Fundamentals of Communication Networks

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1. **Exercise (5 pts)**:
   Two hosts A and B are connected to a host C. Let $P(A)$ be the packet error rate on the link from A to C and $P(B)$ the packet error rate on the link from B to C. Consider the following joint probability distribution:

	B	$\bar{B}$
A	0.05	0.05
$\bar{A}$	0.1	0.8

Table 1: Joint probability distribution

   (a) Show that the distribution in Table 1 is a valid joint probability distribution.
   (b) Compute the packet error rate on the two links by computing the marginal probabilities $P(A)$ and $P(B)$.
   (c) Are the packet errors on the two links independent?
   (d) Compute the probability that a packet received from A is corrupted when a packet from B is corrupted.

   Solution
   (a) It is enough to sum all entries and show that they sum up to 1: 0.05+0.05+0.1+0.8 = 1.
   (b) $P(A) = 0.05 + 0.05 = 0.1$, $P(B) = 0.05 + 0.1 = 0.15$
   (c) For independence we need the joint probability to be equal to the product of the marginal probabilities. It is easy to show that this is not true, e.g. $P(A, B) = 0.05 \neq P(A)P(B) = 0.015$
   (d) $P(A|B) = \frac{P(A,B)}{P(B)} = \frac{0.05}{0.15} = 0.33$

2. **Exercise (7 pts)**
   A small enterprise purchases the IP address 175.203.80.0/20.
   (a) Define an addressing plan to serve the following requirements:
   - 2 subnets, 1000 hosts each
   - 2 subnets, 500 hosts each
   - 3 subnets, 200 hosts each
   - 5 subnets, 15 hosts each

   (b) How many point-to-point links can be addressed, in addition to the subnets specified at point (a)?

   Solution
   (a) 1000 hosts need 10 bits. Therefore we can use 2 bits and create 4 subnets such as:
   sn1: 175.203.80.0/22 - netmask: 255.255.252.0 - broadcast: 175.203.83.255
   sn2: 175.203.84.0/22 - netmask: 255.255.252.0 - broadcast: 172.203.87.255
   sn3: 175.203.88.0/22 - to be divided
   sn4: 175.203.92.0/22 - to be divided

   500 hosts need 9 bits. We can use sn3 and use 1 additional bit for the network part:
   sn5: 175.203.88.0/23 - netmask: 255.255.254.0 - broadcast: 175.203.89.255
   sn6: 175.203.90.0/23 - netmask: 255.255.254.0 - broadcast: 175.203.91.255

   200 hosts need 8 bits. We can use sn4 and use 2 additional bits for the network part:
   sn7: 175.203.92.0/24 - netmask: 255.255.255.0 - broadcast: 175.203.92.255
   sn8: 175.203.93.0/24 - netmask: 255.255.255.0 - broadcast: 175.203.93.255

sn9: 175.203.94.0/24 - netmask: 255.255.255.0 - broadcast: 175.203.94.255
sn10: 175.203.95.0/24 - to be divided

For the 15 hosts nets we need 15+2 = 17 addresses, that is 5 bits for the host part. We take sn10 and use 3 bits for the network part, giving birth to 8 subnets:
sn11: 175.203.95.0/27 - netmask: 255.255.255.224 - broadcast: 175.203.95.31
sn12: 175.203.95.32/27 - netmask: 255.255.255.224 - broadcast: 174.203.95.63
sn13: 175.203.95.64/27 - netmask: 255.255.255.224 - broadcast: 174.203.95.95
sn14: 175.203.95.96/27 - netmask: 255.255.255.224 - broadcast: 174.203.95.127
sn15: 175.203.95.128/27 - netmask: 255.255.255.224 - broadcast: 174.203.95.159
sn16: 175.203.95.160/27 da suddividere
sn17: 175.203.95.192/27 da suddividere
sn18: 175.203.95.224/27 da suddividere

(b) From (a) we have only 3 available subnets, each one with 5 bits available for the host part. This gives a total of 96 addresses. Knowing that each point-to-point links requires 4 addresses (2 bits), the number of p2p links that can be accommodated is 96/4 = 24.

3. **Exercise (6 pts)**

Host A is connected to host B through a router R and it establishes a TCP connection with host B. The capacities and propagation delays of the two links (A-R) and (R-B) are: $C_1 = 1$ Mbps, $\tau_1 = 0.5$ms and $C_2 = 5$ Mbps, $\tau_2 = 1$ms, respectively.

Assuming:

- MSS = 1000 byte
- SSTHRESH = 4000 byte
- RCWND = 8000 byte
- ACK and headers are negligible
- bidirectional links

Compute the time needed to transfer a 300 kB file from A to B (from the connection setup to the reception of last ACK at A).

Solution

The transmission times of one MSS on the two links are $T_1 = MSS{\cdot}8/10^6 = 8$ms and $T_2 = MSS{\cdot}8/5{\cdot}10^6 = 1.6$ms.

Therefore, $RTT = T_1 + T_2 + 2\tau_1 + 2\tau_2 = 12.6$ ms

The connection setup takes $T_{setup} = 2\tau_1 + 2\tau_2 = 3$ ms

The dimension of the window after which transmission becomes continuous is: $W > RTT/T_1 = 2$ MSS

Therefore, as illustrated in the figure, we can compute the time needed for the transmission of the entire file (300 MSS) as: $T_{tot} = T_{setup} + 298 \cdot T_1 + RTT = 3\text{ms} + 12.6\text{ms} + 2384\text{ms} + 12.6\text{ms} = 2.4122$ s

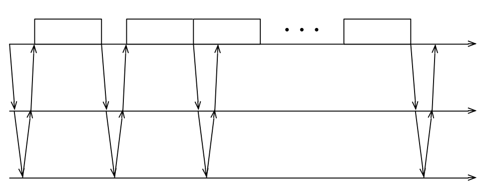

Figure 1: TCP transmission

4. **Exercise (4 pts)**

Two hosts A and B are connected through a switch S. Let MAC-A and IP-A be the layer 2 and 3 addresses of A and MAC-B, IP-B the addresses of B. Host A transmits an IP packet to B. Assuming that (i) the forwarding table of S is already stable and (ii) the ARP table of A is empty, indicate which packets are generated and transmitted in order to deliver the IP packet to B. For each packet indicate the addresses included in the layer 2 (MAC) and layer 3 (IP or ARP) headers.

Solution

1. A knows the IP of B but not its MAC (ARP tables are empty). First of all, an ARP request is issued with the following headers: Layer 2 [SRC: MAC-A, DST: BROADCAST], Layer ARP [IP-A, MAC-A, IP-B, ?]
2. The ARP request is forwarded to all ports by the switch and it reaches B. B recognizes its IP address in the ARP request and issues an ARP reply: Layer 2 [SRC: MAC-B, DST: MAC-A], Layer ARP [IP-A, MAC-A, IP-B, MAC-B]
3. The ARP reply is forwarded by the switch to A. Now A knows the MAC address of B and can transmit the IP packet: Layer 2 [SRC MAC-A, DST: MAC-B] Layer IP [SRC IP-A, DST IP-B]

5. **Question (6 pts)**

Given the two networks:

- eth0: 129.174.16.0/20
- eth1: 129.174.128.0/20

Indicate for each of the following addresses if it is a host or broadcast address and to which network it belongs (eth0, eth1 or none of the above).

(a) 129.174.130.255

(b) 129.174.28.66

(c) 129.174.0.255

(d) 129.174.31.255

(e) 129.174.17.255

(f) 129.174.143.255

Solution

(a) eth1, host

(b) eth0, host

(c) none of the above

(d) eth0, broadcast

(e) eth0, host

(f) eth1, broadcast

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

In case the answer is FALSE, briefly explain why.

- [T] [F] Let η_{GBN} and η_{SR} denote the efficiency of go-back-N and selective repeat ARQ mechanisms, respectively. We always have: $\eta_{\text{GBN}} < \eta_{\text{SR}}$.

  FALSE. In case of no errors the efficiency of go-back-n is equal to the one of selective repeat.
- [T] [F] In an IP network, two packets with the same source and destination addresses will always take the same route.

  FALSE. The packets may take different routes due to routing tables update mechanisms.
- [T] [F] Flow control avoids that the traffic on a link exceeds the link capacity.

  FALSE. Congestion control is used to avoid such a situation, while flow control avoids buffer overflow at the receiver side.
- [T] [F] IP could be used as an unreliable transport protocol if hosts executed only one application.

  TRUE.