Circuit Switching:
Advantages:
1. No noise, no latency
2. Dedicated path, very reliable
3. No worries of lost and out of order packets
4. Simple forwarding - low overhead

Disadvantages:
1. Possible idle resources
2. Not able to use statistical multiplexing
3. Blocked connections
4. Connection setup delay

Packet Switching:
Advantages:
1. Messages divided into globally addressable packets
2. Packets may travel separately through network
   - Different paths
   - Redundancy

Disadvantages:
1. Packets reaching destination out of order

Why Packet Switching:
1. Flexibility
2. Data traffic is bursty
3. Don’t waste bandwidth
4. Packets better for multiplexing
5. Packet can be delivered by almost anything

However, packet switching might be inefficient due to extra header bits

Difference between POTS and Internet:
POTS: Intelligent network, dumb terminal
Internet: Dumb network, intelligent endpoint
Link Layer Protocols

Links:

Links rely on some sort of electromagnetic radiation propagating through a medium or, in some cases through free space as 1’s and 0’s.

Characteristics:
1. Medium
2. Frequency
3. Wavelength (Speed of light divided by frequency gives wavelength)

Encoding:
Placing binary data on a signal.

1. NRZ
   a. Encoding:
      i. Use a fixed interval to represent one bit. High voltage represents 1 and low voltage represents 0.
   
   b. Problem:
      i. Baseline wander
         1. The receiver keeps an average of the signal received so far and averaging out the amplitude. Using this to distinguish between a lower and high signal.
         2. If there’s too many consecutive 0’s or 1’s this may cause the average to change making it more difficult to detect the correct value.
      ii. Clock recovery
         1. Both ends of the transmission must be in sync, using a clock, to allow both sending and decoding.
         2. Every clock cycle, the sender transmits a bit and the receiver recovers a bit.
   
   c. Improvement:
      i. Non return to zero inverted (NRZI)
         1. Sender makes a transition from the current signal to encode 1 and stay at the current signal to encode a 0
         2. Solves for consecutive 1’s issue
   
2. Manchester
a. Encoding:
   i. Merging the clock with signal by transmitting EX-OR of the NRZ encoded data and the clock.
   ii. Clock is an internal signal that alternates from low to high, a low/high pair is considered as one clock cycle
   iii. 0: low -> high transition
   iv. 1: high -> low transition

b. Problem
   i. Doubles rate at which the signal transitions are made on the link
      1. Which means the receiver has half of the time to detect each pulse.
         a. Baud rate
            i. Rate at which the signal changes
            ii. With Manchester the bit rate is half the baud rate

3. 4B/5B
   a. Encoding:
      i. Inserts extra bits into bit stream so as to break up the long sequence of 0’s and 1’s
      ii. Every 4-bits of actual data is encoded in a 5 bit code that is transmitted to the receiver.
      iii. 5 bit codes are selected in such a way that each one has no more than one leading 0 and no more than two trailing 0’s
      iv. No pair of 5 bit codes results in more than three consecutive 0’s

Framing:
When node A wishes to transmit a frame to node B, it tells its adaptor to transmit a frame from the node’s memory. This results in a sequence of bits being sent over the link.

The adaptor on node B then collects together the sequence of bits arriving on the link and deposits the corresponding frame in B’s memory.

Recognizing exactly what set of bits constitute a frame—that is, determining where the frame begins and ends—is the central challenge faced by the adaptor

1. Byte-oriented Protocols:
   Based on the number of bytes rather than bits

   Examples:
      i. BISYNC (Binary Synchronous Communication)
      ii. DDCMP (Digital Data Communication Protocol)
• Sentinel Approach  
  Based on the use of special characters (Flags) starting the frame and ending the frame.
  
  1. BISYNC  
  2. PPP  
     a. Commonly run over the internet links  
  
• Byte-counting Approach  
  1. DDCMP (Digital Data Communication Protocol)  
     - Size can be negotiated  
  2. Bit-oriented Protocol  
     Sees the transmitted data as an opaque stream of bits.  
     
     Example:  
     i. HDLC  

Error Detection:  
  1. CRC (Cyclic Redundancy Check) - Used by link layer  
     a. Used in HDLC, DDCM, CSMA/CD, Token Ring  
        i. Reduces the number of extra bits and maximize protection  
  2. Two dimensional parity  
     a. Simplest  
        b. Can catch all 1, 2, 3 bit errors and most 4-bit errors  
  3. Checksum - Used by IP layer  

Idea of error detection:  
  1. Sender sends m + r (m is the original message, r is computed from m).  
  2. Receiver computes r’ using m. If r and r’ match, means there is no error during transmission.  
  3. Note that error might be in m or in r, but it is hard to tell where exactly the error is.  

Notes:  
  More powerful detection code means it can detect more errors.  
  Error correction is done by retransmission.