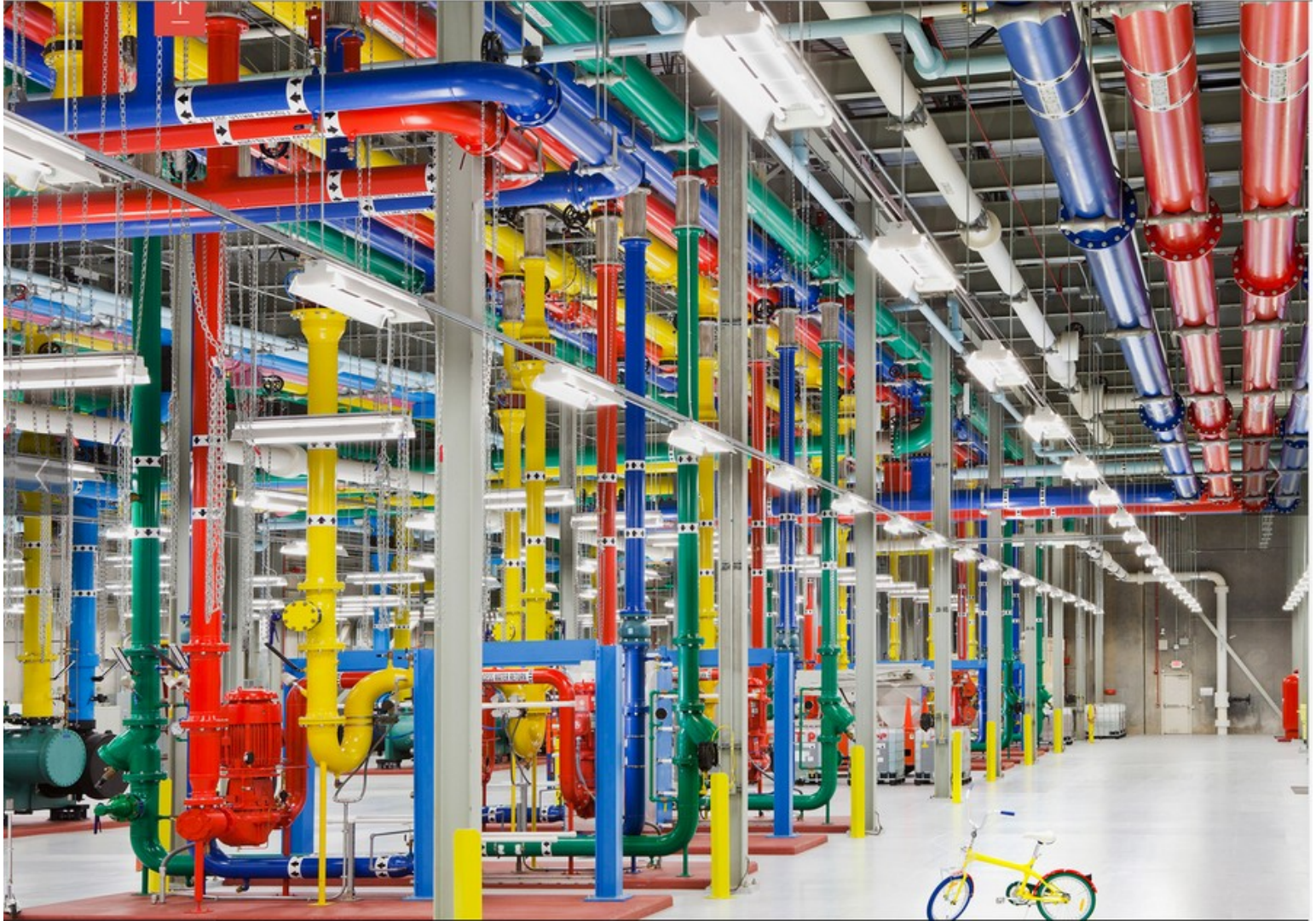
CS 447/647

Physical Networking



Protocol

- Processes must agree on a set of rules
  - Protocol
- Enables
  - Connection
  - Communication
  - Transfer of data
- Not a standard
  - Some standards were never turned into protocols

Protocol

Physical Connection - Speed, endpoint presence

Handshaking - Rules for initial exchange

Negotiation of Parameters - rules and limits - TTL, MSS

Message Delimiters - Start and end of a message

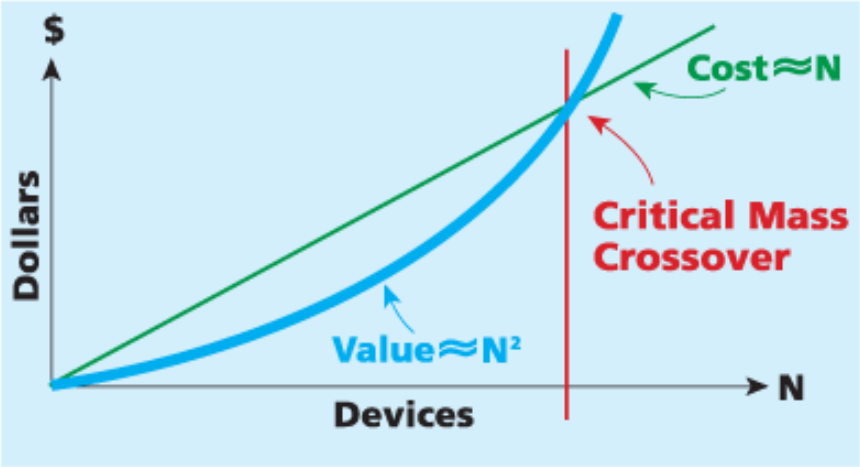
Error Detection - Detect corruption

Error Correction - How to handle errors

Termination - How to gracefully stop communication

Networking

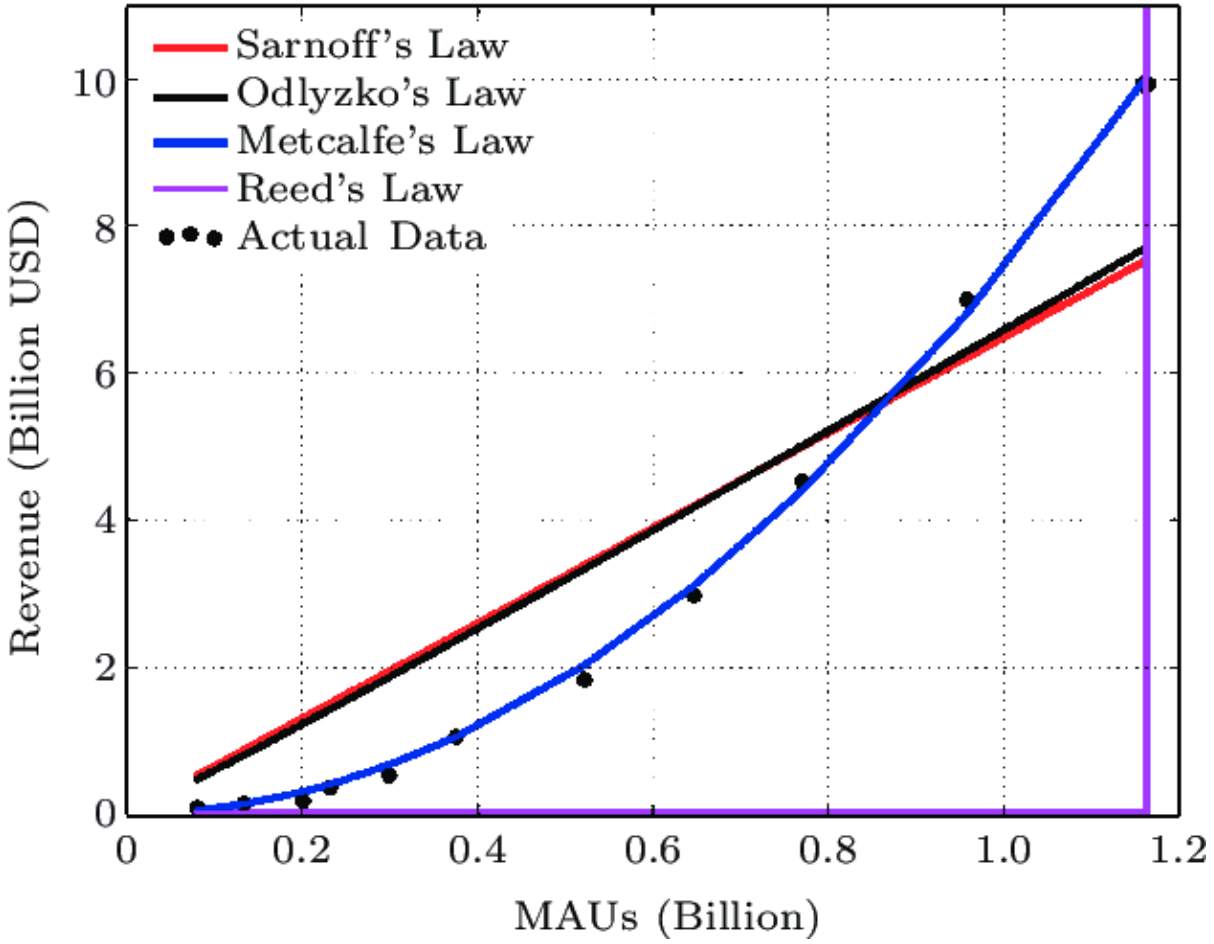
- Metcalfe’s Law
  - n^2



The Network Effect

Originally conceived as a way to sell more Ethernet cards, Metcalfe’s Law postulates that the value of a network is proportional to the square of the number of users. In this essay the author wonders whether his law applies to other networks—namely, neurons in the human brain and transistors in supercomputers.

https://www.forbes.com/forbes/2007/0507/052.html#4b9538ca47d3



https://www.researchgate.net/publication/273895436_Tencent_and_Facebook_Data_Validate_Metcalfe's_Law

Networking

- Packetized data transport the most influential UNIX technology
  - CISCO - Stanford CS Department
- Fast and reliable networking is essential
- Virtualization Increasing
  - tap, tun, veth, virtio, software-defined
- Encapsulation
  - VXLAN
- Real-world networking experience essential
- Ethernet is king
  - Some niche contenders: RDMA, Infiniband, Omni-Path

Elements of a Successful Network

- Develop a reasonable network design
- Select high-quality hardware
- Proper installation and documentation
- Competent ongoing operations and maintenance

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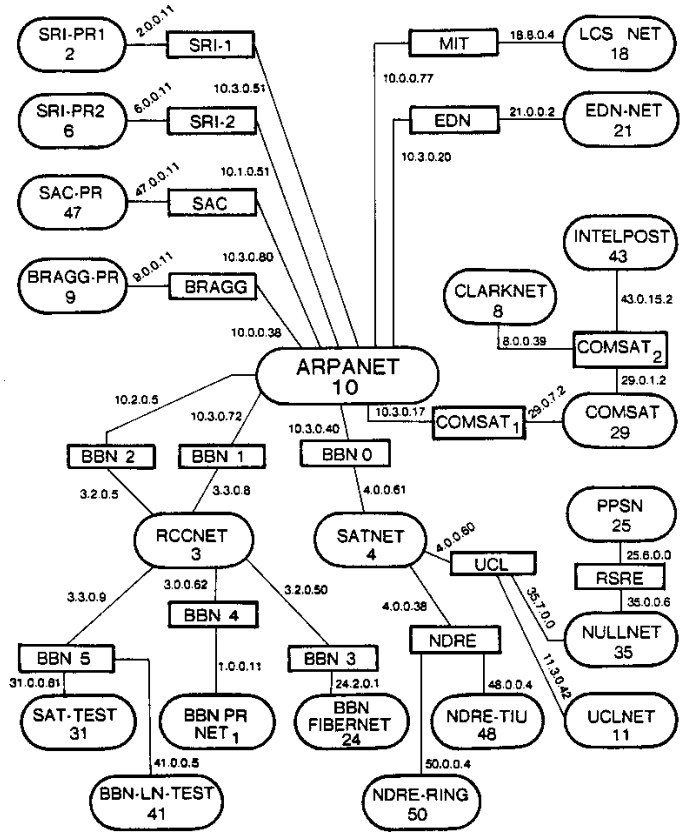


Ethernet

- 95% of the world market
  - Bob Metcalfe’s Ph.D dissertation at MIT
- CSMA/CD Model
  - Carrier Sense
    - See if anyone is talking before talking
  - Multiple Access
    - Anyone can talk – no tokens
  - Collision Detection
    - Did I interrupt someone else?
- Less important now with Point-to-Point switches
  - ARP

Year	Speed	Common name	IEEE#	Dist	Media[a]
1973	3 Mb/s	Xerox Ethernet	–	?	Coax
1976	10 Mb/s	Ethernet 1	–	500m	RG-11 coax
1989	10 Mb/s	10BASE-T	802.3	100m	Cat 3 UTP copper
1994	100 Mb/s	100BASE-TX	802.3u	100m	Cat 5 UTP copper
1999	1 Gb/s	1000BASE-T ("gigabit")	802.3ab	100m	Cat 5e, 6 UTP copper
2006	10 Gb/s	10GBASE-T ("10 gig")	802.3an	100m	Cat 6a, 7, 7a UTP
2009	40 Gb/s	40GBASE-CR4	P802.3ba	10m	UTP copper
		40GBASE-SR4		100m	MM fiber
2009	100 Gb/s	100GBASE-CR10	P802.3ba	10m	UTP copper
		100GBASE-SR10		100m	MM fiber
2018[b]	200 Gb/s	200GBASE-FR4	802.3bs[c]	2km	CWDM fiber
		200GBASE-LR4		10km	CWDM fiber
2018[b]	400 Gb/s	400GBASE-SR16	802.3bs	100m	MM fiber (16 strand)
		400GBASE-DR4		500m	MM fiber (4 strand)
		400GBASE-FR8		2km	CWDM fiber
		400GBASE-LR8		10km	CWDM fiber
2020[b]	1 Tb/s	TbE	TBD	TBD	TBD

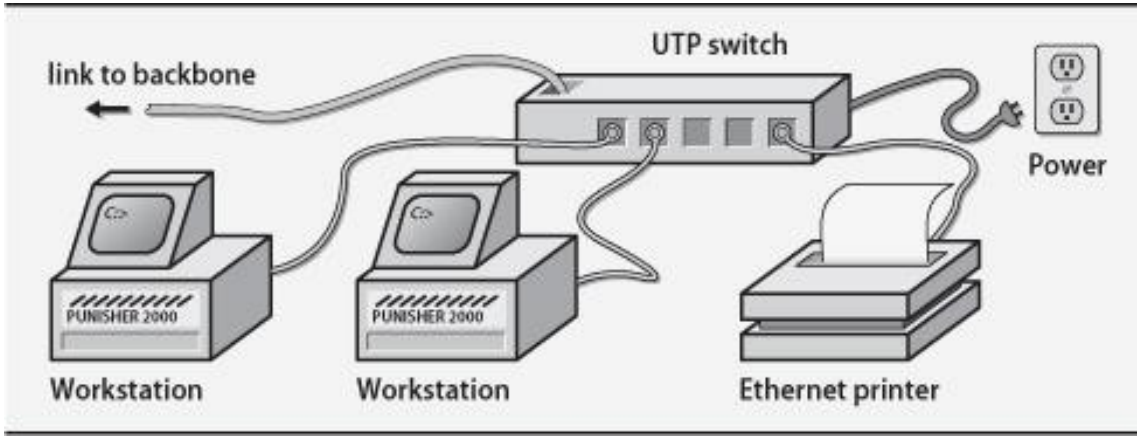
a. MM = Multimode, SM = Single-mode, UTP = Unshielded twisted pair, CWDM = Coarse wavelength division multiplexing

b. Industry projection

c. We'll give the benefit of the doubt and assume this lettering choice was an unfortunate coincidence.

Ethernet topology

- Branching bus with no loops



Packet Types

- Unicast Single host
- Multicast Group of hosts
- Broadcast All hosts on a segment

- Broadcast domain: the set of hosts that receive packets destined for the hardware broadcast address
  - 172.20.195.0/24
  - Gateway: 172.20.195.1
  - Broadcast: 172.20.195.255
  - 8 bit host network = 256 - 2

UTP Unshielded twisted pair

- TIA/EIA-568A RJ-45 Wiring Standard

Pair	Colors	Pins
1	White/Blue	5/4
2	White/Orange	3/6
3	White/Green	1/2
4	White/Brown	7/8

- Gigabit and up require all 4 pairs

Parameter	Units	Cat 5[b] Class D	Cat 5e	Cat 6 Class E	Cat 6a Class EA	Cat 7 Class F	Cat 7a Class FA	Cat 8 Class I
Frequency range	MHz	100	100	250	500	600	1000	2000
Attenuation	dB	24	24	21.7	18.4	20.8	60	50
NEXT[a]	dB	27.1	30.1	39.9	59	62.1	60.4	36.5
ELFEXT[a]	dB	17	17.4	23.2	43.1	46.0	35.1	–
Return loss	dB	8	10	12	32	14.1	61.93	8
Propagation delay	ns	548	548	548	548	504	534	548

a. NEXT = Near-end crosstalk, ELFEXT = Equal level far-end crosstalk
b. Includes additional TIA and ISO requirements TSB95 and FDAM 2, respectively

Optical Fiber

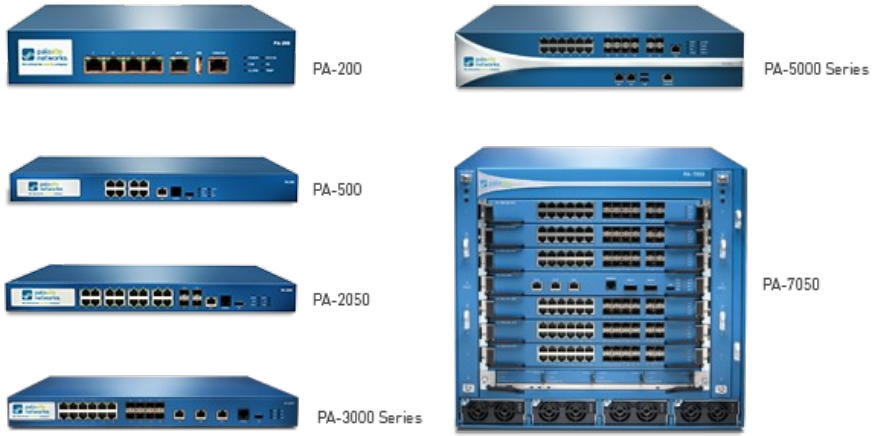
- Used in cases where copper is not adequate
- Carries signal further than copper
- Resistant to electrical interference
- Types of fiber:
  - Multi-mode: multiple rays of light - LEDs
    - 850 nm and 1300 nm wavelengths
  - Single mode: expensive endpoints - Lasers
    - 1310 or 1550 nm wavelengths
- Coarse wavelength division multiplexing
  - Uses multiple wavelengths of light

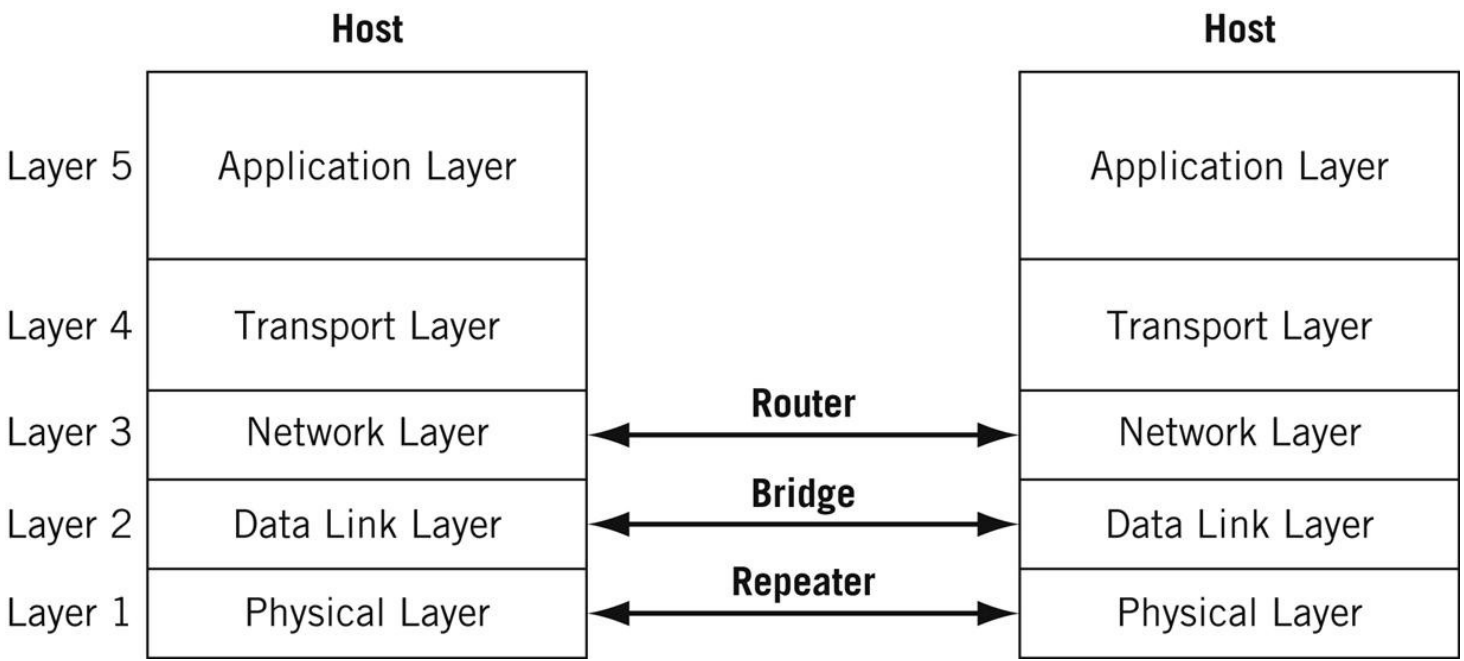
Optical Fiber

- Over 30 types of connectors
  - SFP+ - 10Gb
  - SFP28 - 25Gb
  - SFP56 - 50Gb
  - SFP112 - 100Gb
  - QSFP+ - 40Gb
  - QSFP28 - 100Gb
  - QSFP56 - 200Gb
  - QSFP112 - 400Gb

Ethernet connection and expansion

- Hubs (Repeaters) - Layer 1 – Physical
  - 10 Mb/s 4 hubs max
  - 100 Mb/s 2 hubs max
  - 1 Gb/s 1 hub max
- Switches – Layer 2 – Data link
  - Ethernet Frames and ARP
- Routers – Layer 3 – Network
  - Connects different network types



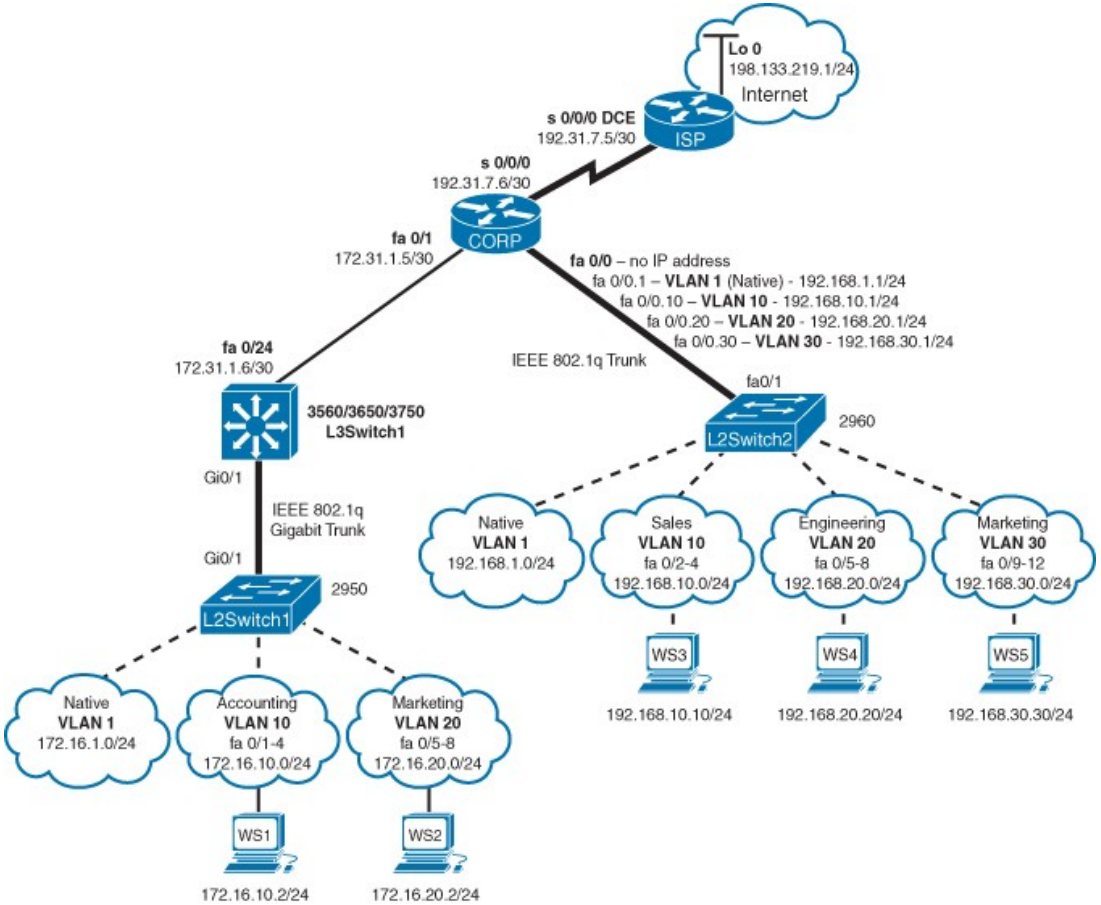

Host
Host
Layer 5
Application Layer
Application Layer
Layer 4
Transport Layer
Transport Layer
Router
Layer 3
Network Layer
Network Layer
Bridge
Layer 2
Data Link Layer
Data Link Layer
Repeater
Layer 1
Physical Layer
Physical Layer

Bridge

• **Forwarded**—The frame is sent only onto the LAN segment where the destination is located. The bridge examines the source MAC address fields to find specific device locations.

• **Filtered**—The frame is dropped by the bridge. No message is sent back to the source.

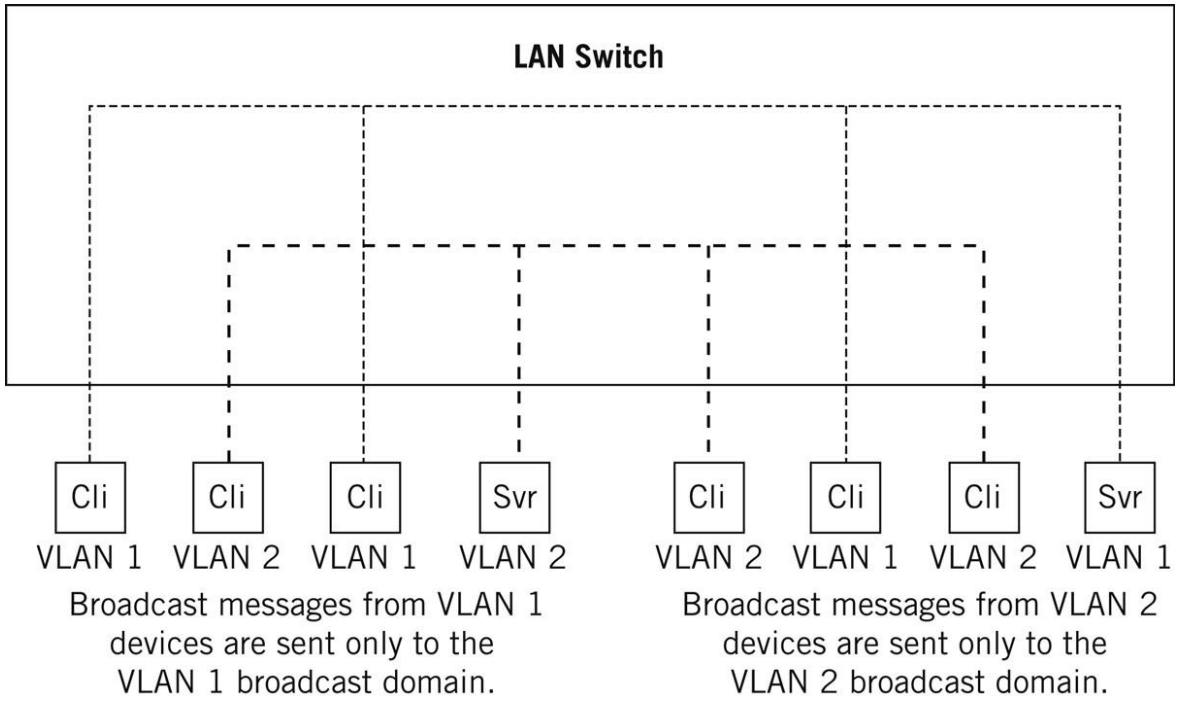
• **Flooded**—The frame is sent to every LAN segment attached to the bridge. This is done for broadcast and multicast traffic.



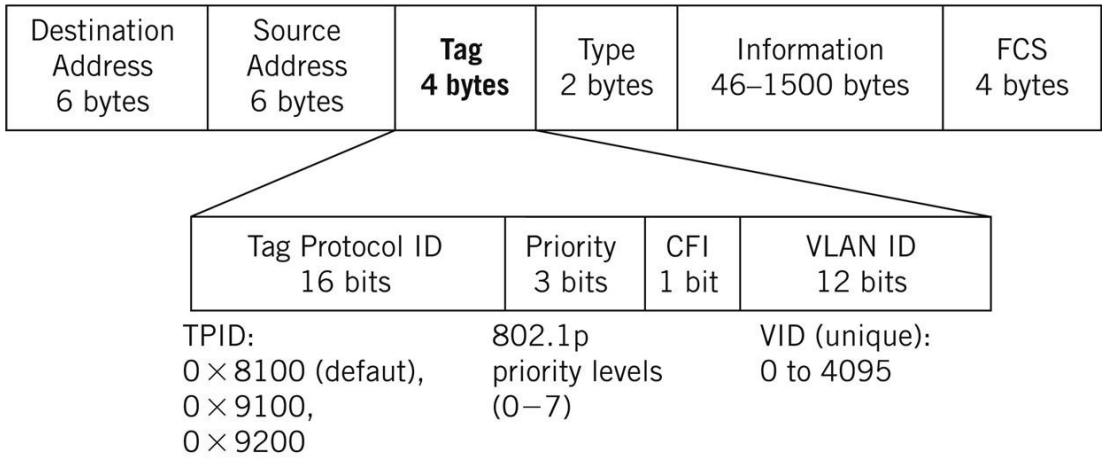
CCNA 200-301 Portable Command Guide, 5th Edition

VLANs

- Virtual Local Area Networks
- VLAN is a group of ports that belong to the same logical segment
- Allows us to isolate traffic on the same switch

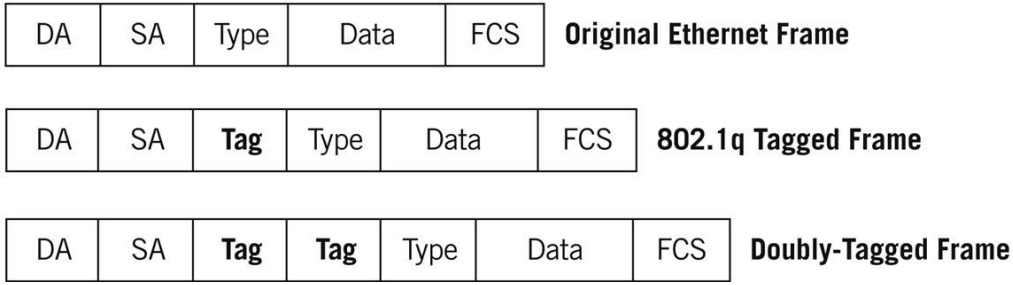

LAN Switch
Cli
Cli
Cli
Svr
Cli
Cli
Cli
Svr
VLAN 1
VLAN 2
VLAN 1
VLAN 2
VLAN 2
VLAN 1
VLAN 2
VLAN 1
Broadcast messages from VLAN 1 devices are sent only to the VLAN 1 broadcast domain.
Broadcast messages from VLAN 2 devices are sent only to the VLAN 2 broadcast domain.

Ethernet Frame Structure



(Canonical Format Indicator: 0 = canonical MAC, 1 = noncanonical MAC)

Ethernet q-in-q VLAN tags



VLAN Why?

Security - Frames are delivered everywhere

Broadcasts - Every systems must process. Rarely carry user data.

Router Delay - Older routers are slower than LAN switches. Boundary without routing.

Modes and Configuration

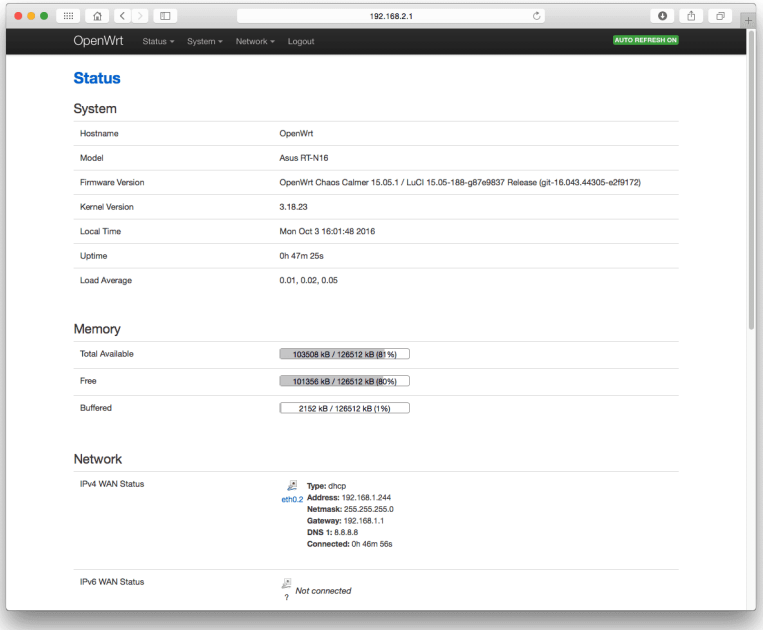
- Auto-negotiation
  - Usually works
- PoE: Power over Ethernet
  - More expensive
  - Additional power requirements
- Jumbo Frames – +10% performance
  - > 1500 bytes
  - 9k – 64k bytes

Wireless Ethernet

- WAPs Wireless access points
  - Apple Airport Extreme
  - OpenWRT Linux based
- 802.11g 2.4 GHz 54Mb/s
- 802.11n 5 GHz 600Mb/s
- 802.11ac 5 GHz 1000Mb/s
- Wireless Security
  - WEP – do not use – not secure < 1min
  - WPA2 – fine, but still not completely safe
  - WPA3 - Use this instead

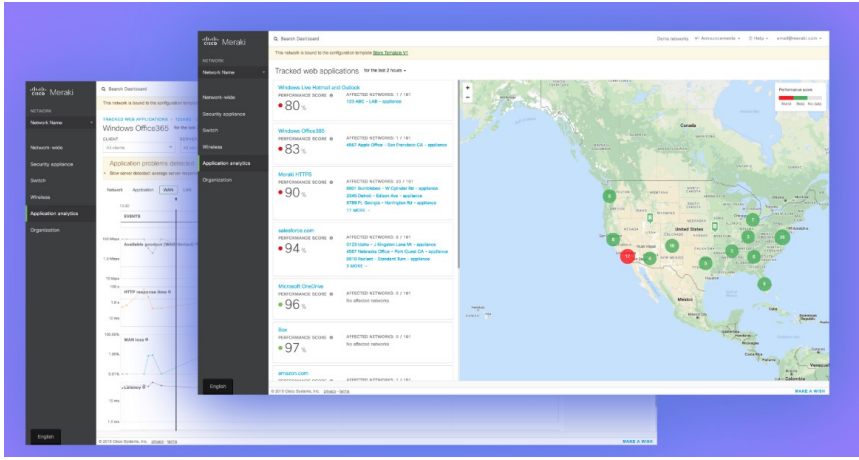
Wireless Ethernet

- OpenWRT
  - Linux Operating System for embedded devices
  - Package Management
  - Performance
  - Stability



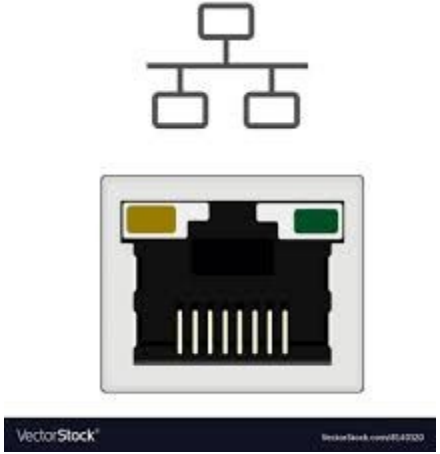
Software Defined Networking

- Separate physical from functional
  - Flexibility
  - Management
- Data-plane is programmable
  - OpenVSwitch
- Same subnet across a geographic area
  - Generic Routing Encapsulation
    - Secure path through a public network
    - Virtual Point-2-Point
- Monitoring



Network Testing and Debugging

- Check the status “idiot” lights
- Hand-held cable analyzer
  - Time domain reflectometry TDR
  - Fluke LanMeter
  - T-berd FireBERD line analyzer jdsu.com
- Packet sniffer – Wireshark
- Cable Testers



Building Wiring

- UTP – use Cat 6a for new wiring
- Connections to offices
  - Install 2 to 4 connections per office
  - Telephones – Visitors – Laptops – Demo
  - Much cheaper to run cables once
  - Materials only 5% - 10% of total cost
  - People buy switches when they run out of ports

Network Design Issues

Network design consists of:

- Type of media to be used UTP vs. Fiber
- Topology and routing of cables
- Use of switches and routers

Network Design (cont.)

- Network architecture vs. building arch.
  - They must coexist
- Existing buildings
  - Maintain integrity of firewalls
  - Run extra cables whenever possible
    - Especially in hard to reach places
- Expansion – plan for the future
  - Single-mode fiber
  - Run a lot of strands

Network Design (cont.)

- Minimize Congestion
  - You network is only as good as its weakest link
  - Subnet high traffic areas, experimentation
- Maintenance and documentation
  - Label cables at both termination points
  - Update network maps
  - Install routers between political and administrative domains
  - Joints useful for debugging - isolation

Management Issues

- Typical environment:
  - Backbone between buildings
  - Departmental subnets
  - Group subnets within a department
  - Connections to the outside world

Things to Centralize

- Network design, subnets, routers, switches, etc.
- The backbone cable, connections
- Host IP Addresses, hostnames, subdomain names
- Protocols, ensure they interoperate
- Routing policy to the Internet