Electrical, Computer, and Systems Engineering
ECSE 4760: Computer Communication Networks

Solutions to Question Set

1.

(a) A can choose from $\{0, 1\}$ while B chooses from $\{0, 1, 2, 3\}$. The set of possible outcomes for $\{k_A, k_B\}$ is:

$\{0, 0\}$ $\{0, 1\}$ $\{0, 2\}$ $\{0, 3\}$

$\{1, 0\}$ $\{1, 1\}$ $\{1, 2\}$ $\{1, 3\}$

A wins outright if $\{k_A, k_B\}$ is among $\{0, 1\}$, $\{0, 2\}$, $\{0, 3\}$, $\{1, 2\}$, $\{1, 3\}$. Thus the probability is 5/8.

(b) In this case, A can choose from $\{0, 1\}$ while B chooses from $\{0, 1, 2, 3i, 4, 5, 6, 7\}$. The set of possible outcomes for $\{k_A, k_B\}$ is:

$\{0, 0\}$ $\{0, 1\}$ $\{0, 2\}$ $\{0, 3\}$ $\{0, 4\}$ $\{0, 5\}$ $\{0, 6\}$ $\{0, 7\}$

$\{1, 0\}$ $\{1, 1\}$ $\{1, 2\}$ $\{1, 3\}$ $\{1, 4\}$ $\{1, 5\}$ $\{1, 6\}$ $\{1, 7\}$

A wins outright if $\{k_A, k_B\}$ is among $\{0, 1\}$, $\{0, 2\}$, $\{0, 3\}$, $\{0, 4\}$, $\{0, 5\}$, $\{0, 6\}$, $\{0, 7\}$, $\{1, 2\}$, $\{1, 3\}$, $\{1, 4\}$, $\{1, 5\}$, $\{1, 6\}$, $\{1, 7\}$. Thus the probability is 13/16.

2. The table at the end of the Dijkstra's algorithm looks like that shown in the Table on the next page. The shortest paths should come out to the same in the Distance Vector algorithm also (the table would look different of course).

3.

(a) Packet switching yiels lower delay than circuit switching.

True. Statistical multiplexing and queueing will lead to delays.

N	a	b	c	d	e	g	h
	inf	inf	inf	3,f	1,f	6,f	inf
e	inf	inf	4,e	2,e		6,f	inf
ed	inf	11,d	3,d			3,d	inf
edc	7,c	5,c				3,d	inf
edcg	7,c	5,c					17,g
edcgb	6,b						7,b
edcgba							7,b

(b) A data link later protocol would be necessary even if there were no bit errors or losses at the physical layer.

True. We still need to do medium access control.

(c) Assuming each is correctly implemented, Selective Repeat should perform better than Go Back N on a fiber optic link between JEC and VCC here at RPI (about 0.5km).

This was an open question and you could probably agrue for either. Just to get your minds thinking.

(d) If error detecting codes are implemented in hardware, then this function is a part of the physical layer.

False. The same function could be implemented either in hardware or software but that does not change the layer to which the function belongs. In practice, the CRC is actually calculated in hardware.

4. We use the M/M/1 formula here. (Note that you could also use M/G/1 with $\sigma^2 = 1/\mu^2$ for the variance of the exponential distribution.

$$\mu = \frac{C}{L} = \frac{1.5Mb/s}{1000b/p} = 1500p/s$$

$$\rho = \frac{\lambda}{\mu} = 0.67$$

1. The expected number in the system

$$E(n) = \frac{\rho}{1-\rho} = 2packets$$

From Little's formula, the expected delay

$$E(T) = \frac{E(n)}{\lambda} \approx 2.0ms$$

2.

$$\lambda = 2000p/s$$
$$\mu = \frac{C}{L} = \frac{3Mb/s}{1000b/p} = 3000p/s$$
$$\rho = \frac{\lambda}{\mu} = 0.67$$
$$E(n) = \frac{\rho}{1-\rho} = 2packets$$
$$E(T) = \frac{E(n)}{\lambda} \approx 1.0ms$$

which is the half of what it is of part 1. Intuitively these results make sense because we have speeded up the time scale of the system by a factor of 2 and so a packet now spends half as much time in the system as before. But the number of packets in the system dosent change.

5. a.

$$\begin{aligned} K &= \text{number of windows that cover the object} \\ &= \min\{k : 3^0 + 3^1 + \cdots + 3^{k-1} \geq O/S\} \\ &= \min\left\{k : \frac{1-3^k}{1-3} \geq O/S\right\} \\ &= \min\{k : 3^k \geq 1 + 2O/S\} \\ &= \lceil \log_3(1 + 2O/S) \rceil \end{aligned}$$

b. Q is the number of times the server would stall for an object of infinite size

$$\begin{aligned} Q &= \max\left\{k : RTT + \frac{S}{R} - \frac{S}{R}3^{k-1} \geq 0\right\} \\ &= \left\lfloor 1 + \log_3\left(1 + \frac{RTT}{S/R}\right)\right\rfloor \end{aligned}$$

c.

$$\begin{aligned}
\text{latency} &= \frac{O}{R} + 2RTT + \sum_{k=1}^{P} \text{stall}_k \\
&= \frac{O}{R} + 2RTT + \sum_{k=1}^{P} \left(RTT + \frac{S}{R} - \frac{S}{R} 3^{k-1} \right) \\
&= \frac{O}{R} + 2RTT + P(RTT + S/R) - \frac{(3^P - 1)}{2} \frac{S}{R}
\end{aligned}$$

6.

Rate	Persistent	Non-persistent
28 Kbps	16.2 sec	20.2 sec
100 Kbps	5.1 sec	10.6 sec
1 Mbps	1.3 sec	8.9 sec
10 Mbps	1.1 sec	8.8 sec