EE 122 1st Term Exam
Date: October 9, 2002

Name:
SID:
ee122 login:
Day/time of section you attend:

Problem	Points
1	/10
2	/10
3	/20
4	/20
5	/20
6	/20
Total	/100

1. **Question 1 (10 pt)**

Use no more than three sentences to answer the questions below:

(a) State the "end-to-end arguments". (4 pt)
(b) Error detection techniques detect corrupt bits. Give an example of an error that can be detected by the transport layer that the link layer cannot. (3 pt)
(c) Given that the transport layer can detect errors that the data link layer cannot, why would you implement error detection in the lower layers? (3 pt)

Solution:

(a) A lower layer should not implement functionality that can be correctly and completely implemented only by a higher layer. The only exception is when partial functionality in a lower layer optimizes performance significantly, and doesn't adversely affect applications at the higher layer that do not require this functionality.

(b) The transport layer can detect errors that occur after a packet has passed the data link layer. For example, a packet can be corrupted in the buffer or the switching backplane of a router.

Another example is when a stronger error detection technique is used at the transport layer. Since the transport later is implemented only at end-hosts and not on every router along the path, typically more computational resources are available at the transport layer.

Note: You have to give an example that some how involves corrupt bits. If you talk about lost or out-of-order packets, you receive partial credit only.

(c) Implementing error detection at a lower layer can improve performance. The transport layer can only detect errors at the destination, and hence the packet with the error is carried over the entire path wasting bandwidth. The retransmission has to be done over the entire path too.

Another example is that different data link layer technologies have different error characteristics, so a high error rate technology (wireless) can have strong error detection, while a low error rate technology (optical) can have weak error detection. We can thus avoid the overhead of having strong error detection over the entire path.

2. **Question (10 pt)**

Compare packet switching and circuit switching using the following criteria: (a) forwarding cost, (b) bandwidth utilization, and (c) ability to handle resource reservations. Briefly explain your reasoning.

Solution:

(a) Packet switching has a higher per-packet forwarding cost because:

- The router has to examine (and possibly rewrite) the header of every packet it forwards.
- The router has to maintain routing tables which may have a large number of entries.
- The router needs to do a longest prefix matching for every packet.

The per-packet forwarding cost is much lower in circuit switching once the connection has been established.

(b) In packet switching, different users use statistical multiplexing to share the bandwidth on any link. In the absence of congestion and packet drops, no bandwidth is wasted and the utilization is typically high.

In circuit switching, bandwidth may be wasted if an established connection is idle. For applications with a high peak to average sending ratio, this wastage can be high.

(c) Circuit switching inherently requires resources to be reserved for a particular connection. On the other hand, in packet switching, the bandwidth available to a particular user (flow) depends on the sending rate of other flows. We need additional scheduling mechanisms at the router to support reservations to a particular flow.

3. **Question (20 pt)**

We want to transfer a file of size *d* bits. Each link has bandwidth *b* bps and fixed delay *f* sec. All the routers on the path are store and forward. We use packets of size *p* bits, which includes headers of size *h* bits. We always pad the last packet so that it is full. There is no setup time for the transfer. Packets are sent continuously and are not lost. There is not queuing delay and processing overhead.

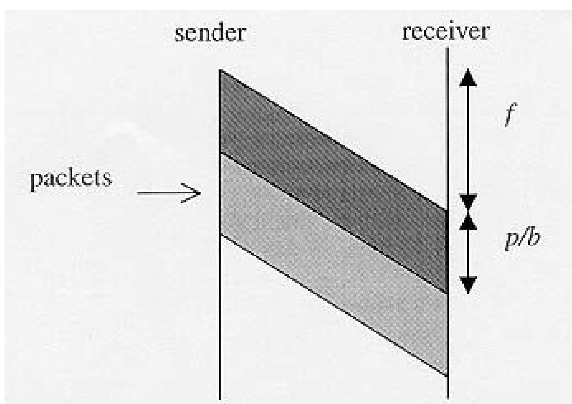
(a) How many packets are sent? (5 pt)
(b) What is the delay to transfer the file across one link? (5 pt)
(c) What is the delay for one packet to arrive at a destination *n* links away? (5 pt)
(d) What is the delay to transfer the file across *n* links? (5 pt)

Solution:

(a) You have to send all your data, only *p* - *h* of your data fits in a packet, and you have to round up because the last packet may not be full, so the number of packets is

$$\left\lceil \frac{file\_size}{data\_per\_packet} \right\rceil = \left\lceil \frac{d}{p-h} \right\rceil.$$

(b)

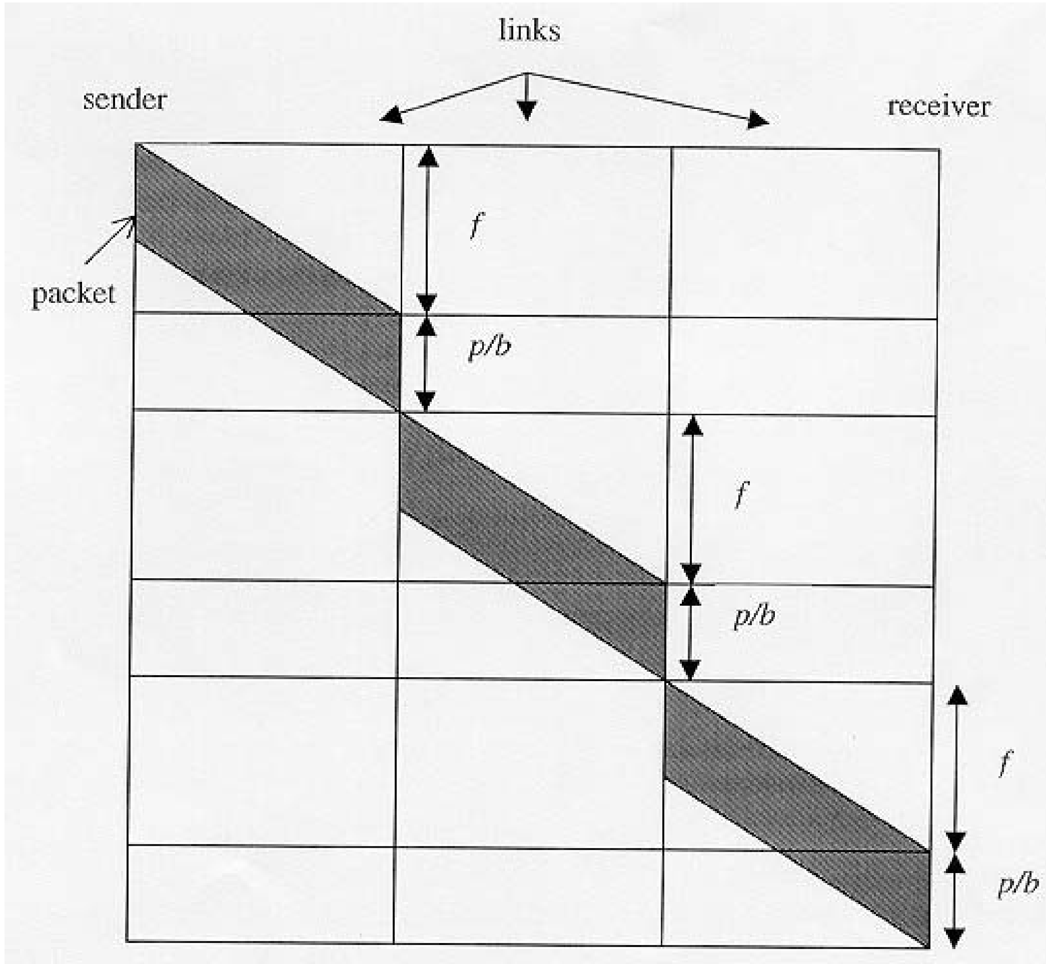


total_delay = transmission_delay + fixed_delay

$$= \frac{number\_of\_packets * packet\_size}{bandwidth} + fixed\_delay$$

$$= \frac{\left\lceil \frac{d}{p-h} \right\rceil p}{b} + f$$

(c)



*delay = (transmission_delay_per_link + fixed_delay_per_link)*num_links*

$$= \left(\frac{p}{b} + f\right)n$$