CN BOOK QS

Link: https://gaia.cs.umass.edu/kurose_ross/interactive/smtp.php

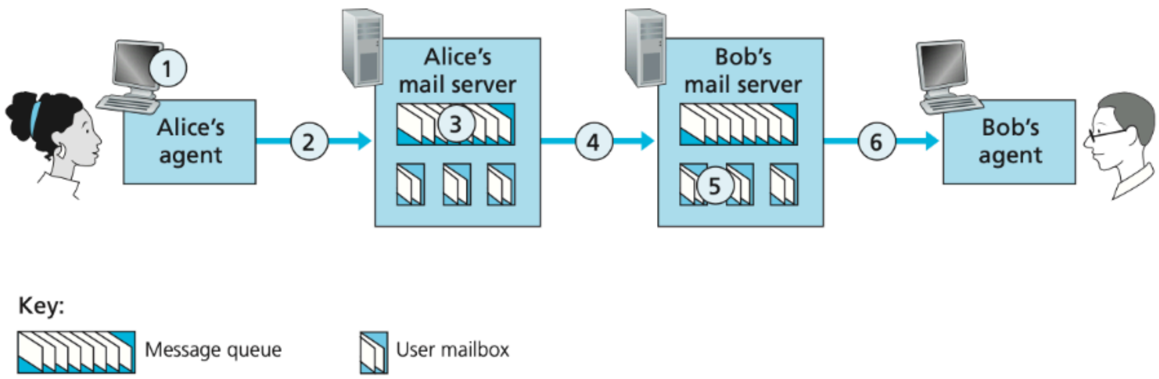


Figure 2.15 ♦ Alice sends a message to Bob

QUESTION LIST

1. At point 2 in the diagram, what protocol is being used?

2. At point 4 in the diagram, what protocol is being used?

3. At point 6 in the diagram, what protocol is being used?

4. Does SMTP use TCP or UDP?

5. Is SMTP a 'push' or 'pull' protocol?

6. Is POP3 a 'push' or 'pull' protocol?

7. What port does SMTP use?

8. What port does POP3 use?

SOLUTION

1. At point 2 in the diagram, the SMTP protocol is used.

2. At point 4 in the diagram, the SMTP protocol is used.

3. At point 6 in the diagram, the POP3 protocol is used.

4. SMTP uses the TCP protocol.

5. SMTP is a 'push' protocol

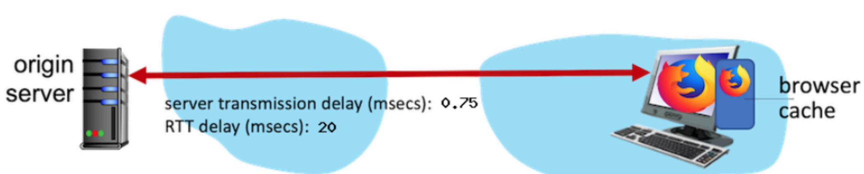
6. POP3 is a 'pull' protocol

7. SMTP uses port 25

8. POP3 uses port 110

BROWSER CACHING

Consider an HTTP server and client as shown in the figure below. Suppose that the RTT delay between the client and server is 20 msecs; the time a server needs to transmit an object into its outgoing link is 0.75 msecs; and any other HTTP message not containing an object has a negligible (zero) transmission time. Suppose the client again makes 60 requests, one after the other, waiting for a reply to a request before sending the next request.



Assume the client is using HTTP 1.1 and the IF-MODIFIED-SINCE header line. Assume 40% of the objects requested have NOT changed since the client downloaded them (before these 60 downloads are performed)

QUESTION LIST

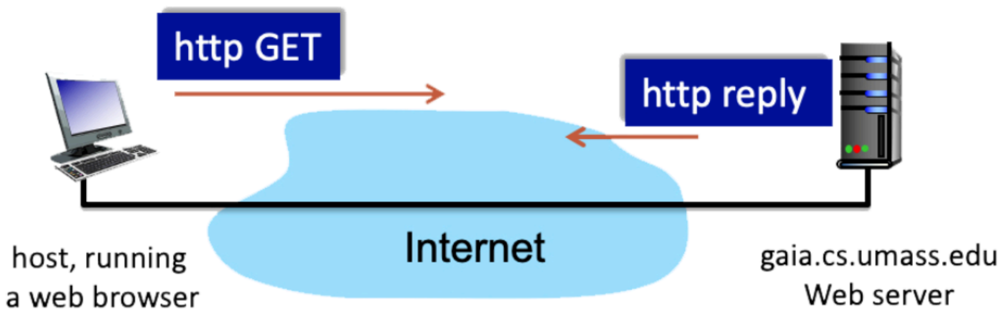
1. How much time elapses (in milliseconds) between the client transmitting the first request, and the completion of the last request?

SOLUTION

1. (RTT * NUM_PACKETS) + (NUM_PACKETS * (PERCENT__NOT_CACHED / 100) * TRANS_DELAY) = (10 * 60) + (60 * ((100-50) / 100) * 1) = 630 ms

THE HTTP RESPONSE MESSAGE

Consider the figure below, where the server is sending a HTTP RESPONSE message back the client.



Suppose the server-to-client HTTP RESPONSE message is the following:

HTTP/1.0 404 Not Found
Date: Wed, 24 Sep 2025 18:05:50 +0000
Server: Apache/2.2.3 (CentOS)
Content-Length: 804
Connection: Close
Content-type: image/html

QUESTION LIST

1. Is the response message using HTTP 1.0 or HTTP 1.1?

2. Was the server able to send the document successfully? Yes or No

3. How big is the document in bytes?

4. Is the connection persistent or nonpersistent?

5. What is the type of file being sent by the server in response?

6. What is the name of the server and its version? Write your answer as server/x.y.z

7. Will the ETag change if the resource content at this particular resource location changes? Yes or No

SOLUTION

1. The response is using HTTP/1.0

2. Since the response code is 404 Not Found, the document was NOT received successfully.

3. The document is 804 bytes.

4. The connection is nonpersistent.

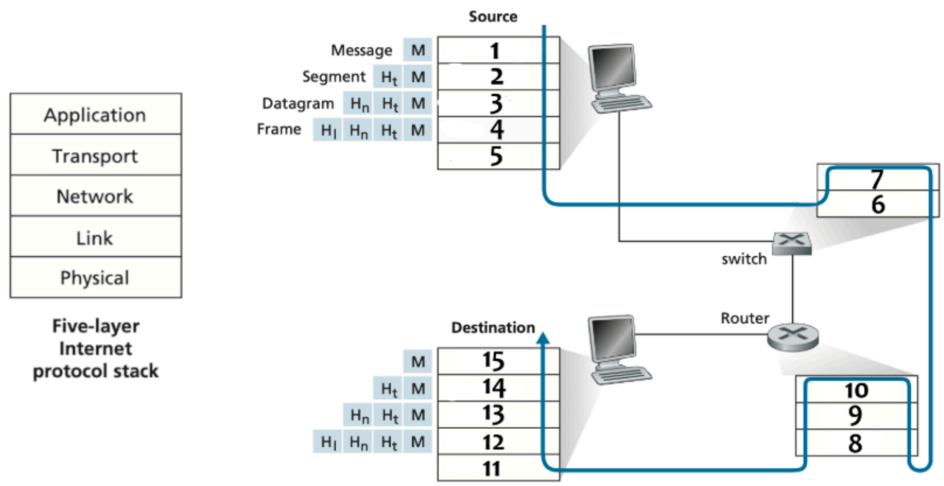
5. The file type the server is sending is image/html.

6. The name and version of the server is Apache/2.2.3

7. Yes. The Etag is a string that uniquely identifies a resource. If a resource is updated, the Etag will change.

THE IP STACK AND PROTOCOL LAYERING

In the scenario below, imagine that you're sending an http request to another machine somewhere on the network.



QUESTION LIST

1. What layer in the IP stack best corresponds to the phrase: 'moves datagrams from the source host to the destination host'

2. What layer in the IP stack best corresponds to the phrase: 'passes frames from one node to another across some medium'

3. What layer in the IP stack best corresponds to the phrase: 'handles messages from a variety of network applications'

4. What layer in the IP stack best corresponds to the phrase: 'handles the delivery of segments from the application layer, may be reliable or unreliable'

5. What layer in the IP stack best corresponds to the phrase: 'bits live on the wire'

SOLUTION

1. The given phrase corresponds to the Network Layer.

2. The given phrase corresponds to the Link Layer.

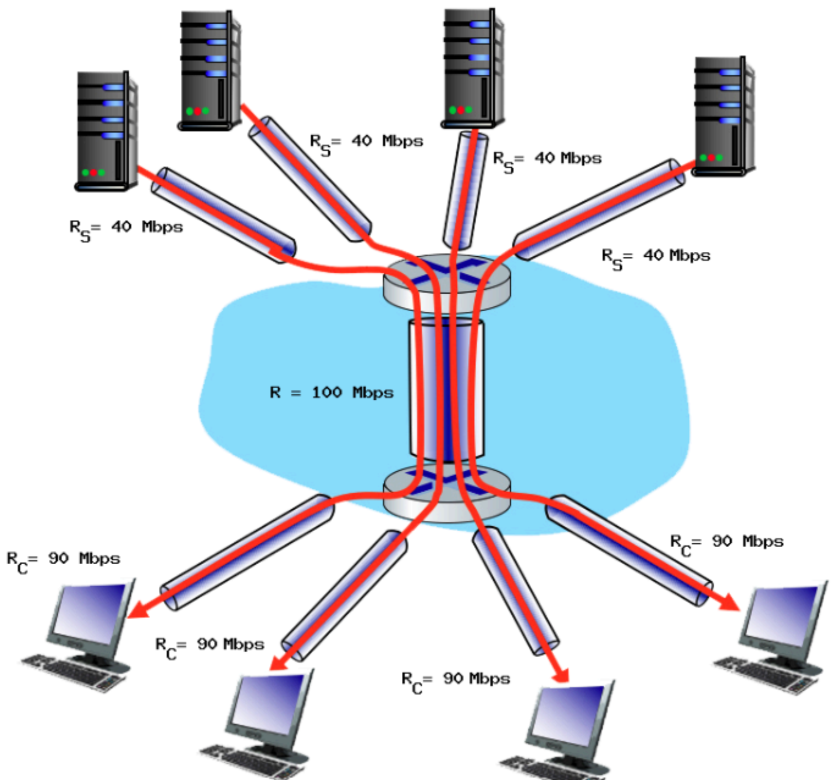
3. The given phrase corresponds to the Application Layer.

4. The given phrase corresponds to the Transport Layer.

5. The given phrase corresponds to the Physical Layer.

END TO END THROUGHPUT AND BOTTLENECK LINKS

Consider the scenario shown below, with four different servers connected to four different clients over four three-hop paths. The four pairs share a common middle hop with a transmission capacity of R = 100 Mbps. The four links from the servers to the shared link have a transmission capacity of R_S = 40 Mbps. Each of the four links from the shared middle link to a client has a transmission capacity of R_C = 90 Mbps.



QUESTION LIST

1. What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally)?

2. Which link is the bottleneck link? Format as Rc, Rs, or R

3. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the server links (R_S)? Answer as a decimal

4. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the client links (R_C)? Answer as a decimal

5. Assuming that the servers are sending at the maximum rate possible, what is the link utilizations for the shared link (R)? Answer as a decimal

SOLUTION

1. The maximum achievable end-end throughput is the capacity of the link with the minimum capacity, which is 25 Mbps

2. The bottleneck link is the link with the smallest capacity between R_S, R_C, and R/4. The bottleneck link is R.

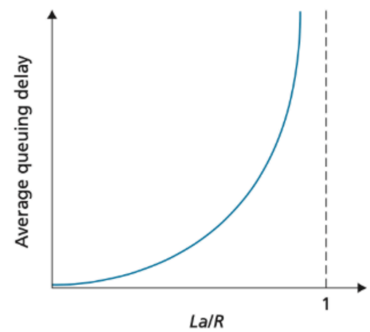
3. The server's utilization = $R_{bottleneck}$ / R_S = 25 / 40 = 0.63

4. The client's utilization = $R_{bottleneck}$ / R_C = 25 / 90 = 0.28

5. The shared link's utilization = $R_{bottleneck}$ / (R / 4) = 25 / (100 / 4) = 1

QUEUING DELAY

Consider the queuing delay in a router buffer, where the packet experiences a delay as it waits to be transmitted onto the link. The length of the queuing delay of a specific packet will depend on the number of earlier-arriving packets that are queued and waiting for transmission onto the link. If the queue is empty and no other packet is currently being transmitted, then our packet's queuing delay will be zero. On the other hand, if the traffic is heavy and many other packets are also waiting to be transmitted, the queuing delay will be long.



Assume a constant transmission rate of R = 2000000 bps, a constant packet-length L = 7600 bits, and a is the average rate of packets/second. Traffic intensity I = La/R, and the queuing delay is calculated as I(L/R)(1 - I) for I < 1.

QUESTION LIST

1. In practice, does the queuing delay tend to vary a lot? Answer with Yes or No

2. Assuming that a = 40, what is the queuing delay? Give your answer in milliseconds (ms)

3. Assuming that a = 83, what is the queuing delay? Give your answer in milliseconds (ms)

4. Assuming the router's buffer is infinite, the queuing delay is 0.8205 ms, and 1938 packets arrive. How many packets will be in the buffer 1 second later?

5. If the buffer has a maximum size of 513 packets, how many of the 1938 packets would be dropped upon arrival from the previous question?

SOLUTION

1. Yes, in practice, queuing delay can vary significantly. We use the above formulas as a way to give a rough estimate, but in a real-life scenario it is much more complicated.

2. Queuing Delay = I(L/R)(1 - I) * 1000 = 0.152*(7600/2000000)*(1-0.152) * 1000 = 0.4898 ms.

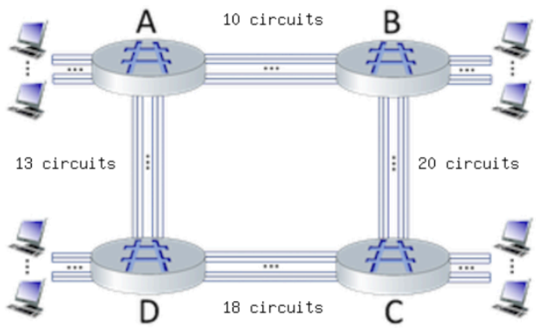
3. Queuing Delay = I(L/R)(1 - I) * 1000 = 0.3154*(7600/2000000)*(1-0.3154) * 1000 = 0.8205 ms.

4. Packets left in buffer = a - floor(1000/delay) = 1938 - floor(1000/0.8205) = 720 packets.

5. Packets dropped = packets - buffer size = 1938 - 513 = 1425 dropped packets.

CIRCUIT SWITCHING

Consider the circuit-switched network shown in the figure below, with circuit switches A, B, C, and D. Suppose there are 10 circuits between A and B, 20 circuits between B and C, 18 circuits between C and D, and 13 circuits between D and A.



QUESTION LIST

1. What is the maximum number of connections that can be ongoing in the network at any one time?

2. Suppose that these maximum number of connections are all ongoing. What happens when another call connection request arrives to the network, will it be accepted? Answer Yes or No

3. Suppose that every connection requires 2 consecutive hops, and calls are connected clockwise. For example, a connection can go from A to C, from B to D, from C to A, and from D to B. With these constraints, what is the is the maximum number of connections that can be ongoing in the network at any one time?

4. Suppose that 11 connections are needed from A to C, and 17 connections are needed from B to D. Can we route these calls through the four links to accommodate all 28 connections? Answer Yes or No

SOLUTION

1. The maximum number of connections that can be ongoing at any one time is the sum of all circuits, which happens when 10 connections go from A to B, 20 connections go from B to C, 18 connections go from C to D, and 13 connections go from D to A. This sum is 61.

2. No, it will be blocked because there are no free circuits.

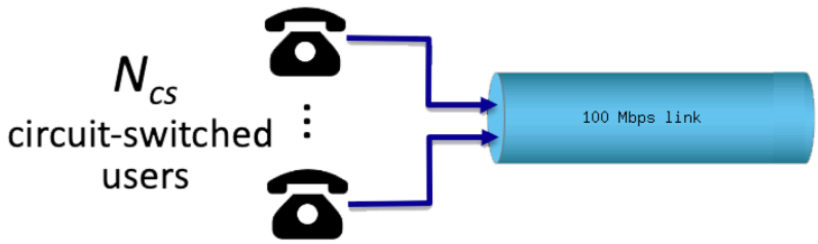
3. There can be a maximum of 28 connections. Consider routes A->C and C->A, sum the bottleneck links, consider any leftover capacity that would allow for B->D and D->B connections, and compare that value to the equivalent of B->D and D->B.

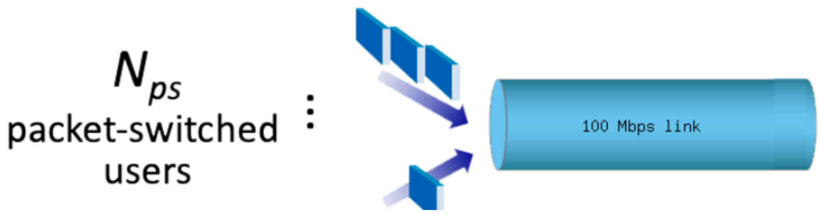
4. Using our answer from question 4, the sum of our needed connections is 28, and we have 28 available connections, so it is possible.

QUANTITATIVE COMPARISON OF PACKET SWITCHING AND CIRCUIT SWITCHING

This question requires a little bit of background in probability (but we'll try to help you though it in the solutions). Consider the two scenarios below:

- A circuit-switching scenario in which N_{cs} users, each requiring a bandwidth of 20 Mbps, must share a link of capacity 100 Mbps.
- A packet-switching scenario with N_{ps} users sharing a 100 Mbps link, where each user again requires 20 Mbps when transmitting, but only needs to transmit 30 percent of the time.





QUESTION LIST

1. When circuit switching is used, what is the maximum number of users that can be supported?

2. Suppose packet switching is used. If there are 9 packet-switching users, can this many users be supported under circuit-switching? Yes or No.

3. Suppose packet switching is used. What is the probability that a given (specific) user is transmitting, and the remaining users are not transmitting?

4. Suppose packet switching is used. What is the probability that one user (*any* one among the 9 users) is transmitting, and the remaining users are not transmitting?

5. When one user is transmitting, what fraction of the link capacity will be used by this user? Write your answer as a decimal.

6. What is the probability that any 6 users (of the total 9 users) are transmitting and the remaining users are not transmitting?

7. What is the probability that *more* than 5 users are transmitting?

SOLUTION

1. When circuit switching is used, at most 5 users can be supported. This is because each circuit-switched user must be allocated its 20 Mbps bandwidth, and there is 100 Mbps of link capacity that can be allocated.

2. No. Under circuit switching, the 9 users would each need to be allocated 20 Mbps, for an aggregate of 180 Mbps - more than the 100 Mbps of link capacity available.

3. The probability that a given (specific) user is busy transmitting, which we'll denote p, is just the fraction of time it is transmitting, i.e. 0.3. The probability that one specific other user is not busy is (1-p), and so the probability that all of the other N_{ps}-1 users are not transmitting is $(1-p)^{N_{ps}-1}$. Thus the probability that one specific user is transmitting and the remaining users are not transmitting is $p*(1-p)^{N_{ps}-1}$, which has the numerical value of 0.017.

4. The probability that exactly one (any one) of the N_{ps} users is transmitting is N_{ps} times the probability that a given specific user is transmitting and the remaining users are not transmitting. The answer is thus N_{ps} * p * $(1-p)^{N_{ps}-1}$, which has the numerical value of 0.16.

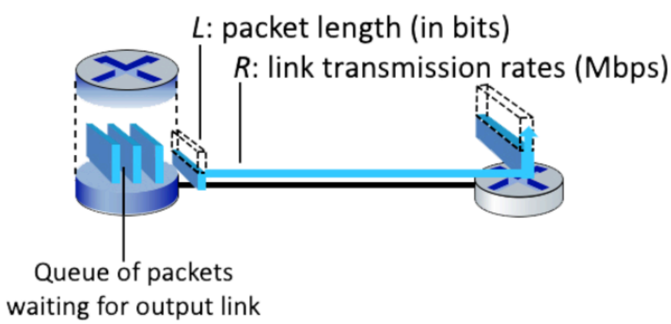
5. This user will be transmitting at a rate of 20 Mbps over the 100 Mbps link, using a fraction 0.2 of the link's capacity when busy.

6. The probability that 6 specific users of the total 9 users are transmitting and the other 3 users are idle is $p^6(1-p)^3$. Thus the probability that any 4 of the 7 users are busy is choose(9, 6) * $p^6(1-p)^3$, where choose(9, 6) is the (9, 6) coefficient of the binomial distribution). The numerical value of this probability is 0.021.

7. The probability that more than 5 users of the total 9 users are transmitting is $\Sigma_{i=6,9}$ choose(9, i) * $p^i(1-p)^{9-i}$. The numerical value of this probability is 0.025. Note that 5 is the maximum number of users that can be supported using circuit switching. With packet switching, nearly twice as many users (9) are supported with a small probability that more than 5 of these packet-switching users are busy at the same time.

COMPUTING THE ONE-HOP TRANSMISSION DELAY

Consider the figure below, in which a single router is transmitting packets, each of length *L* bits, over a single link with transmission rate *R* Mbps to another router at the other end of the link.



Suppose that the packet length is *L*= 12000 bits, and that the link transmission rate along the link to router on the right is *R* = 1 Mbps.

Round your answer to two decimals after leading zeros

QUESTION LIST

1. What is the transmission delay?

2. What is the maximum number of packets per second that can be transmitted by this link?

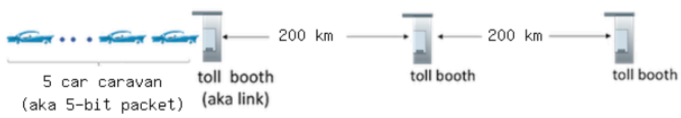
SOLUTION

The transmission delay = L/R = 12000 bits / 1000000 bps = 0.012 seconds

The number of packets that can be transmitted in a second into the link = R / L = 1000000 bps / 12000 bits = 83 packets

CAR - CARAVAN ANALOGY

Consider the figure below, adapted from Figure 1.17 in the text, which draws the analogy between store-and-forward link transmission and propagation of bits in packet along a link, and cars in a caravan being serviced at a toll booth and then driving along a road to the next tollbooth.



Suppose the caravan has 5 cars, and that the tollbooth services (that is, transmits) a car at a rate of one car per 2 seconds. Once receiving serving a car proceeds to the next tool both, which is 200 kilometers away at a rate of 10 kilometers per second. Also assume that whenever the first car of the caravan arrives at a tollbooth, it must wait at the entrance to the tollbooth until all of the other cars in its caravan have arrived, and lined up behind it before being serviced at the toll booth. (That is, the entire caravan must be stored at the tollbooth before the first car in the caravan can pay its toll and begin driving towards the next tollbooth).

QUESTION LIST

1. Once a car enters service at the tollbooth, how long does it take until it leaves service?

2. How long does it take for the entire caravan to receive service at the tollbooth (that is the time from when the first car enters service until the last car leaves the tollbooth)?

3. Once the first car leaves the tollbooth, how long does it take until it arrives at the next tollbooth?

4. Once the last car leaves the tollbooth, how long does it take until it arrives at the next tollbooth?

5. Once the first car leaves the tollbooth, how long does it take until it enters service at the next tollbooth?

6. Are there ever two cars in service at the same time, one at the first toll booth and one at the second toll booth? Answer Yes or No

7. Are there ever zero cars in service at the same time, i.e., the caravan of cars has finished at the first toll both but not yet arrived at the second tollbooth? Answer Yes or No

SOLUTION

1. Service time is 2 seconds

2. It takes 10 seconds to service every car, (5 cars * 2 seconds per car)

3. It takes 20 seconds to travel to the next toll booth (200 km / 10 km/s)

4. Just like in the previous question, it takes 20 seconds, regardless of the car

5. It takes 28 seconds until the first car gets serviced at the next toll booth (5-1 cars * 2 seconds per car + 200 km / 10 km/s)

6. No, because cars can't get service at the next tollbooth until all cars have arrived

7. Yes, one notable example is when the last car in the caravan is serviced but is still travelling to the next toll booth; all other cars have to wait until it arrives, thus no cars are being serviced