CS305: Computer Networking
2023 Fall Semester Written Assignment # 1

Due: Oct. 21th, 2023, please submit through Blackboard

Please answer questions in English. Using any other language will lead to a zero point.

Q 1 *Explain the five-layer Internet protocol stack. Please include the following details:*

- *What are the five layers?*
- *What is the functionality or description of each layer?*
- *What are the typical protocols of each layer (if any)?*

Solution:

Layers	Functionality or Description	Protocols
Application layer	This layer is where network applications reside. Typical applications include web, email, video streaming, etc.	HTTP, FTP, SMTP, DNS
Transport layer	This layer transports application-layer messages between application endpoints, i.e., processes.	TCP, UDP
Network layer	This layer is responsible for moving network packets from one host to another.	IP
Link layer	This layer is responsible for moving a packet from one node (i.e., host or router) to another.	Ethernet, WiFi
Physical layer	This layer moves individuals bits from one node to another over the wire or wireless medium.	The protocols depend on the actual transmission medium (e.g., twisted-pair cooper wire, radio)

Q 2 *Answer the following questions:*

(a) What type of applications is TCP better suited for? Any application examples?

(b) What type of applications is UDP better suited for? Any application examples?

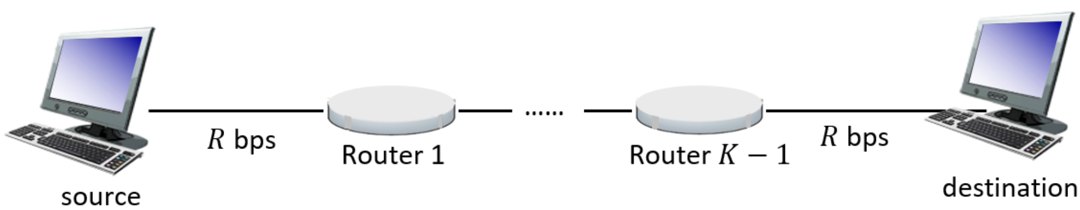
Solution:

(a) Those applications that require reliable data transfer, e.g., email, file transfer.

(b) Those applications that are time-sensitive, e.g., real-time video streaming, real-time gaming.

Students may have other answers. He or she can get the points as long as the answer is reasonable.

Q 3 *Consider a packet of L bits sending from the source to destination through a K-hop path. That is, there are $K-1$ routers between the source and destination. Suppose each link has a transmission rate of R bits per*



second (bps), and the propagation delay is d for each hop.

(a) Consider a packet switching network. Suppose there is no nodal processing delay and queuing delay. What is the end-to-end delay?

(b) *Consider a circuit switching network. Suppose the circuit setup time is τ seconds. Links in the network use frequency division multiplexing (FDM), where the associated frequency band is divided into F subbands, each being allocated to a user (or circuit). [Hint: As a result, the transmission rate allocated to each user (or circuit) is R/F.] What is the end-to-end delay?*

(c) *Consider a packet switching network with $L = 1000$ bits, $K = 2$, $R = 20$ Mbps, $d = 10\mu s$. There are two packets sent one after the other, and there are no other packet in the system. Let the nodal processing delay at the router be $5\mu s$. We ignore the nodal processing delay at the source and destination. Compute the time required to send both packets from the source and destination. [Note: In our lecture, we set 1 Kbit $= 10^3$ bits and 1 Mbit $= 10^6$ bits.]*

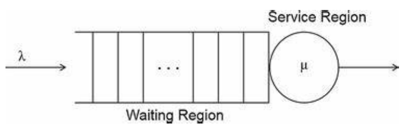
Solution:

(a) The one-hop delay is equal to the one-hop transmission delay plus the one-hop propagation delay, i.e., $L/R + d$. Since packet switching exploits a store-and-forward scheme, the end-to-end delay along this K-hop path is equal to $K(L/R + d)$.

(b) Since the links uses FDM with F subbands, the transmission rate of each subband is R/F bps. It takes τ seconds for circuit setup, takes $L/(R/F)$ seconds to transmit the packet, and Kd seconds for each bit to propagate. Thus, the end-to-end delay is equal to $\tau + L/(R/F) + Kd$.

(c) Consider the first packet. It is received by the router at $L/R + d = 50 + 10 = 60\mu s$. The router starts to send the first packet at $60 + 5 = 65\mu s$ and finishes the sending at $65 + L/R = 115\mu s$. The destination completely receives the first packet at $115 + d = 125\mu s$. Now, consider the second packet. It is received by the router at $2L/R + d = 110\mu s$. Then, it is sent by the router at $\max\{115, 110 + 5\}\mu s = 115\mu s$. The second packet receives by the destination at $115 + L/R + d = 175\mu s$.

Q 4 *Consider a set of packets with size 10 Mbits and a queue. These packets arrive at the queue with certain patterns defined in (a) and (b), waiting for transmission. The transmission rate is 10 Mbps.*



(a) *Suppose there is one packet arrival every second. What is the average queuing delay of these packets?*

(b) *Suppose K packets arrive simultaneously every K seconds. What is the average queuing delay of these packets?*

(c) *What are the traffic intensity of the scenarios considered in (a) and (b)? Any insights?*

Solution:

(a) Without loss of generality, suppose the first packet arrives at time $t = 0$ second. Since the queue is empty, it does not need to wait. The first packet is completely sent at time $t = 1$ second. Then, according to the description, the second packet arrives at time $t = 1$ second. Since the first packet has been sent completely, the second packet does not need to wait. The second packet is completely sent at time $t = 2$ second, so and so forth. As a result, when a new packet arrives, all previous packets have been sent, so that packet can be sent immediately without queuing delay. That is, the average queuing delay is zero.

(b) Without loss of generality, suppose the first K packets arrive at time $t = 0$ second simultaneously.Then, the first packet in the queue is sent immediately after its arrival. The second packet waits for 1 seconds in the queue. The k^{th} packet waits for $(k - 1)$ seconds. Thus, the average queuing delay for these K packets arrived at time slot 0 is equal to

$$\frac{1}{K}\sum_{k=1}^{K}(k-1) = \frac{(K-1)}{2} \tag{1}$$

Then, at time K seconds, all the aforementioned K packets have been sent completely, and K new packets arrive at the queue simultaneously. It is easy to show that these K new packets have an average queuing delay of $(K - 1)/2$, so and so forth. Thus, the average delay is $(K - 1)/2$.

(c) In (a), the traffic intensity is $(1 \times 10Mbps)/10Mbps = 1$. In (b), the traffic intensity is

$$(K \times 10Mbits/K)/10Mbps = 1.$$

Although two scenarios have the same traffic intensity, the average queuing delay can be different. The average queuing delay highly depends on the arrival patterns of the packets. Under the bursty traffic in (b), the average queuing delay tends to be larger. The queuing delay can vary from packet to packet.

Q 5 *Consider the following message and answer questions.*

```
HTTP/1.1 200 OK\r\n
Date: Sun, 26 Sep 2010 20:09:20 GMT\r\n
Server: Apache/2.0.52 (CentOS)\r\n
Last-Modified: Tue, 30 Oct 2007 17:00:02
   GMT\r\n
ETag: "17dc6-a5c-bf716880"\r\n
Content-Length: 2652\r\n
Keep-Alive: timeout=10, max=100\r\n
Connection: Keep-Alive\r\n
Content-Type: text/html; charset=ISO-8859-
   1\r\n
data data data data data ...
```

(a) Is this message an HTTP request message or an HTTP response message?

(b) Does this message corresponds to a non-persistent or a persistent connection? Explain the idea of persistent connection.

(c) There is one formatting mistake in this message. What is this mistake?

(d) Why do we need the header of "Last-Modified"? Consider from the perspective of proxy server.

Solution:

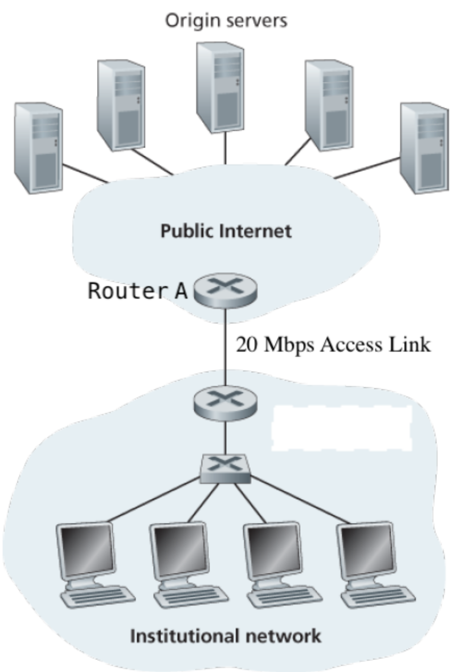
(a) HTTP response message.

(b) Persistent connection. With persitent connection, multiple objects can be sent over single TCP connection between client and server.

(c) There should be an extra carriage return and line-feed (or equivalently, a blank line) between the header lines and the entity body.

(d) Proxy server can use the filed of "Last-Modified" to check whether a certain object has been modified or not at the origin server. To achieve this, the proxy server sends a Conditional GET message to the origin server, with the header of "If-modified-since".

Q 6 *Consider the following figure with an institutional network connected to the Internet. There are a set of objects with size 1 Mbits. Suppose the institution's browsers has an average request rate of 10 requests per second, and all those requests are sent to the origin servers.*



The average response time is determined as follows:

$$\texttt{Average Response Time} = \texttt{Internet Delay} + \texttt{Average Access Delay}. \tag{2}$$

- *Internet delay is the round trip time between router A and the origin server. It is equal to 2 seconds.*

- *Average access delay is the delay from Router A to the institution router. The transmission rate of the access link is 20 Mbps. The average access delay is equal to $\Delta/(1-\Delta\beta)$, where Δ is the average time required to transmit an object over the access link (i.e., the transmission delay of an obejct); β is the arrival rate (in requests per second) at the access link.*

- *Note: The delays over other links, e.g., local area network (LAN) delay, are regarded as zero.*

Answer the following questions:

(a) *Derive average response time of the system.*

(b) *Suppose there is a cache installed in the institutional LAN. Compute the hit rate $x \in [0,1]$ that leads to an average response time that is less than 1 second.*

Solution:

(a) The average access delay is equal to $\Delta/(1-\Delta\beta)$, where $\Delta = 1Mbits/20Mbps = 0.05$ second, and $\beta = 10$ requests per second. Thus, the average access delay is equal to $0.05/(1-0.05\times 10) = 0.1$ second. The average response time $= 0.1 + 2 = 2.1$ seconds.

(b) Suppose the hit rate is $x \in [0,1]$. Then, $10x$ requests per second are served by the cache within LAN, which has a delay of zero. Meanwhile, $10(1-x)$ requests per second are served by the origin server. Their associated response delay is equal to $0.05/(1-0.05\times 10\times(1-x))+2$. Thus, the average response delay of all requests is

$$(1-x)\times(0.05/(1-0.05\times 10\times(1-x))+2)+x\times 0.$$

To ensure this value to be less than 1 second, we have $x > 0.515965$.

Q 7 *Suppose you click a web page within your Web browser, and your local DNS server has stored the related resource records. Let RTT_0 denote the round trip time (RTT) between your host and your local DNS server. On the web page you visit, there are an HTTP basic file and 12 referenced objects. Let RTT_1 denote the RTT between the local host and the Web server. The HTTP basic file has a size of L Mbit, and each referenced object has a size of L Mbit. The transmission rate is R Mbps. Compute how much time elapses from when you click the link until your web browser receives the objects.*

(a) *Non-persistent HTTP with no parallel TCP connections?*

(b) *Non-persistent HTTP with the browser configured for 4 parallel connections?*

(c) *Persistent HTTP? Note that in this case, if a client knows the URLs of its requested referenced objects, the client can send requests of referenced objects back-to-back without waiting for the responses.*

Solution:

(a) $RTT_0 + (2RTT_1 + L/R) + 12\times(2RTT_1 + L/R)$

(b) $RTT_0 + (2RTT_1 + L/R) + 3\times(2RTT_1 + L/R)$

(c) $RTT_0 + RTT_1 + (RTT_1 + L/R) + RTT_1 + 12\times L/R$

Q 8 *Answer the following questions:*

(a) *Explain the differences between HTTP and SMTP.*

(b) *Can HTTP be used as a mail access protocol? Why?*

(c) *Can we place the receiver's mail server at the receiver's PC? How about placing the sender's mail server at the sender's PC?*

Solution:

(a)
- HTTP is a pull protocol; SMTP is a push protocol
- In HTTP messages, the headers should be encoded in ASCII; in SMTP messages, both the header and body must be encoded in ASCII
- With HTTP, each object is encapsulated in its own HTTP message; with SMTP, all objects of a message can be placed in one SMTP message

(b) Yes. For mail access, the receiver's user agent obtains messages from the receiver's mail server using a pull operation. Since HTTP is a pull protocol, it can be used.

(c) No, because the receiver's mail server should be always-on. No, because the sender's mail server may fail in sending messages sometimes, and it needs to try multiple times until it succeeds. Having the sender's mail sever locate at the sender's PC will put too much load on that PC.

Q 9 *Suppose you want to register your domain name* exmple.com *with a TLD server, you need to provide the TLD server with the information of your authoritative DNS server:*

- *The hostname of your authoritative DNS server is* dns.example.com.
- *The IP address of your authoritative DNS server is 200.200.200.[last-two-digits-of-your-SID]. Note that [last-two-digits-of-your-SID] should be fill in with the last two digits of your own student ID.*

Answer the following questions:

(a) *At which TLD server you need to register the information of your authoritative DNS server?*

(b) *A Type NS and a Type A record are needed to be inserted into the TLD server. What are these records?*

Solution:

(a) TLD com server. [As long as the student mentioned "com", he or she can get the point.]

(b) (example.com, dns.example.com, NS)

(dns.example.com, 200.200.200.[last-two-digits-of-your-SID], A)

Q 10 *Consider a server distributes a file of $F = 20$ Gbits to N peers. The server has a upload rate of $u_s = 15$ Mbps. Each peer has a upload rate of u Mbps and a download rate of $d = 4$ Mbps. Please plot or draw the following curves with x-axis corresponding to N (ranging from 1 to 1000) and y-axis corresponding to the minimum distribution time.*

(a) *Client-server distribution;*

(b) *P2P distribution with $u = 100$ Kbps, 600 Kbps, 4 Mbps, respectively.*

Please draw all the aforementioned four curves in the same figure.

(c) *Based on (a) and (b), which one is better in terms of reducing the distribution time, P2P or client-server? Why? How does u affect the distribution time?*

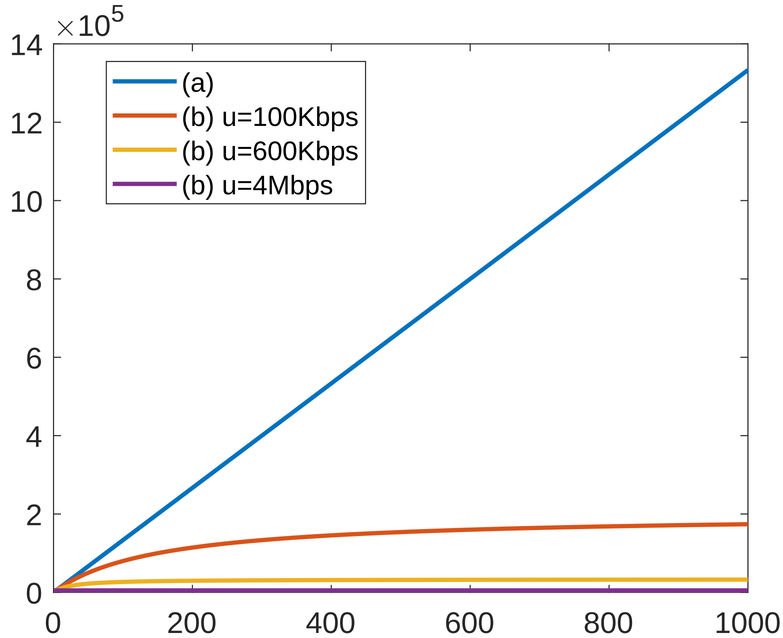
Solution:

(a) Client-server distribution: The minimum distribution time is equal to

$$\max\{\frac{NF}{u_s}, \frac{F}{d}\} = \max\{\frac{20000N}{15}, \frac{20000}{4}\} \tag{3}$$

(b) P2P distribution: The minimum distribution time is equal to

$$\max\{\frac{F}{u_s}, \frac{F}{d}, \frac{NF}{u_s + Nu}\} = \max\{\frac{20000}{15}, \frac{20000}{4}, \frac{20000N}{15 + Nu}\} \tag{4}$$



The distribution time under P2P model increases less drastically as the number of peers increases, when compared to that under client-server model. This is because under a P2P model, a new peer brings not only additional demands but also additional supplying capacity. Under P2P model, when u is larger (i.e., each peer has a higher capacity in distributing files), the increase of the distribution time in N is less drastically. (Students can get the points as long as their answers are reasonable.)