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CS6014; MSD; UofU
Spring semester - 2024
Homework 3 - Lower Network Layers

Question 1: Reliable Data Transfer

Design the protocol state machines for S and R (both R1 and R2 should use the same protocol).

Senders State Machine:
~States: S0, S1.

Initial State: S0

Events - :	Transition
udt_send(data0)	Send packet with sequence number 0, start timer0
udt_send(data1)	Send packet with sequence number 1, start timer1
receive(ack0)	Transition to S1 if received ack is sequence 0, stop timer0
receive(ack1)	Transition to S0 if received ack is sequence 1, stop timer1
timeout(0)	Retransmit packet with sequence number 0, restart timer0
timeout(1)	Retransmit packet with sequence number 1, restart timer1

//When sender sends a packet, let's say with sequence 0, it starts a timer associated with that packet. The timer timer is set to specific duration that allows acknowledgement to be received. If the timer expires before acknowledgement the timeout occurs where triggers transition to retransmit the packet associated with that timer.

Receives State Machine:
~States: R0, R1

Initial State: R0

Events	Transition
receive(packet0)	Send ACK for packet with sequence number 0 and deliver if not duplicate.
receive(packet 1)	Send acknowledgement for packet with sequence number 1 and deliver if not duplicate.
timeout(ack0)	Retransmit acknowledgement for sequence number 0
timeout(ack1)	Retransmit acknowledgement for sequence number 1

Question 2: Throttling

What is the difference between flow control and congestion control? Describe the way TCP implements each of these features.

Flow control is a mechanism to regulate the flow of data between a sender and a receiver to ensure that the sender does not overwhelm the receiver with data. In **TCP implementation**; TCP uses a sliding window mechanism for flow control where each TCP segment contains a window size field indicating how much data the sender is allowed to transmit before receiving acknowledgement. The receiver tells its available buffer space (in terms of window size) to the sender and then the sender adjusts its transmission rate based on this window size to avoid overwhelming the receiver.

Congestion control is a mechanism to prevent network congestion; which occurs when the network is unable to handle the amount of data being transmitted. Congestion control's objective is to avoid network congestion by adjusting the transmission rate of data based on the network's capacity. In **TCP implementation**; TCP uses what is called a slow start, congestion avoidance and fast retransmit algorithms whereas slow start increases the sending rate exponentially until a threshold is reached and then congestion avoidance maintains a more linear increase, if congestion is detected, then TCP reacts by reducing its transmission rate and fast retransmit is the mechanism that allows TCP to quickly retransmit a lost packet without waiting for a timeout.

Flow control is more concerned with regulating data flow between send and receiver to avoid the receiver from being overwhelmed and congestion control is concerned with avoiding network congestion by adjusting the transmission rate based on network conditions.

Question 3: NAT

From A to X behind the NAT:

- Source IP address: 10.0.0.1 (private IP of host A)
- Source port: A randomly assigned port number by host A or ephemeral A
- Destination IP address: 1.2.3.4 (public IP of host X)
- Destination port: 80 (HTTP port)

From B to X behind the NAT:

- Source IP address: 10.0.0.2 (B's private IP)
- Source port: A randomly assigned port number by host B
- Destination IP address: 1.2.3.4 (public IP of host X)
- Destination port: 80 (HTTP port)

From A to X between the NAT and X:

- Source IP address: 5.6.7.8 (public IP of the NAT router)
- Source port: A port assigned by the NAT router for communication with host X
- Destination IP address: 1.2.3.4 (public IP of host X)
- Destination port: 80 (HTTP port)

From B to X between the NAT and X:

- Source IP address: 5.6.7.8 (public IP of the NAT router)

- Source port: A port assigned by the NAT router for communication with host X
- Destination IP address: 1.2.3.4 (public IP of host X)
- Destination port: 80 (HTTP port)

From X to A between X and the NAT:
- Source IP address: 1.2.3.4 (public IP of host X)
- Source port: 80 (HTTP port)
- Destination IP address: 5.6.7.8 (public IP of the NAT router)
- Destination port: The port assigned by the NAT router for communication with host A

From X to A between the NAT and A:
- Source IP address: 1.2.3.4 (public IP of host X)
- Source port: 80 (HTTP port)
- Destination IP address: 10.0.0.1 (private IP of host A)
- Destination port: The port assigned by the NAT router for communication with host A

NAT translation table contains mappings between the private IP addresses and ports of the internal hosts (A and B) and the public IP address and ports assigned by the NAT router for communication with external hosts like X.

- A's private IP and port -> NAT public IP and port
- B's private IP and port -> NAT public IP and port
- X's public IP and port -> NAT private IP and port (for communication with A or B)

Question 4: Routers

Number of Subnets and Smallest IP Prefix:
- Group A: Subnet 1.1.1.0/24
- Group B: Subnet 1.1.2.0/24
- Group C: Subnet 1.1.3.0/24
- Links between routers:
  - A to B: Subnet 1.1.4.0/30 (2 addresses, smallest IP prefix)
  - A to C: Subnet 1.1.5.0/30 (2 addresses, smallest IP prefix)
  - B to C: Subnet 1.1.6.0/30 (2 addresses, smallest IP prefix)

1- The total number of subnets is 6, and the smallest IP prefix used is /30 for the links between routers.

2- Cheapest IP Prefix for Internet Connection:
- The smallest IP prefix the company could purchase without wasting too many addresses is a /29 prefix, which provides 8 usable addresses (6 for devices and 2 for network and broadcast).

3- Router A's Forwarding Table:
- Port 1: Connected to Group A's subnet 1.1.1.0/24
- Port 2: Connected to Router B, interface address 1.1.4.0/30
- Port 3: Connected to Router C, interface address 1.1.5.0/30
- Port 4: Connected to ISP

Forwarding Table for router A:

- Destination: 1.1.1.0/24, Port: 1
- Destination: 1.1.2.0/24, Port: 2
- Destination: 1.1.3.0/24, Port: 3
- Destination: 1.1.4.0/30, Port: 2
- Destination: 1.1.5.0/30, Port: 3
- Destination: default, Port: 4

Question 5: Routing