Internetwork (Internet)
- connected networks, not hosts
- uses common protocols
- acts like a single network system

TCP/IP
- Internet Architecture Board (IAB)
  - ↳ Internet Activities Board originally
  - → Evolved from Internet Research Group
  - → Forum for exchange among researchers
  - → ~12 members
  - → Reorganization in '89 and '93 and since
  - → Merged into Internet Society in '92
- IETF (Internet Engineering Task Force)
- ICANN (Internet Coporation for Assigned Names and Numbers
  - not for profit managed by international board
  - → Address allocation (ASO)
  - → Domain Names (DNSO)
  - → Protocol Parameter Assignments (PSO)
- World Wide Web Consortium

Request For Comment (RFC)
- Proposals, Surveys and Measurements, protocol standards
- Edited but not peer reviewed

Application	- program to network interface
Presentation	- information, datatype conversions, encryption, compression
Session	- establishes process to process sessions, checkpointing
Transport	- first host to host layer, end to end flow and error control
Network	- subnet, addressing, routing
DataLink	- bit frames point to point
Physical	- raw bits

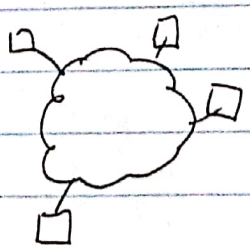
Connectionless, Connection Oriented

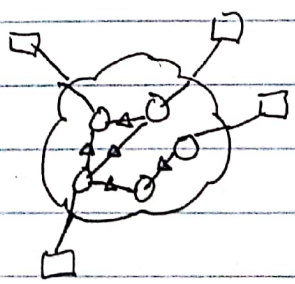
IP

Application → Telnet, FTP, SMTP, HTML, user apps, etc.
Transport → TCP, UDP, RTP
Network → First real IP Layer, Manages "internet"
Link → not part of IP as such but there are standard ways to encapsulate IP packet into ~~frames~~

Connection-less protocol (Datagram) (to the network layer)

- No guaranteed delivery
- May arrive out of order
- May have errors
- Multiple Packets are assumed to have no relation





- Hosts connect to physical Networks
- Dedicated computer called gateways (Layer 3 (router))
  interconnect networks
- Every host is assigned an Internet Address
- Protocol Software on hosts and gateways use Internet Address
  when sending and ~~receiving~~ delivering packets

Physical Connection
  Ethernet Card
  Token Ring Card
  ATM Card
  Modem
  Serial Port connected to other device
Must be configured to avoid other devices
  - interrupts or I/O addresses
    - switch select
    - Jumper
    - Software configured

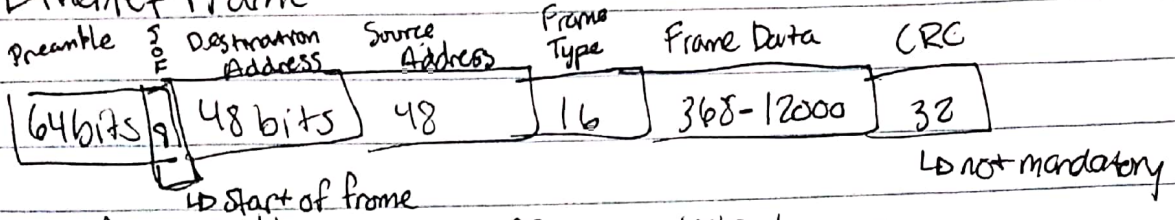
Multiple Protocols on the same machine
↳ each protocol wanted to own the card
→ multiple cards on the same machine was not a good solution

Protocal Stack and Mutiple Cards (from many different vendors) would each write to the "shim" which acted as a middleman converting notations and directing data to the right cards
Shims ⇄ - NDIS, ODI, PacketDrivers

802.3 LANs (ethernet)
- CSMA/CD
  - Carrier Sense → listen until the medium is idle
  - Multiple Access → multiple connections at the same time that worked around each other
  - Collision Detection → listen for detection while transmitting and halt on collision, try again after random wait
    → Backoff → double wait time if recollision to a point
- 36% throughput underload
- looks like broadcast media

MAC ADDRESS (Med

Ethernet Frame



Min 64 bytes, Max 1518 bytes

Preamble - frame is comming and sync clocks
Look at destination first, stop listening if its not for you

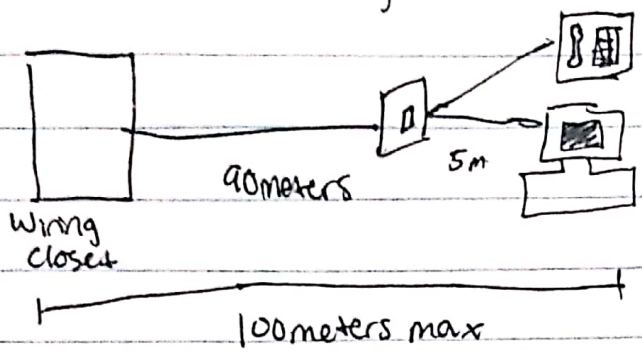
Special: all 1s → everybody
multicast → 1 to many (subgroups)

- Unacknowledged connectionless
- Lookup Address Vendor Info
  - can pay extra to not be on the list
  - originally crowd sourced → kind of still is today due to the paywall
  - can imply vendor loads (production)
  - help network managers identify packet source devices

To IP a repeated and/or bridged set of ethernet segments appears to be just a single physical network
- bridges/repeaters are not seen
- the frist IP layer is the network layer
- routers can be seen
- no physical or datalink layer in IP

EIA/TIA/ANSI 568 Standard

Commercial Wiring Standards



- use cat 5e twisted pair or better
- wire categories must match plugs and connectors

Workstation

Voice 3 or better (foolish, the cable is not the cost)

data 5e or better

Other issues addressed

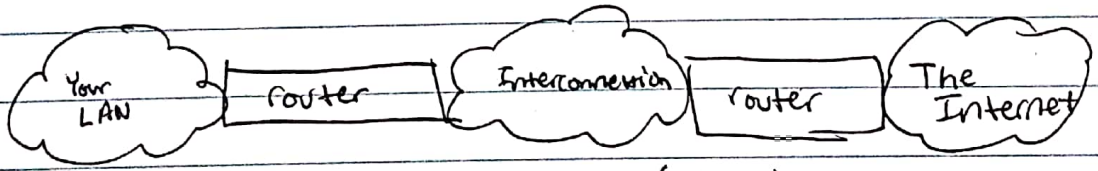
Corners, Power Lines, how much twisting, cable support, tension

0800 → DOD Internet Protocol (IP)

86dd → IPv6

To IP, a repeated and/or bridged set of ethernet segments appears to be a single physical network

- IP address assigned to network interface



Internet Service Provider (ISP) is usually the interconnection between your network and the internet

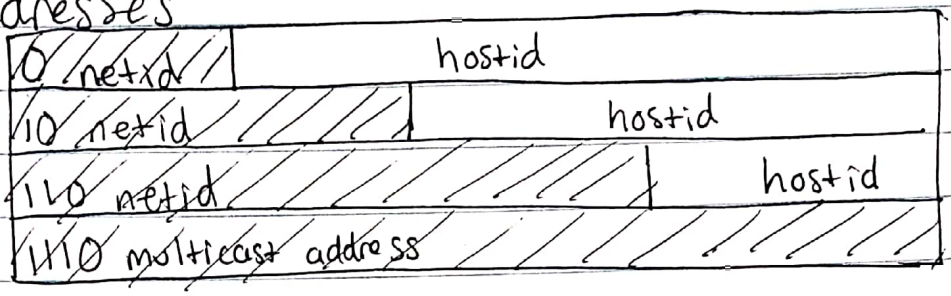
Variety of Connection Types

frame relay, X.25, leased Line, ATM, cable modems, DSL, cellular, ADSL

Additional Hardware: CSU/DSU, PAD, modem, ATM switch

Formula Translated into executable arithmetic/logic code
↳ FOR-TRAN → FORTRAN

IPv4 Addresses



- 32 bits fixed length
- uniquely identify network interfaces
  - ↳ multiple interfaces means multiple addresses
- flat (no topographical information)
- 2 part address
  - ↳ network ID
    - ↳ identifies physical networks
  - ↳ host ID
    - ↳ identifies the host interface connected to the network

Dotted Decimal Notation
1.2.3.4
0-01.0-10.0-11.0-100

Class A -0.1.0.0 to 126.0.0.0
B -128.0.0.0 to 191.255.0.0
C -192.0.1.0 to 223.255.255.0
D -224.0.0.0 to 239.255.255.255

255.-.-.- → broadcast to everyone
127.0.0.x → loopback
x.x.255.255 → broadcast to everyone on netid x.x (class B)
x.x.0.0 → network address (class B)

Reasons for a Language → communication, information, feelings, ideas → "data"
↳ "data type"

Notational Languages - P→Q, XML, Electronic Symbols etc.

Why Study (a) Language(s) → communications → write → read
→ expressibility, readability, writable,
* learnable, cost effective
→ choose one language over another
→ design a new language
→ for better interpretation of programs
↳ better at fixing problems
→ Advances in CS

Principles of Language Design
1. Simple
2. Ease of Use ~~of~~, Learning, and teaching
3. Unambiguous
4. Efficient
5. Unrestricted

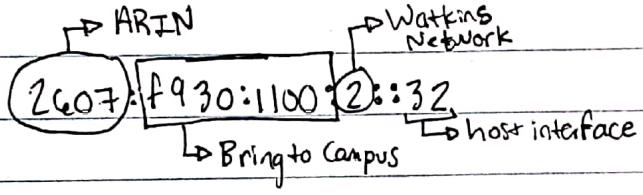
Top Level Paradigms of PL
Imperative/Procedural (Von Neumann structure)
↳ one line by line
Program = Algorithm + Data
↳ Instructions that manipulate data
Object oriented ⇒ Concepts (objects) + Interactions = System

Logical → knowledge and interpretation
Functional → mathematical expressions in λ calculus

10.0.0.0 - 10.255.-.- (10/8 prefix) 1 class A
172.16.0.0 - 172.31.255.255 (172.16/12 prefix) 16 class B
192.168.0.0 - 192.168.255.255 (192.168/16 prefix) 256 class C

IPv6 vs IPv4
128 bit vs 32bit
hex vs decimal per byte
hierarchical vs flat
no broadcast in IPv6 but you can multicast
fec0:x.. is site local (192.168.x.x) &
fe80:x is link local (no IPv4 equivalent)

Provider Based Unicast Address Structure



Instruction Set Based on Machine and goals
Short Code:

01 — + 02 — - 03 — * 04 — /

Automation Principle
↳ "Automate mechanical, tedious, or error-prone activities"

Orthogonality Principle
↳ "~~Indirect~~ Independent functions should be controlled by Independent Mechanisms"

Labeling Principle
↳ do not require the user to know the exact location/position of a listed item, Instead associate labels with that position

Univac Compiling System – Grace Hopper

Fortran 0 – never implemented
Fortran 1 – quickly caught on
Fortran 77 – popular in 78, character string handling, logical loop control statement, IF-THEN-ELSE statement

Big/Little Endian Nnnn...n → Big, ← Little

"Helper Protocol"

Address Resolution Protocol (ARP)
- ↳ Broadcast Based IP Finder
- ↳ Review Packet Format (32 bit)
- → "Where is "Adam"" → "I am here!"
- → cache addresses for future use but this data will tend to change as nodes move around
  - ↳ cache must be flushed periodically
    - ↳ often a timeout system (when was last comm.)

Reverse ARP (Who Am I?)
- ↳ Requires central server to manage IP/MAC Address database

IP - Network Layer

First Real Layer of the IP Protocol

IPv4 Packet Layout

Version, Length (header), Type of Service, Total Length

Identification, Flags, Fragment Offset

Time to Live (TTL), Protocol (Upper Level), Header Checksum

Source IP Address

Destination IP Address

Options, Padding

Data

Max Packet Size 2^{16}

Packet is too big to put on Ethernet (~5000 bit packet size)
- ↳ artificially limit packet size → inefficient
- ↳ break packet into pieces

Same header except for → fragment Offset, Header Checksum (Sanity Check)
- ↳ where does this fragment fit?

TTL → IP version of a hopcount
- ↳ everytime you make a hop subtract one, and subtract 1 for each second it sits in a router waiting to be sent

usually turned off in routers
→ measure TTL (hop count) in Lab

Type of Service

3	4	5		7
Precedence	D	T	R	unused

- Precedence
  - 000 normal
  - 111 net control (often unimplemented)
- D - low delay
- T - high throughput
- R - high reliability

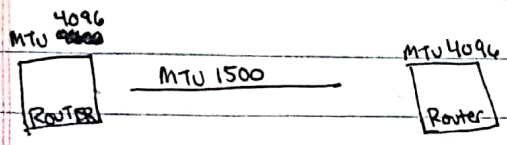
Options
- debugging, net control
  - ↳ record route, source route, timestamp

Don't Use This Anymore, it's outdated

Encapsulation

↳ The IP Packet is the only end to end data unit

MTU - Maximum Transfer Unit



IP → Fragment when needed and leave fragments until final destination is reached

↳ fragments may need to be fragmented again

↳ fragments may take different paths, thus resulting in different fragment sizes

→ IPv6 MTU DiscoverLab

↳ "safesize" is 576 MTU

→ first router that needs to fragment will do so

→ if a fragment is lost the whole packet is thrown away

→ can disable fragmenting via packet flag

↳ if it's too big the router will respond after throwing the packet away

IPv6 Header

Goals: ~~Fixed Sized Format~~, Minimize Router Work, Increase Address Space

Version, Class, Flow Label

Payload Length, Next Header, Hop Limit

Source Address → "Cheater Options"

Sequence of Packets From Same Source

Destination Address