IWP

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1 Introduction

2 Lecture (1)

- R1. What is the difference between a host and an end system? List several different types of end systems. Is a Web server an end server?
  - It is the same.
- R19: Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R1 = 500 kbps, R2 = 2 Mbps, and R3 = 1 Mbps.

  a. Assuming no other traffic in the network, what is the throughput for the file transfer?
  b. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B?
  c. Repeat (a) and (b), but now with R2 reduced to 100 kbps.
  - a. To calculate the throughput, we need to determine the bottleneck link, which is the link with the smallest bandwidth. In this case, the bottleneck link is R1 with a bandwidth of 500 kbps. Therefore, the throughput for the file transfer is 500 kbps.

    b. The file size is 4 million bytes, which is equivalent to 32 million bits (since there are 8 bits in a byte). Dividing the file size by the throughput, we get the time required to transfer the file:

    Time = File size / Throughput
    Time = 32,000,000 bits / 500,000 bits/sec

Time = 64 seconds

Therefore, it will take approximately 64 seconds to transfer the file to Host B.

c. With R2 reduced to 100 kbps, the new bottleneck link becomes R2 with a bandwidth of 100 kbps. Therefore, the throughput for the file transfer is 100 kbps.

Using the same formula as before, we can calculate the time required to transfer the file:

Time = File size / Throughput
Time = 32,000,000 bits / 100,000 bits/sec
Time = 320 seconds

Therefore, it will take approximately 320 seconds (or 5 minutes and 20 seconds) to transfer the file to Host B.

- R23 What are the five layers in the Internet protocol stack? What are the principal responsibilities of each of these layers?
  - Physical Layer: This layer is responsible for transmitting bits over a physical medium, such as copper wire, optical fiber, or wireless radio waves. The Physical Layer handles the transmission of raw bits over a physical medium.
  - Data Link Layer: This layer is responsible for transferring data between adjacent network nodes, such as between a router and a host. It provides error detection and correction, flow control, and access to the physical layer. The Data Link Layer handles the transmission of data frames between adjacent network nodes.
  - Network Layer: This layer is responsible for routing packets from the source host to the destination host across multiple network nodes. It provides network addressing, fragmentation and reassembly, and congestion control. The Network Layer handles the routing of packets across multiple network nodes.
  - Transport Layer: This layer is responsible for reliable end-to-end delivery of data between processes running on different hosts. It provides error recovery, flow control, and multiplexing and demultiplexing of data streams. The Transport Layer provides reliable end-to-end delivery of data between processes running on different hosts.
  - Application Layer: This layer is responsible for providing network services to applications running on the hosts. It includes protocols for file transfer, email, remote login, and other

network applications. The Application Layer provides network services to applications running on the hosts.

- R24 What is an application-layer message? A transport-layer segment? A network-layer datagram? A link-layer frame?
  - An application-layer message, transport-layer segment, network-layer datagram, and link-layer frame are all different types of data units used in the communication process between networked devices.
  - Application-layer message: This is data generated by an application program running on a host device. Examples of application-layer messages include email messages, web pages, and file transfers. These messages are composed of a header and a payload, with the header containing information such as the type of data, source and destination addresses, and other metadata.
  - Transport-layer segment: This is data generated by the transport layer of the protocol stack. Examples of transport-layer protocols include TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). Transport-layer segments are used to segment the data received from the application layer into smaller units that can be sent over the network. They include a header and a payload, with the header containing information such as the source and destination port numbers, and sequence numbers for reliable data delivery.
  - Network-layer datagram: This is data generated by the network layer of the protocol stack. The network layer is responsible for routing data between different networks, and as such, network-layer datagrams include information such as the source and destination IP addresses. Network-layer datagrams also include a header and a payload, with the header containing information such as the type of protocol used and the time-to-live value.
  - Link-layer frame: This is data generated by the link layer of the protocol stack. The link layer is responsible for transmitting data between devices on the same physical network, and link-layer frames include information such as the source and destination MAC addresses. Link-layer frames also include a header and a payload, with the header containing information such as the type of frame and error detection information.
  - In summary, each of these data units represents a different layer in the protocol stack, with each layer responsible for adding its own header information and preparing the data for transmission over the network.

- Solution to first few tasks in http://gaia.cs.umass.edu/kurose_ross/interactive/end-end-delay.php.

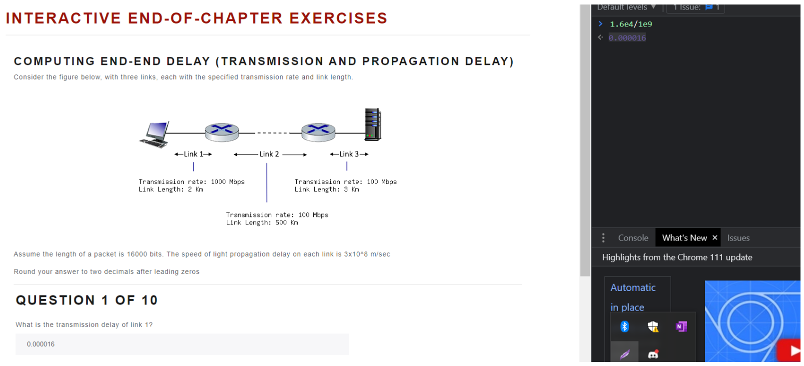

Figure 1: Question 1

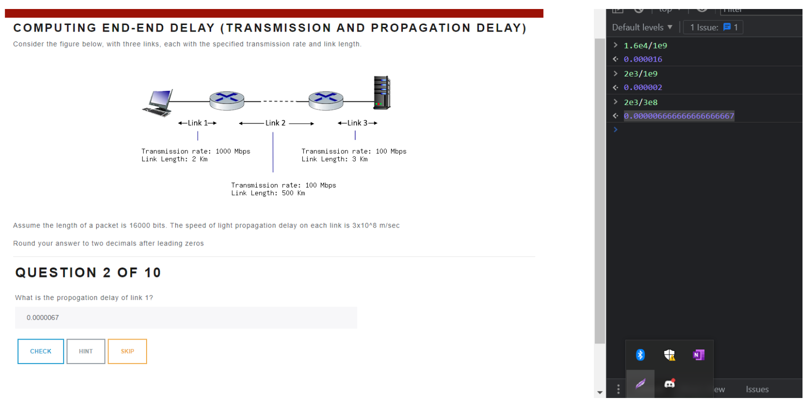

Figure 2: Question 2

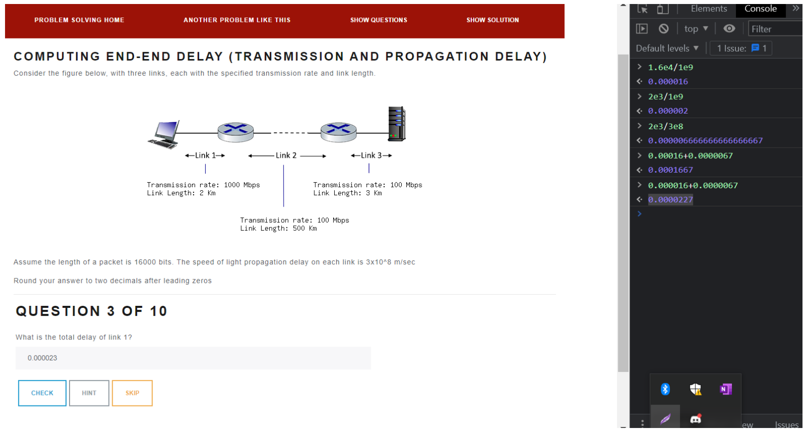

Figure 3: Question 3

- Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of R = 5 Mbps. Suppose the propagation speed over the link is $2.5 \cdot 10^8$ meters/sec.
  - a) Calculate the bandwidth-delay product, R $\cdot d_prop$
    - Propagation Delay = Distance / Propagation Speed
    - Propagation Delay = $20,000km/(2.5x10^8$ m/s)
    - Propagation Delay = 0.08 seconds or 80 milliseconds
    - Now we can calculate the bandwidth-delay product as:
    - Bandwidth-Delay Product = R x Propagation Delay
    - Bandwidth-Delay Product = 5 Mbps x 0.08 seconds
    - Bandwidth-Delay Product = 0.4 Mb or 400 kbits
  - b) Consider sending a file of 800,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?
    - Maximum Number of Bits in Transit = Bandwidth-Delay Product / 2
    - Maximum Number of Bits in Transit = 400 kbits / 2
    - Maximum Number of Bits in Transit = 200 kbits (200,000 bits)
  - c) Provide an interpretation of the bandwidth-delay product.
    - The bandwidth-delay product is the maximum amount of data that can be in transit on a network link. It is calculated by multiplying the link's bandwidth (data rate) by the propagation delay.

For example, if a link has a bandwidth of 10 Mbps and a propagation delay of 100 milliseconds, the bandwidth-delay product would be 1,000,000 bits (10 Mbps x 0.1 seconds). This means that the link can hold up to 1,000,000 bits of data in transit at any given time before it becomes congested or the performance is degraded.

- d) What is the width (in meters) of a bit in the link? Is it longer than a football field?
  * width of bit = (speed of light) / (spectral bandwidth) = $(2 \cdot 10^8 m/s)/(5 \cdot 10^6 Hz) = 40 meters$. This means that a bit in the link is approximately 40 meters wide, and an American football field is 48.8 meters.
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  * The width of a bit (also known as the bit time or bit period) can be defined as the time taken for a single bit to travel across the link. It can be expressed as the sum of the transmission time and the propagation time for a single bit.

    The transmission time for a single bit is the time taken to transmit the bit at the given transmission rate R. This is given by:

    $$\text{transmission time} = \frac{1}{R}$$

    The propagation time for a single bit is the time taken for the bit to travel the length of the link m at the given propagation speed s. This is given by:

    $$\text{propagation time} = \frac{m}{s}$$

    Therefore, the width of a bit can be expressed as:

    $$\begin{aligned} \text{bit width} &= \text{transmission time} + \text{propagation time} \\ &= \frac{1}{R} + \frac{m}{s} \end{aligned}$$

    Hence, the general expression for the width of a bit in terms of the propagation speed s, the transmission rate R, and the length of the link m is:

    $$\textit{bit width} = \frac{1}{R} + \frac{m}{s}$$

- 6) Et streaming firma skal have uploadet et ny datasæt på 40 terabytes til en server, der er placeret tæt hos forbrugerne, men et stykke væk fra firmaet. Deres Internet forbindelse til serveren tillader en gennemsnitlig upload hastighed på 100 Mbps. Hvor lang tid tager det? Sammenlig tid og pris med at sende en fysisk pakke med et speditionsfirma med næste-dags levering. Antag firmaet køber en dedikeret forbindelse til serveren, med 10 gange højere kapacitet. Hvor lang tid tager det så? Hvad bliver den gennemsnitlige udnyttelsesgrad af denne, under antagelse af at et nyt datasæt uploades en gang om måneden, og den daglige trafik (email, web-surfing, etc) udgør 20 Mbps i gennemsnit. Overvej de praktiske konsekvenser i scenariet.

- Hvor lang tid tager det?
  - $\frac{40TB}{100MB/S} = \frac{351843720.8MB}{100MB/S} = 3,518,437.2 seconds$ In other words $\approx$ 977 hours or 41 days.
- Sammenlig tid og pris med at sende en fysisk pakke med et speditionsfirma med næste-dags levering.
- Hvor lang tid tager det så?
- Hvad bliver den gennemsnitlige udnyttelsesgrad