National University of Singapore
School of Computing
CS2105: Introduction to Computer Networks
Semester 1, 2018/2019

Tutorial 1

These questions will be discussed during the next week's discussion group meetings. Please be prepared to answer these questions during the session in class. Some of the questions are taken from the textbook, so please bring it along for reference.

1. **[KR, Chapter 1, P6]** Consider two hosts, A and B, connected by a single link of rate $\boldsymbol{R}\,bps$. Suppose that the two hosts are separated by $\boldsymbol{m}\,metres$, and suppose the propagation speed along the link is $\boldsymbol{s}\,m/s$. Host A is to send a packet of size $\boldsymbol{L}\,bits$ to Host B.

   (a) Express the propagation delay, $\boldsymbol{d}_{prop}$, in terms of $\boldsymbol{m}$ and $\boldsymbol{s}$.
   Ans: $\boldsymbol{d}_{prop} = \boldsymbol{m}/\boldsymbol{s}$ sec

   (b) Determine the transmission time of the packet, $\boldsymbol{d}_{trans}$, in terms of $\boldsymbol{L}$ and $\boldsymbol{R}$.
   Ans: $\boldsymbol{d}_{trans} = \boldsymbol{L}/\boldsymbol{R}$ sec

   (c) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay $\boldsymbol{d}_{end-to-end}$.
   Ans: $\boldsymbol{d}_{end-to-end} = \boldsymbol{d}_{prop} + \boldsymbol{d}_{trans}$ sec

   (d) Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = \boldsymbol{d}_{trans}$, where is the last bit of the packet?
   Ans: The last bit just left Host A.

   (e) Suppose $\boldsymbol{d}_{prop}$ is greater than $\boldsymbol{d}_{trans}$. At time $t = \boldsymbol{d}_{trans}$, where is the first bit of the packet?
   Ans: The first bit is following in the link and has not reached Host B.

   (f) Suppose $\boldsymbol{d}_{prop}$ is less than $\boldsymbol{d}_{trans}$. At time $t = \boldsymbol{d}_{trans}$, where is the first bit of the packet?
   Ans: The first bit has already reached host B.

   (g) Suppose $\boldsymbol{s} = 2.5 \times 10^8$, $\boldsymbol{L} = 120\,bits$, and $\boldsymbol{R} = 56\,kbps$. Find the distance $\boldsymbol{m}$ so that $\boldsymbol{d}_{prop}$ equals $\boldsymbol{d}_{trans}$.
   Ans: $\boldsymbol{m} = \boldsymbol{L}/\boldsymbol{R} \times \boldsymbol{s} = 120 \times 2.5 \times 10^8/(56 \times 10^3) = 535714$ m

2. **[KR, Chapter 1, P31]** In modern packet-switched networks, including the Internet, the source host segments long, application-layer messages (for example, an image or a music file) into smaller packets and sends the packets into the network. The receiver then reassembles the packets back into the original message. We refer to this process as message segmentation. Figure 1.27 illustrates the end-to-end transport of a message with and without message segmentation.

   Consider a message that is 8×10^6 bits long that is to be sent from a source to destination, through two packet switches. Suppose each link is $\mathbf{2}\,Mbps$. Ignore propagation, queuing and processing delays.

   (a) Consider sending the message from source to destination without message segmentation. How long does it take to move the message from the source host to the first packet switch?

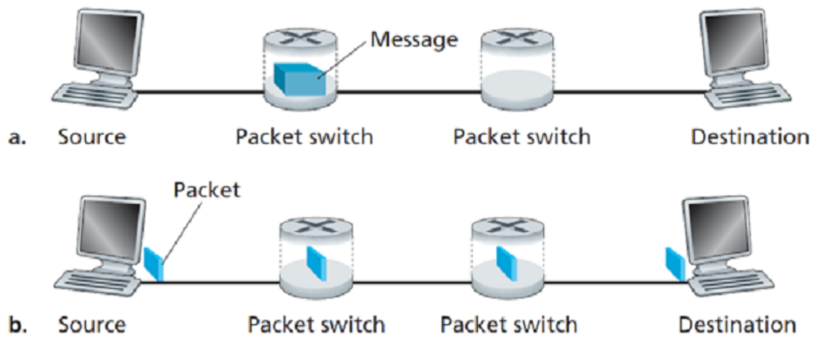

Figure 1.27 ♦ End-to-end message transport: (a) without message segmentation; (b) with message segmentation

Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

Ans: Time for source to send out the message is $8 \times 10^6 / 2 \times 10^6 = 4\,\text{s}$. Since we assume no propagation delay, packet reaches the first switch at t = 4 s.

(b) Following a), what is the total time to move the message from source host to destination host? Keeping in mind that each switch uses store-and-forward packet switching.

Ans: The 1st switch needs to receive the entire message (at $t = 4\,\text{s}$) before it starts forwarding the packet onto the outgoing link. So does the 2nd switch.

With store-and-forward switching, the total time to move the message from source host to destination host $= 4 + 4 + 4 = 12\,\text{s}$.

(c) Now suppose that the message is segmented into 800 packets, with each packet being 10,000 bits long. How long does it take to move the first packet from source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At what time will the second packet be fully received at the first switch?

Ans: Time to send the 1st packet to the 1st switch $= 10000/2 \times 10^6 = 5\,\text{ms}$. The source starts sending the 2nd packet at $t = 5\,\text{ms}$. It takes another 5 ms to send this packet to the 1st switch. Time when the 2nd packet reaches the 1st switch is therefore $5 + 5 = 10\,\text{ms}$.

(d) How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

Ans: The 1st packet reaches destination at $t = 15\,\text{ms}$. After that, every 5 ms, one more packet arrives at the destination. Thus, the time the 800th packet reaches the destination is $15 + 799 \times 5 = 4010\,\text{ms} = 4.01\,\text{s}$.

It can be seen that the end-to-end delay in using message segmentation (4.01 s) is significantly less than sending a big file as one message (12 s).

(e) In addition to reducing delay, what are reasons to use message segmentation?

Ans:

i. Without message segmentation, if bit errors are not tolerated, if there is a single bit error, the whole message has to be retransmitted (rather than a single packet).

ii. Without message segmentation, huge packets (e.g. HD videos) are sent into the network. Routers have to accommodate these huge packets. Smaller packets have to queue behind enormous packets and suffer unfair delays.

(f) Discuss the drawbacks of message segmentation.

Ans:

i. Packets have to be put in sequence at the destination (network may re-order packets).

ii. Message segmentation results in many smaller packets. Each packet needs to carry packet header of size tens of bytes (e.g. to specific destination address and port number). This is the header overhead of each packet.

3. There are $\boldsymbol{N}$ devices that need to be connected. There can either be 0 or 1 link between 2 devices.

(a) What is the minimum number of links needed to connect all nodes? Discuss the property of the network topologies that can be formed.

Ans: $N-1$ links. Organize all devices into a tree topology, chain topology or star topology.

(b) What is the maximum number of links that can be used to connect all nodes?

Ans: $N(N-1)/2$ links. All devices are directly connected to all other devices.

(c) What are the pros and cons of the solutions in part (a) and (b)?

Ans: In (a), it is a simple topology but failure of a single node or link partitions network. Also it tends to have longer paths between 2 nodes.

In (b), it is the most robust topology, 1-hop distance between all nodes, but is most expensive.

4. **[KR, Chapter 1, P25]** Suppose two hosts, A and B, are separated by 20,000 kilometers and are connected by a direct link of $\boldsymbol{R} = 2\,Mbps$. Suppose the propagation speed over the link is $2.5 \times 10^8\,m/s$.

(a) Calculate the bandwidth-delay product, $\boldsymbol{R} \times \boldsymbol{d}_{prop}$.

Ans: $2 \times 10^6 \times 20000 \times 10^3/(2.5 \times 10^8) = 1.6 \times 10^5$,bits

(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 flowing in the link at any given time?

Ans: The first bit arrives at Host B at $t = \boldsymbol{d}_{prop} = 20000 \times 10^3/(2.5 \times 10^8) = 8 \times 10^{-3}$ s.

By that time, the sender has sent out $2 \times 10^6 \times 8 \times 10^{-3} = 1.6 \times 10^5$ bits and they are all in the link. In fact, this is just the 'bandwidth-delay' product.

(c) Provide an interpretation of the bandwidth-delay product.

Ans: The bandwidth-delay product of a link shows the maximum number of bits that can be flowing in the link at one time.