Chapter 2: Getting Connected

→ **Links** → ex. last-mile or backbone links

→ can be classified by the medium they use
→ can be characterized by: freq. (Hz), speed of light (m/s), & wavelength (m)
→ can eval. performance using **Shannon-Hartley Theorem**:
↳ finds channel capacity/throughput as an upper bound of the data rate over that medium.

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

→ B is bandwidth (Hz)
→ S is signal power at receiver
→ N is noise power at receiver.

→ **Encoding**

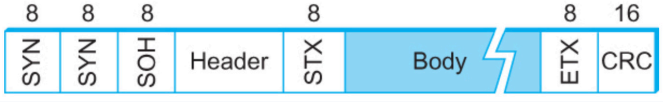
→ **NRZ**
↳ con: baseline wander w/ too many consec. 1's or 0's, which affects the average.
↳ con: clock recovery w/ too many consec. 1's or 0's.

→ **NRZI**
↳ solves NRZ issue w/ consec. 1's, but not consec. 0's.

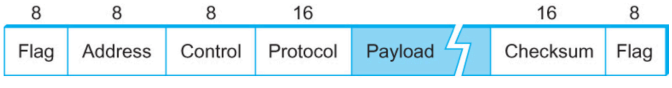
→ **Manchester**
↳ pro: solves consec. 1's and 0's problem.
↳ con: doubles the rate. Rcvr. has half time to detect each pulse of the signal.
↳ i.e. it consumes more bandwidth.

→ **4B/5B**
↳ inserts extra bit to break up 1's and 0's then transmitted using NRZI
↳ 80% effective

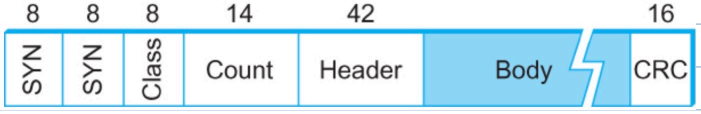
→ **Byte-Oriented Framing**



→ **BISYNC**
↳ uses DLE (data link escape) to precede any data portion equal to DLE or ETX.



→ **PPP**
↳ payload is negotiated. default 1500 bytes → uses demultiplexing
↳ LCP (link control prot.) negotiates some field sizes



→ **DDCMP**
↳ count holds # of bytes in frame body
↳ if count corrupted, get a framing error (usually back-to-back frames rcvd.)

→ Bit-Oriented Framing: HDLC

→ beginning seq: 01111110
↳ also sent when idle
→ after 5 consec 1's if next is:
0 → stuffed, discard (01111110)
10 → end of frame marker (0111 1110)
11 → error, must get seq. again before it can rcv. again. (0 111 111 1)

→ Error Detection – add redundant info to determine if errors have been introduced.

Know how to do ★
→ CRC (HDLC, DDCMP, CSMA/CD, Token Ring) – XOR
→ 2D Parity (BISYNC)
↳ guaranteed to catch all 3-bit errors. Can get most 4-bit.
→ Checksum (IP) → used at network level.
↳ carryout added to LSB.
↳ uses 1's complement

★ Why is error detection implemented in dif. OSI layers?

For CRC

Properties of Generator Polynomial

It is possible to detect the following types of errors by a C(x) with degree r

- All single-bit errors, as long as the xr and x0 terms have nonzero coefficients.
- All double-bit errors, as long as C(x) has a factor with at least three terms.
- Any odd number of errors, as long as C(x) contains the factor (x+1).
- Any "burst" error (i.e., sequence of consecutive error bits) for which the length of the burst is less than *r* bits. (Most burst errors of larger than *r* bits can also be detected.)

→ Reliable Transmission

↳ send an ACK (acknowledgement) to show frame was rcv'd. successfully.
↳ timeout if ACK is not rcv'd.
↳ using ACK and timeout combo = ARQ

→ ARQ

→ Stop-and-Wait - use frame # (0 or 1) to avoid confusion.

↳ sending rate = bits per frame / time per frame = RTT

↳ 1 outstanding frame at a time → poor use of capacity.

→ Sliding Window

→ on sender: LFS - LAR ≤ SWS

→ on rcvr: LAF - LFR ≤ RWS

↳ largest acceptable frame

→ to check:

→ Seq. # ≤ LFR or Seq. # > LAF

↳ discard. outside rcving window

→ LFR < Seq. # ≤ LAF

↳ accept and send an ACK

→ Seq. Num to ACK = largest Seq. # not yet ACKed.

↳ if higher Seq. # rcv'd., holds ACK until Seq. Num to ACK is rcv'd.

↳ then adjust window w/ Seq. Num to ACK = LFR.

→ Can be improved w/ NAKs (negative ACKs), or additional or selective ACKs. (solicitate, duplicate, explicit)

→ Use SWS = Delay x Bandwidth / frame size to keep pipe full.

→ RWS should not be greater than SWS.

↳ if RWS = SWS

$SWS < (MaxSeqNum + 1)/2$ or $MaxSeqNum > 2*SWS - 1$

↳ if RWS < SWS

$MaxSeqNum \leq 2*SWS - 1$

→ Ethernet → uses CSMA/CD, uses ALOHA as root prot.

↳ classic ethernet has an upper limit to its length → 500 m coax

Chapter 2 Terminology

→ **Encoding** - converting a string of binary data to a stream of pulse signal

→ **Modulation** - modifying (freq., amp., and phase) of the base-band signals to the carrier frequency.

→ **NRZ** (non-return to zero) - a bit encoding scheme that encodes a 1 as a high signal and 0 as the low sig.

→ **NRZI** (non-return to zero inverted) - a bit encoding scheme that makes a transition from the current signal encode to a 1 and stays at current sig. to encode a 0.

→ **Manchester** - a bit encoding scheme that transmits the XOR of the clock and the NRZ-encoded data. Used on Ethernet.

0: low → high transition
1: high → low transition.

→ **4B/5B** - a type of bit encoding scheme used in Fiber Distributed Data Interface (FDDI), in which every 4 bits of data are transmitted as a 5-bit seq.

→ **Frame** - another name for packet, usually used in ref. to packets sent over a single link rather than a whole network.

↳ **Framing** - imp. problem about how rcvr. detects the beginning and ending of a frame.

→ **BISYNC** (Binary Synchronous Communication) - a byte-oriented link-level protocol dev'd. by IBM in the 60's.

→ **PPP** (Point-to-Point Protocol) - data link protocol usually used to connect computers over a dial-up line.

→ **DDCMP** (Digital Data Communication Message Protocol) - a byte-oriented link-level protocol used in DECnet.

→ **HDLC** (High-Level Data Link Control) - an ISO-standard link-level protocol. It uses bit stuffing to solve the framing problem.

→ **ARQ** (automatic repeat request) - retransmit if don't rcv. an ACK before timeout.

↳ Stop-and-Wait and Sliding Window are ex. ARQ protocols.

→ Ethernet – popular LAN technology that uses CSMA/CD and has a bandwidth of 10 Mbps. Ethernet is just a passive wire – all aspects of Ethernet transmission are imp. by host adaptors.

→ CSMA/CD (Carrier Sense Multiple Access w/ Collision Detection)
- ↳ CS – all nodes can distinguish btw a busy + active link.
- ↳ MA – a set of nodes can send + rcv. frames over a shared link.
- ↳ CD – a node listens as it transmits, so it can detect when a frame it is transmitting has collided w/ one transmitted by another node.