Fundamentals of Communication Networks

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July, 13 2016

1. **Exercise (5 pts)**:

   Two hosts A and C are connected to a host B, which acts as a relay for packets traveling from A to C. Let $P(E_{\text{AB}}) = 10^{-2}$ be the packet error rate on the link from A to B and $P(E_{\text{BC}}) = 10^{-3}$ the packet error rate on the link from B to C.

   Host B suffers from periodic malfunctionings due to over-heating: during the hottest hours of day (1PM - 6PM), host B is down 75% of the times. During the rest of the day, host B works fine.

   (a) Compute the average daily packet error rate from A to C.

   (b) Compute the packet error rate from A to C during a working day (8 AM - 6 PM)

   (c) Compute the packet error rate from A to C during the afternoon (1 PM - 6 PM)

   Solution

   Let $P(\bar{B})$ be the probability that B doesn't work, the following holds:

   $$P(\bar{B}) = \begin{cases} 0.75 & \text{if } 1\text{PM} \leq t \leq 5\text{PM} \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

   Let $P(E_{\text{AC}})$ be the packet error rate from A to C. When B works correctly, we can write:

   $$P(E_{\text{AC}}|B) = P(E_{\text{AB}}) + P(E_{\text{BC}}, \bar{E}_{\text{AB}}) = 10^{-2} + 10^{-3} \cdot (1 - 10^{-2}) = 0.011 \tag{2}$$

   that is, we can lose a packet from A to C either because it was lost on the first link, or, in case the packet arrived to B, it was lost on the second link. Equivalently, we can also write:

   $$P(E_{\text{AC}}|B) = 1 - P(\bar{E}_{\text{AC}}) = 1 - (P(\bar{E}_{\text{AB}}) \cdot (\bar{E}_{\text{BC}})) = 1 - (1 - P(E_{\text{AB}})) \cdot (1 - P(E_{\text{BC}})) \tag{3}$$

   that is computing the probability of receiving a packet at C by multiplying the packet reception rates on the two links AB and BC.

   Clearly, when B does not work, we have:

   $$P(E_{\text{AC}}|\bar{B}) = 1 \tag{4}$$

   (a) The average daily packet error rate is:

   $$P(E_{AC}) = P(E_{\text{AC}}|B) \cdot P(B) + P(E_{\text{AC}}|\bar{B}) \cdot P(\bar{B}) \tag{5}$$

   During a 24 hours day, B has problems only for 5 over 24 hours. The probability that B works during an entire day is hence $P(B) = 0.75 \cdot \frac{5}{24} + 1 \cdot \frac{19}{24} = 0.948$. Plugging this in (5) leads to:

   $$P(E_{AC}) = (P(E_{\text{AB}}) + P(E_{\text{BC}}, \bar{E}_{\text{AB}})) \cdot P(B) + 1 \cdot P(\bar{B}) = 0.011 \cdot 0.948 + 1 \cdot 0.0520 = 0.0624 \tag{6}$$

   (b) During a working day, B has problems for 5 over 10 hours. That means $P(B) = 0.5 \cdot 0.75 + 0.5 = 0.8750$. Plugging this in X leads to:

   $$P(E_{AC}) = (P(E_{\text{AB}}) + P(E_{\text{BC}}, \bar{E}_{\text{AB}})) \cdot P(B) + 1 \cdot P(\bar{B}) = 0.011 \cdot 0.875 + 1 \cdot 0.125 = 0.1346 \tag{7}$$

   (c) During the afternoon, B has always problems. Hence $P(B) = 0.75$. We have:

   $$P(E_{AC}) = (P(E_{\text{AB}}) + P(E_{\text{BC}}, \bar{E}_{\text{AB}})) \cdot P(B) + 1 \cdot P(\bar{B}) = 0.011 \cdot 0.75 + 1 \cdot 0.25 = 0.2582 \tag{8}$$

2. **Exercise (8 pts)**

   An ISP owns the following IP address space 29.88.192.0/22 Define an addressing plan to serve the following subnetworks:

- NET 1: 500 hosts
- NET 2: 100 hosts
- NET 3: 100 hosts
- NET 4: 50 hosts
- NET 5: 50 hosts
- NET 6: 50 hosts
- NET 7: 25 hosts
- 5 point-to-point links

For each subnet indicate network address, broadcast address and netmask.
Solution

- NET1: 29.88.192.0/23, BC: 29.88.192.255, NM: 255.255.254.0
- NET2: 29.88.194.0/25, BC: 29.88.194.127, NM: 255.255.255.128
- NET3: 29.88.194.128/25, BC: 29.88.194.255, NM: 255.255.255.128
- NET4: 29.88.195.0/26, BC: 29.88.195.63, NM: 255.255.255.192
- NET5: 29.88.195.64/26, BC: 29.88.195.127, NM: 255.255.255.192
- NET6: 29.88.195.128/26, BC: 29.88.195.191, NM: 255.255.255.192
- NET7: 29.88.195.192/27, BC: 29.88.195.223, NM: 255.255.255.224
- PP1: 28.99.195.224/30, BC: 29.88.195.227, NM: 255.255.255.252
- PP2: 28.99.195.228/30, BC: 29.88.195.231, NM: 255.255.255.252
- PP3: 28.99.195.232/30, BC: 29.88.195.235, NM: 255.255.255.252
- PP4: 28.99.195.236/30, BC: 29.88.195.239, NM: 255.255.255.252
- PP5:28.99.195.240/30, BC: 29.88.195.243, NM: 255.255.255.252

3. **Exercise (7 pts)**

Consider the network in Fig 1. At time $t = 0$ the output queue of R1 has five packets with destinations A,A,B,B,C. Assuming packet length of 1024 bits, compute the time each packet is completely received by its destination.

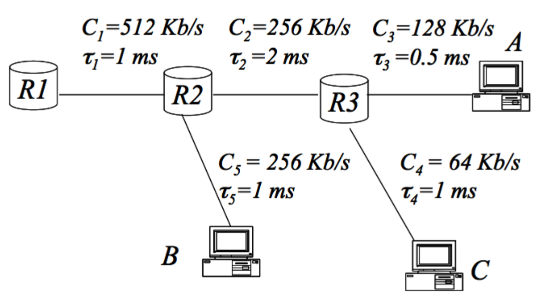

Figure 1: Network

Solution

We have: $T_1 = 2$ms, $T_2 = 4$ms, $T_3 = 8$ms, $T_4 = 16$ms, $T_5 = 4$ms. Therefore:
$t_{A_1} = T_1 + \tau_1 + T_2 + \tau_2 + T_3 + \tau_3 = 17.5$ms
$t_{A_2} = t_{A_1} + T_3 = 25.5$ ms
$t_{B_3} = 3T_1 + \tau_1 + T_5 + \tau_5 = 12$ ms
$t_{B_4} = t_{B_3} + T_5 = 16$ ms
$t_{C_5} = T1 + \tau_1 + 3T2 + \tau_2 + T_4 + \tau_4 = 34$ ms

Table 1: Routing table

Network	Next-hop	Cost
Net1	R1	1
Net2	R2	4
Net3	R3	3
Net4	R3	3
Net5	R1	2
Net6	R2	1

Table 2: distance vector

Net1	2
Net2	3
Net3	4
Net4	1
Net5	16
Net6	2

4. **Exercise (4 pts)**

   A router R runs the RIP protocol (link cost equal to 1) on all its interfaces. The neighbouring routers are R1, R2 and R3 and R has the routing table illustrated in Table 1:

   Assuming that R receives from R1 the distance vector reported in Table 2, write the new routing table on R after updating. What happens if R receives a packet with destination Net5?

   Solution

   If R receives a packet with destination Net5, the packet is discarded because a value of 16 indicates an infinite cost (Net5 is unreachable from R).

Table 3: New table

Network	Next-hop	Cost
Net1	R1	3
Net2	R2	4
Net3	R3	3
Net4	R1	2
Net5	R1	16
Net6	R2	1

5. **Question (6 pts)** Host A has to transmit a 76KByte file to Host B using UDP. The link from A to B has a capacity of 1Mbps and a propagation delay of 2ms. The maximum length of a UDP packet (including all headers) on the link from A to B is 1.5 KBytes. Considering that the layer 2 header is 36 bytes, the IP header is 160 bytes and the UDP header is 64 bytes, and assuming no errors, compute:

   (a) How many UDP datagrams will be transmitted

   (b) How much overhead information is transmitted in percentage

   (c) The transfer time of the file (assume a stop-and-wait transmission scheme with ACKs of negligible length)

   Solution

   (a) 62 UDP datagrams

   (b) 17.3 %

   (c) $62 \cdot (12 + 4)\text{ms} = 992$ ms

6. **Questions (4 pts - each answer can be either TRUE or FALSE)**

   In case the answer is FALSE, briefly explain why.

   - [T] [F] HTTP in non-persistent mode requires to open one TCP connection for each request-response cycle. TRUE.

- T F FTP requires a single TCP connection between the client and the server for each file exchanged.
  FALSE. FTP requires two connections: one for control and one for data transfer.
- T F Store-and-Forward is always less efficient than Cut-Through
  FALSE. Cut-through doesn't check correctness of packets, therefore it may be less efficient than Store-and-forward
- T F The TTL field of an IP packet can be used to count the number of routers from the source of the destination
  TRUE.