Layering Law of Demeter
Peer entities communicate

Channels Symbols, delay, fidelity, cost, security, ordering, connectivity..

Definition Noise: systematic/random
Attenuation: radiation loss/spatial dispersion/absorption
Baud rate: symbol transmit rate
Modulation: systematic alteration of carrier by information signal
Baseband: *not* carrier modulated

Synchronisation Asynchronous: divide transmission into frames. Oscillators in rx/tx are close in frequency, sync. clocks w/ start/stop bits
Synchronous: transmission continuous, continually sync frequency of rx (PLL, Manchester coding)

Modulation Of Analog Info. Amplitude:
$A(mx(t)+1)\cos(2\pi f_c t)$
Frequency:
$A\cos(2\pi(f_c t + f_\Delta x(t)t))$
Phase:
$A\cos(2\pi(f_c t + \phi_\Delta x(t)))$

Modulation Of Digital Info. Amplitude Shift Keying:
$A(mx(t)+1)\cos(2\pi f_c t)$
Frequency Shift Keying:
$A\cos(2\pi(f_c t + f_\Delta x(t)t))$
Phase Shift Keying:
$A\cos(2\pi(f_c t + \phi_\Delta x(t)))$

Phase Shift Keying Finale Filter to remove high frequency shifts
Also have QPSK (4 levels)
Can have > 1 bit/Hz
Coherence: sync. phase change to carrier freq.

Coding Information ↔ Symbols
One entities symbols are another's information..
Digitisation (has one time quantisation noise)
Sampling (sample at 2B)

FEC Introduce redundant info.

Block Codes Divide info into fixed size messages (length m), messages encoded into codewords (length k)
Have m < k for FEC
Called a (m, k) code, code rate = m / k
Distance between codewords: number of bits in which they differ
Decode by looking at received word and pick the closest valid codeword
If minimum distance d then can detect d – 1 errors or correct (d – 1) / 2 errors

Compression Perfect, imperfect, stable
Exploit domain e.g. JPEG quality table, MPEG moving blocks

Encryption Symmetric secret keys allows authentication (w/ challenge), integrity (w/ encrypted signature), confidentiality (clearly!)

Multiplexing Produce many higher layer channels from lower chan.
Policy: determine who gets a part of lower layer

Sharing Media Trivial routing, requires trust due to fragility
Non-shared scales better

Orthogonal Multiplexing FDM, TDM (discriminate by content/schedule), STDM (periodic slots, constant delay/bandwidth)
ATDM (use packets)

ATDM Packets on shared media
Appropriate if demands from higher layer variable

ATDM Contention Statistical multiplexing, not fixed delay/capacity
Have policy, may be a distributed one
Random access: check for collision for 2*channel delay. If collision time < packet time then stop transmitting else retry. Simple, fault tolerant, but access time not bounded
Token passing: has problems with maintaining single token all the time
Reservations: useful with large delays, still need

reservation channel
Slotted: channel has slots like STDM but "cells" are contended for. Reservation system lets you run a synchronous service by periodic allocation

Non Orthogonal Multiplexing CDMA
Use functions which are "nearly" orthogonal
Each channel has a unique pseudo-random sequence
Cycle through sequence transmit it XOR with data
Receiver XORs same sequence with received data, looks for correlations to get sequence sync
Good for mobiles: single frequency, codes don't change during handoff

Ethernet
Shared using CSMA/CD
Collision window is twice the cable length, same as minimum packet size
Retransmit lightens up given a busy network by backing off longer
Routers isolate collisions
Throughput depends on distribution of requests

Token Ring
Tokens have priority
High throughput, low latency guaranteed
Monitor station ensures only one token: stations contend to be the monitor

Slotted Ring
To prevent circulating full slots a monitor sets/ checks the monitor bit in each circulating frame
Good latency if source delete, pass empty slot on

Error Control ARQ
Error detect + retransmit
Transmit information in frames, receiver acknowledges frames with correct CRC. Transmitter resends unacknowledged frames after a timeout / gets a potential NACK
Time from beginning of one data frame to next is: $2\tau_d + \frac{p}{b}$ (frame size p)
This shows a dependency on latency being low

Continuous ARQ
Have multiple frames in transmit at once
If window is big enough the link can be kept full
Upon missing frame, either go back or do selective retransmission

Flow Control
Balance long term information rates

X-On X-Off
Receiver needs to receive 2 channel delays of information after stop

Sliding Window
Combine error/flow control
Receiver tells transmitter what frames are received, how far ahead it allows
Change window with buffer availability

Definitions
Name: denotes something
Address: denotes where something is
Route: tells you how to get there
Name lookup: binding a name to an address
Routing: bind an address to a route

Address Spaces
Flat (moved addresses without modification)
Hierarchical (divided to aid the routing process)

Routing
Static/dynamic
Central/distributed
e.g. ARP via broadcast
Repeater (regenerates signal), bridge (forwards between two MACs), routers (knows about structure of addresses, uses it to route)
Flood (robust, tries shortest path), random, shortest path (but requires knowledge of whole network, inconsistencies cause e.g. loops)
Source routing: sender

	decides route, embedded in packet. Can be *loose*
When To Route	Per packet (robust, adapts to network, no ordering) Per connection (less computation, ordering, lets resources be allocated) Virtual circuits *have* connection setup and state but *don't have* fixed resource allocations Datagrams have neither: they can be routed solely based on their contents
The Internet	IP addresses have network and host parts Router checks for network being one of its networks If not, consult routing table of (network address, next router) pairs Also have default route Routers exchange info.
TCP	Streaming, connection oriented, reliable, full duplex, flow controlled Determine capacity by loss
UDP	Datagrams only
Standards	ITU (UN: modems, framing etc), IEEE (LANs), ISO (models), IETF (applications! RFCs etc.)
Circuit Switching	You and a receiver share a dedicated channel Hardware is dedicated to you, so typically latency and capacity are fixed
Packet Switching	Multiple senders and receivers Entities can transmit at different rates Stateless routing Send to many receivers without circuit setup overhead Intelligent local routing Graceful degradation