Solutions to Homework #2

Due 11:59pm, Sunday, 18 February, 2018

100 points total
Multiple submissions accepted.

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Name

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PeopleSoft ID

1. (10x2 pts) Access the HTTP Delay Estimation simulator at https://media.pearsoncmg.com/aw/ecs_kurose_compnetwork_7/cw/content/interactiveanimations/http-delay-estimation/index.html

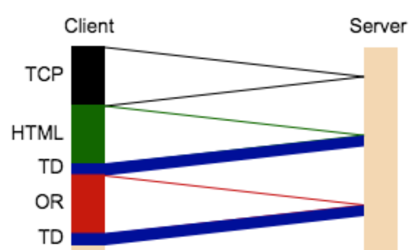
   This simulator shows how a web page and its objects are delivered from a server to a client via HTTP by a web server. For this simulation, choose 4 objects and any non-zero per-object transmission delay.

   a. Which connection type always requires the greatest total time to retrieve the page and its obejcts?
   Answer: Non-Persistent connections.

   b. Which type requires the least amount of total time?
   Answer: Persistent connection with pipelining.

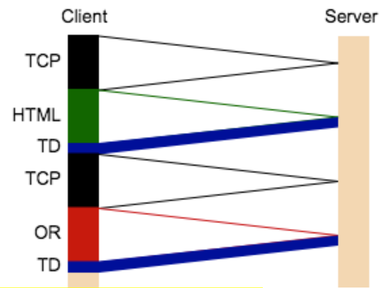
   For the following four questions, there are 4 objects being transmitted, and when we have the chance we will choose 4 parallel connections.

   c. Which type of connection does this represent (assume 4 objects)?



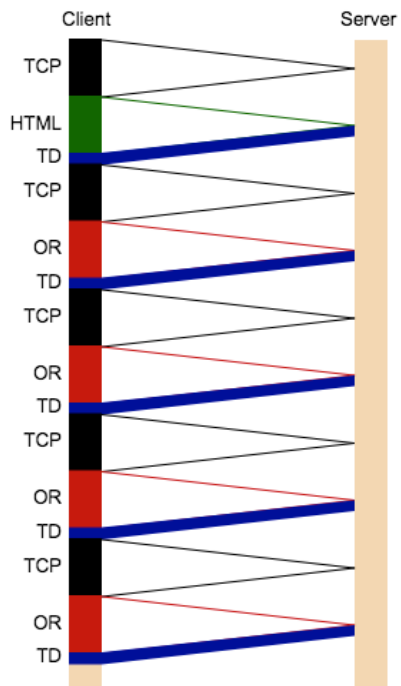
   Answer: Persistent connection with pipelining

   d. Which type of connection does this represent (assume 4 objects)?



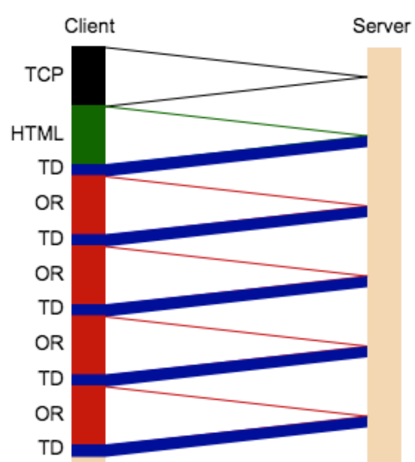
Answer: Non-persistent with parallel connections

e. Which type of connection does this represent (assume 4 objects)?



Answer: Non-Persistent Connections (without parallelism)

f. Which type of connection does this represent (assume 4 objects)?

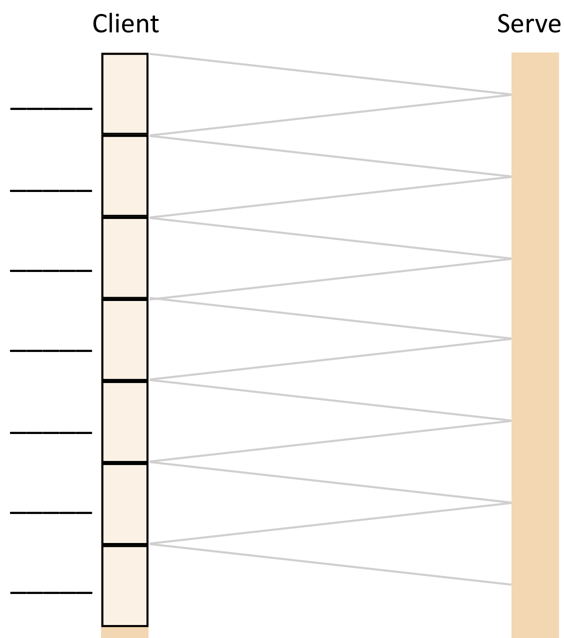


Answer: Persistent connection without pipelining

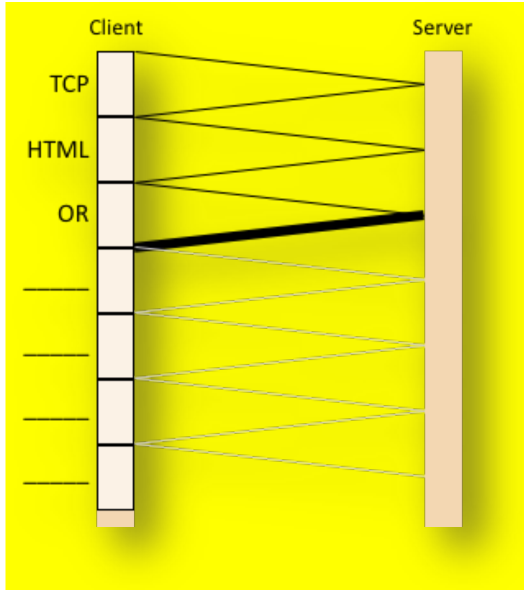
g. What do the persistent connections eliminate from the transmissions?
Answer: additional TCP connection establishment messages.

h. Compare a persistent connection with pipelining to a non-persistent connection with parallel connections with as many parallel connections as you can get. What part of the transmission just can't be eliminated from the non-persistent connection?
Answer: the delay due to TCP connection establishment.

i. Draw a trace for an html page and 6 objects using a persistent connection with pipelining by marking over the light grey lines, as many as required. Use TCP, HTML and OR labels on the left. You can ignore writing TD for Transmission Delay. However, please do assume the transmission time of web page objects are substantial and noticeable. Therefore, you should darken those lines.



Answer:



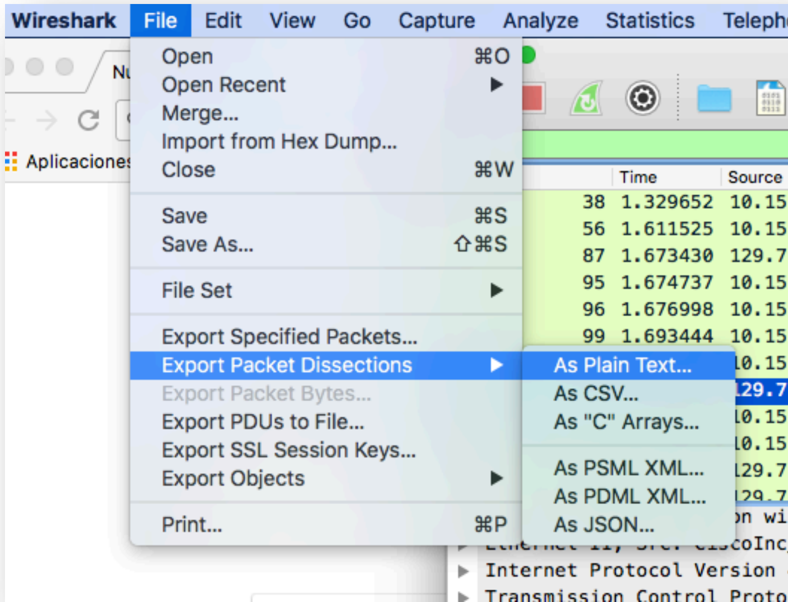
j. Despite the requirement in HTTP/1.1 that servers support pipelining, only one major browser supports pipelining by default. What is it, and briefly why is it disabled in all other major browsers? You'll find the answer in Wikipedia's page on HTTP pipelining.

Answer: Opera.

2. (5x1 pts)What is the unit of information called that each layer produces in the TCP/IP model? None of the answers are "packet".
   a. Application layer:
   b. Transport layer:
   c. Network layer:
   d. Data Link layer:
   e. Physical layer:

   Answer: a. Message, b. Segment, c. Datagram, d. Frame, e. Bit

3. (8x2 pts) Use Wireshark to capture a trace to http://www.uh.edu. Filter for HTTP, and export it using Wireshark's File menu. I had the best results choosing Export Packet Dissections as Plain Text.



Throw all the packet traces away except the very first GET and its response. If you click on the first GET, Wireshark will give you the number of its corresponding response. Then you know what to toss from your export. Paste the resulting pair of packets below as plain text, and then answer the following questions, highlighting in your packets where you found the answers. If you use Word, you can just use its built-in highlighting tool.

Paste your two packets here.
Answer: here is my trace. Yours will be different.

```
No.     Time           Source                Destination           Protocol Length Info
     38 1.329652       10.15.244.51          129.7.97.54           HTTP     1308   GET / HTTP/1.1

Frame 38: 1308 bytes on wire (10464 bits), 1308 bytes captured (10464 bits) on interface 0
Ethernet II, Src: Apple_96:2d:52 (10:40:f3:96:2d:52), Dst: CiscoInc_25:1a:40 (24:01:c7:25:1a:40)
Internet Protocol Version 4, Src: 10.15.244.51, Dst: 129.7.97.54
Transmission Control Protocol, Src Port: 55082, Dst Port: 80, Seq: 1, Ack: 1, Len: 1254
Hypertext Transfer Protocol
    GET / HTTP/1.1\r\n
    Host: www.uh.edu\r\n
    Connection: keep-alive\r\n
    User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_13_2) AppleWebKit/537.36 (KHTML, like Gecko)
    Chrome/63.0.3239.132 Safari/537.36\r\n
    Upgrade-Insecure-Requests: 1\r\n
    Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,image/apng,*/*;q=0.8\r\n
    Accept-Encoding: gzip, deflate\r\n
    Accept-Language: es-ES,es;q=0.9,en;q=0.8\r\n
     [truncated]Cookie: _ga=GA1.2.876338600.1483481021;
    optimizelyEndUserId=oeu1511972382979r0.43047823799794305;
    __gads=ID=865dec44aeb7f9c5:T=1511972395:S=ALNI_MbDcdfblG0gbJWfBO3nl-gGnk3rpA;
    AMCV_4D6368F454EC41940A4C98A6%40AdobeOrg=2096510701
    \r\n
    [Full request URI: http://www.uh.edu/]
    [HTTP request 1/4]
    [Response in frame: 106]
    [Next request in frame: 109]


No.     Time           Source                Destination           Protocol Length Info
    106 1.695685       129.7.97.54           10.15.244.51          HTTP     163    HTTP/1.1 200 OK
    (text/html)

Frame 106: 163 bytes on wire (1304 bits), 163 bytes captured (1304 bits) on interface 0
Ethernet II, Src: CiscoInc_25:1a:40 (24:01:c7:25:1a:40), Dst: Apple_96:2d:52 (10:40:f3:96:2d:52)
```

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Internet Protocol Version 4, Src: 129.7.97.54, Dst: 10.15.244.51
Transmission Control Protocol, Src Port: 80, Dst Port: 55082, Seq: 17681, Ack: 1255, Len: 109
[14 Reassembled TCP Segments (17789 bytes): #42(1360), #43(1360), #45(1360), #46(1360), #60(1360),
    #61(1360), #62(1360), #63(1360), #64(1360), #65(1360), #66(1360), #67(1360), #104(1360), #106(109)]
Hypertext Transfer Protocol
    HTTP/1.1 200 OK\r\n
    Date: Thu, 08 Feb 2018 22:42:47 GMT\r\n
    Server: Apache\r\n
    Access-Control-Allow-Origin: http://api.uh.edu\r\n
    nnCoection: close\r\n
    Content-Type: text/html\r\n
    Set-Cookie: NSC_xg-xxx.vi.fev-wt-iuuq=ffffffffaf1d287a45525d5f4f58455e445a4a423660;expires=Thu, 08-
    Feb-2018 22:44:47 GMT;path=/\r\n
    Cache-Control: private\r\n
    Content-Encoding: gzip\r\n
    Transfer-Encoding: chunked\r\n
    \r\n
    [HTTP response 1/4]
    [Time since request: 0.366033000 seconds]
    [Request in frame: 38]
    [Next request in frame: 109]
    [Next response in frame: 212]
    HTTP chunked response
    Content-encoded entity body (gzip): 17407 bytes -> 53643 bytes
    File Data: 53643 bytes
Line-based text data: text/html
```

a. What is the URL of the document requested by the browser as shown in the packet?

Answer: The file requested is just the default home page, "/".

b. What version of HTTP is the browser running?

Answer: Depends on your browser, but almost certainly HTTP/1.1

c. Does the browser request a non-persistent or a persistent connection? What makes you say that?

Answer: Most browsers will request a persistent, indicated by "keep-alive"

d. What is the IP address of the host on which the browser is running? Is that part of the HTTP data?

Answer: Mine was 10.15.244.51. Yours will be different. It is not part of the HTTP data.

e. What type of browser initiates this message?

Answer: You need to answer with what is inside the packet, not the commercial name of your browser. In my case, Mozilla/5.0.

f. Why is the browser type needed in an HTTP request message?

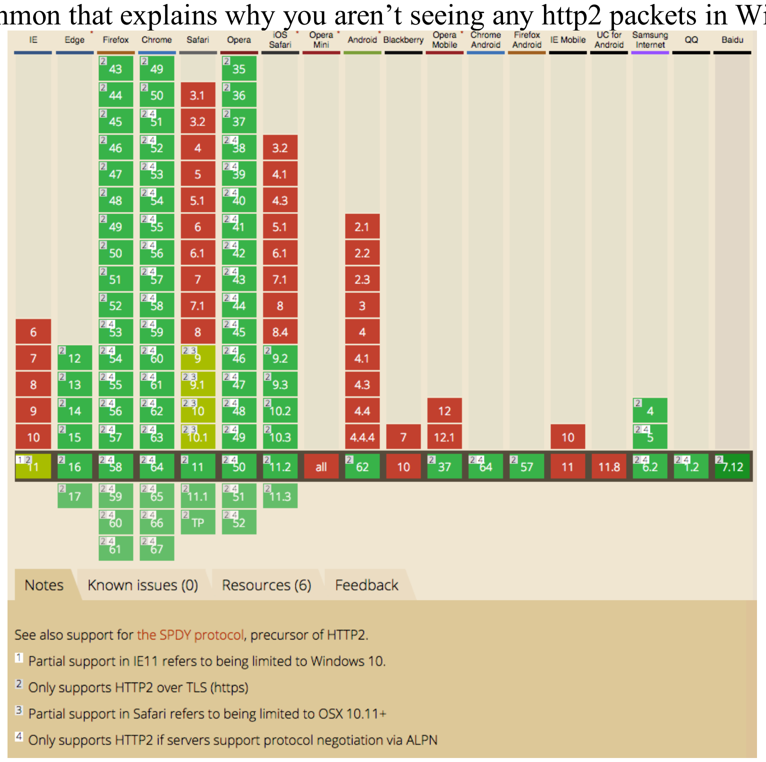
Answer: It is needed to allow the server to properly format a page that the browser can handle and display.

g. Verify that your browser supports http/2 by going to https://http2.akamai.com/. Copy and paste the message near the top of the page that states whether or not you are using HTTP/2. Ignore any comments about server push.

Answer: the message you want is: **You are using HTTP/2 right now!**

h. Now restart Wireshark's capture and navigate to www.google.com. Now that you know your browser uses HTTP/2, filter for "http2". You will come up empty. Why?

The diagram here might help you understand, from here: https://caniuse.com/#search=http%2F2. What do you see the HTTP/2-capable browsers all have in common that explains why you aren't seeing any http2 packets in Wireshark?



Answer: because all packets are encrypted/they all use TLS.

4. (6x1 pts) Not all devices process all layers all the time.
   a. Which layers in the Internet protocol stack does a router process?

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   Answer: Routers process network, link and physical layers (layers 1 through 3).

   b. Which layers does a link-layer switch process?

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   Answer: Link layer switches process link and physical layers.

   c. Which layers does a host process?

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   Answer: Hosts process all five layers.

   d. If we have a device that receives an electrical signal on a twisted pair cable, filters off high frequencies to remove noise, and amplifies the signal strength, but is completely passive and otherwise knows of the meanings of the signals, at what layer does it operate?

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   Answer: A repeater operates at the physical layer.

   e. A router offers a way for an administrator to log in and manage the device. Code to run a secure shell has been added to the router, and the administrator can log into the router remotely and change the configuration. This is an example of the router running what layers of the stack?

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   Answer: Router with secure shell is all five.

   f. We want to build a device that runs only the application layer. Is this possible?

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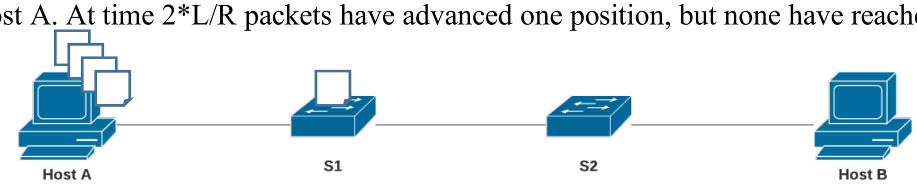
   Answer: Application layer only is not possible.

5. (2x5 pts) Equation 1.1 gives a formula for the end-to-end delay of sending one packet of length L over N links of transmission rate R which ignores propagation delay:

$$d_{end-to-end} = N\frac{L}{R}$$

Consider a network 2 two hosts, 2 switches (and thus 3 links), and 10 packets.
At time 0, all 10 packets are at Host A.

L/R is the transmission delay, so we have to wait that amount of time for a packet to leave a device.
Therefore, at time 1*L/R, one packet has moved to the first switch, and 9 packets remain at Host A. At time 2*L/R packets have advanced one position, but none have reached Host B yet:



Not until time 3*L/R does a packet arrive at Host B. 10-1=9 packets remain in transit or awaiting transmission.

Also, once the first packet arrives, the 2nd packet is at S2, only one transmission (L/R) away from Host B. Then the 3rd packet will be at S2, one transmission away. So after the first packet arrived at Host B, we need 9 more rounds of L/R to bring the remaining packets to Host B.

a. Can you generalize the equation to 2 hosts, N links (and so N-1 network devices), and P packets?

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Answer: The first packet took N*L/R, and the rest require (P-1)(L/R), so the total is (N+P-1)*(L/R) total time.

b. If we add propagation delay d_{prop} to each link, can you generalize the equation further?

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Answer: $N*(L/R + d_{prop}) + (P-1)(L/R + d_{prop}) = (N+P-1)*((L/R) + d_{prop})$

6. (2x4 pts) Review the car-caravan analogy in Section 1.4. Assume a propagation speed of 100 km/hour.
   a. Suppose the caravan travels 150 km, beginning in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth. What is the end-to-end delay? Hint: assume tollbooths are 75km apart. Then calculate how many seconds a tollbooth needs to service one car. Then you can work out how many seconds to service all cars, and how long each car's propagation delay is for the 75km before arriving at the second tollbooth. How long before they're all in front of the second tollbooth? You repeat the

whole process again from the second to the third tollbooth, where there is a servicing delay once again. That's your total.

Answer: 96 minutes
Tollbooths are 75 km apart, and the cars propagate at 100km/hr. A tollbooth services acar at a rate of one car every 12 seconds.
a) There are ten cars. It takes 120 seconds, or 2 minutes, for the first tollbooth to service the 10 cars. Each of these cars has a propagation delay of 45 minutes (travel 75 km) before arriving at the second tollbooth. Thus, all the cars are lined up before the second tollbooth after 47 minutes. The whole process repeats itself for traveling between the second and third tollbooths. It also takes 2 minutes for the third tollbooth to service the 10 cars. Thus the total delay is 96 minutes.

b. Repeat (a), now assuming that there are 12 cars in the caravan instead of ten.

Answer: Delay between tollbooths is 12*12 seconds plus 45 minutes, i.e., 47 minutes and 24 seconds. The total delay is twice this amount plus 12*12 seconds, i.e., 94 minutes and 48 seconds.

7. (8x2 pts) Consider two hosts, A and B, connected by a single link of rate R bps. Suppose that the two hosts are separated by m meters, and suppose the propagation speed along the link is s meters/sec. Host A is to send a packet of size L bits to Host B.
   a. Express the propagation delay, d_{prop}, in terms of m and s.

      Answer: $d_{prop} = m/s$ seconds.

   b. Determine the transmission time of the packet, d_{trans}, in terms of L and R.

      Answer: $d_{trans} = L/R$ seconds.
   c. Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

      Answer: $d_{end\text{-}to\text{-}end} = (m/s + L/R)$ seconds.
   d. Suppose Host **A** begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?

      Answer: The bit is just leaving Host A
   e. Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

      Answer: The first bit is in the link and has not reached Host B.

f. Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

Answer: The first bit has reached Host B.

g. After how much time will the first bit be delivered to the waiting application on Host B?

Answer: Only after all bits have arrived, at time $d_{prop} + d_{trans}$.

h. Suppose $s = 2.5 \times 10^8 m/s$, $L = 200$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}. Round to the nearest kilometer.

Answer:

$$m = \frac{L}{R} \times s = \frac{200\ bits}{56000\ bits/second} \times \left(2.5 \times 10^8 \frac{meters}{second}\right) \approx 893\text{km}$$

8. (2x3 pts) Consider a packet of length L which begins at end system A and travels over l links to a destination end system B. These three links are connected by (l-1) routers. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link i, for $i = 1, 2, 3$. Each router adds d_{proc} processing delay, and d_{queue} queueing delay.

a. What is the total end-to-end delay d_t for the packet?

Answer:

$$d_t = \sum_{i=1}^{l-1} (d_{proc} + d_{queue}) + \sum_{i=1}^{l} (d_{trans_i} + d_{prop_i})$$

The keys are the term d_{trans_i} and d_{prop_i} which change from one link to the next. We can substitute for $d_{trans} = L/R_i$ and $d_{prop} = d_i/s_i$ and get the final formula:

$$d_t = \sum_{i=1}^{l-1} (d_{proc} + d_{queue}) + \sum_{i=1}^{l} \left(\frac{L}{R_i} + \frac{d_i}{s_i}\right)$$

b. Suppose now there are 2 routers and 3 links. The packet is 1,500 bytes, the propagation speed on all links is 2.5×10^8 m/s, the transmission rates of all the links are 2 Mbps, the router processing delay is 1ms for processing, 2ms for queueing, the length of the first link is 5,000 km, the length of the second link is 4,000 km and the last 1,000km. For these values, what is the end-to-end delay?

Answer:

$$d_t = 2 \times (1\text{ms} + 2\text{ms}) + \frac{1500\ bytes * 8 \frac{bits}{byte}}{2Mbps} \times \left(\frac{5{,}000km \times \frac{1000m}{km}}{2.5 \times 10^8 \frac{m}{s}} + \frac{4{,}000km \times \frac{1000m}{km}}{2.5 \times 10^8 \frac{m}{s}} + \frac{1{,}000km \times \frac{1000m}{km}}{2.5 \times 10^8 \frac{m}{s}}\right)$$
$$= 6ms + 6ms \times (20ms + 16ms + 4ms)$$

$$= 246ms$$

9. (4 pts) In the above problem, suppose all transmission rates $R_i = R$, and dqueue = $d_{proc} = 0$. Further suppose the packet switch does not store-and-forward packets but instead immediately transmits each bit it receives before waiting for the entire packet to arrive. What is the end-to-end delay?

Answer: Because bits are immediately transmitted, the packet switch does not introduce any delay; in particular, it does not introduce a transmission delay. So we have just the propagation delay of 9000 km of cable, and the time to get the bits on the wire from A, which is 1,500 bytes * 8 bits/byte / 2 Mbps for transmission and 36ms for propagation, or 42ms.

10. (4 pts) Consider a router buffer preceding an outbound link. Let *N* denote the average number of packets in the buffer plus the packet being transmitted. Let *a* denote the rate of packets arriving at the link. Let *d* denote the average total delay (processing, queueing, and transmission delay) per packet. Little's formula is

$$N = a \times d$$

Suppose that on average, the buffer contains 10 packets, and the average packet queuing delay is 10 msec. The link's transmission rate is 100 packets/sec.
Using Little's formula, what is the average packet arrival rate in packets per second, assuming there is no packet loss?

Answer:
Because $N = a \times d$, $(10 + 1) = a \times (d_{queue} + d_{trans})$. So:

$$11 = a \times (.01\,sec + \frac{1pkt}{100sec}) = a \times .02$$

Therefore,

$$a = \frac{.02sec}{11pkt} = .00\overline{18}\frac{sec}{pkt}$$

Invert for packets per second.

$$\frac{1}{a} = 550 packets/second$$

11. (5 pts) A packet arrives at a router which makes a decision about the next link over which it is to travel. There is a buffer for that link which currently holds 4 packets. There is one packet that is 50% transmitted. Assume packets are all 1,500 bytes, and the link has a bandwidth of 2 Mbps.
    a. How long will this packet have to wait before its transmission can begin? This is the queueing delay.
    Answer:

$$\frac{1500\frac{bytes}{packet} \times 8\frac{bits}{byte} \times 4.5\,packets}{\frac{2 \times 10^6 bits}{sec} \times 1000\frac{ms}{sec}} = 27ms$$

    b. Can you generalize the equation for queueing delay for a particular queue if arriving packets have length *L bits*, the transmission rate is *R*, *x* bits of the currently-being-transmitted packet have been transmitted, and *n* packets are already in the buffer (queue)?
    Answer:

$$\frac{Ln + (L - x)\ bits}{R\ bits/sec}$$