Fundamentals of Communication Networks

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January, 25 2016

1. **Exercise (6 pts)**:

   A string composed of 4 bits is transmitted over a channel characterized by a bit error probability $p = 0.05$.

   (a) Compute the probability mass function (pmf) of the discrete random variable $X = \{\text{number of bits correctly received}\}$

   (b) Compute the expected value and the variance of X

   Solution

   (a) The probability of correct reception of one bit is 1-p = 0.95. To compute the pmf we need to compute the probabilities P($X = x$), with $x = 0 \ldots 4$, that is the probabilities that 0,1,2,3 or 4 bits are correctly received. We can use the binomial distribution for computing such probabilities, that is:

   $$P(X = x) = \binom{4}{x}(0.95)^x(0.05)^{4-x}$$

   This gives:

   $$P(X = 0) = 0.05^4 = 6.25 \cdot 10^{-6}$$
   $$P(X = 1) = 4 \times 0.95 \times 0.05^3 = 4.75 \cdot 10^{-4}$$
   $$P(X = 2) = 6 \times 0.95^2 \times 0.05^2 = 0.0135$$
   $$P(X = 3) = 4 \times 0.95^3 \times 0.05 = 0.1715$$
   $$P(X = 4) = 0.95^4 = 0.8145$$

   It is easy to show that such probabilities sum up to 1, as it is expected.

   (b) The expected value of X can be computed as:

   $$\mathrm{E}(X) = 0 \times 6.25 \cdot 10^{-6} + 1 \times 4.75 \cdot 10^{-4} + 2 \times 0.0135 + 3 \times 0.1715 + 4 \times 0.8145 = 3.8$$

   The variance of X can be compute as:

   $$\mathrm{Var}(X) = (0-3.8)^2 \times 6.25 \cdot 10^{-6} + (1-3.8)^2 \times 4.75 \cdot 10^{-4} + (2-3.8)^2 \times 0.0135 + (3-3.8)^2 \times 0.1715 + (4-3.8)^2 \times 0.8145 = 0.1899$$

2. **Exercise (6 pts)**

   In the network illustrated in Figure 1, host A transmits to B a file of 2 kB. Suppose that the communication takes place with a Stop-And-Wait protocol with a timeout of 25ms, packets of 200 bytes and end-to-end acknowledgments of negligible size. Assume that R1 operates with a store-and-forward strategy and all queues are empty.

(a) Compute the total transfer time for the file and the actual end-to-end transmission rate in case of no errors.

(b) Repeat the computation at point (a) assuming that the third packet is lost.

(c) Repeat the computation at point (a) assuming a Go-Back-N protocol with optimal window size and no errors.

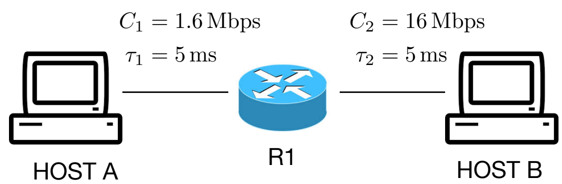

Figure 1: Network topology

Solution

(a) Let T_1 be the transmission time of one packet from A to R1 and T_2 the transmission time of one packet from R1 to B. We have $T_1 = 1$ms and $T_2 = 0.1$ms. The RTT for one packet is then

$$RTT = T_1 + \tau_1 + T_2 + \tau_2 + \tau_2 + \tau_1 = 21.1\text{ms} \tag{1}$$

The total time for the Stop-and-Wait protocol is hence $2000/200 \times 21.1 = 211$ ms and the corresponding end-to-end transmission rate is $2000 \times 8/0.211 = 75.83$ kbps.

(b) If the third packet is lost, the timeout will expire and the third packet will be retransmitted. The total time is hence 211 ms + 25 ms = 236 ms and the corresponding transmission rate is equal to 67.8 kbps.

(c) First, let's compute the optimal window length W. We would like the window to be long enough to receive the ACK of the first packet before the window itself ends. Therefore we should impose $W * T_1 \geq RTT$. This gives $W \geq RTT/T_1 = 22$. The system will therefore work in continuous transmission mode (we have only 10 packets) and the transmission time will be $9 \times T_1 + RTT = 30.1$ ms. The corresponding transmission rate is 531.56 kbps.

3. **Exercise (6 pts)**

An organization is given the following IP addressing space: 165.107.140.0/22. The organization needs to divide the network in the following subnets:

- 1 subnets with at least 500 hosts
- 1 subnet with at least 60 hosts
- 5 subnets with at least 35 hosts
- 2 point-to-point links

Define an addressing plan for the network and indicate for each subnet: IP address, netmask, direct broadcast address and maximum number of hosts.

Solution

The first subnet requires 502 addresses, hence 9 bits for the host part. Since only 10 bits are available, only 1 bit can be used for subnetting (i.e., two subnetworks). A possible network address is 165.107.140.0/23, netmask 255.255.254.0, serving up to 510 hosts. The other address (165.107.142.0) can be further divided for the other subnets. Subnets requiring 60 and 35 hosts require 6 bits for the host address. This leaves 3 bits for the subnet address, for a total of 8 subnets. We require 6 subnets (1 of 60 hosts + 5 of 35 hosts), so 2 addresses are left for other purposes. One of these can be subdivided for the point-to-point links. Figure **??** shows a possible assignment.

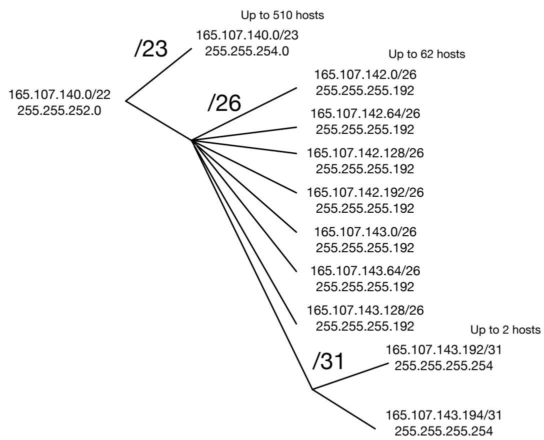

Figure 2: A possible addressing plan

4. **Exercise (6 pts)**

Between two hosts A and B a TCP connection is established with the following parameters:

- MSS: 200 bytes
- SSTHRES: 4 kB
- RCWND: 8 kB

(a) Calculate the time taken to transfer a file of 6kB from A to B (including the time needed to set up the connection), assuming that the channel is characterized by a capacity of 1Mbps and a propagation time $\tau = 10$ms and that ACK lengths are negligible.

(b) Draw the evolution of the CWND assuming that at t = 129.62ms the RCWND changes to 10 MSS

Solution

(a) Let's first compute the round trip time:

$$RTT = 200 * 8/10^6 + 2 * 10 = 21.6\text{ms}$$

The setup time can be computed as $T_{\text{setup}} = 2\tau = 20$ ms, since ACK are negligible.

Let's also compute the dimension of the CWND after which the transmission becomes continuous as:

$$W \geq RTT/T \geq 21.6/1.6 = 13.5$$

Therefore, transmission will become continuous when the CWND is greater or equal than 14 MSS.

To compute the total transmission time, it is easy to show that

$$T_{\text{tx}} = T_{\text{setup}} + 4RTT + 14T + RTT = 150.40ms \tag{2}$$

(b) The evolution of the CWND is illustrated in Figure

5. **Question (4pts)**
A layer 2 device (bridge) has three ports (Port 1, 2 and 3) and the following forwarding table:

Table 1: Forwarding Table

MAC Address	Output Port
MAC-A	Port 1
MAC-B	Port 1
MAC-C	Port 2
MAC-D	Port 1

For each of the following scenarios, describe the behaviour of the bridge (forwarding port and new)

(a) A frame is received on port 1 with source MAC-B and destination MAC-A

(b) A frame is received on port 3 with source MAC-E and destination MAC-A

(c) A frame is received on port 2 with source MAC-C and destination MAC-F

(d) A frame is received on port 2 with source MAC-B and destination MAC-A

Solution

(a) The frame is dropped since the input port is equal to the output port. The forwarding table does not change.

(b) The frame is forwarded on Port 1. A new entry is added to the forwarding table: (MAC-E, Port 3).

(c) The frame is broadcasted on Port 1 and Port 3 since the destination is unknown. The forwarding table does not change.

(d) The frame is forwarded on Port 1. The forwarding table is updated with the entry (MAC-B, Port 2).

6. **Questions (4 pts - each answer can be either TRUE or FALSE)**
In case the answer is FALSE, briefly explain why.

- [T] [F] In RIP, each router transmits its distance vectors to all routers in the network.
  FALSE. In a distance vector protocol the DV is sent to directly connected routers only.
- [T] [F] The efficiency of a Stop and Wait protocol increases as the propagation delay increases.
  FALSE. The efficiency of Stop and Wait is inversely proportional to the propagation delay.
- [T] [F] Flow control in TCP is performed through the RCWND field.
  TRUE.
- [T] [F] FTP performs data transfer and control on a single persistent TCP connection.
  FALSE. FTP sets up two different connections for data transfer (non-persistent) and control (persistent).