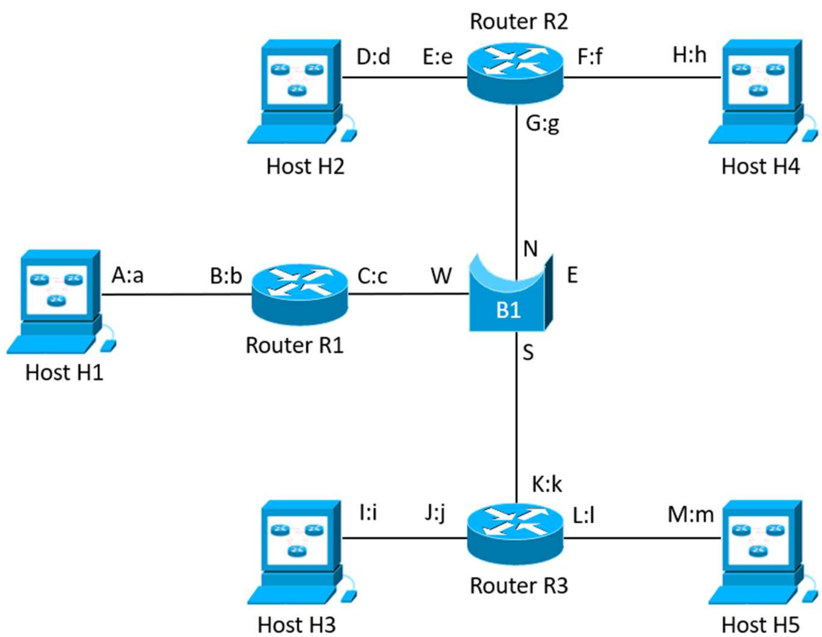
EP2120 Internetworking
IK2218 Protocols and Principles of the Internet

Homework assignment 2
(Solutions due 19:00, Mon.,18 Sep 2023)
(Review due 19:00, Wed., 20 Sep 2023)

1. ARP (20/100)



The figure above illustrates five hosts H_1, H_2, H_3, H_4, and H_5 connected by an internetwork running IPv4. The learning bridge B_1 connects routers R_1, R_2 and R_3. For the hosts and routers, the interfaces' logical (IP) addresses are shown with capital letters, and physical (MAC) addresses are shown with small letters. The North, East, South, and West interfaces of the bridge are denoted by N, E, S and W.
Assume that the ARP caches of the routers and of the hosts, and the MAC address tables of the bridges are initially empty and that no packets have been sent yet. The forwarding tables of all hosts and routers are correctly configured. All hosts know the IP addresses of each other. ARP snooping (also called passive ARP learning) is enabled.
Consider that host H_1 sends an IPv4 unicast datagram to host H_5.

a) Provide the state of the ARP caches of the hosts and routers as they will appear after the IPv4 unicast datagram has been delivered to host H_5, that is, after dynamic ARP resolution has been made (12p).

b) Provide the state of the MAC table of bridge B_1 as it will appear after the IPv4 unicast datagram has been delivered to host H_6, that is, after dynamic ARP resolution has been made. (4p)

c) Assume now that ARP snooping was disabled from the beginning on all the hosts and routers. Provide the state of the eight ARP caches of the hosts and routers as they would appear after the IPv4 unicast datagram has been delivered to host H_5, that is, after dynamic ARP resolution has been made (4p).

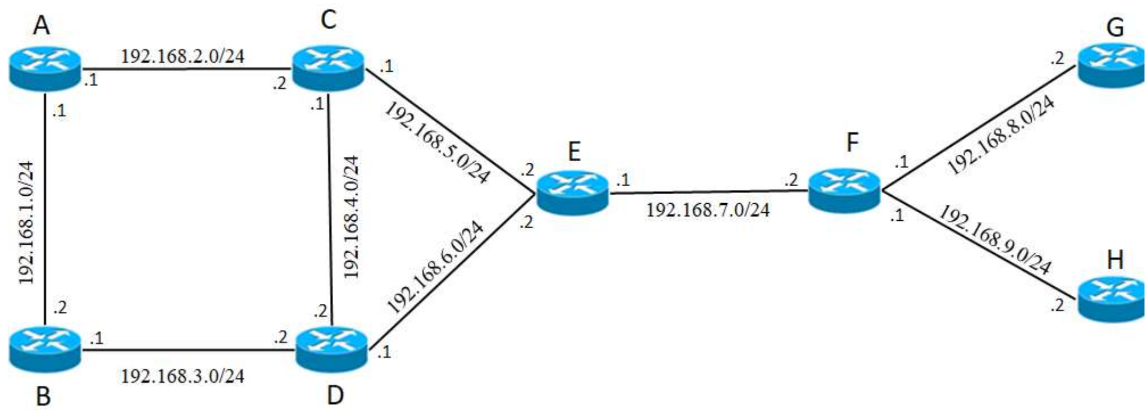
2. UDP and fragmentation (15/100)

Assume that an Ethernet network with an MTU of 1000 bytes connects hosts A and B. An application process on Host A sends 6592 bytes of application data via UDP to a process on Host B. IPv4 is used at the network layer. IP options are not used.

a) How many fragments are transmitted? (5p)

b) Give the values of the MF bit, the offset and the total length field of the IP header of each fragment. (10p)

3. Routing (25/100)



In the IPv4 network shown in the figure, all routers (A-H) run RIPv2 and all link metrics are 1. The address block of the subnets and the associated interface addresses are given in the figure. Note that the letters A-H denote routers. Assume that initially only the addresses of the directly connected networks are known to the routers. All destinations in the network are /24 prefixes. Assume also that all RIP implementations support Equal-cost-multi-path (ECMP). All routers implement split horizon with poison reverse.

For the following questions, express routes as 'destination, metric, next-hop'. If the destination is a directly connected network, the route is given as 'destination, metric, -'.

a) What is the initial routing state of D? (2p)

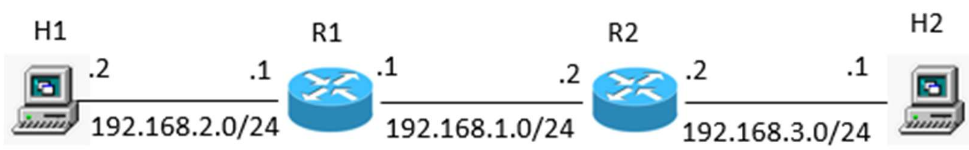
b) Assume that the first event that happens in the network is that E starts by sending RIP responses to its neighbors. What is the routing state of D after it has received the distance-vector from E? (4p)

c) Assume that the second event that happens in the network is that router F sends RIP responses to its neighbors. Please list the RIP responses that F sends. You should indicate the source and destination address of each RIP response, on which interface they are sent out (and to which IP address(es)) and which distance-vectors (destination, metric tuples) are contained in each message. (10p)

d) After step (c) the routers send out RIP responses to their neighbors simultaneously every 30 seconds. Denote by t=0 the time instant when the first RIP responses after (c) are sent out. How long does it take for G to learn all the networks? Motivate your answer. (5p)

e) Assume now that the routers in the above network run OSPF instead of RIPv2. Propose a set of designated routers (DRs) for the network. Given the DRs you identified, how many network link state advertisements (LSAs) and how many router LSAs does the link state database consist of? (4p)

4. ICMP (15/100)



The hosts H1 and H2 are connected by an internetwork running IPv4. The forwarding tables of all hosts and routers are correctly configured.

a) H2 performs a traceroute to host H1 relying on ICMP. Traceroute is configured to send one message for each hop. Please list the first and the last ICMP messages that H2 sends, and the corresponding replies that H2 receives. For each IP datagram specify the source and the destination IP address, the value of the TTL field and the payload. (10p)

b) Assume that a program on H1 sends a UDP unicast datagram to 192.168.3.1 with the DF flag set to 1. The datagram size is below the MTU for the networks 192.168.2.0/24 and 192.168.1.0/24 but it exceeds the MTU of the network 192.168.3.0/24. Router R2 can thus not forward the datagram to H2. Will H1 receive any ICMP error message? If yes, then what is the type of message? (5p)

5. TCP (25/100)

Consider a recently established TCP connection between processes P_A and P_B, running on hosts A and B, respectively. The three-way handshake has been completed, but no data has been sent yet. TCP on Host B announced a receiver window size of 2400 bytes to TCP on Host A, and Process P_B can read the received data from TCP as soon as they arrive. Process P_A has 6000 bytes to send via TCP. The path MTU between the two hosts is known to be 640 bytes. The one-way propagation time is 60ms, and the link speed is 1.6 Mbps. It takes *1ms* for TCP to generate a segment (with or without data) and this can be done in parallel with sending a previously generated segment.

The receiver uses delayed acknowledgments with a delay of 200*ms* (or at most two full segments). The size of a segment having a TCP header only is negligible in terms of transmission time. Moreover, for segments containing TCP payload, the size of the headers can be neglected when computing the transmission time of the segment. IPv4 is used as the network layer protocol and IP options are not used. Process P_A sends the first segment at time t_0 with sequence number 0. CWND is originally set to 1 MSS (packet loss was experienced during connection establishment, as per RFC5681) and the slow start threshold is 65535 bytes. Assume that the granularity G of the heartbeat timer is 0.5 seconds.

a) What is the MSS used by TCP? (2p)

b) What is the bandwidth-delay product of the communication channel? Is the advertised receiver window of *B* big enough to fully utilize the channel? If not, how big should it be for *A* to be able to fully utilize the channel? (5p)

c) Provide the sequence of segments sent by TCP from host *A*. For each segment sent from host *A* provide the time it is sent and the sequence number of the first byte it contains. For the first *five* segments sent from host A, also provide the SRTT, RTTVAR and the RTO values of the sender TCP at the time the segment is sent. Assume that outgoing segments are handled before incoming segments in case more than one event happens at the same time! (15p)

d) At what time does A receive the acknowledgement for the last segment? (3p)

Hint 1: Try to first draw the sequence of segment exchanges to get the order of the segments right.

Hint 2: Consult RFC 6298 for details on how to calculate the SRTT, RTTVAR and the RTO. The description provided in the course book (3ed and 4ed) is not correct. Consult RFC5681 for congestion control.