Computer Networks
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Quiz Sheet #2

Problem 2.1: *IP layer tools and algorithms* (1+2+2 = 5 points)

a) How does `ping` work?

b) How does `traceroute` work?

c) Briefly explain how path MTU discovery works.

Solution:

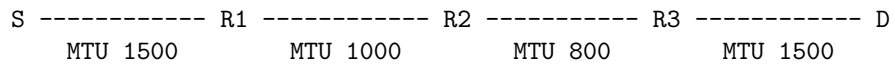
a) `ping` uses ICMP ECHO request messages. A node receiving ICMP ECHO messages sends back ICMP ECHO reply messages. This exchange may be used not only test reachability of a node but also to measure the round trip time (RTT) of the traversed path.

b) `traceroute` uses ICMP messages to determine the set of routers along a path towards a destination. It sends a series of IP datagrams to the destination with increasing TTL values set in the packet header. The routers on observing the expiry of the TTL value, discard the IP datagram and return an ICMP error response. The source uses these ICMP messages to learn the IP addresses of the routers along the path.

c) Path MTU discovery is implemented by sending a packet with the MTU of the outgoing link with the DF (Don't Fragment) bit set to 1. If this packets hits a link requiring fragmentation, the router will drop the packet and send an ICMP error message back to the sender. The sender then tries again with a smaller MTU and repeats this procedure until the packet reaches the destination.

Problem 2.2: *IPv4 fragmentation* (3+1+1 = 5 points)

4000 octets (bytes) of IP payload are send from the source S to the destination D. Assume that no transport protocol is used, i.e., payload data follows immediately the IP header. No IP options are used. The length of the IPv4 header is 20 octets (bytes) and the length of the IPv6 header is 40 octets (bytes). The IPv4 path between S and D looks as follows:



Assume that no packets are lost or corrupted. Write down your calculations so that we can verify the steps and give you partial points should you make simple mistakes. It might help to write down the packet trains (the sequence of packet sizes) carried on the various links.

a) How many IPv4 packets will arrive at D if the sender does *not* use path MTU discovery?

b) How many IPv4 packets will arrive at D if the sender does use path MTU discovery?

c) Assume S uses IPv6 instead of IPv4. Are changes necessary for the links? How many packets will arrive at D in the worst case if IPv6 is used?

Solution:

a) The source S will send 3 packets. The first 2 packets have a size of 1500 bytes and carry 1480 bytes of payload each. The 3rd packet has a size of 4000 - 2*1480 + 20 = 1060 bytes. This leads to the following packet train:

   (1500, 1500, 1060)

   All 3 packets will be fragmented at R1. The first 2 packets will be split into a fragment of 1000 bytes (carrying 980 bytes of payload) and a fragment of 520 bytes (carrying 500 bytes of payload and an additional IPv4 header). The 3rd packet will be fragmented into a fragment of 1000 bytes (carrying 980 bytes of payload) and a fragment of 80 bytes (carrying 60 bytes of payload).

   (1000, 520, 1000, 520, 1000, 80)

   At R2, packets larger than 800 bytes will be fragmented again. The 1000 bytes packets will be fragmented into a fragment of 800 bytes and a fragment of 220 bytes. This leads to the following packet train:

   (800, 220, 520, 800, 220, 520, 800, 220, 80)

   Hence, 9 packets will be received by D.

b) With path MTU discovery, the source S will generate packets that fit the smallest MTU, 800 bytes in this case. Each packet will carry a maximum of 780 bytes of payload and hence $\lceil 4000/780 \rceil = 6$ packets will be received by D. The resulting packet train looks like this:

   (800, 800, 800, 800, 800, 120)

c) IPv6 requires the use of path MTU discovery. Furthermore, IPv6 requires that every link supports a minimum MTU of 1280 bytes. Hence, the following packet train would be the worst case scenario:

   (1280, 1280, 1280, 320)