1. (a) Compare and contrast a packet-switched network and a circuit-switched network. What are the relative advantages and disadvantages of each?

(b) Explain why STDM (Synchronous Time-Division Multiplexing) is a cost-effective form of multiplexing for a voice telephone network and FDM (Frequency-Division Multiplexing) is a cost-effective form of multiplexing for television and radio networks, yet we reject both as not being cost effective for a general-purpose computer network.

Solution

(a) Features of a circuit-switched network:
- Dedicated connection and reserved bandwidth between end points
- Data is transmitted directly from sender to receiver with no conversion

Features of a packet-switched network:
- Only use the medium when there is data to transmit
- Data is transmitted between routers by store-and-forward with possible speed or code conversion

See Table 9.1 from dcc5e for a more complete comparison.

(b) STDM is cost-effective for a voice telephone network because the audio data is assumed to be continuously sampled and transmitted in real-time at a constant bit rate, ideal for multiplexing by STDM. For television and radio networks, FDM is cost-effective because of its ability to handle multiple channels simultaneously. However, for a general-purpose computer network, neither technique is cost-effective since computer network data bandwidth usage tends to be bursty with many channels being idle most of the time, and the number of connections (or channels) needed at any one time is highly variable.

2. (a) One useful property of an address is that it is unique; without uniqueness, it would be impossible to distinguish between nodes. List other useful properties that addresses might have.

(b) A packet or frame can be lost due to bit errors or intermediate resources (e.g. buffers or queues) becoming unavailable forcing the packet or frame to be literally dropped. What should the sender do if a large proportion of the packets / frames are “lost”? Does your solution work for both types of losses?

Solution

(a) Addresses can be used to identify make and model (e.g. vendor field in MAC addresses), identify groups of hosts for routing (IP network and subnet classes) and geographical vicinity (e.g. FQDN addresses like ftp.ee.uwa.edu.au).

(b) If the packets are lost due mainly to network congestion (full queues) the sender should decrease the rate of transmission to avoid exacerbating the situation. On the other hand, if the losses are due to transmission errors the sender should actually increase the rate of transmission (and retransmission) in order to increase the proportion of successful transmissions.

3. Two blue armies are each poised on opposite hills preparing to attack a single red army in the valley. The red army can defeat either of the blue armies separately but will fail to defeat both blue armies if they attack together. The blue armies communicate by an unreliable communications system with a 50% success rate (a foot soldier that can go AWOL or get shot by the red army). The commander, with one of the blue armies, would like to attack at noon. His problem is this: If he sends a message ordering the attack, he cannot be sure it will get through. He could ask for an acknowledgment but that might not get through. Sketch your solution to the problem. [Note: What has this got to do with computer networks? TCP has the same problem since IP is unreliable]

Solution

There is no solution except a best-effort compromise. Since either or both of the message or the acknowledgment can fail to get through the commander will always have a problem. The TCP solution would be for the commander to send the message and wait for an acknowledgment. The wait should be as long as it would take for the message to reach the other blue army and the acknowledgment to be returned. If the acknowledgment takes too long then the commander will resend (retransmit) the message, and keep doing this until an acknowledgment arrives.

4. (a) How “wide” is a bit on a 1-Gbps fibre optic link?

(b) How long does it take to transmit x KB over a y-Mbps copper wire link to a station z-meters away?

Solution

(a) Each bit will take $10^{-9}$ seconds to be transmitted. Assuming a propagation velocity of $c = 3 \times 10^8$ m/sec then the bit will be $3 \times 10^8 \times 10^{-9} = 30$ cm wide.

(b) Data transfer time ($T_D$) = data transmission time + propagation delay. Assuming a propagation velocity of $(2/3)c = 2 \times 10^8$ m/sec for copper:

$$T_D = \frac{1024 \times 8 \times x}{10^6 y} + \frac{z}{2 \times 10^8}$$

5. Consider a two stations A and B, 50 km apart that can communicate using either a 50 Mbps satellite link or a 33.6 Kbps telephone link.

(a) Which link would you use to transfer a large file? Why?

(b) Which link would you use for a telnet session? Why?

Solution

(a) The satellite link since it has the highest data rate (response delay is not an issue)

(b) The telephone link since it has the shortest delay and be more responsive (throughput is not an issue)

6. A broadcast network is one in which a transmission from any one attached station is received by all other attached stations over a shared medium. Examples are a bus-topology local area network, such as Ethernet, and a wireless radio network. Discuss the need or lack of need for a network layer in a broadcast network.

Solution

There is no solution except a best-effort compromise. Since either or both of the message or the acknowledgment can fail to get through the commander will always have a problem. The TCP solution would be for the commander to send the message and wait for an acknowledgment. The wait should be as long as it would take for the message to reach the other blue army and the acknowledgment to be returned. If the acknowledgment takes too long then the commander will resend (retransmit) the message, and keep doing this until an acknowledgment arrives.
A broadcast network does need a network layer since the main routing functionality of a network layer is not necessary. A broadcast network should be considered equivalent to a point-to-point link in this context. For inter-connecting different homogenous broadcast networks a bridge can be used which operates just below the link layer. However a network router is usually needed when inter-connecting heterogenous or distant networks or hosts.

7. Hosts A and B are located on Ethernet LANs in two different cities (Perth and Albany). Cities are interconnected by Frame Relay networks. A user on host A in Perth needs to send some data to a user on host B in Albany over a TCP/IP connection. Sketch how the data is handled through each layer of the network, especially encapsulation and segmentation and reassembly effects (Ethernet has an MTU of 1500 bytes, and Frame Relay can have an MTU as low as 200 bytes).

**Solution**

1. `user@hostA` gives data to TCP layer indicating the destination host (DH) and port (DP)
2. The TCP layer creates a TCP segment, `[TCP header (SP, DP) | Data]` where SP = Source Port, the TCP layer gives the TCP segment to the IP layer with instructions to send it to DH.
3. The IP layer creates an IP datagram, `[IP header (SH, DH) | TCP | Data]` where SH = Source Host, the IP layer then consults the routing table and gives the IP datagram to the Ethernet layer with instructions to send it to destination Ethernet station (DE) for routing over the Frame Relay network.
4. The Ethernet layer creates an Ethernet frame, `[ MAC header (DE, SE) | IP | TCP | Data | FCS ]` where SE = Source Ethernet station address and broadcasts this frame on the network.
5. The Frame Relay router/gateway with address DE receives the frame and seeing that it is the correct destination retrieves the complete frame, checks the integrity of the data, strips off the MAC header (and FCS) and passes `[IP | TCP | Data]` to the IP layer.
6. The IP layer reads the IP header information, checks the DH and consults its routing table. The packet needs to be forwarded over the frame relay connection on the Albany interface. The IP layer gives the IP datagram to the Frame Relay network layer with instructs to send the datagram over the Albany link.
7. The Frame Relay layer encapsulates the IP datagram in an LAPF frame, `[ Flag | Destination Albany | IP | TCP | Data | FCS | Flag ]` and transmit it over the Frame Relay link to Albany.

What happens at Albany? Well now its your turn.

- Regarding segmentation and reassembly, if the TCP segment is greater than the Ethernet MTU the IP layer on host A in Perth will use IP fragments to represent the TCP segment where each IP fragment is of Ethernet MTU size. The IP fragments will be reassembled by the IP layer on host B in Albany.
- If the Frame Relay has an MTU less than the Ethernet MTU the IP fragments themselves will be further segmented into a sequence LABF frames by the IP layer on the Frame Relay router in Perth. The IP layer in the Frame Relay router in Albany will perform the reassembly operation.