50.012 Networks (2021 Term 6)

Homework 1

Internet & Application Layer Overview

Hand-out: 21 Sep

Due: 2 Oct 23:59

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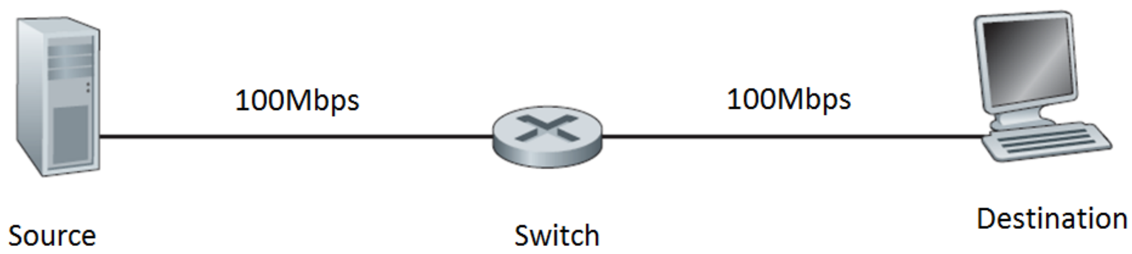
1. Why two ISPs peer with each other? (Hint: consider the different types of peering: Regional ISP with Regional ISP, Tier 1 with Tier 1, and Regional ISP with content provider) What is the role of an IXP? How does an IXP generate revenue? (Hint: study some IXP, e.g., https://www.sgix.sg/)

Answer: Two ISPs at the same level of the hierarchy often peer with each other to send and receive traffic directly without paying to any intermediate ISP providers, thus potentially reducing their costs, and becoming more cost-efficient. They can also minimize their external dependencies and would not suffer from any outages that might affect IXPs. Both ISPs would also be in direct contact with each other when solving problems, and they can both be sure that each of them can use the full dedicated bandwidth capacity of the interconnecting link to-and-fro the other ISP. Other benefits might include network reachability, increased redundancy (in terms of network connectivity), increased routing control, improved traffic management and traffic predictability, as well as reduced latency and congestion. An example would be a Regional ISP that provides Internet connectivity to a content provider, which would then provide access to content to those connected to a Regional ISP – which could be another Regional ISP or a Tier 1.

The primary role/purpose of an IXP is to allow networks to efficiently interconnect directly via the exchange points (actual physical infrastructure) that they provide, which serve as shorter and more direct routes for Internet traffic, rather than going through third-party networks. This would lower the overall interconnectivity costs and improve network performance for all peering members of said IXP. IXPs often provide peering LANs that could potentially stretch over multiple datacenters spanning large geographical distances. IXPs can also offer route servers, allow larger ISPs to private peer with smaller ISPs without much operational costs, as well as free up the availability of router ports used by ISPs. This can reduce the costs for end users. IXPs can generate revenue and earn money by charging the ISPs that connect to itself. A possible scheme could be by charging each ISP based on the amount of traffic sent to or sent by the IXP.

2. (2019's mid-term exam question): Calculate the end-to-end delay (i.e., the duration from the first bit sent by the source to the last bit received by the destination) for a packet with size of 1500 bytes (12,000 bits) for the following settings:

2.1 The source and the destination are connected via a store-and-forward switch (as in the figure below). Assume that each link in the figure has a propagation delay of 12 μs (1 μs = 10^{-6}s) and operates at 100Mbps (consider 1M = 10^6). The switch begins forwarding immediately after it finishes receiving the whole packet. Assume zero processing and queueing delay.



Single switch case

Answer:

$$\text{Transmission delay in 1 node} = \frac{12000}{100 \times 10^6} = 0.00012 \text{ seconds} = 120\ \mu s$$

$$\text{Total end-to-end delay} = (2 \times 120) + (2 \times 12) = \mathbf{264\ \mu s}$$

2.2 Same scenario as **2.1** above, calculate the end-to-end delay when there are four switches chained together (each switch and each link have the same setting as in scenario **2.1**) in the path between the source and the destination.

Answer:

$$\text{Total end-to-end delay} = (5 \times 120) + (5 \times 12) = \mathbf{660\ \mu s}$$

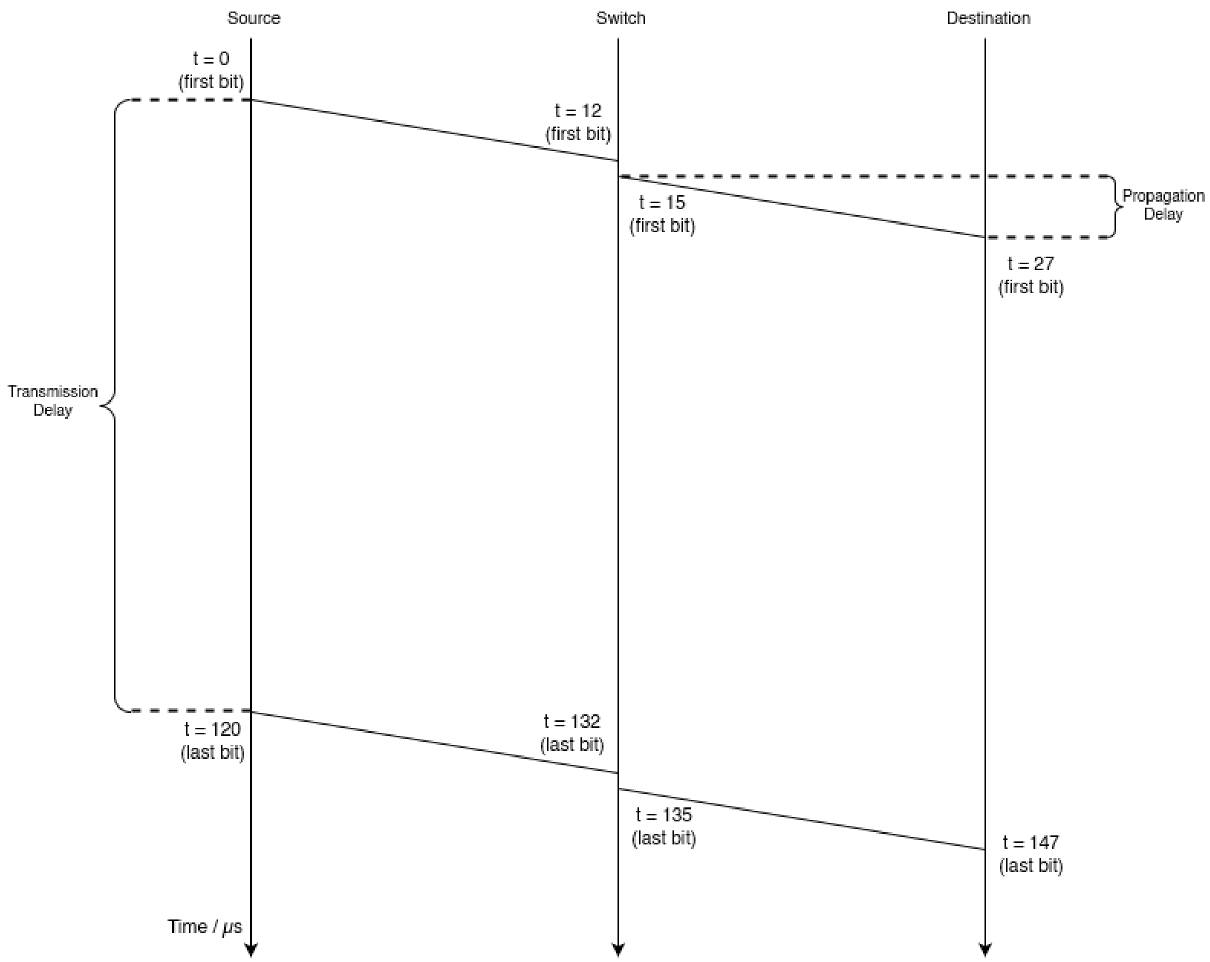
2.3 Same scenario as **2.1** above, i.e., there is only a single switch between the source and the destination, but assume the switch implements "cut-through" switching, i.e., the switch begins to forward the packet after the first 300 bits of the packet have been received. Calculate the end-to-end delay. (Hint: Draw a space-time diagram.)

Answer:

$$\text{Delay until switch starts forwarding} = \frac{300}{100 \times 10^6} \times 10^6 = 3\ \mu s$$

$$\text{Total end-to-end delay} = 3 + 120 + (2 \times 12) = \mathbf{147\ \mu s}$$

Space-time diagram (drawn to scale):



3. (textbook chapter 2, review problem R26): In Section 2.7 of the textbook, the UDP server described needed only one socket, whereas the TCP server needed two sockets. Why? If the TCP server were to support n simultaneous connections, each from a different client host, how many sockets would the TCP server need?

Answer: The UDP server does not need/have a welcoming socket, and hence all incoming data from different multiple clients would enter the server through this one socket that would handle all the data. Hence, the UDP server needed only one socket.

The TCP server, on the other hand, needs/has a welcoming socket that waits for connection establishment request packets. Each time a client initiates a connection to the server, a new socket would then be created to handle the incoming data. Hence, the TCP server needed two sockets.

Thus, for the TCP server to support n simultaneous connections, the server would need **n+1 sockets**.

4. (textbook problem chapter 2, problem 4) Consider the following string of ASCII characters that were captured by Wireshark when the browser sent an HTTP GET message (i.e., this is the actual content of an HTTP GET message). The characters <cr><lf> are carriage return and line-feed characters (that is, the italicized character string <cr> in the text below represents the single carriage-return character that was contained at that point in the HTTP header). Answer the following questions, indicating where in the HTTP GET message below you find the answer.

GET /cs453/index.html HTTP/1.1<cr><lf>Host: gaia.cs.umass.edu<cr><lf>User-Agent: Mozilla/5.0 (Windows;U; Windows NT 5.1; en-US; rv:1.7.2) Gecko/20040804 Netscape/7.2 (ax) <cr><lf>Accept:ext/xml, application/xml, application/xhtml+xml, text/html;q=0.9, text/plain;q=0.8, image/png,*/*;q=0.5<cr><lf>Accept-Language: en-us,en;q=0.5<cr><lf>Accept-Encoding: zip,deflate<cr><lf>Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7<cr><lf>Keep-Alive: 300<cr><lf>Connection:keep-alive<cr><lf><cr><lf>

a. What is the URL of the document requested by the browser?

Answer: http://gaia.cs.umass.edu/cs453/index.html

The value of the Host field indicates the server's name and the value of the resource specified after the GET method indicates the filename.

b. What version of HTTP is the browser running?

Answer: 1.1

The HTTP version is indicated just after the HTTP/ text and just before the first <cr><lf> pair.

c. Does the browser request a non-persistent or a persistent connection?

Answer: Persistent

The requested connection type is indicated by the keep-alive value of the Connection field.

d. What is the IP address of the host on which the browser is running?

Answer: Unknown

This information is not contained in an HTTP message anywhere. To know what the IP address of the host is, we would need to know the IP datagrams (that carried the TCP segment that carried the HTTP GET request), instead of just by using HTTP messages alone.

e. What type of browser initiates this message? Why is the browser type needed in an HTTP request message?

Answer: Mozilla/5.0

This browser information can be found as the value of the User-Agent field. The browser type is needed by the server to provide and send different versions of the same object to different types of browsers. One browser might handle, process, and display data differently from another browser.

5. (textbook problem chapter 2, problem 5) The text below shows the reply sent from the server in response to the HTTP GET message in the question above. Answer the following questions, indicating where in the message below you find the answer.

HTTP/1.1 200 OK<cr><lf>Date: Tue, 07 Mar 2008 12:39:45GMT<cr><lf>Server: Apache/2.0.52 (Fedora)<cr><lf>Last-Modified: Sat, 10 Dec2005 18:27:46 GMT<cr><lf>ETag: “526c3-f22-a88a4c80”<cr><lf>Accept-Ranges: bytes<cr><lf>Content-Length: 3874<cr><lf>Keep-Alive: timeout=max=100<cr><lf>Connection:Keep-Alive<cr><lf>Content-Type: text/html; charset=ISO-8859-1<cr><lf><cr><lf><!doctype html public “//w3c//dtd html 4.0 transitional//en”><lf><html><lf><head><lf> <meta http-equiv=”Content-Type”content=”text/html; charset=iso-8859-1”><lf> <meta name=”GENERATOR” content=”Mozilla/4.79 [en] (Windows NT 5.0; U) Netscape]”><lf> <title>CMPSCI 453 / 591 / NTU-ST550A Spring 2005 homepage</title><lf></head><lf> <much more document text following here (not shown)>

a. Was the server able to successfully find the document or not? What time was the document reply provided?

Answer: Yes, the server located the document successfully. The document reply was provided on Tuesday, 07 March 2008 12:39:45 Greenwich Mean Time.

The successful attempt is indicated by the 200 status code and the OK phrase. The time is indicated by the value of the Date field.

b. When was the document last modified?

Answer: Saturday, 10 December 2005 18:27:46 Greenwich Mean Time

The time that the document was last modified at is indicated by the value of the Last-Modified field.

c. How many bytes are there in the document being returned?

Answer: 3874 bytes

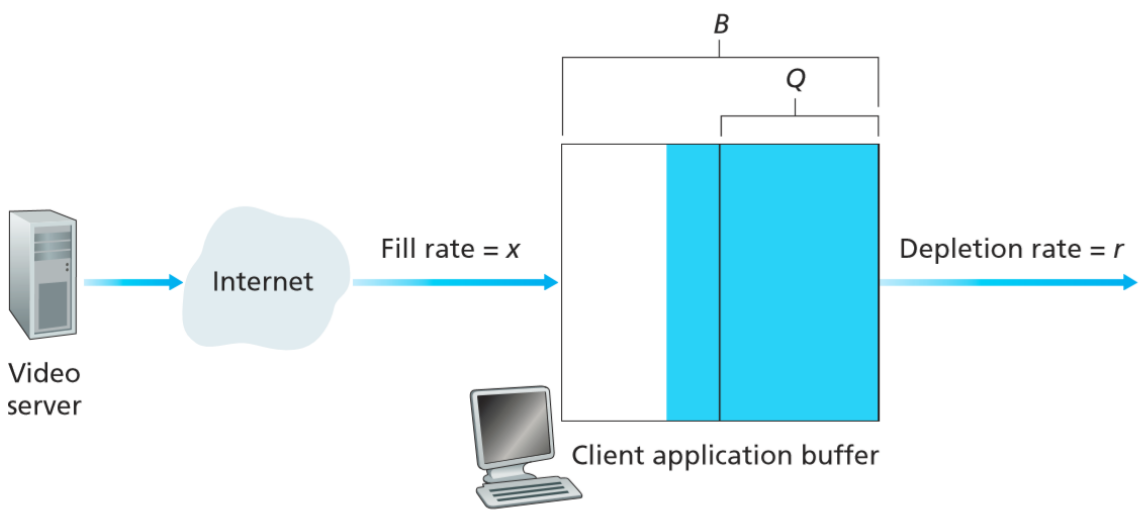
The size of the document’s content is indicated by the Content-Length field.

d. What are the first 5 bytes of the document being returned? Did the server agree to a persistent connection?

Answer: <!doc

The value of the first 5 bytes can be obtained after the double <cr><lf> consecutive pairs. Yes, the server agreed to a persistent connection, as indicated by the Keep-Alive value of the Connection field.

6. Recall the simple model for HTTP streaming shown in the Figure below. Let B denote the size of the client's application buffer, and let Q denote the number of bits that must be buffered before the client application begins playout. Also, let r denote the video consumption rate. Assume that the server sends bits at a constant rate x whenever the client buffer is not full.



6.1 Suppose that x < r. In this case playout will alternate between periods of continuous playout and periods of freezing. Determine the length of each continuous playout and freezing period as a function of Q, r, and x.

Answer: During a playout period, the buffer starts with Q bits and decreases at a rate of r – x.

Assuming that r and x are constants, after $\frac{Q}{r-x}$ units of time after starting playback, the buffer becomes empty, and hence the continuous playout period is: $\boldsymbol{\frac{Q}{r-x}}$ **units of time**

Once the buffer becomes empty, it fills at a rate of x for $\frac{Q}{x}$ units of time, at which it would have Q bits and playback begins. Therefore, the freezing period is: $\boldsymbol{\frac{Q}{x}}$ **units of time**

6.2 Now suppose that x > r. At what time does the client application buffer become full?

Answer: Assuming that we currently have no bits in the buffer in the present moment, and assuming that r and x are constants, then the time needed until the buffer has Q bits would be $\frac{Q}{x}$ units of time. Then, the time needed to add additional B-Q bits would be $\frac{B-Q}{x-r}$ units of time.

Therefore, the time needed until the client application buffer becomes full would be: $\boldsymbol{\frac{Q}{x} + \frac{B-Q}{x-r}}$ **units of time**

7. (2019's midterm exam question) Consider distributing a file of F = 6 x 10^9 bits to N=100 peers. The server has an upload rate of u_s = 30 Mbps, and each peer has a download rate of d_i = 2 Mbps and an upload rate of u_i=1 Mbps. Assume 1M = 10^6. Calculate the minimum distribution time (i.e., to let every peer have a copy of the file) for:

7.1 the client-server distribution mode, and

Answer:

$$\begin{aligned}\text{Minimum distribution time} &= \max\left\{\frac{NF}{u_s}, \frac{F}{d_i}\right\} \\ &= \max\left\{\frac{100 \times 6 \times 10^9}{30 \times 10^6}, \frac{6 \times 10^9}{2 \times 10^6}\right\} \\ &= \max\{20000{,}3000\} \\ &= \mathbf{20000\ seconds}\end{aligned}$$

7.2 the P2P distribution mode.

Answer:

$$\text{Minimum distribution time} = \max\left\{\frac{F}{u_s}, \frac{F}{d_i}, \frac{NF}{u_s + \sum_1^N u_i}\right\}$$

$$= \max\left\{\frac{6 \times 10^9}{30 \times 10^6}, \frac{6 \times 10^9}{2 \times 10^6}, \frac{100 \times 6 \times 10^9}{(2 \times 10^6) + (100 \times 1 \times 10^6)}\right\}$$

$$= \max\left\{200{,}3000, \frac{100000}{17}\right\}$$

$$= \frac{100000}{17}\ \text{seconds} \approx 5882.35\ \text{seconds}$$

=== END ===