1. What are the various types of ISPs? Briefly explain the different ways by which the various ISPs can interconnect to form the network core. Depict the resulting interconnection model.

   ANSWER:

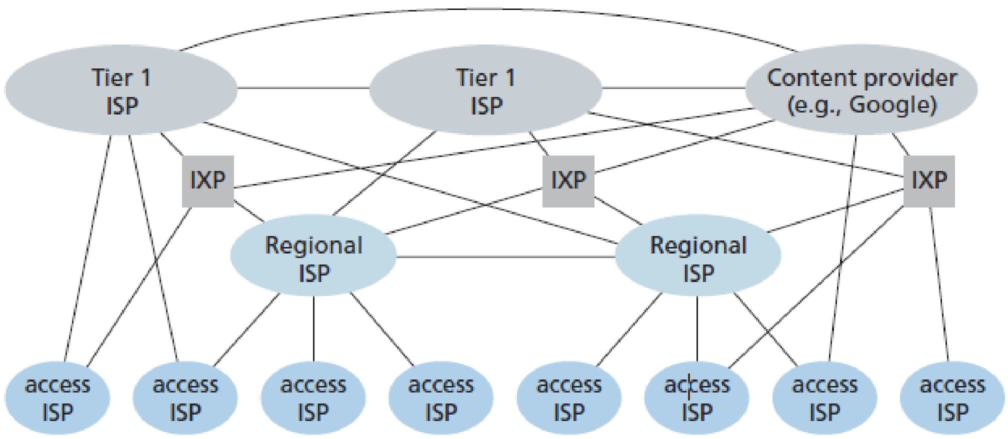
   Various types of ISPs include the following: Access ISPs, Regional ISPs and Tier-1.

   ISPs in the hierarchy may be interconnected using multi-homing, peering, and Internet exchange points (IXPs) .

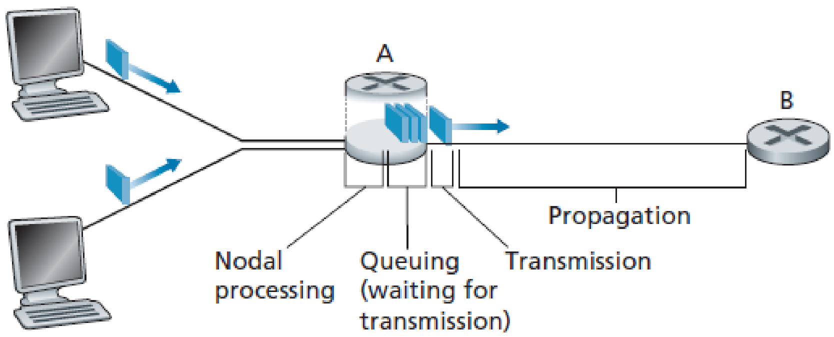
   Any ISP (except for Tier-1 ISPs) may choose to multi-home, that is, to connect to two or more provider ISPs. For example, an access ISP may multi-home with two regional ISPs, or it may multi-home with two regional ISPs and also with a tier-1 ISP. Similarly, a regional ISP may multi-home with multiple tier-1 ISPs.

   ISPs at the same level of the hierarchy can peer, that is, they can directly connect their networks together so that all the traffic between them passes over the direct connection rather than via upstream intermediaries.

   Along these same lines, a third-party company can create an Internet Exchange Point (IXP) (typically in a stand-alone building with its own switches), which is a meeting point where multiple ISPs can peer together.



2. Consider the network illustrated below. Assume the two hosts on the left of the figure start transmitting packets of 1500 bytes at the same time towards Router B. Suppose the link rates between the hosts and Router A is 4-Mbps. One link has a 6-ms propagation delay and the other has a 2-ms propagation delay. Will queuing delay occur at Router A?



ANSWER:
Packet length $L = 1500\ bytes$

Packet from one of the hosts arrives at the router A at time t_1 which is given by

$$t_1 = \frac{L}{R} + d_{prop} = \frac{1500 \times 8}{4 \times 10^6} + 6 \times 10^{-3} = 9\ ms$$

Packet from the other host arrives at the router A at time t_2 which is given by

$$t_1 = \frac{L}{R} + d_{prop} = \frac{1500 \times 8}{4 \times 10^6} + 2 \times 10^{-3} = 5\ ms$$

The above calculation shows that the inter-arrival time between the packets is 4 ms.

Queuing delay will not occur at router A as long as the transmission delay at router A is less than 4 ms. In other words, queuing delay will not occur at router A as long as the link rate between routers A and B is greater than $L/4ms = 3\ Mbps$

3. What is traffic intensity? Explain the impact of traffic intensity on queuing delay. What is the impact of queuing delay on throughput?

ANSWER:
Traffic intensity is the ratio of the mean rate of arrival of packets at a packet switch to the rate of departure of the packets from the packet switch. Under negligible processing delay, traffic intensity is simply the ratio of the packet incoming rate of the outgoing link rate.

Consider a packets of length L arriving at a router whose outgoing link rate is R. The traffic intensity of the router is given by La/R. As long as the traffic intensity is less than 1, the queue is finite and the queuing delay is finite. However, as the traffic intensity becomes greater than or equal to one, the queuing delay reaches the peak value (in case buffer at the router is infinite, the queuing delay becomes infinity).

When the queuing delay increases, the throughput decreases.

4. Consider the following string of ASCII characters that were captured by Wireshark when the browser sent an HTTP GET message (i.e., this is the actual content of an HTTP GET message). The characters <*cr*><*lf*> are carriage return and line-feed characters (that is, the italicized character string <*cr*> in the text below represents the single carriage-return character that was contained at that point in the HTTP header). Answer the following questions, indicating where in the HTTP GET message below you find the answer.

```
GET /cs453/index.html HTTP/1.1<cr><lf>Host: gai
a.cs.umass.edu<cr><lf>User-Agent: Mozilla/5.0 (
Windows;U; Windows NT 5.1; en-US; rv:1.7.2) Gec
ko/20040804 Netscape/7.2 (ax) <cr><lf>Accept:ex
t/xml, application/xml, application/xhtml+xml, text
/html;q=0.9, text/plain;q=0.8,image/png,*/*;q=0.5
<cr><lf>Accept-Language: en-us,en;q=0.5<cr><lf>Accept-
Encoding: zip,deflate<cr><lf>Accept-Charset: ISO
-8859-1,utf-8;q=0.7,*;q=0.7<cr><lf>Keep-Alive: 300<cr>
<lf>Connection:keep-alive<cr><lf><cr><lf>
```

   a. What is the URL of the document requested by the browser?
   b. What version of HTTP is the browser running?
   c. Does the browser request a non-persistent or a persistent connection?
   d. What is the IP address of the host on which the browser is running?
   e. Will this HTTP message generate a HTTP reply with the status code and phase 304 and Not Modified respectively?

   ANSWER:

   a. The URL of the requested document is /cs453/index.html as indicated in the request line.
   b. The browser is running the HTTP version 1.1 as indicated in the request line
   c. The browser requests for a persistent connection as the indicated in the header line Connection: keep-alive
   d. The IP address of the host cannot be determined as this is a HTTP message. We should look for the IP header instead.
   e. This HTTP message will not generate the reply 304 Not Modified as the HTTP request does not contain the IF-MODIFIED-SINCE header line.

5. What are the various fields contained in a DNS resource record? Provide the significance of these fields.

   ANSWER:

   The various fields in the DNS resource record are Name, Value, Type and TTL

   TTL is the time to live of the resource record; it determines when a resource should be removed from a cache

   Name and Value depend on Type:

   If Type=A, then Name is a hostname and Value is the IP address for the hostname

If Type=NS, then Name is a domain (such as foo.com) and Value is the hostname of an authoritative DNS server that knows how to obtain the IP addresses for hosts in the domain.

If Type=CNAME, then Value is a canonical hostname for the alias hostname Name.

If Type=MX, then Value is the canonical name of a mail server that has an alias hostname Name.