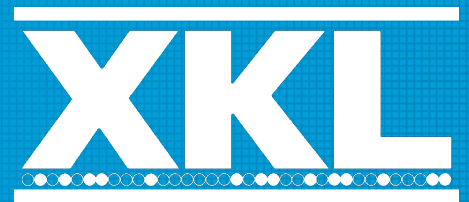# From Data Links to Internets

Adventures from 1979 to 1990

L. Bosack, XKL

XKL

Starting out

- My 4th career
  - Mathematician
  - Symbolic Computing
  - Computers
    - Hardware and Software
  - Networks
    - Hardware and Software

Just before Dawn, Network Age

- New arrival to a thriving community
  - RFC760
  - Network HW Ideas In Bloom
    - Point to point
    - Bus
    - Ring – Physical Ring or Star Shaped
    - Wireless
  - Protocols
    - Pup/XNS
    - IP

Starting Out: 1

- Hosts
  - Network HW
  - Drivers
  - Protocol
    - In OS
    - User Programs

Starting Out: 2

- Arpanet already running
  - Full-Function Non-Internet
    - Remote Access
    - File Transfer
    - Mail
    - Misc: Time, Finger, etc
  - Enabled Collaboration Needed for Rapid Progress

Starting Out: 3

- Choose Your Network
  - Every Medium Used
  - Real Life Proof of IP Network Independence
- We chose Ethernet
  - Close Ties to PARC
  - Running Alto IIs on 3Mb coax Ethernet

Starting Out: 4

- Bigger hosts needed better interfaces
  - Back-to-back receive and send
  - Efficient buffering
- First near-interconnect grade interface
- Dual networks, either 3 Mb or 10 Mb

Starting Out: 5

- Growing Early Networks

- Length and Topology

  - Analog Repeaters

  - Digital Repeaters

- Number of Hosts and Topology

  - Switch

  - Router

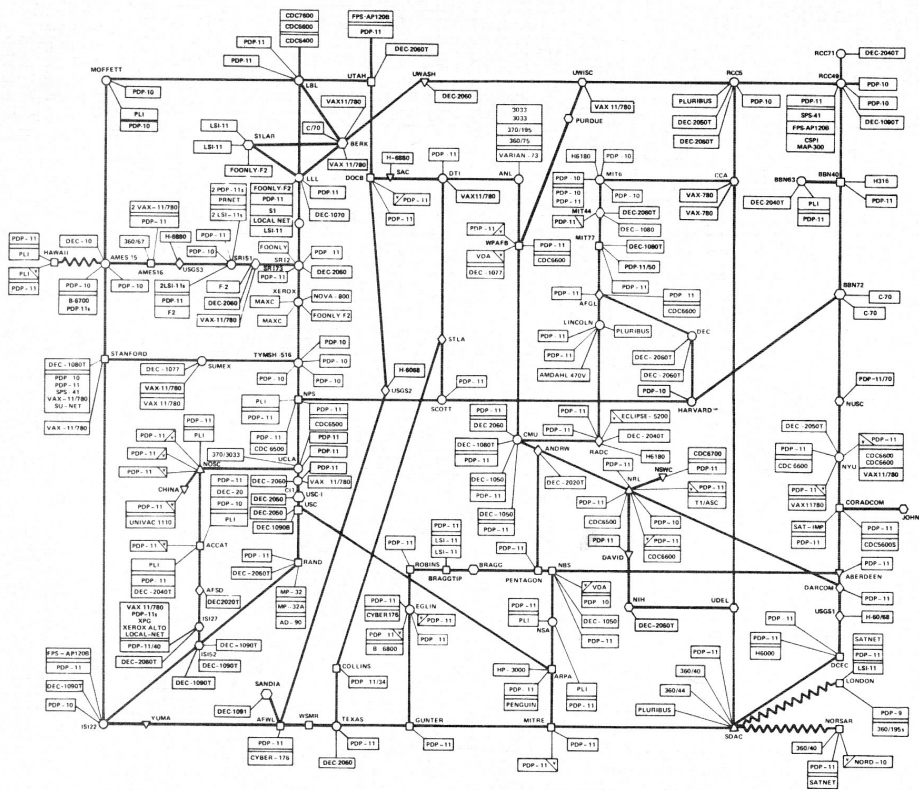# Early Routers

- Started with Small Computer Systems

    - Honeywell 516

    - PDP-11

    - SUN components
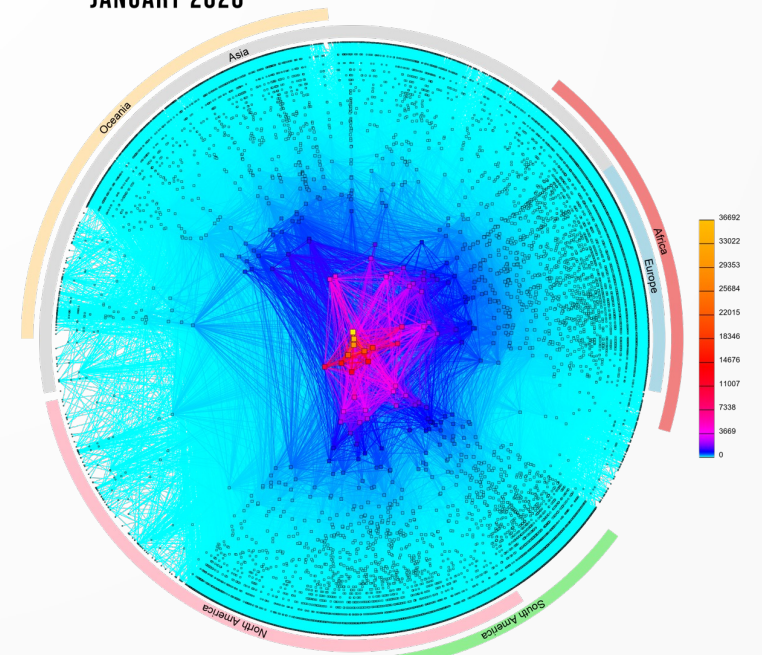
Early Switch ca 1982

- SUN processor and 3 Ethernets
- Broadcast storm soon after debugged
  - Usual cause, Host interaction/bugs.
  - Primitive router was result

Will this be useful? - 1

ARPANET LOGICAL MAP, DECEMBER 1981

CAIDA'S IPV4 AS CORE GRAPH
JANUARY 2020

COPYRIGHT © 2020 UC REGENTS

Will this be Useful? - 2

- Worries and Criticism
  - Too much computation
  - Too much software
- Nobody understands it

Growing Pain

- Needed Better Routers

- First pass depended on PUP routing

  - Mapped IP address

    - 36.N.0.H routed as PUP N.H

- Slowly added pure IP and TCP functions

- Worked Surprisingly well

- Our colleagues wanted them!

Commercialization

- Many request for interfaces and routers
- Not what research projects do
- DARPA encouraged industrial transition

Better Routers: 1

- Routers are not general purpose computers
  - Need Interconnect-grade interfaces
  - Specialized computations
    - Address manipulation
    - Address lookup
  - Bus Bandwidth

Better Routers: 2

- Interconnect Grade Interfaces
  - Operate at line rate – no dead time
  - Quick recovery from off-normal conditions
    - Errors handled without further consequence
    - Next frame normal
  - Live network diagnostics
    - Avoid Black Hole problem

Specialization: 1 - MCI

- 2 – 10Mb Ethernet
- 2 – 4 Mb HDLC Serial (usually T1/E1)
- Local Memory-Based Router on a Board
    - 100b VLIW
    - General enough to Switch/Route
- >250K shipped

ITU conference 1987

- Presentation about Packet Networks

  - Concept review

  - Very brief Protocol overview

  - Efficiency Data

- Last technical talk on last day

- Grand Finale: "Voice will become a minor contaminant in the Computer Data flow and no one will bother to separately charge for it"

Specialization 2: Cbus 1

- Controller

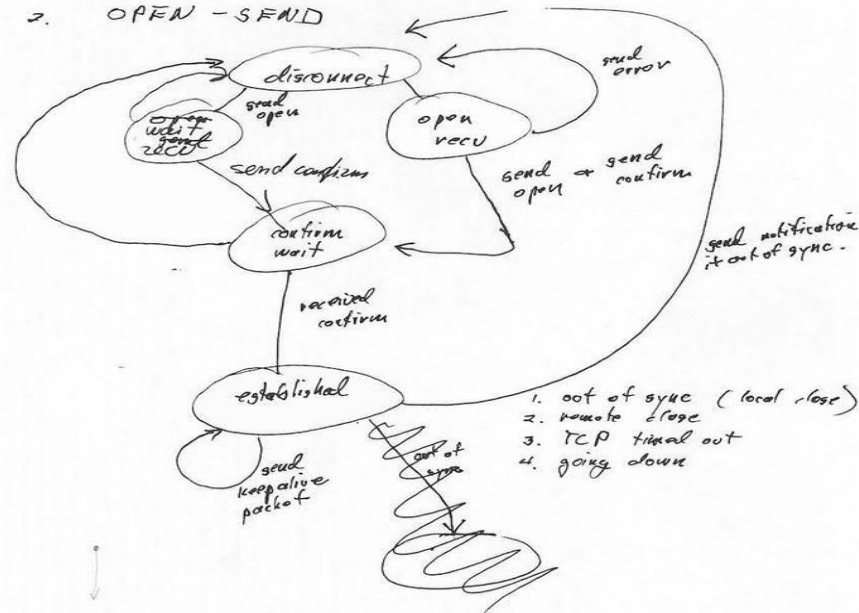- Interfaces

  - 6 10 Mb Ethernet

  - FDDI

  - 80 Mb Serial

Jon, I think I can do it

- IP was proving useful at moderate size
- Could networks keep growing:
  - Larger
  - Faster

BGP and growth: 1

BGP and growth: 2

- 1988 and ARPAnet was still the routing backbone
  - EGP reaching practical limits
  - Single updates exceeded Imp MTU, so fragmented
- Routing protocol wars in full cry
- I needed to get something new
  - At least 2 important organizations
  - Routing decision algorithm independent

Specialization 2: Cbus+

- Path for further growth
  - Bus Bandwidth
    - 0.5 Gbps to 2 Gbps
  - Interface Types
  - Switching Rate
    - 1 MPPS to 2 MPPS
  - Memory
    - Size
    - Organization

Let us not Forget

- Interface performance matter

- Worse than Poisson tails

- It is all about the pins

Questions

- Questions?

Thanks

- Thank you!