A10>=$B$3,A10<$B$4),1,0)	=IF(AND(A10>=$B$5,A10<$B$6),1,0)	=B10*C10	=B10*D10	=C10*D10		collsion prob=	=IF(J8>0, J9/J8,0)
11	=A10+0.5	=IF(AND(A11>=$B$1,A11<$B$2),1,0)	=IF(AND(A11>=$B$3,A11<$B$4),1,0)	=IF(AND(A11>=$B$5,A11<$B$6),1,0)	=B11*C11	=B11*D11	=C11*D11		total data transmitted=	2840
12	=A11+0.5	=IF(AND(A12>=$B$1,A12<$B$2),1,0)	=IF(AND(A12>=$B$3,A12<$B$4),1,0)	=IF(AND(A12>=$B$5,A12<$B$6),1,0)	=B12*C12	=B12*D12	=C12*D12		data/transmit=	=IF(J8>0,J11/J8,0)
13	=A12+0.5	=IF(AND(A13>=$B$1,A13<$B$2),1,0)	=IF(AND(A13>=$B$3,A13<$B$4),1,0)	=IF(AND(A13>=$B$5,A13<$B$6),1,0)	=B13*C13	=B13*D13	=C13*D13			
14	=A13+0.5	=IF(AND(A14>=$B$1,A14<$B$2),1,0)	=IF(AND(A14>=$B$3,A14<$B$4),1,0)	=IF(AND(A14>=$B$5,A14<$B$6),1,0)	=B14*C14	=B14*D14	=C14*D14			
15	=A14+0.5	=IF(AND(A15>=$B$1,A15<$B$2),1,0)	=IF(AND(A15>=$B$3,A15<$B$4),1,0)	=IF(AND(A15>=$B$5,A15<$B$6),1,0)	=B15*C15	=B15*D15	=C15*D15		Transmit	
16	=A15+0.5	=IF(AND(A16>=$B$1,A16<$B$2),1,0)	=IF(AND(A16>=$B$3,A16<$B$4),1,0)	=IF(AND(A16>=$B$5,A16<$B$6),1,0)	=B16*C16	=B16*D16	=C16*D16			
17	=A16+0.5	=IF(AND(A17>=$B$1,A17<$B$2),1,0)	=IF(AND(A17>=$B$3,A17<$B$4),1,0)	=IF(AND(A17>=$B$5,A17<$B$6),1,0)	=B17*C17	=B17*D17	=C17*D17			
18	=A17+0.5	=IF(AND(A18>=$B$1,A18<$B$2),1,0)	=IF(AND(A18>=$B$3,A18<$B$4),1,0)	=IF(AND(A18>=$B$5,A18<$B$6),1,0)	=B18*C18	=B18*D18	=C18*D18			
19	=A18+0.5	=IF(AND(A19>=$B$1,A19<$B$2),1,0)	=IF(AND(A19>=$B$3,A19<$B$4),1,0)	=IF(AND(A19>=$B$5,A19<$B$6),1,0)	=B19*C19	=B19*D19	=C19*D19			
20	=A19+0.5	=IF(AND(A20>=$B$1,A20<$B$2),1,0)	=IF(AND(A20>=$B$3,A20<$B$4),1,0)	=IF(AND(A20>=$B$5,A20<$B$6),1,0)	=B20*C20	=B20*D20	=C20*D20			
21	=A20+0.5	=IF(AND(A21>=$B$1,A21<$B$2),1,0)	=IF(AND(A21>=$B$3,A21<$B$4),1,0)	=IF(AND(A21>=$B$5,A21<$B$6),1,0)	=B21*C21	=B21*D21	=C21*D21			
22	=A21+0.5	=IF(AND(A22>=$B$1,A22<$B$2),1,0)	=IF(AND(A22>=$B$3,A22<$B$4),1,0)	=IF(AND(A22>=$B$5,A22<$B$6),1,0)	=B22*C22	=B22*D22	=C22*D22			
23	=A22+0.5	=IF(AND(A23>=$B$1,A23<$B$2),1,0)	=IF(AND(A23>=$B$3,A23<$B$4),1,0)	=IF(AND(A23>=$B$5,A23<$B$6),1,0)	=B23*C23	=B23*D23	=C23*D23			
24	=A23+0.5	=IF(AND(A24>=$B$1,A24<$B$2),1,0)	=IF(AND(A24>=$B$3,A24<$B$4),1,0)	=IF(AND(A24>=$B$5,A24<$B$6),1,0)	=B24*C24	=B24*D24	=C24*D24		RESET	
25	=A24+0.5	=IF(AND(A25>=$B$1,A25<$B$2),1,0)	=IF(AND(A25>=$B$3,A25<$B$4),1,0)	=IF(AND(A25>=$B$5,A25<$B$6),1,0)	=B25*C25	=B25*D25	=C25*D25			
26	=A25+0.5	=IF(AND(A26>=$B$1,A26<$B$2),1,0)	=IF(AND(A26>=$B$3,A26<$B$4),1,0)	=IF(AND(A26>=$B$5,A26<$B$6),1,0)	=B26*C26	=B26*D26	=C26*D26			
27	=A26+0.5	=IF(AND(A27>=$B$1,A27<$B$2),1,0)	=IF(AND(A27>=$B$3,A27<$B$4),1,0)	=IF(AND(A27>=$B$5,A27<$B$6),1,0)	=B27*C27	=B27*D27	=C27*D27			
28	=A27+0.5	=IF(AND(A28>=$B$1,A28<$B$2),1,0)	=IF(AND(A28>=$B$3,A28<$B$4),1,0)	=IF(AND(A28>=$B$5,A28<$B$6),1,0)	=B28*C28	=B28*D28	=C28*D28			
29	=A28+0.5	=IF(AND(A29>=$B$1,A29<$B$2),1,0)	=IF(AND(A29>=$B$3,A29<$B$4),1,0)	=IF(AND(A29>=$B$5,A29<$B$6),1,0)	=B29*C29	=B29*D29	=C29*D29			

The statement in `B1`

```
=FLOOR(10*(10-$F$2)*RAND(),1)/10
```

computes the random start time for a packet that is contained within the packet interval. Similarly for start times in `B3` *and* `B5`.

The VBA code follows.

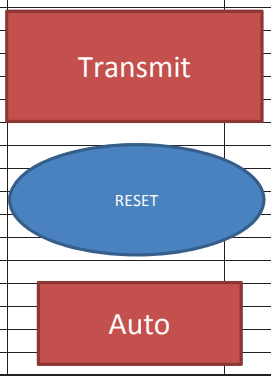
```
Sub transmit()
Dim P1P2 As Integer
Dim P1P3 As Integer
Dim P2P3 As Integer
' store collision values so that writes do not change values
P1P2 = Range("F3").Value
P1P3 = Range("F4").Value
P2P3 = Range("F5").Value

If P1P2 = 1 Then   ' P1 P2 collision
    Range("J9").Value = Range("J9").Value + 1 ' increment collision count
Else
    Range("J11").Value = Range("J11").Value + 10 ' data transmitted
End If
If P1P3 = 1 Then   ' P1 P3 collision
    Range("J9").Value = Range("J9").Value + 1 ' increment collision count
Else
    Range("J11").Value = Range("J11").Value + 10 ' data transmitted
End If
If P2P3 = 1 Then   ' P2 P3 collision
    Range("J9").Value = Range("J9").Value + 1 ' increment collision count
Else
    Range("J11").Value = Range("J11").Value + 10 ' data transmitted
End If
Range("J8").Value = Range("J8").Value + 3 ' increment xmits and gen new P's
End Sub
'--
Sub reset()
Range("J8").Value = 0
Range("J9").Value = 0
Range("J11").Value = 0
End Sub
```

)

Project 11.3 (Data throughput simulation) *Using Example 13.55 as a guide determine the packet duration in Problem 11.2 assuming 10-bit/ms data packets that provides the maximum data throughput.*

(ans: The formulas are the same as in Problem 11.2.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	P1 start=	0.20										duration (ms)	Throughtput (bps)
2	P1 end=	5.70			duration (ms)=	5.5							
3	P2 start=	0.60			P1/P2 collision?	1						0.5	47
4	P2 end=	6.10			P1/P3 collision?	1						1	84
5	P3 start=	1.60			P2/P3 collision?	1						1.5	103
6	P3 end =	7.10										2	125
7												2.5	127
8	**time (ms)**	**P1**	**P2**	**P3**	**P1 * P2**	**P1 * P3**	**P2 * P3**		transmits=	1002		3	102
9	0.0	0	0	0	0	0	0		collisions=	1000		3.5	86
10	0.5	1	0	0	0	0	0		collsion prob=	1.00		4	49
11	1.0	1	1	0	1	0	0		total data transmitted=	100		4.5	24
12	1.5	1	1	0	1	0	0		data/transmit=	0.10		5	1
13	2.0	1	1	1	1	1	1						
14	2.5	1	1	1	1	1	1						
15	3.0	1	1	1	1	1	1						
16	3.5	1	1	1	1	1	1						
17	4.0	1	1	1	1	1	1						
18	4.5	1	1	1	1	1	1						
19	5.0	1	1	1	1	1	1						
20	5.5	1	1	1	1	1	1						
21	6.0	0	1	1	0	0	1						
22	6.5	0	0	1	0	0	0						
23	7.0	0	0	1	0	0	0						
24	7.5	0	0	0	0	0	0						
25	8.0	0	0	0	0	0	0						
26	8.5	0	0	0	0	0	0						
27	9.0	0	0	0	0	0	0						
28	9.5	0	0	0	0	0	0						
29	10.0	0	0	0	0	0	0						



The VBA code changes the number of bits/packet to maintain the 10b/ms packet density.

```
Sub transmit()
Dim P1P2 As Integer
Dim P1P3 As Integer
Dim P2P3 As Integer
' store collision values so that writes do not change values
P1P2 = Range("F3").Value
P1P3 = Range("F4").Value
P2P3 = Range("F5").Value
If P1P2 = 1 Then   ' P1 P2 collision
    Range("J9").Value = Range("J9").Value + 1 ' increment collision count
Else
    Range("J11").Value = Range("J11").Value + 10 * Range("F2").Value ' data transmitted
End If
If P1P3 = 1 Then   ' P1 P3 collision
    Range("J9").Value = Range("J9").Value + 1 ' increment collision count
Else
    Range("J11").Value = Range("J11").Value + 10 * Range("F2").Value ' data transmitted
End If
If P2P3 = 1 Then   ' P2 P3 collision
    Range("J9").Value = Range("J9").Value + 1 ' increment collision count
Else
    Range("J11").Value = Range("J11").Value + 10 * Range("F2").Value ' data transmitted
End If
Range("J8").Value = Range("J8").Value + 3 ' increment xmits and gen new P's
End Sub
'---
Sub reset()
Range("J8").Value = 0
Range("J9").Value = 0
Range("J11").Value = 0
End Sub
'---
Sub auto()
Dim Row As Integer
Range("F2").Value = 0.5 ' initial duration
Row = 3 ' starting row of table
Do While Range("F2").Value <= 10 / 2 ' half duration
    Range("L" & Row).Value = Range("F2").Value
    reset
    Do While Range("J8").Value < 1000 ' 1000 transmits for each duration
        transmit
    Loop
    Range("M" & Row) = Range("J11").Value / (1000 * 0.1)
    ' total bits transmitted/total interval
    Range("F2").Value = Range("F2").Value + 0.5 ' increment duration
    Row = Row + 1
Loop
End Sub
```

)