Fundamentals of Communication Networks

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1. **Exercise (6 pts)**:
Two hosts A and B are connected to a host C. Assuming that:
   - Host A produces twice the traffic than host B.
   - Host A transmits packets of 1000 bits
   - Host B transmits packets of 500 bits.
   - The bit error rate on the link from A to C is 10^{-3}
   - The bit error rate on the link from B to C is 10^{-4}
   - A packet is marked as corrupted at C if at least one of its bits is corrupted

   Compute:
   (a) The probability of receiving a corrupted packet at C.
   (b) The probability that a corrupted packet received at C was transmitted from A.

   Solution Let's use the following notation:
   - $P(A)$ = probability that a packet is transmitted from A
   - $P(B)$ = probability that a packet is transmitted from B
   - $P(E)$ = probability that a packet is marked as corrupted in C
   - $P(E|A)$ = probability that a packet coming from A is marked as corrupted at C (packet error rate on the link A-C)
   - $P(E|B)$ = probability that a packet coming from B is marked as corrupted at C (packet error rate on the link B-C)

   We know from the text that $P(A) = 2P(B)$. Since $P(A) + P(B) = 1$ we have $P(A) = 0.67$ and $P(B) = 0.33$. Let's now compute the packet error rates. We know that we need at least 1 corrupted bit for the packet to be marked as corrupted. That is:

   $$P(E|X) = 1 - P(\text{no bits are corrupted in a packet transmitted from } X).$$

   Host A transmits packets of 1000 bits, therefore $P(E|A) = 1 - (1 - 10^{-3})^{1000} = 0.6323$ and $P(E|B) = 1 - (1 - 10^{-4})^{500} = 0.0488$.
   (a) $P(E) = P(E|A) \times P(A) + P(E|B) \times P(B) = 0.6323 \times 0.67 + 0.0488 \times 0.33 = 0.4397$
   (b) $P(A|E) = \frac{P(E|A) \times P(A)}{P(E)} = \frac{0.6323 \times 0.67}{0.4397} = 0.9635$

2. **Exercise (6 pts)**

In the network illustrated in Figure 1, the output queue of host A is composed by packets with the following destinations: B B C B. Each packet is composed by a 15 byte header and a 135 byte payload (for a total of 150 bytes).

(a) Compute the time each packet reaches its destination assuming R1 operates in store and forward mode and no ARQ mechanism is implemented on A.

(b) Repeat the computation in (a) assuming that R1 operates in cut-through mode.

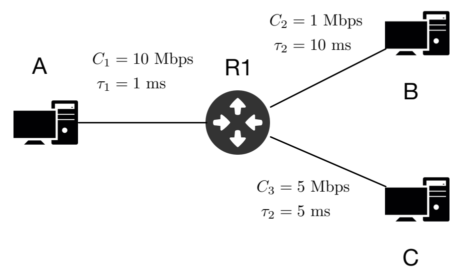

Figure 1: Network topology

Solution

(a) We have that: $T_A = 150 \cdot 8/10 \cdot 10^6 = 0.12$ ms, $T_B = 1.2$ ms and $T_C = 0.24$ ms. The time diagram is illustrated in Figure 2. The arrival times are 12.32, 13.52, 6.60 and 14.72

(b) The header is 1 tenth of the total packet size. Therefore we have $T_A^H = 15 \cdot 8/10 \cdot 10^6 = 0.012$ ms, $T_B^H = 0.12$ ms and $T_C^H = 0.024$ ms. The time diagram is illustrated in Figure 3. The arrival times are 12.212, 13.412, 6.492 and 13.612

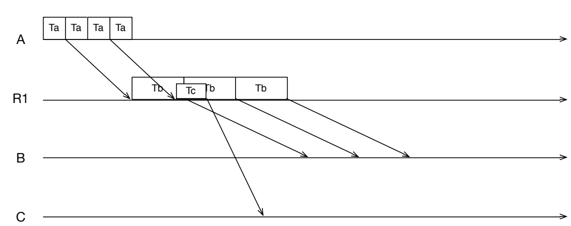

Figure 2: Time diagram for store and forward

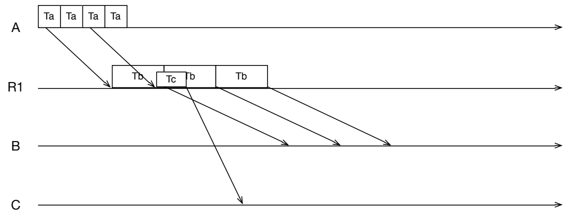

Figure 3: Time diagram for cut-through

3. **Exercise (6 pts)**

   An organization has the network topology illustrated in Figure 4 and is given the following IP addressing space: 131.175.0.0/20. Define an addressing plan for the network and indicate for each subnet: IP address, netmask, direct broadcast address and maximum number of hosts.

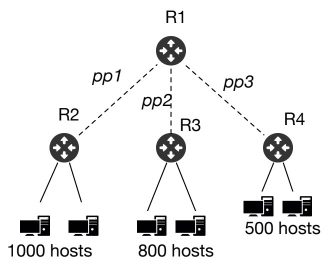

Figure 4: The network topology

   Solution

   A possible solution is illustrated in Figure 5

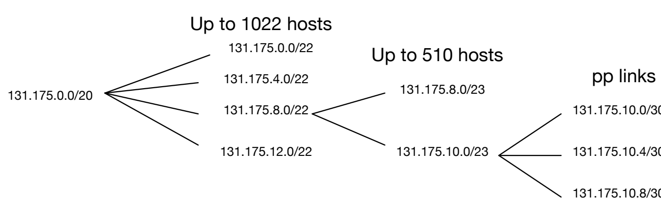

Figure 5: A possible solution

4. **Exercise (4 pts)**

   Given the network graph illustrated in Figure 6, compute the shortest path between R1 and all other nodes using Dijkstra algorithm.

   Solution The iterations of the algorithms are shown in Table 1

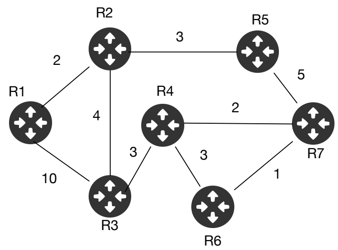

Figure 6: Network graph

Table 1: Dijkstra algorithms

R1	R2	R3	R4	R5	R6	R7
0	**<2,R1>**	<10,R1>	∞	∞	∞	∞
0	**<2,R1>**	<6,R2>	∞	**<5,R2>**	∞	∞
0	**<2,R1>**	**<6,R2>**	∞	**<5,R2>**	∞	<10,R5>
0	**<2,R1>**	**<6,R2>**	**<9,R3>**	**<5,R2>**	∞	<10,R5>
0	**<2,R1>**	**<6,R2>**	**<9,R3>**	**<5,R2>**	<12,R4>	**<10,R5>**
0	**<2,R1>**	**<6,R2>**	**<9,R3>**	**<5,R2>**	**<11,R7>**	**<10,R5>**

5. **Question (6 pts)**

A router has the following interface configuration and routing table:

Eth0	145.170.123.76/25
Eth1	145.174.124.169/25

Network	Mask	Next Hop
145.170.122.128	255.255.255.128	145.174.124.254
145.170.122.0	255.255.254.0	145.170.123.1
145.174.124.0	255.255.255.128	145.170.123.2
145.174.122.0	255.255.254.0	145.170.123.3
0.0.0.0	0.0.0.0	145.174.124.253

Indicate how packets with the following destination are handled (indicate if direct or indirect forwarding is used and what is the next hop).

(a) 145.170.123.134

(b) 145.170.122.134

(c) 145.174.123.12

(d) 145.174.124.136

(e) 140.170.124.6

Solution

(a) Indirect forwarding, line 2, Next Hop: 145.170.123.1

(b) Indirect forwarding, line 1, Next Hop: 145.174.124.254

(c) Direct forwarding on Eth0

(d) Direct forwarding on Eth1

(e) Indirect forwarding on default router, Next Hop: 145.174.124.253

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

   - [T] [F] Cut-through is a more efficient choice than store-and-forward
     FALSE. Cut-through allows corrupted packets to be forwarded by switches and routers, thus wasting bandwidth.
   - [T] [F] The Spanning Tree Protocol solves the problem of loops among routers.
     FALSE. STP avoid loops at level 2, so among bridges.
   - [T] [F] The codes $c_1 = \{1,1,1,1\}$ and $c_2 = \{-1,-1,1,1\}$ cannot be used in Code Division Multiplexing
     FALSE. They can be used since they are orthogonal (their dot product is equal to 0).
   - [T] [F] DNS requests are transported in an unreliable way.
     TRUE. UDP is used as transport protocol for the DNS service