Answers to the mid-term examination on Introduction to the Internet

Christian Rinderknecht

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1 Review questions

1. *What advantage does a circuit-switched network have over a packet-switched network? What advantage does TDM have over FDM in a circuit-switched network?*

   A circuit-switched network can guarantee a certain amount of end-to-end bandwidth for the duration of the call. Most packet-switched networks today (including the internet) cannot make any end-to-end guarantees for bandwidth. In a circuit-switched network using TDM, an application can use the full bandwidth at periodical moments.

2. *Why is it that packet switching is said to employ statistical multiplexing? Contrast statistical multiplexing with the multiplexing that takes place in TDM.*

   In a packet-switched network, the packets from different sources flowing into a link do not follow any fixed pattern, or route. This is why packet switching is said to employ statistical multiplexing. In case of TDM circuit switching, each host gets the same slot in a revolving TDM frame: this is completely predictable.

3. *What is meant by connection state information in a virtual circuit network?*

   In a virtual circuit network, each packet switch keeps in memory some information (like a table translating interface numbers to virtual circuit numbers) about the virtual circuits passing through them.

4. *Suppose you are developing a standard for a new type of network. You need to decide whether your network will use VCs or datagram routing. What are the pros and cons for using VCs?*

The cons of VC's include

- the need to have a signaling protocol to set up and teardown the VCs;
- the need to maintain connection state in the packet switches.

The main advantage of VC networks is that they allow to guarantee an end-to-end delay.

5. *What are the advantages of message segmentation in packet-switched networks? What are the disadvantages?*

   One advantage of message segmentation is that it allows for pipelined transmission over a series of links. Another advantage is that, without it, small messages would be stuck behind much bigger ones in routers.

6. *What is the key distinguishing difference between a tier-1 ISP (backbone) and a tier-2 ISP?*

   A tier-1 ISP connects to all other tier-1 ISPs; a tier-2 ISP connects to only a few tier-1 ISPs. Also, a tier-2 ISP is a customer of one or more tier-1 ISPs.

7. *Is HFC bandwidth dedicated or shared among users? Are collisions possible in a downstream HFC channel?*

   HFC bandwidth is shared among the users. On the downstream channel all the packets emanate from a single source, called the head end, so there are no collisions on this channel.

8. *Consider sending a series of packets from a sending host to a receiving host over a fixed route. List the delay components in the end-to-end delay for a single packet. Which of these delays are constant and which are variable?*

   The delay components are nodal processing delays, transmission delays, propagation delays and queuing delays. Over a fixed route, all these delays are fixed, except the queuing delay, which is unpredictable.

9. *List five tasks that a protocol layer can perform. Is it possible that one (or more) of these tasks could be performed by two (or more) layers?*

   Five generic tasks are error control, flow control, segmentation and reassembly, multiplexing and connections set-up. These tasks can be duplicated at different levels. For example, error control is often provided at more than one layer.

10. *What are the five layers in the Internet protocol stack? What are the principal responsibilities of each of these layers?*

    The five layers of the Internet are, from top to bottom – the application layer, the transport layer, the network layer, the link layer and the physical layer.

11. *What information is used by a process running on one host to identify a process running on another host?*

    The IP address of the destination host and the port number of the destination socket.

12. *What is the difference between persistent* HTTP *with pipelining and persistent* HTTP *without pipelining?*

    In persistent HTTP without pipelining, the browser first waits to receive a HTTP response from the server before issuing a new request. In persistent HTTP with pipelining, the browser issues requests as soon as it has the need to do so, without waiting for response messages from the server.

2 Problems

1. *True or false?*

    (a) *Suppose a user requests a Web page that consists of some text and two images. For this page the client will send one request and receive three response messages.*

    False.

    (b) *Two distinct Web pages can be sent over the same persistent connection.*

    True.

    (c) *With non-persistent connections between browser and origin server, it is possible for a single TCP segment to carry two distinct* HTTP *request messages.*

    False.

    (d) *The* `Date:` *header in the* HTTP *response message indicates when the object in the response was last modified.*

    False.

2. *Consider sending a file of $M \times L$ bits over a path of Q links. Each link transmits at R bits per second. The network is lightly loaded so that there are no queuing delays. When a form of packet switching is used, the $M \times L$ bits are broken up into M packets, each packet with L bits. Propagation delay is negligible.*

   (a) *Suppose the network is a packet-switched virtual circuit network. Denote the VC set-up time by t_s seconds. Suppose the sending layers add a total of h bits of header to each packet. How long does it take to send the file from source to destination?*

   The time to transmit one packet onto a link is $(L + h)/R$. The time to deliver the first of the M packets to the destination is $Q(L + h)/R$. Every $(L + h)/R$ seconds a new packet from the $M - 1$ remaining packets arrives at destination (this is due to pipelining). We must also add the initial setup time, because we use a VC network. Thus the total delay is

   $$t_s + (Q + M - 1)\frac{L + h}{R}$$

   (b) *Suppose the network is a packet-switched datagram network and a connectionless service is used. Now suppose each packet has $2h$ bits of header. How long does it take to send the file?*

   Using a datagram network with a connectionless service implies there is no setup needed. Another difference with the previous situation is the header size. Therefore the total delay is simply

   $$(Q + M - 1)\frac{L + 2h}{R}$$

   (c) *Repeat case 2b but assume message switching is used (that is, $2h$ bits are added to the message, and the message is not segmented).*

   The time to transmit the entire message over one link is $(ML + 2h)/R$. The time to transmit the entire message over Q links (i.e. to destination) is thus

   $$Q\frac{ML + 2h}{R}$$

   (d) *Finally, suppose that the network is a circuit-switched network. Further suppose that the transmission rate of the circuit between source and destination is R bit/s. Assuming t_s seconds of set-up* *and h bits of header appended to the entire file, how long does it take to send the file?*

Because there is no store-and-forward delay at the switches, the total delay does not depend on the number of links. Also we must add the setup time. Therefore the end-to-end delay is

$$t_s + \frac{ML + h}{R}$$

3. *Consider sending a large file of F bits from host A to host B. There are two links (and one switch) between them and the links are uncongested (that is, no queuing delays). Host A segments the file into segments of S bits each and adds 40 bits of header to each segment, forming packets of $L = 40 + S$ bits. Each link has a transmission rate of R bit/s. Assuming that F/S is an integer, find the value of S that minimises the delay of moving the file from host A to host B. Disregard propagation delay.*

We can generalise the answer to any header size. So let $h = 40$. Then the size of each packet is $L = h + S$. The number of packets is F/S, which is an integer by assumption. One packet takes L/R seconds to cross over one link. So the first packet takes $2L/R$ seconds from source to destination. Then, every L/R seconds another packet, among the $F/S - 1$ remaining, arrives to destination, because of pipelining. So the total time to receive all the packets is

$$2\frac{L}{R} + \left(\frac{F}{S} - 1\right)\frac{L}{R} = \left(1 + \frac{F}{S}\right)\frac{L}{R} = \left(1 + \frac{F}{S}\right)\frac{h + S}{R}$$

In other words, the delay $\mathcal{D}$ in function of S is expressed as

$$\mathcal{D}(S) = \frac{1}{R}\frac{(S + F)(h + S)}{S} = \frac{1}{R}\left(h + F + S + \frac{hF}{S}\right)$$

The minumum of this function is reached at S_m such as

$$\frac{d}{dS}\mathcal{D}(S_m) = 0$$

Since

$$\frac{d}{dS}\mathcal{D}(S) = \frac{1}{R}\left(1 - \frac{hF}{S^2}\right)$$

We deduce finally $S_m = \lfloor \sqrt{hF} \rfloor$, where $\lfloor x \rfloor$ is the biggest integer which is smaller than x (in this example, we could choose also the smallest integer which is bigger than x).