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COMP3331/9331 — Computer Networks and Applications

Term 1, 2023

Mid-term Examination

Instructions:

1. TIME ALLOWED: **1 hours and 15 minutes**.
2. TOTAL MARKS AVAILABLE: **20 marks worth 20% of the total marks for the course**.
3. THERE ARE 21 QUESTIONS. ALL QUESTIONS MUST BE ANSWERED.
4. MARKS AVAILABLE FOR EACH QUESTION ARE SHOWN IN THE EXAM. THERE IS NO NEGATIVE MARKING, IN THAT THE MINIMUM MARK FOR EACH QUESTION IS ZERO.
5. THE EXAM IS OPEN BOOK, OPEN NOTES. USE OF CALCULATORS IS PERMITTED.
6. STUDENTS ARE ADVISED TO READ THE EXAMINATION QUESTION BEFORE ATTEMPTING TO ANSWER THE QUESTION.
7. THIS EXAM CANNOT BE COPIED, FORWARDED, OR SHARED IN ANY WAY.
8. STUDENTS ARE REMINDED OF THE UNSW RULES REGARDING ACADEMIC INTEGRITY AND PLAGIARISM. STUDENTS CANNOT USE ANY GENERATIVE AI SOFTWARE FOR ASSISTANCE.
9. YOUR WORK WILL BE SAVED PERIODICALLY THROUGHOUT THE EXAM AND WILL BE AUTOMATICALLY SUBMITTED PROVIDED YOU ARE CONNECTED TO THE INTERNET.

Suppose a number of users share a 4 Mbps link. Also, suppose that each user transmits continuously at 2 Mbps when transmitting, but each user transmits only 20% of the time.

Answer the 3 questions.

1 When circuit switching is used, how many users can be supported? No explanation is required.

Simply enter the numeric value in the space provided: [ ]

Maximum marks: 0.25

Answer: 2

Explanation:
In circuit switching, the percentage of time a user is active is irrelevant. A circuit needs to be established for each active user. Since each user requires 2Mbps and the link capacity is 4Mbps, 2 users can be supported.

2 Now suppose packet switching is used. Why will there be essentially no queuing delay before the link if two or fewer users transmit at the same time? Why will there be queuing delay if three users transmit at the same time? Be brief (2 sentences at most for each question).

Fill in your answer here

Format

Words: 0

Maximum marks: 0.75

Answer:

Since each user requires 2 Mbps when transmitting, if two or fewer users transmit simultaneously, a maximum of 4 Mbps will be required. Since the available bandwidth of the shared link is 4 Mbps, there will be no queuing delay before the link. (0.25 marks)

Whereas, if three users transmit simultaneously, the bandwidth required will be 6 Mbps which is more than the available bandwidth of the shared link. In this case, there will be queuing delay before the link. (0. 5 marks)

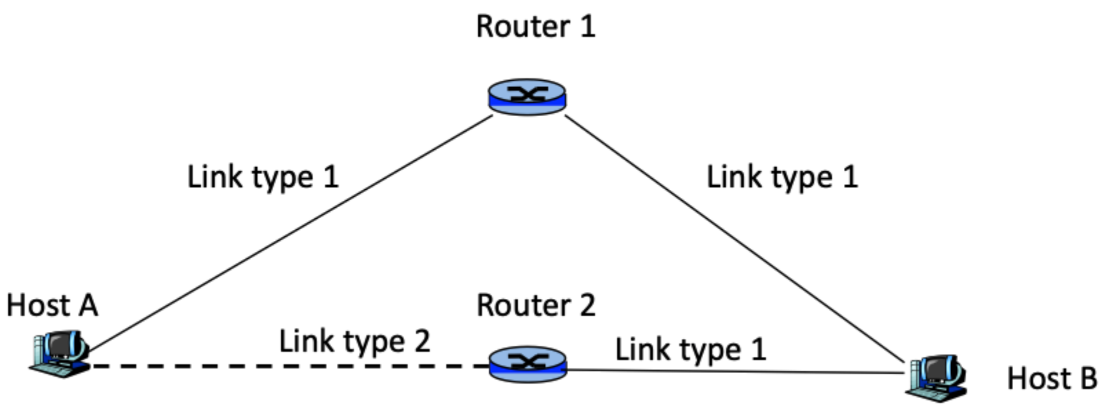
3 Suppose with packet switching, there are three users. Find the probability that at any given time, all three users are transmitting simultaneously. No explanation is required.Simply enter the numeric value in the space provided: ______

Maximum marks: 0.5

Answer: 0.08

Explanation:
The probability that all three users are transmitting simultaneously =(0.2)^3 = 0.008

Consider the network in the figure below. Host A can choose between two different paths to communicate with host B. Host can choose to send packets via either Router 1 or Router 2 to host B. The communication links are of two different types, as indicated in the figure. The characteristics of these two types of links are:



Link type 1: Each link is of length 2000km, propagation speed is 2×10^8 m/s and bandwidth is 100kbps.

Link type 2: Each link is of length 4000km, propagation speed is 2×10^8 m/s and bandwidth is 50kbps.

Host A wishes to transmit a message of size 4Kbytes to host B. It breaks this message into 4 packets of equal size. Neglect any packet headers. Remember that routers work on the store-and-forward principle.

Assume that the processing delay and queuing delay in the routers are negligible. You may also approximate file sizes to be an order of 10 (i.e. 4Kbytes = 4000 bytes instead of 4096 bytes).

4 If host A chooses to send the packets via Router 1, determine the time it takes to move the packets from host A to host B, i.e., beginning from the time that host A starts to send the first bit of the first packet till the time that host B receives the last bit of the last packet.

You are encouraged to draw a timing diagram to help you visualise the delays. However, you are NOT required to upload such a diagram with your answers.

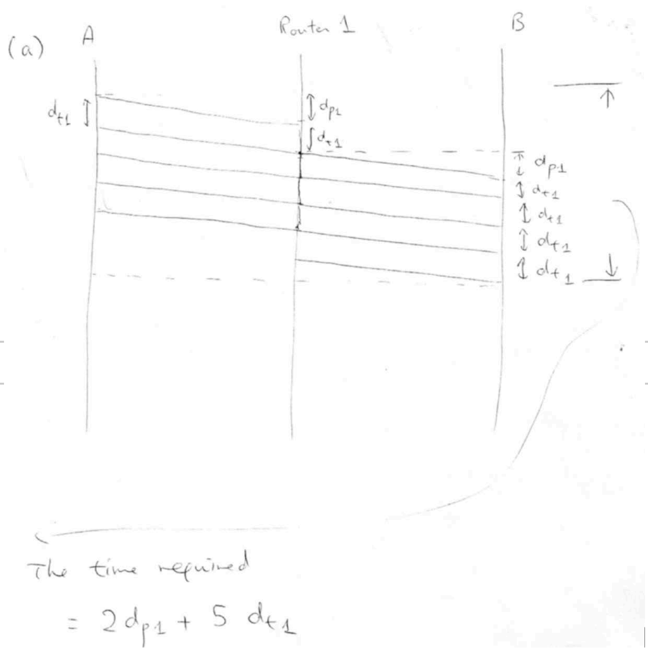
Do not simply write the final answer. Show us your work (just type it in the space provided).

Fill in your answer here

Format

Let us begin with a number of basic calculations:
Propagation delay in link type 1 (dp1) = 2000 x 10^3/2 x 10^8 = 0.01 s
Transmission delay in link type 1 (dt1) = 8 x 1024/100 x 10^3 = 0.08 s (approx. 1024 by 1000)
Propagation delay in link type 2 (dp2) = 4000 x 10^3/2 x 10^8 = 0.02 s
Transmission delay in link type 2 (dt2) = 8 x 1024/50 x 10^3 = 0.16 s (approx. 1024 by 1000)

The time required as per the timing diagram below = 2(0.01) + 5(0.08) = 0.42 s.



Words: 0

Maximum marks: 2

5 Now assume that host A chooses to send the packets via Router 2 to host B. Determine the time it takes to move the packets from host A to host B, i.e., beginning from the time that host A starts to send the first bit of the first packet till the time that host B receives the last bit of the last packet.

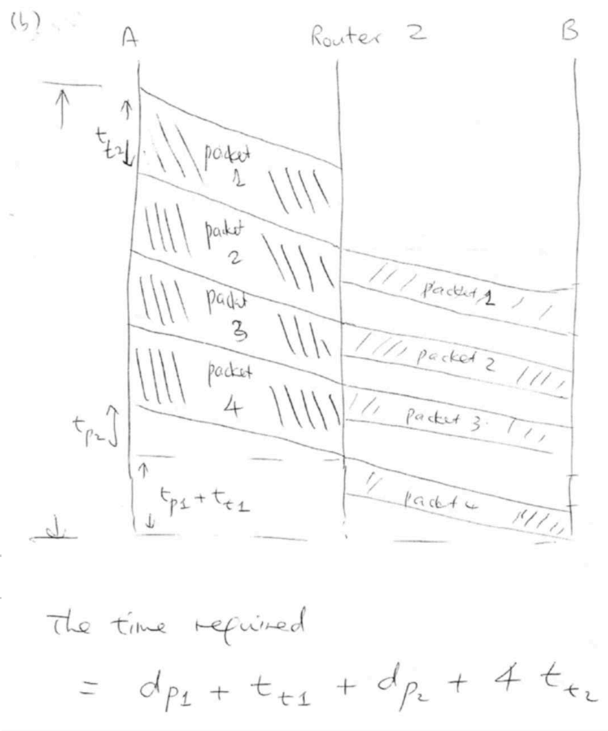
You are encouraged to draw a timing diagram to help you visualise the delays. However, you are NOT required to upload such a diagram with your answers.

Do not simply write the final answer. Show us your work (just type it in the space provided).

Fill in your answer here

Format

From the timing diagram below, the time required = dp1 + dt1 + dp2 + 4dt2 = 0.01 + 0.08 + 0.02 + 4(0.16) = 0.75 s.



Words: 0

Maximum marks: 2

Assume a webpage comprised of 10 objects which includes the index.html file, 8 embedded images and one embedded audio clip. The 10 objects are so small that: (i) their transmission time is negligible and (ii) each object can be completely transmitted in one TCP segment. Consider a client wishing to download the webpage.

You are asked to make the following assumptions:

- the round trip time between the client and all servers is **T**
- the time to set up and tear down a TCP connection is **S** and **F**, respectively. You must account for both these times in your computations. Note that, **S** includes the 3-way handshake (SYN, SYN-ACK, ACK) and **F** includes the time for sending FINs and ACKs from both endpoints.
- there are no packet losses.
- the client knows the IP address of all servers (i.e. neglect DNS resolution delay).
- neither the client nor any of the servers support parallel TCP connections.

Answer the following 5 questions. No explanations are required. Simply write the expression for each answer which should ONLY contain the variables **T**, **S** and **F** (e.g., 20T+100S+50F) in the space provided.

6 Assume that the client uses non-persistent HTTP for downloading the web page. What is the time required to complete the transfer of the web page (including the time for setting up and tearing down each TCP connection involved)?

Fill in your answer here

Maximum marks: 0.6

In non-persistent HTTP, every object is downloaded over a fresh TCP connection. Since parallel connections are not supported, this would mean the ten objects are fetched serially.

The time required to fetch one object = time to setup TCP connection + RTT for sending GET request and receiving response + time to tear down TCP connection = S + T + F.

Thus, the total time = 10(S +T + F) = 10S + 10T + 10F

7 Assume that the client uses persistent HTTP without pipelining for downloading the web page. What is the time required to complete the transfer of the web page (including the time for setting up and tearing down each TCP connection involved)?

Fill in your answer here

Maximum marks: 0.6

In this instance, all objects can be fetched over one single TCP connection but serially (one after the other).
Thus the total time = time to setup TCP connection + 10 x (RTT for sending GET request and receiving the object) + time to tear down TCP connection
= S + 10T + F.

8 Assume that the client uses persistent HTTP with pipelining for downloading the web page. What is the time required to complete the transfer of the web page (including the time for setting up and tearing down each TCP connection involved)?

Fill in your answer here

Maximum marks: 0.6

In this instance, since pipelining is used once the index page is fetched and the client knows of the 9 embedded objects, these 9 objects can be requested back-to-back (simultaneously) and the corresponding objects would also be received back-to-back.

Thus the total time = time to setup TCP connection + RTT for sending GET request for the index page and receiving that page + RTT for sending 9 GET requests for embedded objects and receiving them + time to tear down TCP connection
= S + T + T + F = S + 2T + F.

9 Now assume that all 10 objects are located on 10 different servers (one object on each server). The client can only have one active TCP connection at any given time. Assume that the round trip time between the client and each of the 10 servers is **T**. Neglect DNS queries. Assume that the client uses persistent HTTP with pipelining for downloading the web page. What is the time required to complete the transfer of the web page (including the time for setting up and tearing down each TCP connection involved)?

Fill in your answer here

Maximum marks: 0.6

Now each object is fetched from a different server. Since parallel connections are not supported, this would mean these objects have to be fetched serially (one after the one).
The time to fetch one object from one server = time to setup TCP connection + RTT for sending GET request for the object and receiving that object + time to tear down TCP connection = S + T + F.
Thus the total time = 10 (S + T + F) = 10S + 10T + 10F

10 Now assume that the index page and 7 embedded images are on one server, while the remaining image and audio clip are on another server. The client can only have one active TCP connection at any given time. Assume that the round trip time between the client and both servers is **T**. Neglect DNS queries. Assume that the client uses persistent HTTP with pipelining for downloading the web page. What is the time required to complete the transfer of the web page (including the time for setting up and tearing down each TCP connection involved)?

Fill in your answer here

Maximum marks: 0.6

In this instance, all objects from each server can be fetched over a single TCP connection established with that server.

The client would first fetch the index page and would become aware of the embedded objects. The 7 objects hosted on this same server (as the index page) are then fetched in one go. Next, the client fetches the other two objects from the other server in one go.

Thus the total time = time to setup TCP connection with the first server + RTT for sending GET request for the index page and receiving that page + RTT for sending 7 GET requests for embedded objects and receiving them + time to tear down TCP connection + time to setup TCP connection with the second server + RTT for sending 2 2 GET requests for embedded objects and receiving them
= S + T + T + F + S + T + F = 2S + 3T + 2F.

Three users are logged into the workstations user1.unsw.edu.au, user2.unsw.edu.au and user3.unsw.edu.au, respectively, all located inside UNSW's network.

The UNSW network has -

(i) a web server offering www.unsw.edu.au

(ii) a web proxy proxy.unsw.edu.au. All workstations have the hostname (not IP address) of the proxy server configured in their browsers.

(iii) a DNS name server ns.unsw.edu,.au which is the authoritative server for the unsw.edu.au domain. This name server also serves as the local DNS servers for all machines on the UNSW network.

Make the following assumptions:

- All DNS servers and workstations maintain DNS caches. Once a record is cached it will remain for the remainder of this multi-part question.
- Web browsers and web proxies perform caching. Once an object is cached it remain for the remainder of this multi-part question.
- Before serving a cached object, the proxy will check with the origin server if the object has been updated.
- None of the objects are ever updated at the origin server.
- All caches (HTTP and DNS) are initially empty.
- None of the hosts have IP addresses for the web proxy and the web server.
- All DNS requests are resolved iteratively
- Application layer messages fit in one packet
- The browsers and proxy use persistent HTTP without parallel connections (HTTP 1.1).
- For simplicity, assume nobody else is generating traffic on the Internet.

Answer the following two questions.

11

User 1 types http://www.unsw.edu.au/index.html in his browser. The only object referenced by the index file is the image http://www.unsw.edu.au/image.png.

List all packets that are exchanged in the entire network, including any TCP connection setup packets, by completing a table similar to one shown below.

For each packet, show the source and destination hostname, the transport-layer protocol, the application-layer protocol, and the purpose of the packet, as in the example. You may assume that the last ACK in the TCP connection setup is piggybacked (combined) with the first data segment. You do not need to show the TCP connection teardown process. You should assume that all persistent connections are closed before the start of the next question.

Here is an example which shows the details for a packet that is not related to this question

Packet	Source hostname	Destination hostname	Application protocol	Transport protocol	Purpose
1	user46.unsw.edu.au	www.opeth.com	HTTP	TCP	Get request for www.tool.com

The menu of the answer window below has an option to create a table. Create a table with 6 columns (as shown in the example above) and several rows (e.g, a large number like 20, you may not require all 20 rows). Each row should depict a packet. The packets should be listed in the chronological sequence in which they are generated.

Fill in your answer here

Format

Σ

Words: 0

Maximum marks: 2

Answer

User1 will first obtain the IP address for the proxy server using DNS (packets 1 and 2). A TCP connection is setup between user1 and the proxy server (packets 3 and 4). The workstation requests for the index page from the proxy (packet 5). The proxy obtains the IP address for the UNSW web server (packets 6 and 7). A TCP connection is setup between the proxy and the web server (packets 8 and 9). The proxy requests for the index page from the web server (packet 10). The web server responds with the index page (packet 11) which is stored in the proxy and forwarded to user1 (packet 12). User1 requests for the embedded image (packet 13) to the proxy. The proxy requests for the image from the web server (packet 14). The web server responds with the image to the proxy (packet 15), which forwards the image to user1 (packet 16).

Packet Number	Source hostname	Destination hostname	Transport Protocol	Application Protocol	Purpose
1	user1.unsw.edu.au	ns.unsw.edu.au	UDP	DNS	Type A query for proxy.unsw.edu.au
2	ns.unsw.edu.au	user1.unsw.edu.au	UDP	DNS	Type A response for proxy.unsw.edu.au
3	user1.unsw.edu.au	proxy.unsw.edu.au	TCP		Connection request (SYN)
4	proxy.unsw.edu.au	user1.unsw.edu.au	TCP		Connection response (SYN ACK)
5	user1.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Get request for www.unsw.edu.au/index.html
6	proxy.unsw.edu.au	ns.unsw.edu.au	UDP	DNS	Type A query for www.unsw.edu.au
7	ns.unsw.edu.au	proxy.unsw.edu.au	UDP	DNS	Type A response for www.unsw.edu.au
8	proxy.unsw.edu.au	www.unsw.edu.au	TCP		Connection request (SYN)
9	www.unsw.edu.au	proxy.unsw.edu.au	TCP		Connection response (SYN ACK)
10	proxy.unsw.edu.au	www.unsw.edu.au	TCP	HTTP	Get request for www.unsw.edu.au/index.html
11	www.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Response with index.html
12	proxy.unsw.edu.au	user1.unsw.edu.au	TCP	HTTP	Response with index.html
13	user1.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Get request for www.unsw.edu.au/image.png
14	proxy.unsw.edu.au	www.unsw.edu.au	TCP	HTTP	Get request for www.unsw.edu.au/image.png
15	www.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Response with image.png
16	proxy.unsw.edu.au	user1.unsw.edu.au	TCP	HTTP	Response with image.png

12

User 2 types http://www.unsw.edu.au/index.html in her browser. In other words, user 2 is accessing the same webpage as User 1.

List all packets that are exchanged in the entire network, including any TCP connection setup packets, by completing a table similar to one shown below.

For each packet, show the source and destination hostname, the transport-layer protocol, the application-layer protocol, and the purpose of the packet, as in the example. You may assume that the last ACK in the TCP connection setup is piggybacked (combined) with the first data segment. You do not need to show the TCP connection teardown process.

Here is an example which shows the details for a packet that is not related to this question

Packet	Source hostname	Destination hostname	Application protocol	Transport protocol	Purpose
1	user46.unsw.edu.au	www.opeth.com	HTTP	TCP	Get request for www.tool.com

The menu of the answer window below has an option to create a table. Create a table with 6 columns (as shown in the example above) and several rows (e.g, a large number like 20, you may not require all 20 rows). Each row should depict a packet. The packets should be listed in the chronological sequence in which they are generated.

Fill in your answer here

Format

Σ

Words: 0

Maximum marks: 2

Answer

User2 will first obtain the IP address for the proxy server using DNS (packets 1 and 2). A TCP connection is setup between user1 and the proxy server (packets 3 and 4). The workstation requests for the index page from the proxy (packet 5). The proxy already has the IP address for the web server and thus no there is no need for a DNS query resolution. A TCP connection is setup between the proxy and the web server (packets 6 and 7). The proxy sends a conditional GET request for the index page to the web server (packet 8). The web server responds that the (packet 9) which is stored in the proxy and forwarded to user1 (packet 10). User2 requests for the embedded image (packet 11) to the proxy. The proxy requests for the image from the web server (packet 12). The web server responds with the image to the proxy (packet 13), which forwards the image to user1 (packet 14).

Packet Number	Source hostname	Destination hostname	Transport Protocol	Application Protocol	Purpose
1	user2.unsw.edu.au	ns.unsw.edu.au	UDP	DNS	Type A query for proxy.unsw.edu.au
2	ns.unsw.edu.au	user2.unsw.edu.au	UDP	DNS	Type A response for proxy.unsw.edu.au
3	user2.unsw.edu.au	proxy.unsw.edu.au	TCP		Connection request (SYN)
4	proxy.unsw.edu.au	user2.unsw.edu.au	TCP		Connection response (SYN ACK)
5	user2.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Get request for www.unsw.edu.au/index.html
6	proxy.unsw.edu.au	www.unsw.edu.au	TCP		Connection request (SYN)
7	www.unsw.edu.au	proxy.unsw.edu.au	TCP		Connection response (SYN ACK)
8	proxy.unsw.edu.au	www.unsw.edu.au	TCP	HTTP	Conditional Get request for www.unsw.edu.au/index.html
9	www.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Not modified Response
10	proxy.unsw.edu.au	user2.unsw.edu.au	TCP	HTTP	Response with index.html
11	user2.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Get request for www.unsw.edu.au/image.png
12	proxy.unsw.edu.au	www.unsw.edu.au	TCP	HTTP	Conditional Get request for www.unsw.edu.au/image.png
13	www.unsw.edu.au	proxy.unsw.edu.au	TCP	HTTP	Not modified Response
14	proxy.unsw.edu.au	user2.unsw.edu.au	TCP	HTTP	Response with image.png

13 BitTorrent uses a "tit-for-tat" incentive mechanism for selecting peers to whom a particular peer would upload chunks. Consider a peer who has finished downloading the file but wishes to continue seeding the file to other peers (i.e. continue uploading chunks of that file) participating in the torrent. Will "tit-for-tat" still be useful for this peer? Explain why or why not in 2-3 sentences. Answers without explanations will not receive marks.

Fill in your answer here

Format

Σ

Words: 0

Maximum marks: 1

No. Tit-for-tat is not useful. This peer is no longer downloading any chunks of this file. So the peer will never be able to determine the top (four) peers that are providing her chunks at the best rate. Recall that "tit-for-tat" selects these top four peers to upload chunks.

NOT EXPECTED IN ANSWER. THIS IS JUST FYI: In this instance, BitTorrent selects the peers who have the best upload rate (in general). This ensures that chunks get uploaded faster, and they get replicated faster.

14 Which of the following is true about how TCP implements reliable data transfer? (Multiple choices may be correct. Selecting additional choices beyond those that is/are correct will be considered as incorrect)

Select one or more alternatives:

- ☐ TCP may retransmit packets upon receiving duplicate acknowledgements TRUE
- ☐ TCP uses multiple timers
- ☐ TCP may retransmit packets upon timer timeout events TRUE
- ☐ TCP receiver always transmits acknowledgement immediately upon receiving a data packet
- ☐ TCP uses cumulative acknowledgements TRUE

Maximum marks: 0.75

15 Host A sends a 128-byte TCP segment carrying a sequence number of 100 to Host B. Host B receives it correctly and sends an ACK to Host A. What is the *acknowledgement number* in the ACK?

Select one alternative:

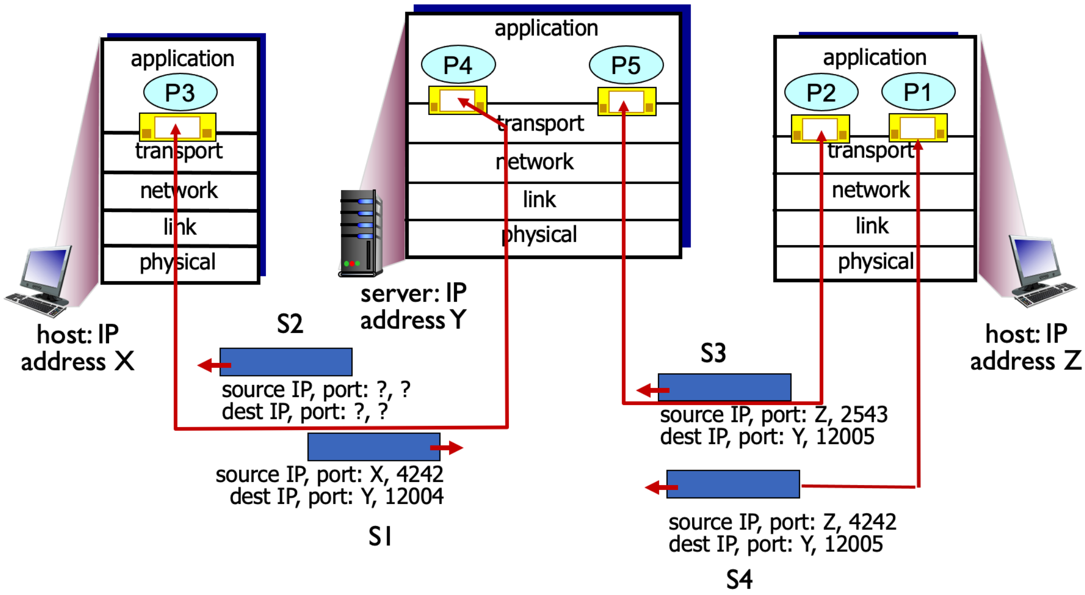
- ○ 228 CORRECT
- ○ 226
- ○ 227
- ○ 101

Maximum marks: 0.75

The segment contains bytes numbered from 100 to 227. The ACK number is always for the next expected sequence number which is 228.

Consider the picture below. Process P3 on the host with IP address X has set up a TCP connection with process P4 on the server with IP address Y. Process P2 on the host with IP address Z has set up a TCP connection with process P5 on the server with IP address Y. There are no other TCP connections open at the server.

4 TCP segments S1 - S4 are shown in the picture. The source and destination IP addresses and port numbers for S1, S3 and S4 are noted. S1 is sent by P3 to P4, S2 is sent by P4 to P3 and S3 is sent by P2 to P5.



Answer the 5 following questions.

16 What is the source IP address for TCP segment S2? No explanation needed.

Answer: Y

Maximum marks: 0.25

17 What is the source port number for TCP segment S2? No explanation needed.

Maximum marks: 0.25

Answer: 12004

18 What is the destination IP address for TCP segment S2? No explanation needed.

Answer: X

Maximum marks: 0.25

19 What is the destination port number for TCP segment S2? No explanation needed

Answer: 4242

Maximum marks: 0.25

20 Consider TCP segment S4 sent by process P1. Assume that S4 contains data. Describe what happens to this segment and why? 2-3 sentences should be sufficient.

Fill in your answer here

Maximum marks: 1

S4 will be routed by the Internet to arrive at server Y. The server will try to match the (source IP, source port, destination port) tuple, i.e. (Z, 4242, 12005) against all active TCP sockets.
The two active TCP connections will have the following entries in the active TCP socket table:
(X, 4242, 12004) -> For the TCP connection between P3 and P4.
(Z, 2543, 12005) -> For the TCP connection between P2 and P5.
Notice that, S4 does not generate an exact match with either. Thus this segment will be dropped.

NOT REQUIRED FOR MARKING: The server would respond to P1 with a TCP RST (Reset) segment.

21 NOTE: THIS QUESTION IS NOT ABOUT TCP. IT FOCUSES ON THE GENERIC GO-BACK-N AND SELECTIVE PROTOCOL.

Host A communicates with Host B using sliding window piepelined protocols (GBN, SR) with sender window size N = 5. The communication channel between A and B may drop packets and ACKS but can neither reorder nor corrupt data packets and ACKs.

A sends a file to B. It does so by splitting the file in 10 packets with sequence numbers from 0 to 9. The file transfer is successful.

You may assume that there are never any premature timeouts at Host A.

Assume that the first four ACKs sent by B are all lost. No other packets or ACKs are lost.

Note down the sequence number of packets sent by host A in the order in which they were sent, including any retransmissions in the space provided below for

(i) Go-Back-N

(ii) Selective Repeat

An example answer (which does not match this question) could be:

Pkt 0

Pkt 1

Pkt 2

Pkt 2

Pkt 3

In the above, Pkt 2 and Pkt 3 are retransmitted.

Hint: We recommend that you draw a timing diagram depicting the transmission of packets and ACKs (similar to the lecture notes and textbook). You are NOT required to include this diagram in your answer.

Fill in your answer here

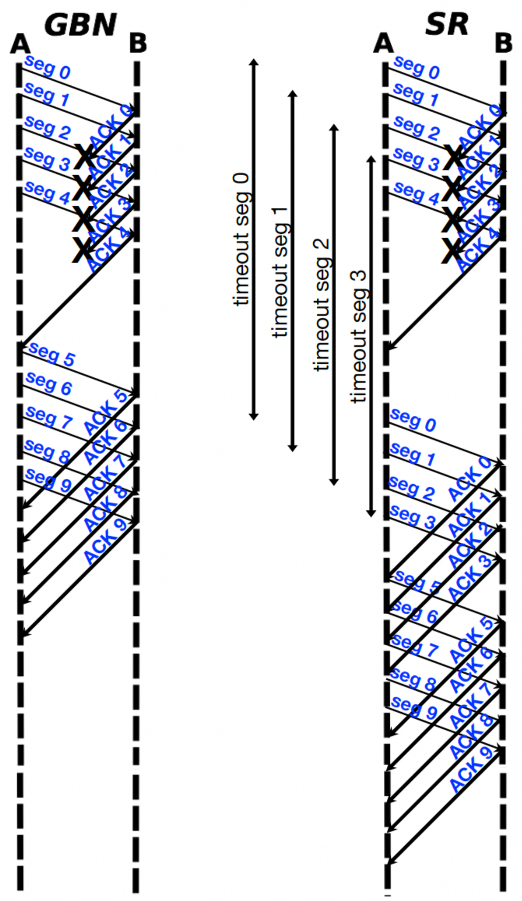
Format

Σ

Maximum marks: 3

Answer:

The timing diagrams for GBN and SR are shown below. Based on these the sequence of packets sent are shown below the figure.



GBN

Pkt 0
Pkt 1
Pkt 2
Pkt 3
Pkt 4
Pkt 5
Pkt 6
Pkt 7
Pkt 8
Pkt 9

SR

Pkt 0
Pkt 1
Pkt 2
Pkt 3
Pkt 4
Pkt 0
Pkt 1
Pkt 2
Pkt 3
Pkt 5
Pkt 6
Pkt 7
Pkt 8
Pkt 9