Problem 1  Routing Table

Solution:
The subnet mask is 11111111.11111111.11111111.10000000.
(a) 128.96.39.10, after applying the mask, it’ll be 128.96.39.0, therefore the router sends the packet
directly to nodes attached to Port 1.
(b) 128.96.40.12, after applying the mask, it’ll be 128.96.40.0, therefore the router sends the packet
to R2 through Port 1.
(c) 128.96.40.151, after applying the mask, it’ll be 128.96.40.128, therefore the router sends the packet
to R3 through Port 2.

Problem 2  The Dijkstra Algorithm

(a)

<table>
<thead>
<tr>
<th>Iteration</th>
<th>N</th>
<th>D₁</th>
<th>D₂</th>
<th>D₃</th>
<th>D₄</th>
<th>D₅</th>
<th>D₆</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial</td>
<td>{4}</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td>1</td>
<td>{2, 4}</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>∞</td>
</tr>
<tr>
<td>2</td>
<td>{2, 3, 4}</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>{2, 3, 4, 5}</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>{2, 3, 4, 5, 6}</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>{1, 2, 3, 4, 5, 6}</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

(b)

<table>
<thead>
<tr>
<th>Destination</th>
<th>Next Node</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Problem 3  TCP Sequencing

Solution:
(a) First, we look at the solution for part (a) of Problem 8.29 in Leon_Garcia.
At a transmission rate of 8 megabits per second, a single byte has a transmission time of 8 bits / 8x10^6 bits/second = 1 microsecond. A distance of 200 meters in optical fiber has a propagation time of 200 meters / 2x10^8 meters/second = 1 microsecond. Therefore a segment of 500 bytes requires 501 microseconds to arrive completely at the receiver. In the following we also assume that the send window is replenished by the receiver as soon as it receives a segment. The time scale below is in microseconds.

(b) The following is an extension from (a) to (b).
Problem 4  Oversubscription Ratio

Solution:
(a) Let \( p \) denote the probability that a subscriber is busy.
\[ r = p \times c + (1 - p) \times 0 \rightarrow p = r/c = 0.1. \]
Method 1:
Use Erlang B formula, with traffic in Erlangs $p \times N = 100$ and blocking probability 0.01. You can use the following free online Erlang B calculator to solve the number of ports needed, i.e. $n$. (
http://www.wiley.com/legacy/wileychi/commstech/norrisprog.html)

We can have $n \approx 117$. Therefore the oversubscription ratio is $N/n = 1000/117 \approx 8.547.$

**Method 2:**

The average number of busy subscribers is $Np = 1000 \times 0.1 = 100$. The graph below shows the probabilities in the vicinity of $k = 100$ using the above approximation:

By adding the probabilities up to a certain number of subscribers, say $n$, we can find the probability that the number of subscribers is less than or equal to $n$. The graph below shows the result.
Therefore the oversubscription ratio is \( N/n = 1000/122 \approx 8.197 \).

(b) Solution:

Plot the figure of oversubscription ratio in \( N \) using the following MATLAB codes:

\[
N = 1000:1E5:1E7; \\
\text{plot}(N, N./\text{norminv}(0.99, 0.1*N, \sqrt{0.09*N}));
\]

From the graph, we can see the oversubscription ratio is increasing in \( N \) and asymptotically approaches...
10. This is intuitively true since each subscriber is busy for 10% of the time, and also the independent Bernoulli trials approximates Gaussian distribution as $N \to \infty$.

**Problem 5 M/M/1 Queue**

*Solution:*

(a) In this case each session is served by an M/M/1 queue. The average service time of a packet will be $1000 \text{ bits} / 5 \text{ Kbit/sec} = 0.2$ seconds. The arrival rate is $150/60 = 2.5$ packet/sec. Thus for each session $\rho = (2.5)(.2) = .5$. Using the special case of the PK formula for a M/M/1 queue (see Lecture 12), the average waiting time in the buffer for each session is

$$W = \rho \frac{\mu(1 - \rho)}{\mu(1 - \rho)} = \frac{.5}{(1/2)(1 - .5)} = 0.2 \text{ sec}.$$  

Thus the average number of packets in the buffer from each session (by Little’s theorem) is $(0.2)(2.5) = 0.5$. Thus the total number of packets in the buffer (from every session) is $(10)(.5) = 5$. The average delay per packet in the buffer and in transmission is

$$T = W + \frac{1}{\mu} = .2 + .2 = .4$$

Thus the average number in the buffer and in transmission is $10\lambda T = 10(.4)(2.5) = 10.$

(b) In this case all packets are served by a single M/M/1 queue. The average service time of a packet will be .02 seconds and the overall arrival rate will be 25 packets/sec. Thus $\rho = (25)(.02) = 0.5$. Using the same formulas as in Part (a) we have $W = .02 \text{ sec}$, so the average number of packets in the buffer = $(.02)(25) = 5$. The average delay per packet in the buffer and in transmission is $T = .02 + .02 = .04$; and the average number in the buffer and in transmission is $(.04)(25) = 1$

Note that by combining the packets into a common buffer the average delay per packet is reduced by a factor of 10 as is the average buffer occupancy.