Exam - Midterm

Due: 11:50am, 13 Mar 2012

Closed Book. Maximum points: 100

NAME:

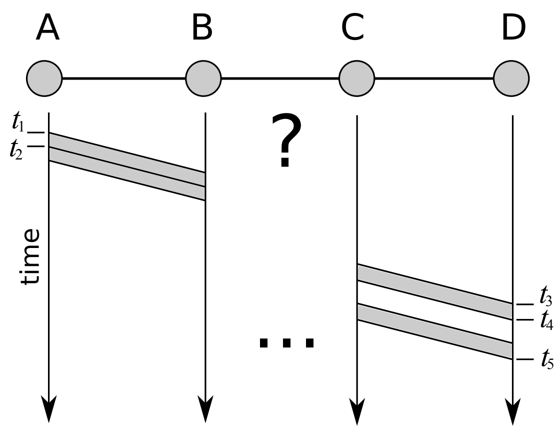
1. Bandwidth and Delay [24 pts]

a. On a generic multi-hop network, **explain the potential causes of delay for a packet:** [6 pts]

- Propagation delay:
- Transmission delay:
- Queueing delay:
- Processing delay:

b. For a fixed network path, **which of these delays are constant over time, and which ones vary with load? Explain why.** [3 pts]

c. (Estimating bottleneck bandwidth). An interesting technique used to estimate the bottleneck bandwidth in a network is called *packet pair*. The idea is simple: you send two packets back-to-back (no gap), at the full bandwidth of the first hop. The receiver at the other end can then determine the bandwidth by measuring the delay between the receptions of the two packets. In this problem we will do just that, with a simplified 3-link network shown in the figure below, with no extra traffic, no queues, and instantaneous access to the medium.



Setup: In the figure, assume there is no queueing or processing delay, and that nodes can forward a packet as soon as (a) *all* bytes for the packet have been received from the previous link, and (b) the outgoing link is free. All three links have a propagation delay of 10ms; link AB has a bandwidth of 10 Mbps (10^7 bits per second), and link CD has a bandwidth of 8 Mbps (8×10^6 bps). You send two probe packets of 1000 bytes each, as depicted in the figure.

(a) In this setup, **calculate the length of the interval $t_1 t_2$ in the figure. Do the same for $t_3 t_4$.**[3 pts]

(b) In the diagram, **draw the transmission of the two packets in the link BC**, paying attention to when they must start and when they must end. [4 pts]

(c) You measure the delay $t_4 t_5$ between the end of the receptions of the two packets to be **8 ms**. Assuming that the link BC is the bottleneck bandwidth in the path, **what is its bandwidth? Explain your reasoning.**[8 pts]

(d) (Bonus) On the Internet it is not reasonable to assume that there won't be queueing or processing delay. **Explain why this may make this technique not work, and why sending a large number of packet pairs may improve the chances of a successful measurement.** [5 pts]

2. Ethernet [19 pts] Shared-medium Ethernet uses Carrier Sense Multiple Access with Collision Detection (CSMA/CD) as its medium access coordination.

a. Ethernet 10Base2 uses Manchester encoding. **What feature of this encoding makes detecting collisions easier?**[4 pts]

b. When two nodes transmit at the same time in the same Ethernet segment, they will detect the collision and engage in exponential backoff. **Explain how exponential backoff works** (assume a baseline waiting time of $51.2\mu s$).[6 pts]

c. In the context of exponential backoff between two transmitting nodes A and B, **give an example, through a sequence of events, of the capture effect.** [9 pts]

3. IP and Local Area Networks [19 pts] Suppose you connect to a network and DHCP provides you with the following information:

- IP address: 192.168.0.4
- Network Mask: 255.255.255.128
- Gateway: 192.168.0.1

a. If your routing table has only one entry, **what is the IP address of the next hop for this entry?**[4 pts]

b. Of all possible IP addresses your computer may want to talk to, **for which range will your computer *not* use this entry in the routing table?**[4 pts]

c. Besides your own computer, there are the following three nodes connected to the network:

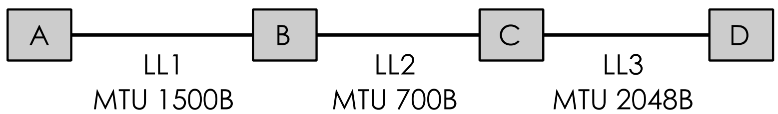
node	IP address	MAC address
router	192.168.0.1	f3:00:21:00:13:44
node1	192.168.0.35	eb:01:06:00:23:12
node2	192.168.0.154	eb:01:06:00:24:ab

Suppose your ARP cache is empty initially, and you send 2 IP packets: one for node 1 and another for node 2.

(a) **What are the IP routes** (sequence of IP addresses visited by the packet, including the source and the destination) **taken by each of these two packets? Explain your reasoning**.[5 pts]

(b) Recall that the ARP cache will map IP addresses to MAC addresses. **What are the two entries in the ARP cache after these two packets are sent? Justify your answer.**[6 pts]

4. IPv4 Fragmentation [19 pts] IPv4 has the provision for fragmenting and reassembling packets. Consider the network in the figure below, where the MTUs of the link layers for the three IP hops is listed. These MTUs *include the header of the packets*. You can consider the IP packets to have no options, with a fixed header size of 20 bytes.



For reference, recall the structure of the IPv4 header, taken from RFC 791:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

a. Suppose you send a packet with a payload of 1400 bytes on this network. **Fill in the table below listing all of the fragments that are transmitted along each link.** The fields in the table (other than the 'Link' field), correspond to the values in the IP header, and we already filled in the first packet for you. (Recall that the Fragment Offset is represented as number of 8-byte increments.) [6 pts]

Link	Total Length	Identification	DF	MF	Fragment Offset	Time to Live
AB	1420	45654	0	0	0	255

b. In the example above, **where are fragments reassembled? Can they be reassembled anywhere else? Why or why not?** [4 pts]

c. Fragmentation can degrade performance and increase the chances of packet loss. IPv6, for example, does not allow fragmentation. In order to avoid fragmentation, one must be sure to send packets that are smaller than the smallest MTU along the path (called the 'path MTU'). **Explain an efficient procedure to find the path MTU of a path.** Assume you control the sender and can set bits in the IP header, and interpret ICMP error messages.[9 pts]

5. Inter-domain routing [19 pts] As we saw in class, BGP, the Border Gateway Protocol, is a path-vector routing protocol used by Autonomous Systems (ASes) to exchange reachability in Internet.

a. **What are the destinations in a BGP routing table? What are the components in the BGP paths?**[4 pts]

b. Prefix hijacking is a serious threat to the integrity of BGP routing. **What is prefix hijacking, and why is it possible on today's Internet? List two measures that limit the effectiveness of this attack.**[6 pts]

c. Two common uses for hijacking are (i) to steal or intercept traffic to a known destination, and to (ii) create routable addresses to send spam. In the former, attackers tend to advertise longer (more specific) prefixes, while in the latter they tend to advertise very short (very broad) prefixes, such as /8s. **In both cases, explain the attackers' rationale.**[9 pts]