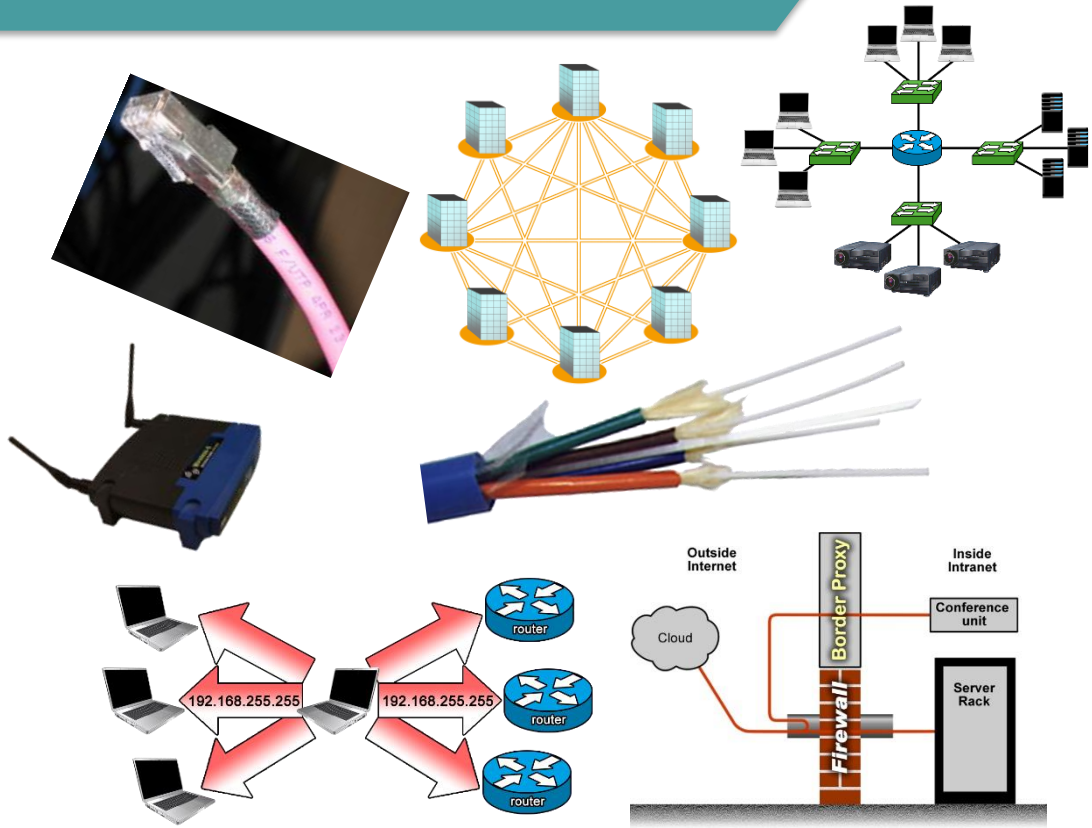
CTS-Prep Workshop III
Networking Part I
Italy, April 2020
Jose Mozota CTS, CTS-I

Networking

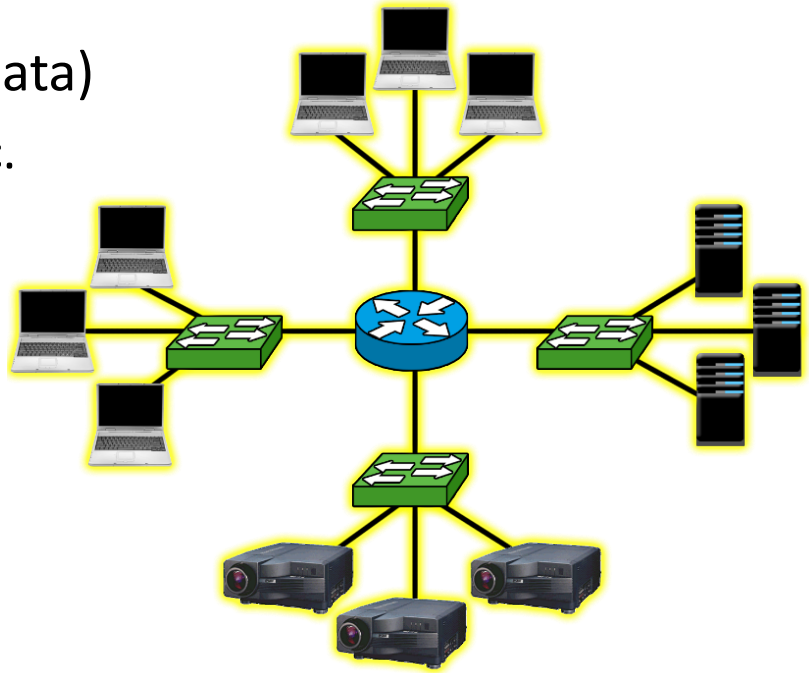
- Part I
  - –Network components
  - –Network connections
  - –Topologies
  - –OSI Model
  - –Ethernet
- Part II
  - –Internet Protocol
  - –Address assignment
  - –Transport protocols
  - –Network security



Network Components

Two main network building blocks:

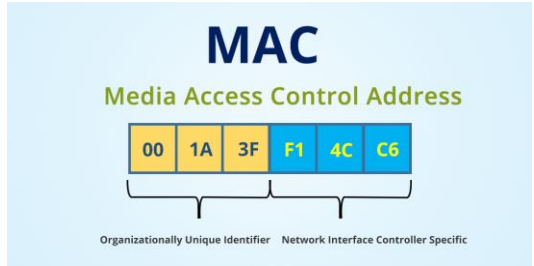
- Nodes (devices that send and receive data)
  - Control CPUs, audio DSPs, projectors, etc.
  - Switches, hubs, routers, gateways, etc.
- Connections
  - Cat cable, fiber, Wi-Fi, etc.

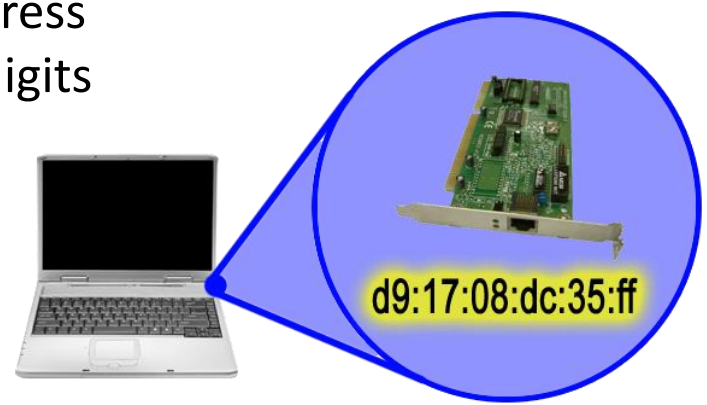


NICs and MACs

- NIC - Network Interface Card
  - Hardware interface that sends network data
  - Every node has at least one NIC
- MAC address – Media Access Control address
  - Every node has a completely unique MAC address
  - 48 bit number, expressed as 12 hexadecimal digits

0000	0	1000	8
0001	1	1001	9
0010	2	1010	A
0011	3	1011	B
0100	4	1100	C
0101	5	1101	D
0110	6	1110	E
0111	7	1111	F

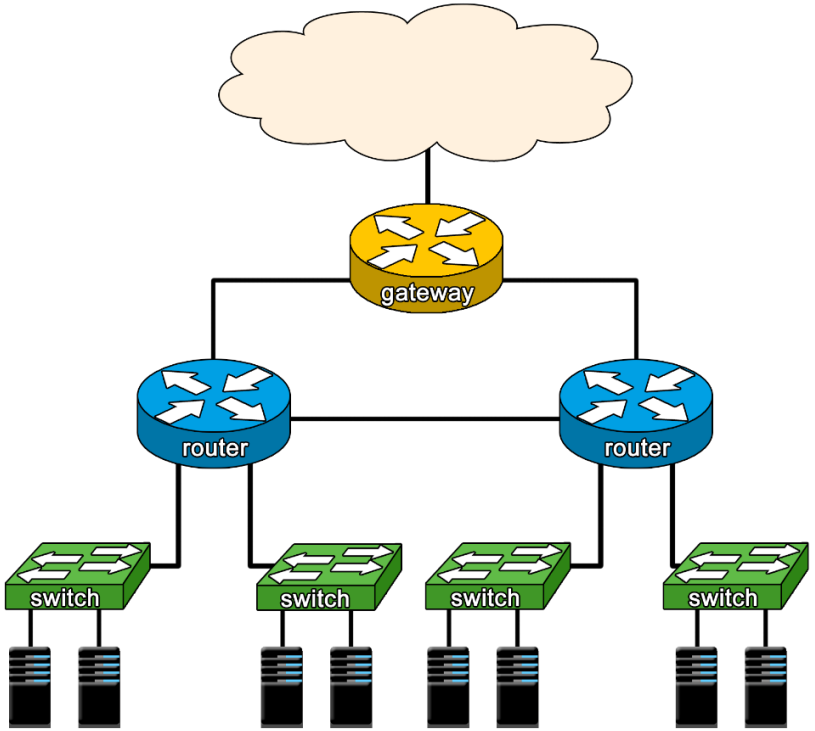




Networking Devices

Common networking devices

- Switches
- Routers
- Gateways
- Servers



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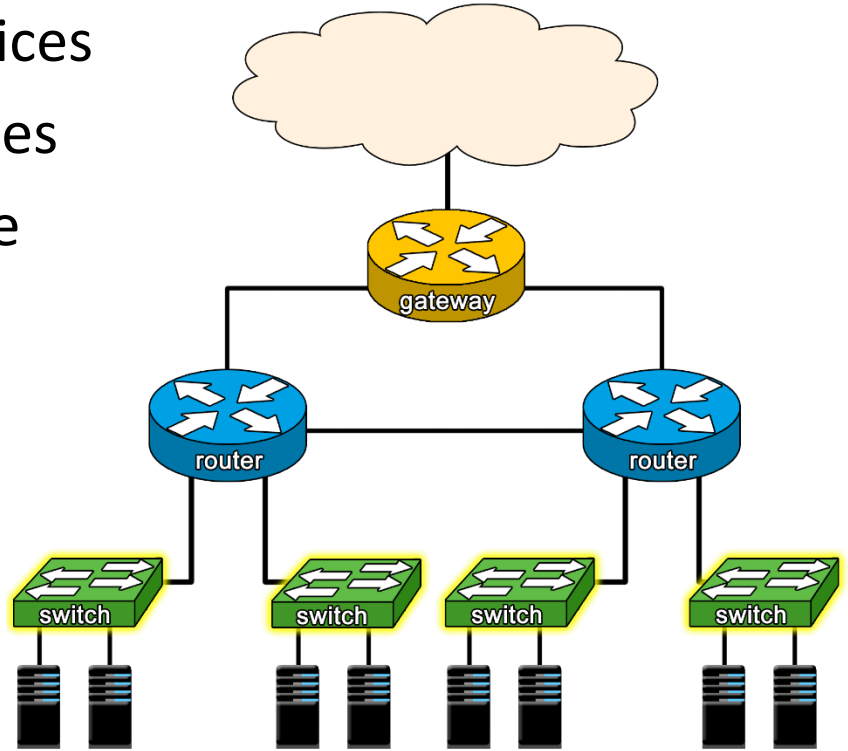
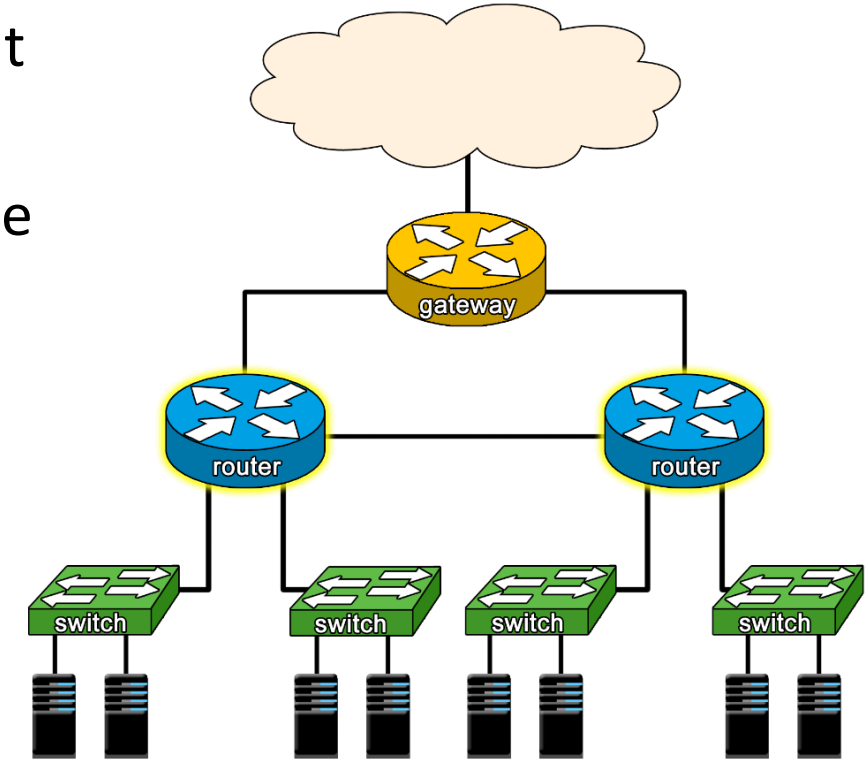
Switches

- Physically connects multiple devices
- Collects and stores MAC addresses
- Forwards data to the appropriate MAC address
- Managed or unmanaged



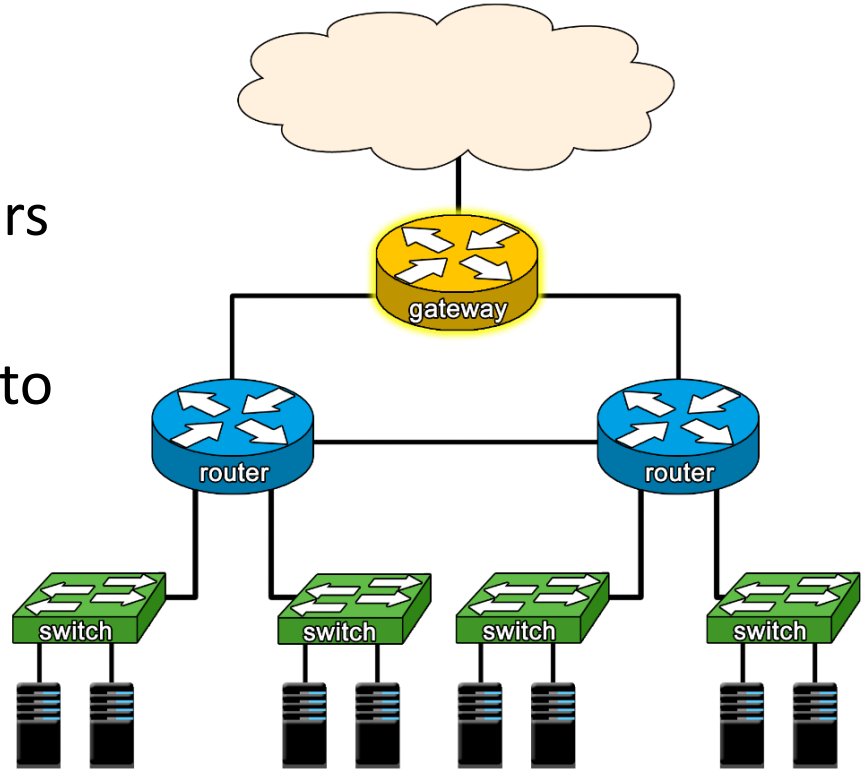
Routers

- Forwards data among devices that aren't physically connected
- Directs traffic that must go outside the LAN
- Uses IP addresses



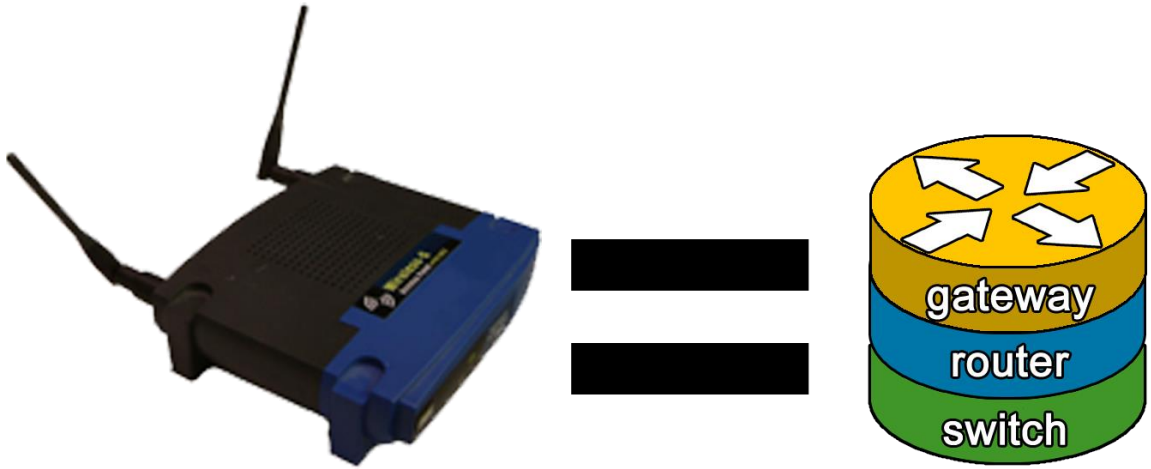
Gateways

- Connects a private network to outside networks
- Forwards data to/from the routers below
- Can translate from one protocol to another



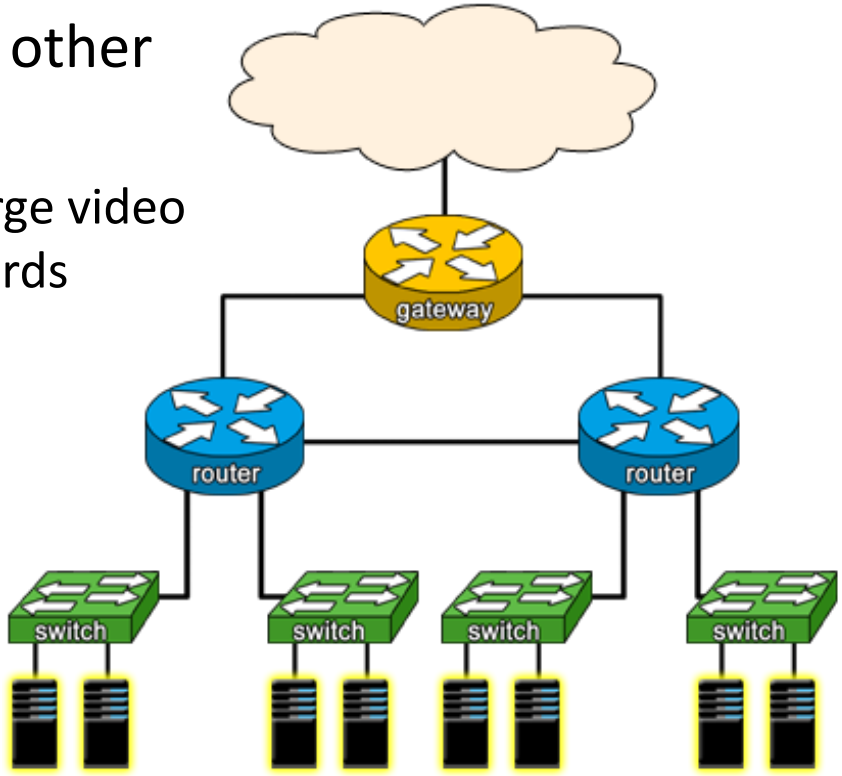
Blended Devices

- Networking devices don't have to be separate physical devices
- A router may act as a switch, a gateway may act as a router, etc.



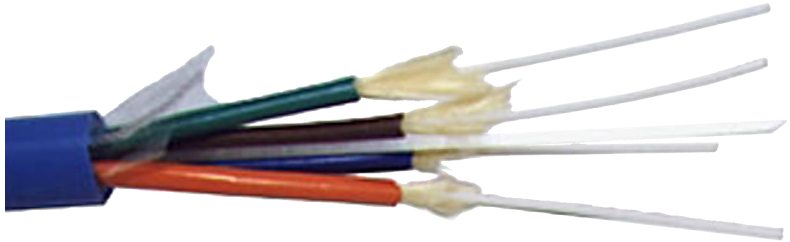
Servers

- Computer that provides services to other nodes
  - Example: Content server that houses large video files; mail server that receives and forwards email, etc.
- Can be hardware or software
- Thin server – server



Network Connections

- AV pros mostly deal with LAN network connections
- Three common methods:
  - Cat cable (copper twisted pair)
  - Optical fiber
  - Wi-Fi (radio frequencies)



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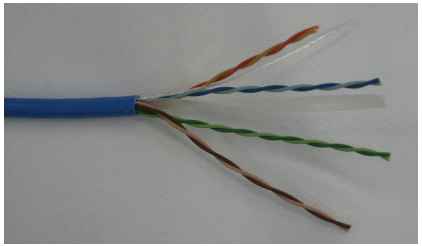
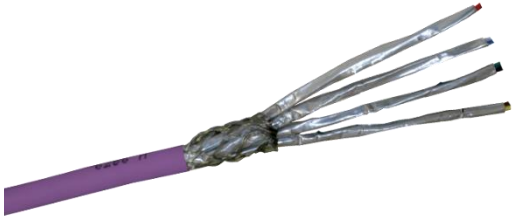
*Copper Twisted pair

- UTP (unshielded twisted pair)



- FTP (foil twisted pair)

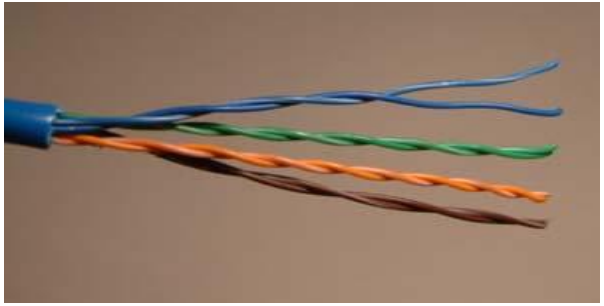
- S/FTP (screened shielded twisted pair)

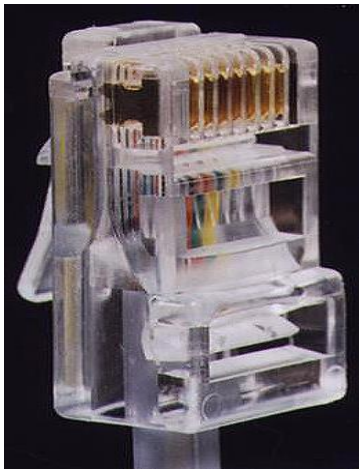


*Copper Twisted Pair

Category Cable	Speed
Cat 1	Telephone and doorbell type connections
Cat 2	4 Mbps
Cat 3	10 Mbps
Cat 4	16 Mbps
Cat 5	**100 Mbps**
Cat 5e	**100 Mbps and 1 Gbps**
Cat 6	**100 Mbps and 1 Gbps**
Cat 6a	10 Gbps
Cat 8	25/40 Gbps (Data centers)

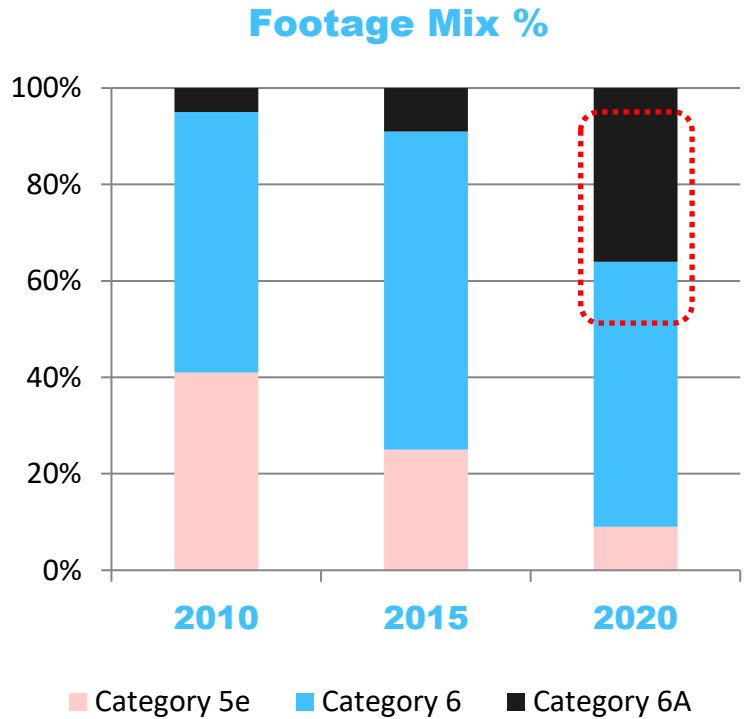
Note – Cat 7 (ISO Class F 10G/600 Mhz) and Cat 7A (ISO Class F 40G/1000 Mhz), was never recognized by TIA





*Category Cabling Life Cycle

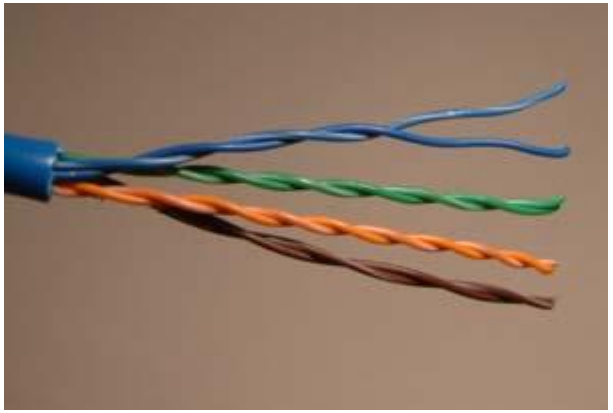
Standard	Bandwidth	Max. Throughput	TIA Recommendation
Category 5e	100 MHz	1G (2.5G*)	Legacy
Category 6	250 MHz	1G (5G*)	Minimum
Category 6A	500 MHz	10G	Recommended
Category 8*	2 GHz	25/40G	Data Center Switch to Server

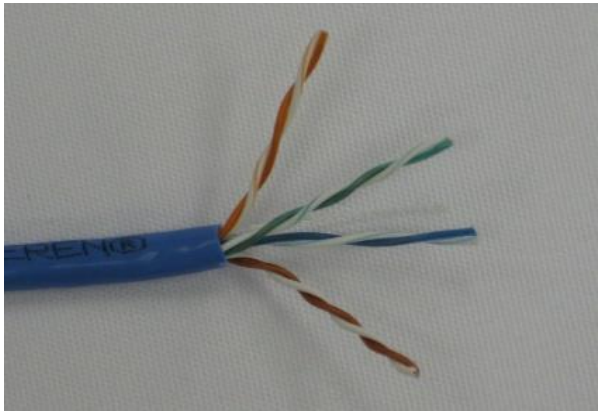


Cat 5e

- Data transmission up to 100 Mbps
- 5e includes specifications for far end crosstalk

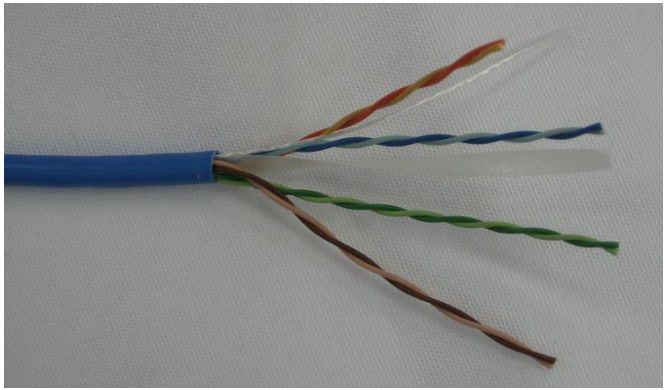
Cat 5e Cables



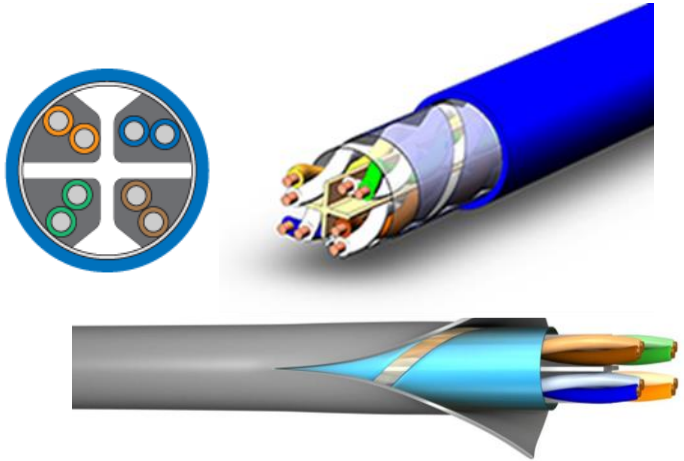


*Cat 6/6A

- Data transmission up to 1 Gbps
- Stringent crosstalk and noise specifications
- Should be shielded for AV signal delivery
- Cat 6a can transmit up to 10 Gbps

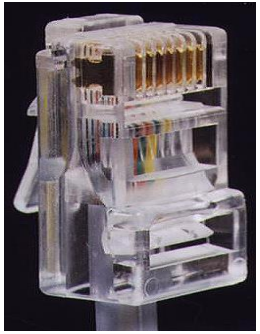


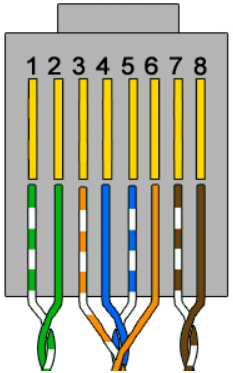
CAT 6 Cables

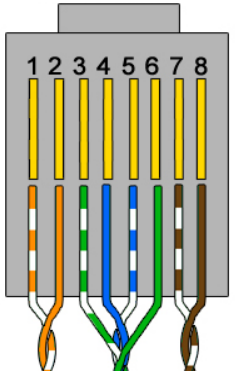


CAT 6A Cables

RJ-45 Connectors





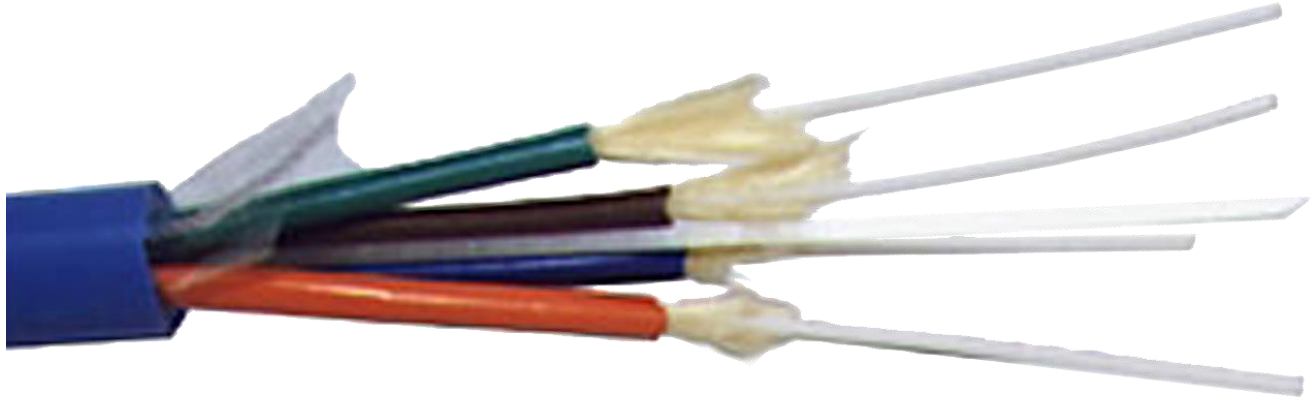


T568A	T568B
Pin/Color	**Pin/Color**
1 – White with green stripe	1 – White with orange stripe
2 – Green	2 – Orange
3 – White with orange stripe	3 – White with green stripe
4 – Blue	4 – Blue
5 – White with blue stripe	5 – White with blue stripe
6 – Orange	6 – Green
7 – White with brown stripe	7 – White with brown stripe
8 – Brown	8 – Brown

Figure 1.114 T568A and T568B standards

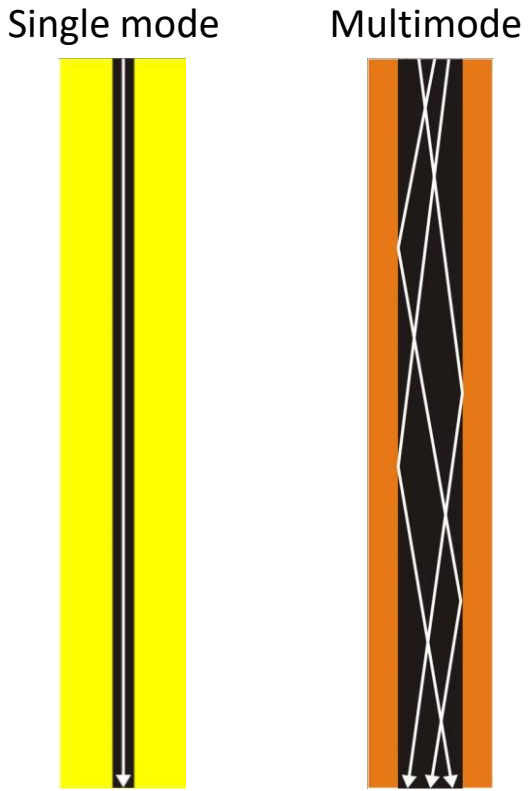
Optical Fiber

- High bandwidth throughput over long distances
- Immune to EMI and RFI
- More secure than copper



Single Mode and Multimode

- Single mode
  - Small core
  - Light shoots straight down the cable
  - Capable of very long distances
- Multimode
  - Signals bounce off cladding
  - Slightly slower than single mode
  - Shorter cable runs than single mode (still much longer than copper)



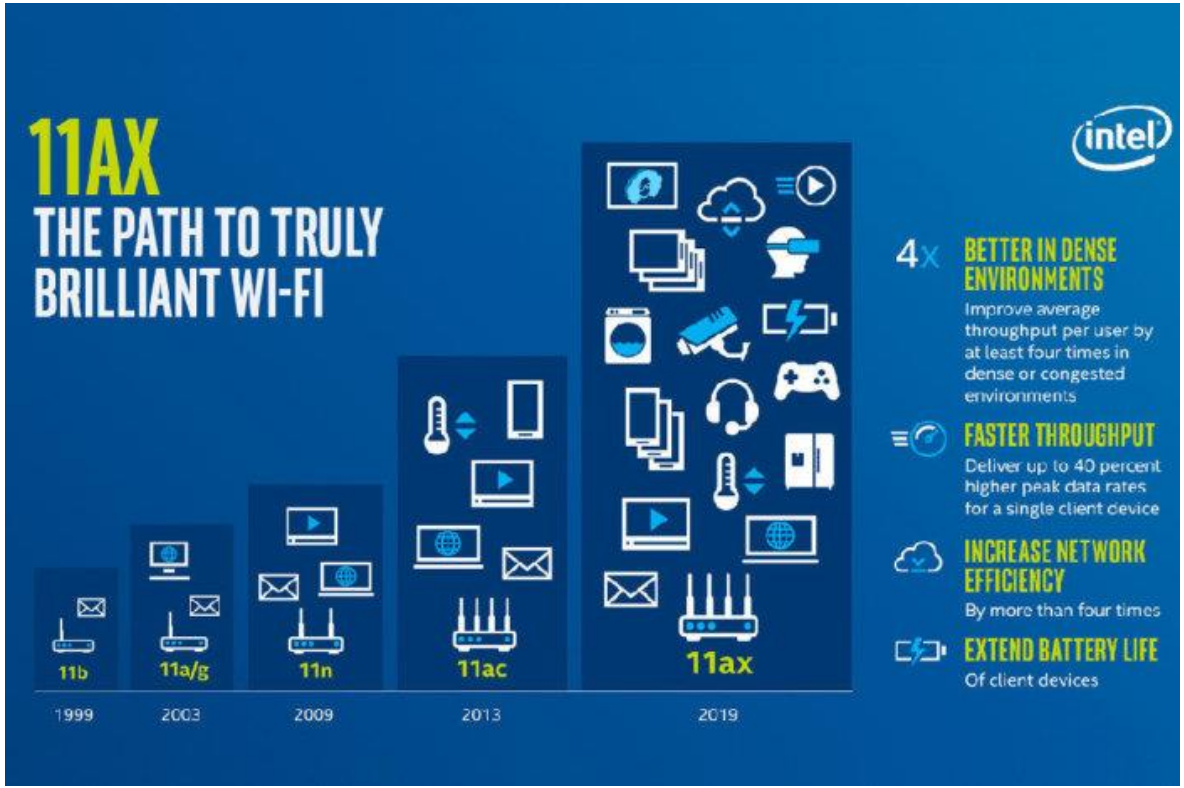
Popular Fiber Connectors

- ST (“stab and twist”)
  - Often used on transmitter/receiver gear
- LC (“push pull connector”)
  - Very small, low loss
- SC (“stab and click”)
  - Larger than LC, good for tight spaces

Wi-Fi

IEEE Standard	802.11a	802.11b	802.11g	802.11n	802.11ac	802.11ax
Year Released	1999	1999	2003	2009	2014	2019
Frequency	5Ghz	2.4GHz	2.4GHz	2.4Ghz & 5GHz	2.4Ghz & 5GHz	2.4Ghz & 5GHz
Maximum Data Rate	54Mbps	11Mbps	54Mbps	600Mbps	1.3Gbps	10-12Gbps

*Wi-Fi



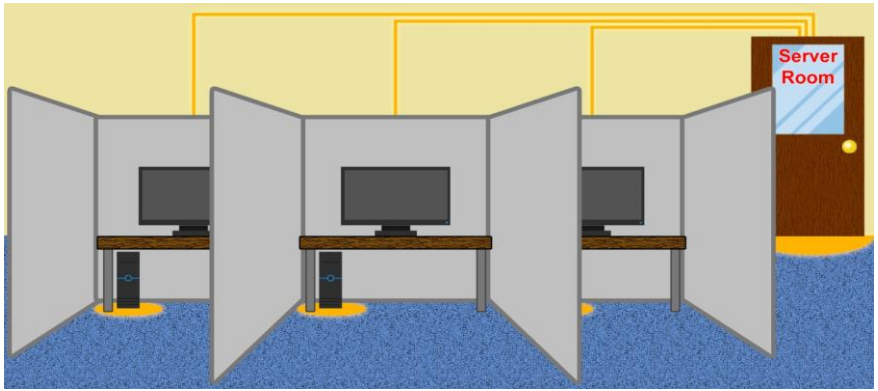
Wi-Fi Pros and Cons

- Pros
  - Convenience
  - Low cost infrastructure
  - Scalability

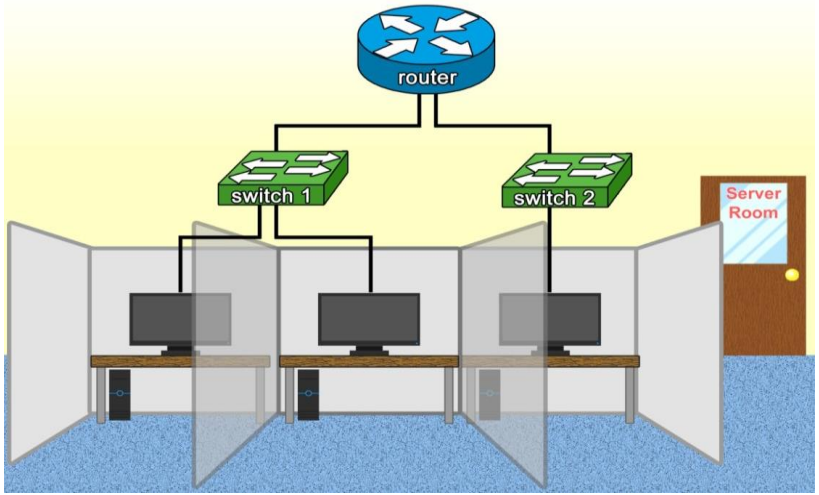
- Cons
  - Limited range
  - Susceptible to RFI
  - Slow
  - Insecure

Physical and Logical Topologies

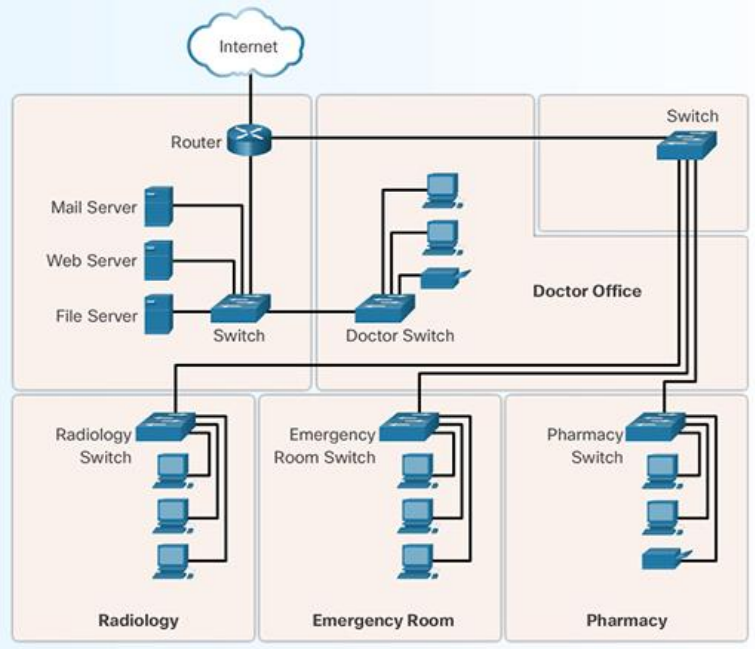
Maps physical placement of network device & cable path

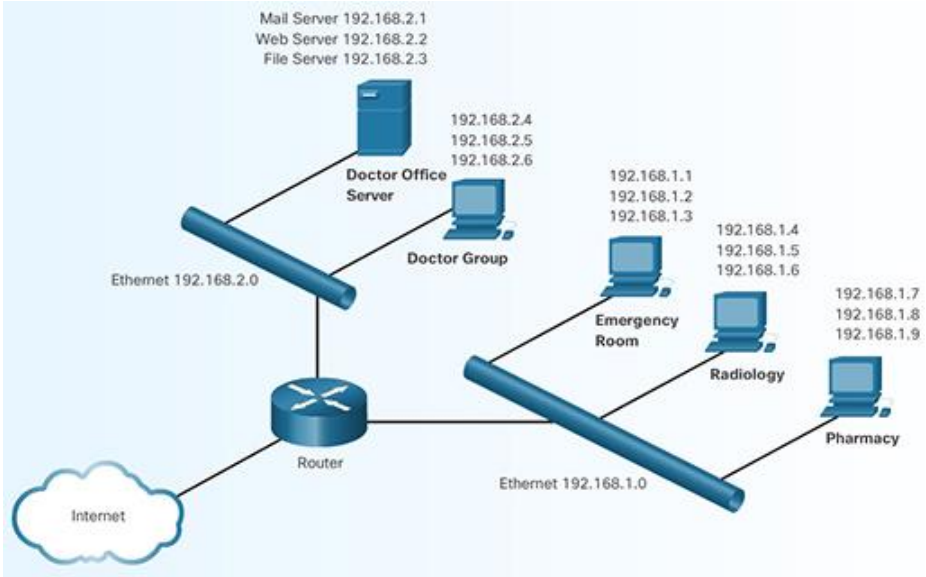


Maps flow of data within network

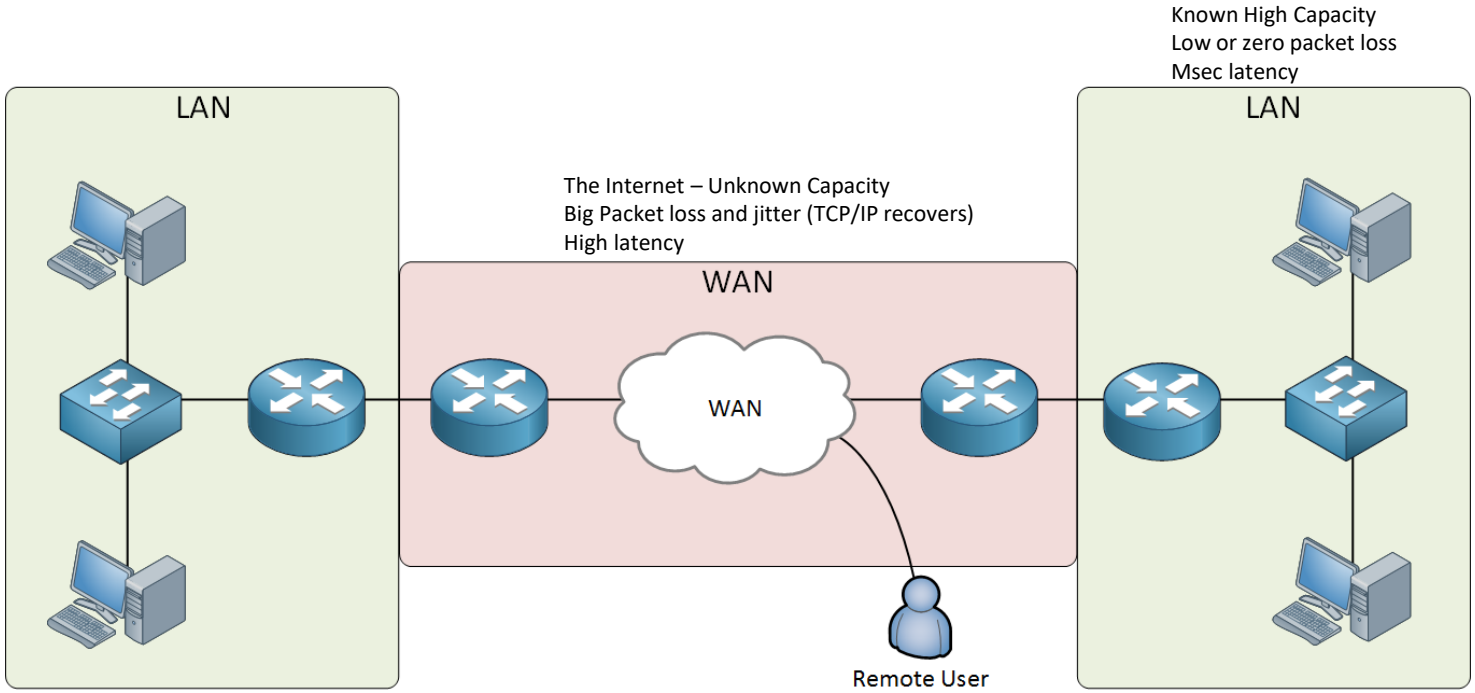


Physical and Logical Topology





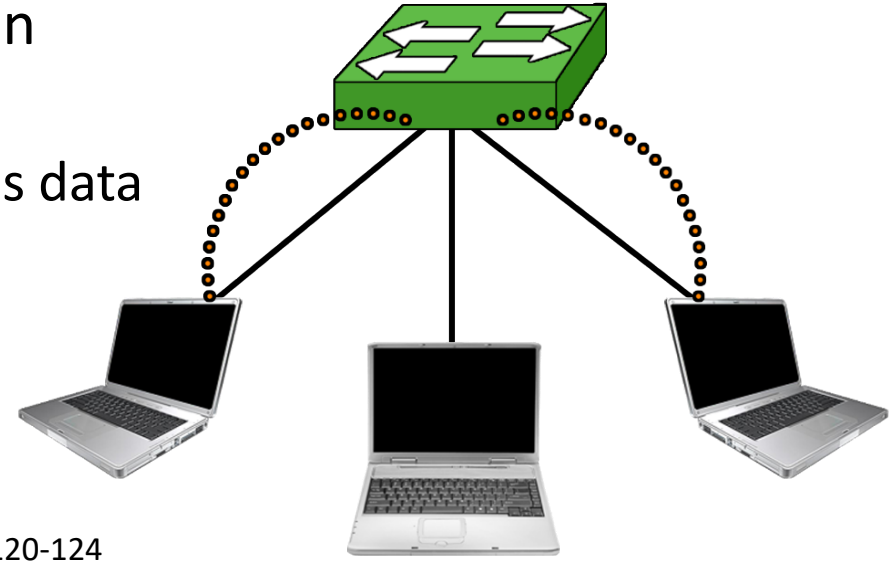
*IT Concepts



Source: https://networklessons.com/cisco/ccna-routing-switching-icnd1-100-105/introduction-to-wans-wide-area-network/

Local Area Networks (LAN)

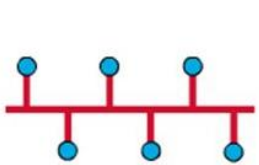
- Sends data to MAC addresses
- Fast, high capacity
- Requires direct physical connection
  - Device sends data to a MAC
  - Switch examines MAC and forwards data



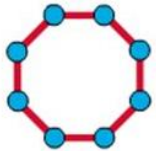
Ch 6 – Pg 120-124

LAN Topologies

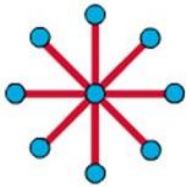
- Star – nodes connect through a central point
  - Often extended
- Meshed – all nodes connect to each other
  - Expensive and rare; partial mesh is more common
- Bus – used for control systems
- Ring – WAN internet services use it ot create redundancy



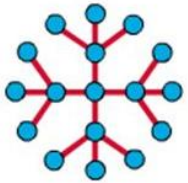
Bus Topology



Ring Topology



Star Topology

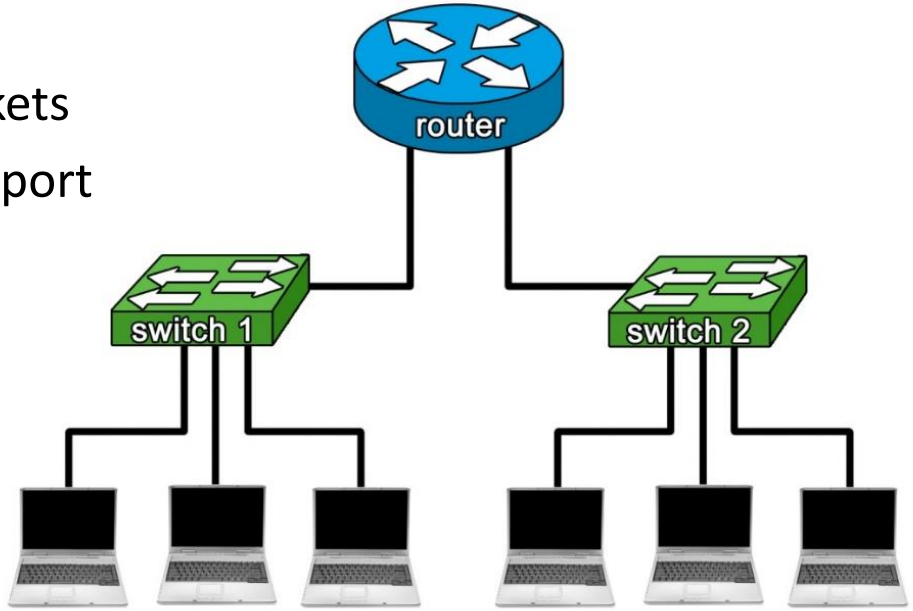


Extended Star Topology

Mesh Topology

Wide Area Networks

- Can use device name translated via DNS
- Connected using routers
- Strips MAC addresses from data packets
- Slower than LANs; real-time AV transport not always possible
- Can be any size



Ch 6 - Pg 120

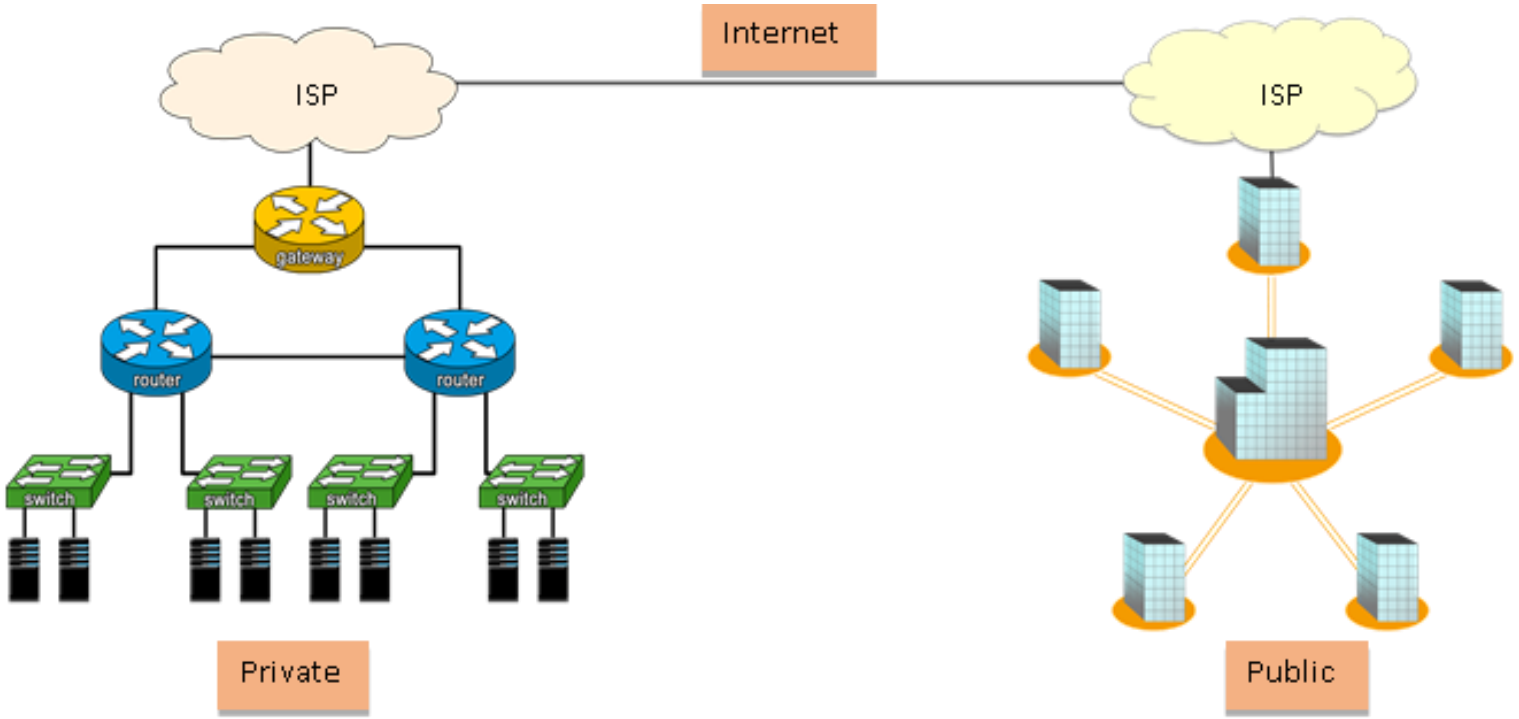
WAN Topologies

Hub and spoke

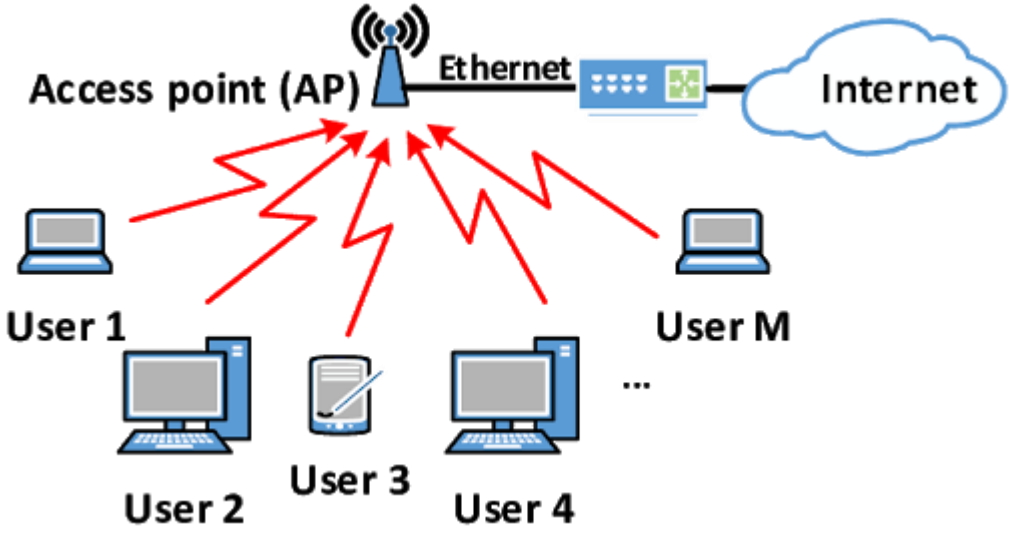
Common Carrier

Meshed

Private and Public Wide Area Networks

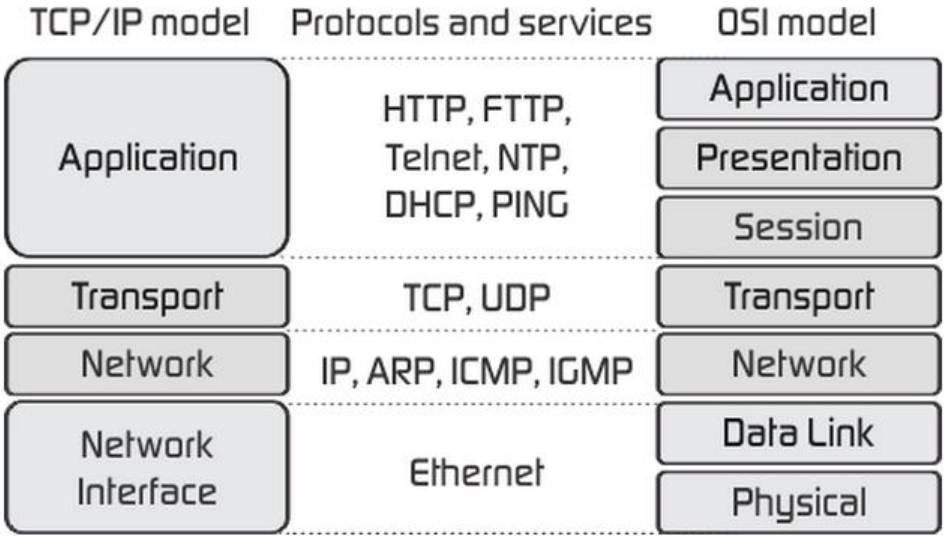


Wireless LAN (WLAN)



*IT Concepts

- TCP/IP and OSI networking model



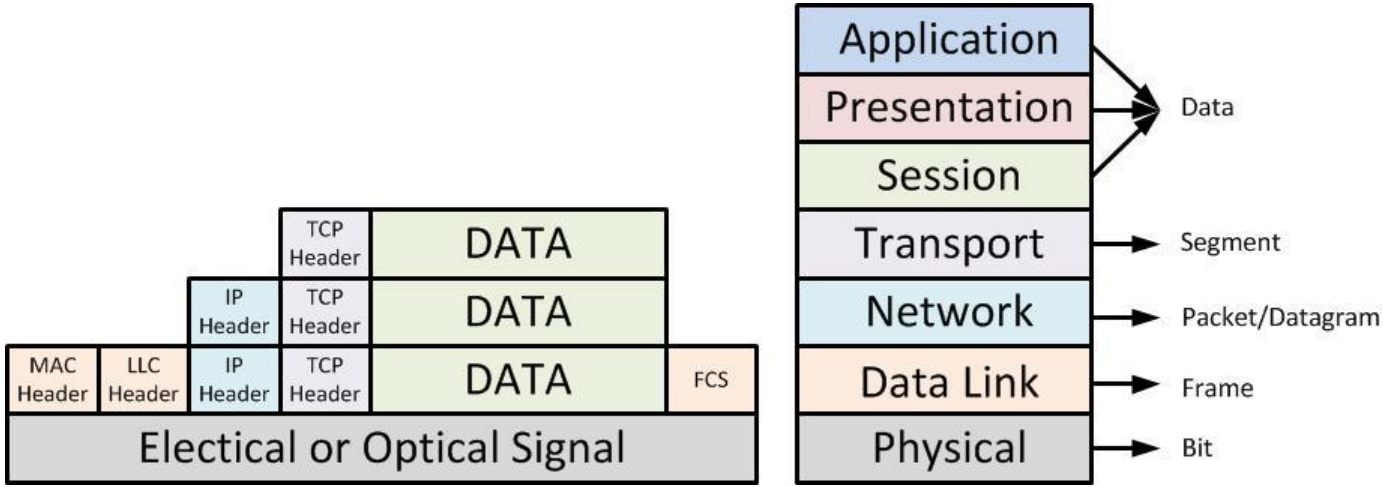
RTP, SMPTE 2022, Streaming

Dante, Q-Sys

Cobranet, Ethersound, AVB

Source: http://fiberbit.com.tw/tcpip-model-vs-osi-model/

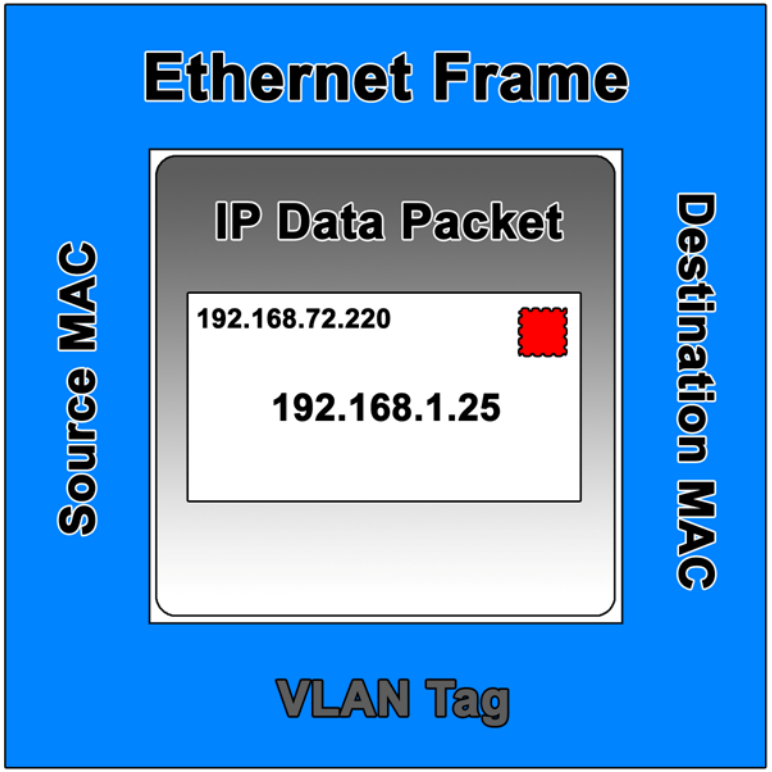
*IT concepts



Source: http://packet-network.blogspot.ca/2011/11/data-encapsulation.html

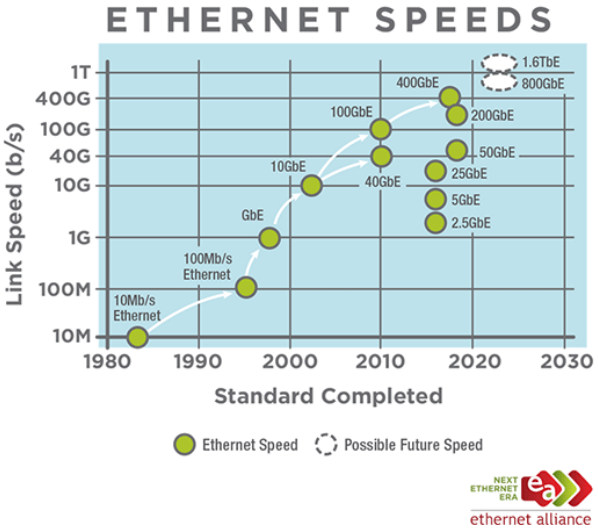
What is Ethernet?

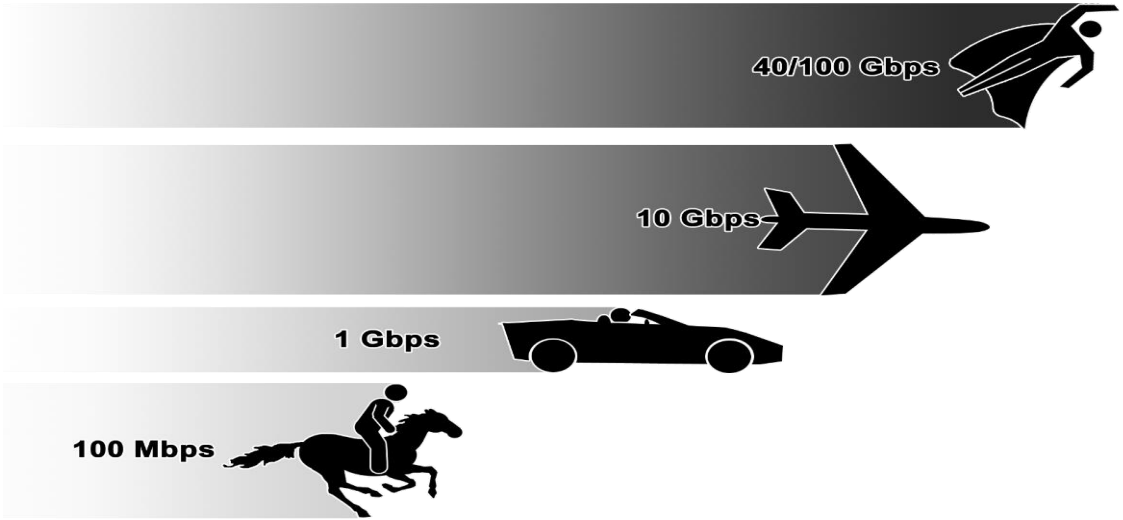
- How data is sent across LANs
- Defined in the IEEE 802.3 suite
- Data is encapsulated in Ethernet frames
- Frames are generated by NICs



*Ethernet Speeds

- Ethernet speed depends on NIC
- Some devices can't handle high speed
- Some AV protocols require 1 Gbps or more





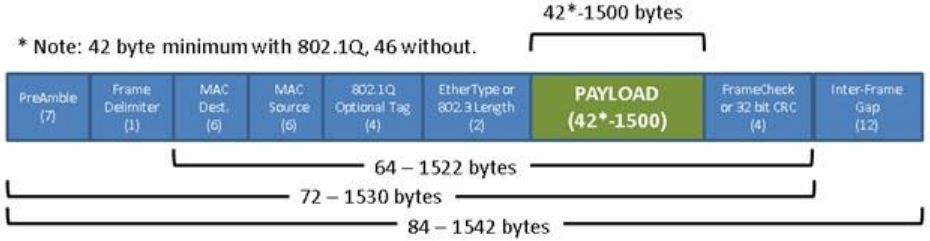
CTS-Prep Workshop IV
Networking Part II
Italy, May 2020
Jose Mozota CTS, CTS-I

Ethernet Format Abbreviations

What does 1000BaseT mean?

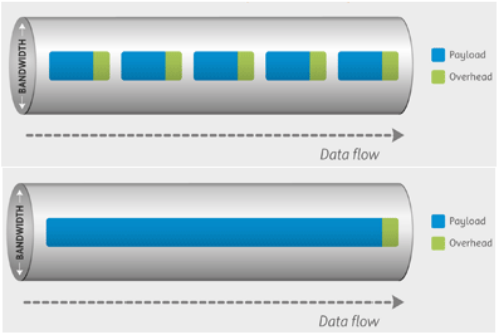
- Megabits per second – 1000 = 1 Gbps
- Broadband or Baseband – almost all are “Base”
- Physical transmission medium – T = twisted pair

*IT Concepts – Frames & Jumbo frames



Source; https://www.pathsolutions.com/run-for-your-lives-attack-of-the-jumbo-frames/

MTU = Maximum Transmission Unit

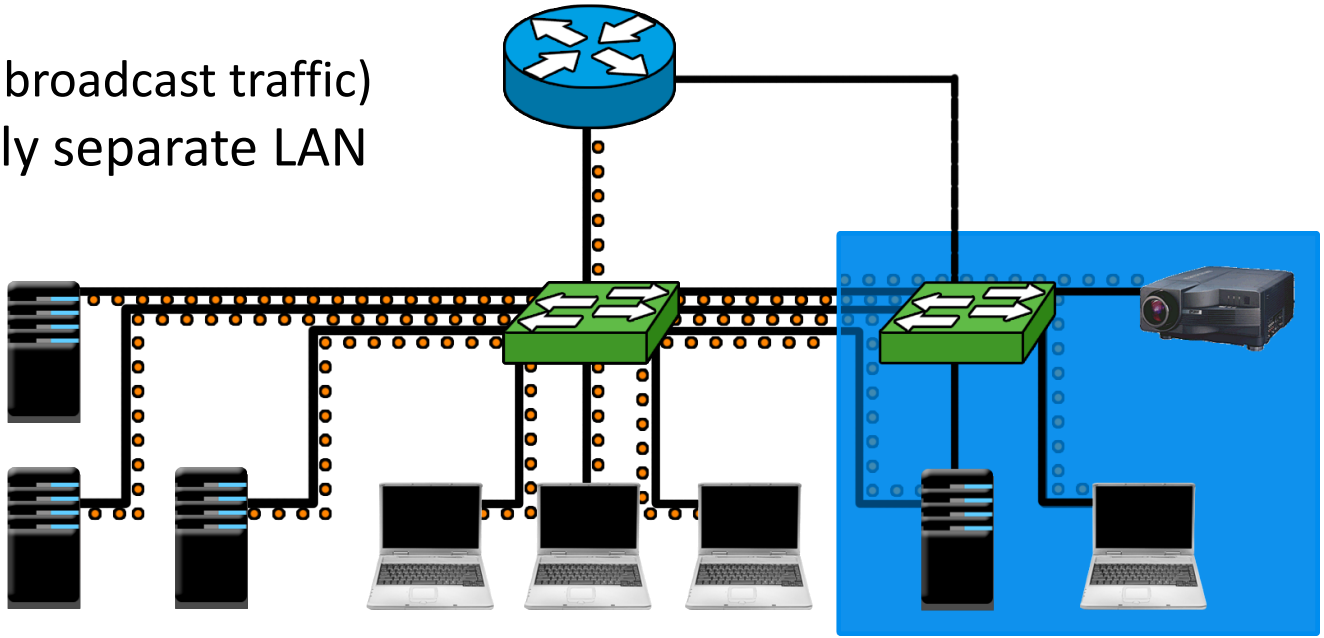


Jumbo frames, that can be used by JPEG200, may cause problems when going through a router, not all routers accept jumbo frames

Source: https://www.routerfreak.com/understanding-ethernet-jumbo-frames/

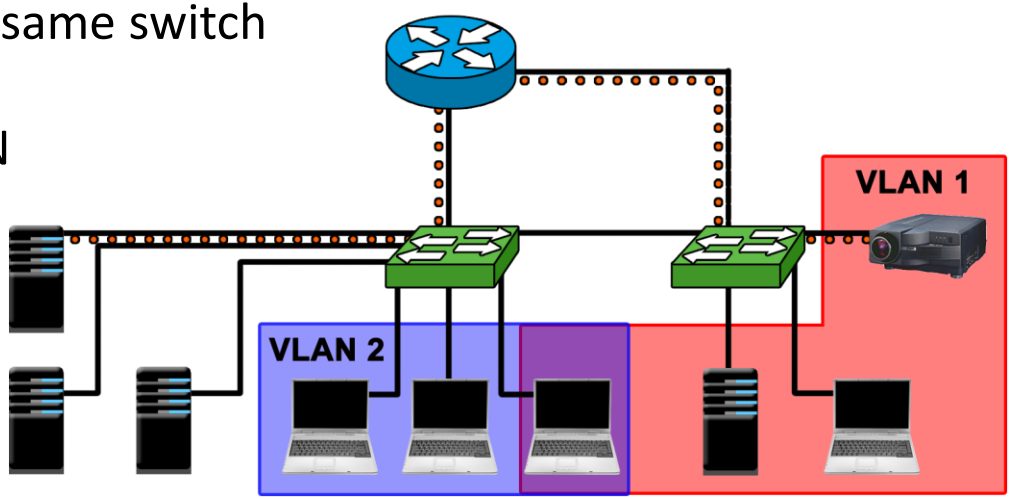
Isolating LAN Devices

- Some devices should be isolated on the LAN
- Reasons:
  - Security
  - Efficiency (limiting broadcast traffic)
- Solution 1: physically separate LAN



Virtual Local Area Networks (VLANs)

- VLAN membership configured on managed switches
- Devices in a VLAN:
  - Don't have to be connected to the same switch (802.1 trunking)
  - Can belong to more than one VLAN
  - Send Ethernet to/from each other (including broadcast)
  - Can't send Ethernet to/from other LAN devices

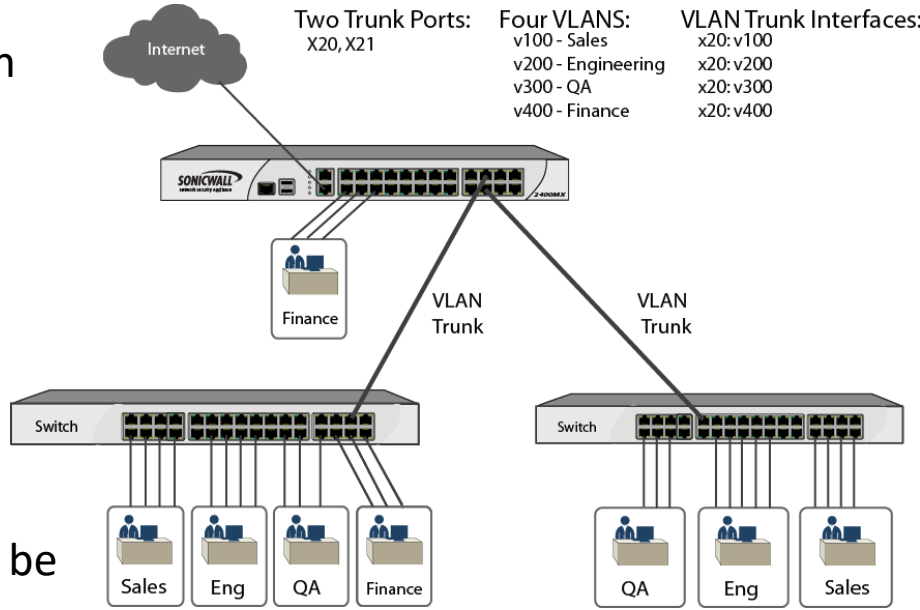


Ch 16 – Pg 407-408

Requesting VLANs

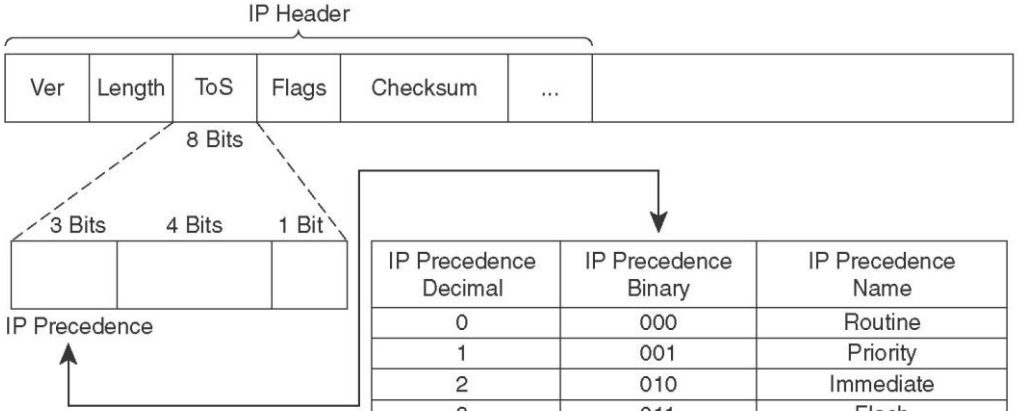
- When:
  - Devices need to communicate mostly with each other
  - Devices shouldn't send/receive a lot of broadcast traffic

- How:
  - Explain what VLANs you need and why
  - List devices in each VLAN
  - Coordinate whether VLAN devices should be accessible via router.



*IT Concepts - QoS

- QoS – Quality of Service
  - DiffServ Classes – IEEE RFC 4594
  - IntServ - RSVP – Resource Reservation Protocol



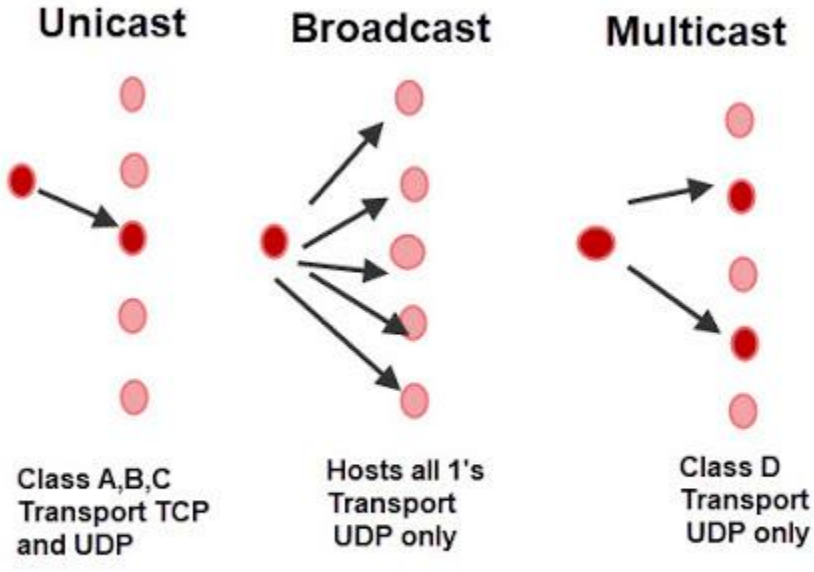
IP Precedence Decimal	IP Precedence Binary	IP Precedence Name
0	000	Routine
1	001	Priority
2	010	Immediate
3	011	Flash
4	100	Flash-Override
5	101	Critical
6	110	Internetwork Control
7	111	Network Control

VPNs (Virtual Private Network)

VPNs use the Internet to "tunnel" between two or more LANs

- May be a dedicated device or built into the firewall.
- Encryption and tunneling wrapper increase bandwidth overhead.
- Make sure video frame size accounts for VPN overhead.
- Use of MLPS (Multilayer Protocol Label Switching) to transport Layer 2 protocols
- Type of VPN (L2TP, IPSec, SSL, MPLS) determined by network admin.

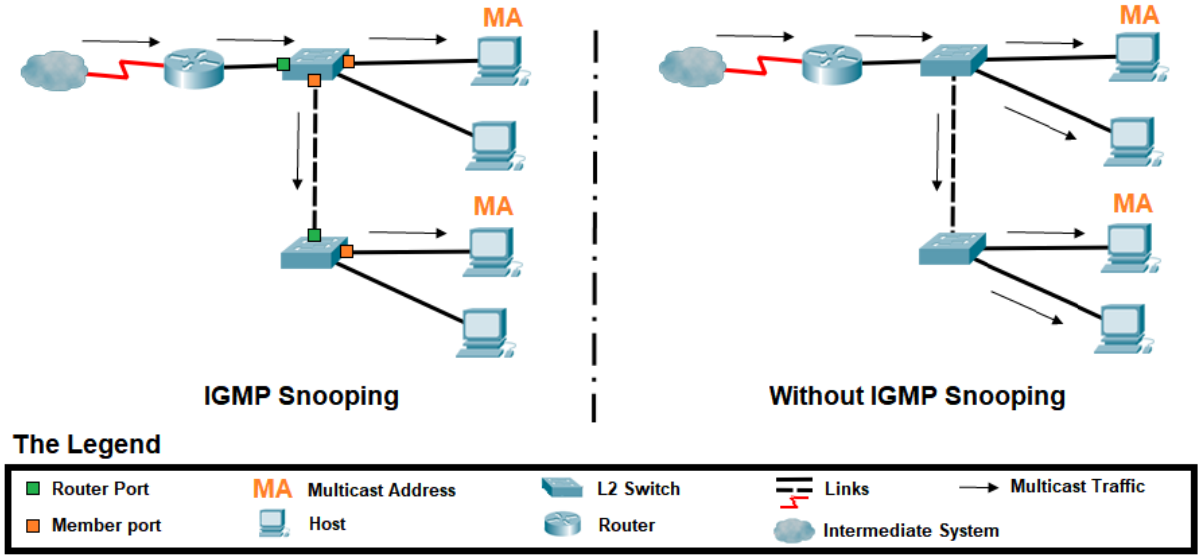
*IT Concepts – Delivery Modes



Unicast,Broadcast and Multicast IP Addressing

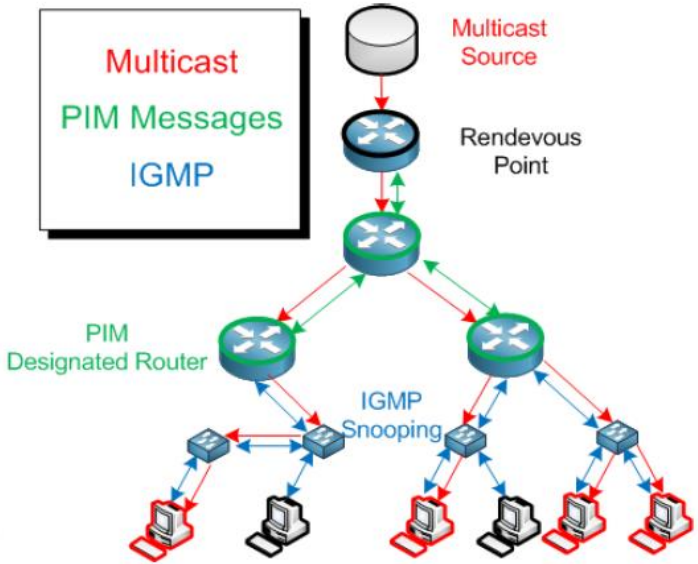
*IT concepts – IGMP and Snooping

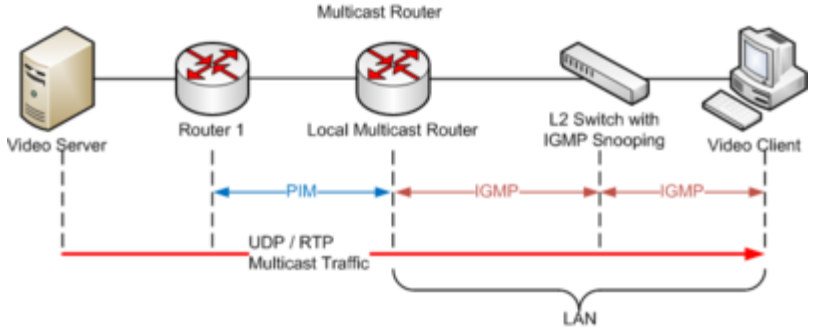
- The Internet Group Management Protocol (**IGMP) or MLD Multicast Listener Discovery in IPv6** is a communications protocol used by hosts and adjacent routers on IPv4 networks to establish multicast group memberships. IGMP Snooping “listens” to the traffic to limit it to the “members”



*IT concepts – PIM

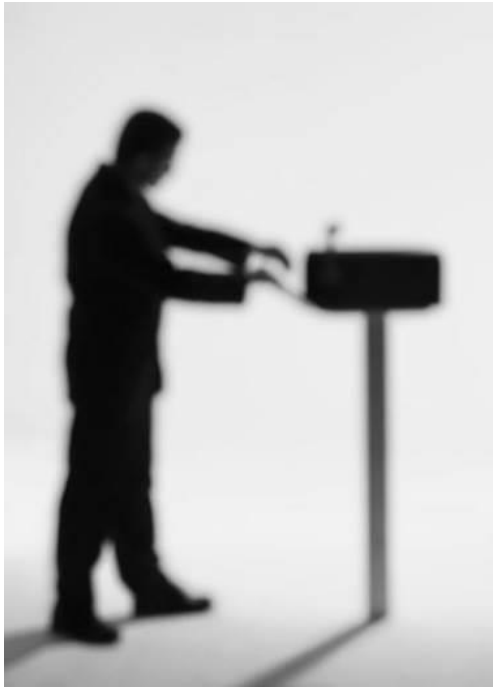
- Protocol-Independent Multicast





What is the Internet Protocol (IP)?

IP = The postal service of the Internet



IP Addresses

Three parts to an IP address:

- Network bits
- Host bits
- Subnet Mask

192.168.1.25

255.255.255.0

Ch 6 – Pg 127-129

IPv4 Addresses

Structure:

- 32 bits, divided into four 8 bit groups
- Expressed as 4 decimal numbers (0 – 255) separated by dots

11000000 10101000 00000001 00011001

192.168.1.25

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IPv4 Subnet Masks

Divides IP address into network and host bits

- Same structure as the IP address
- 1's ID network bits, 0's ID host bits

192.	**168.**	**1.**
11000000	**10101000**	**00000001**
255.	**255.**	**255.**
11111111	**11111111**	**11111111**
00000000		

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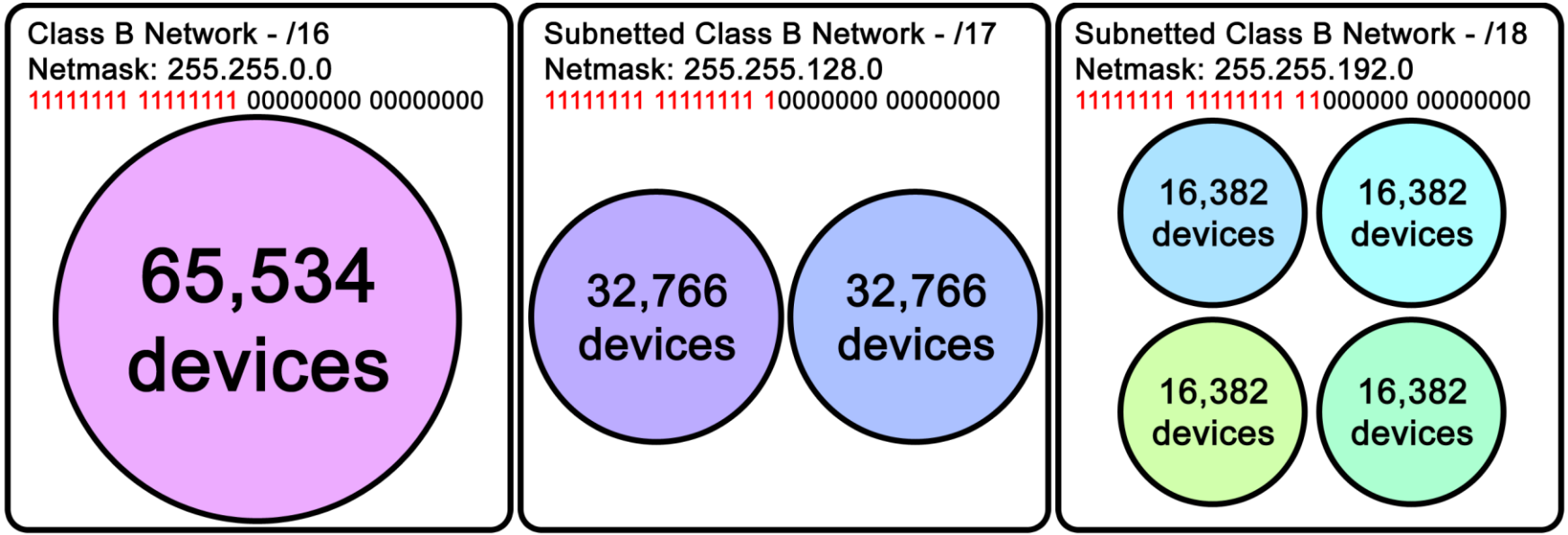
IPv4 Subnet Notation

- Two ways to write
- Dot decimal ex. 255.255.192.0
- Classless Inter-Domain Routing (CIDR) notation - ex. 137.72.231.0/18

Subnetting

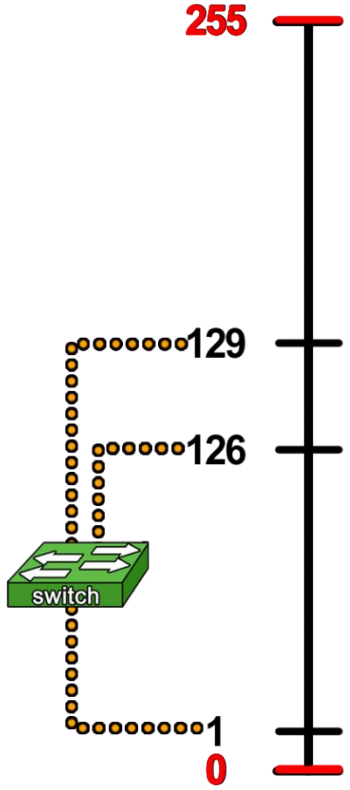


- Only devices in same subnet can communicate via Ethernet or belong to the same VLAN
- Subnetting can improve efficiency and security

Ch 6 – 127-129

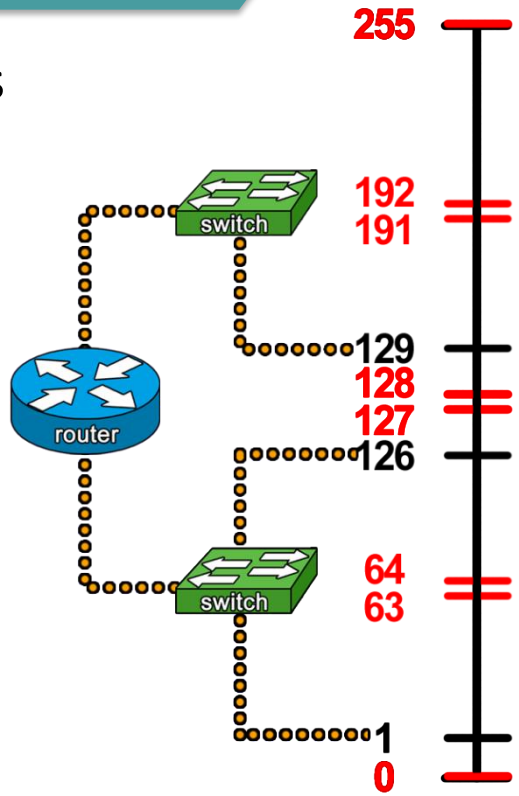
How Subnetting Works

- 255.255.255.0 = 256 possible “slots”
  - Host 0 is taken – network address
  - Host 255 is taken – broadcast address
- Remaining slots can send each other Ethernet/broadcast messages



How Subnetting Works - Continued

- 255.255.255.128 = 2 networks, each with 128 slots
  - Hosts 0 and 127 taken
  - Hosts 128 and 255 taken
- Devices in the same subnet send each other Ethernet/broadcast messages
- Must go through router to talk outside the subnet
- You can continue to divide into 1/4s, 1/8ths, etc.



IPv6 Addresses

Structure:

- 128 bits, divided into 8 hexadecimal “words”
- First three words ID network
- Fourth word IDs subnet
- Last four words ID host
- Host ID can be MAC address

fec8:ba98:7694:8000:fdec:ba98:7694:3201

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Reserved IP Addresses

Dirección de red	Rango	Objetivo
0.0.0.0/8	0.0.0.1 - 0.225.255.255.254	Reservada - IP desconocida
10.0.0.0/8	**10.0.0.0 - 10.255.255.254**	**Local - grandes**
127.0.0.0/8	**127.0.0.0 - 127.255.255.254**	**Reservada - Loopback**
169.254.0.0/16	**169.254.0.0 - 169.254.255.254**	**Reservada - APIPA**
172.16.0.0/12	**172.16.0.0 - 172.31.255.254**	**Local - Redes medianas**
192.168.0.0/16	**192.168.0.0 - 192.168.255.254**	**Local - Redes pequeñas**
224.0.0.0/4	224.0.0.0 - 239.255.255.254	Reservada - Multidifusión
240.0.0.0/4	240.0.0.1 - 255.255.255.254	Reservada - Experimental
255.255.255.255/32	**255.255.255.255**	**Reservada - Transmisión**

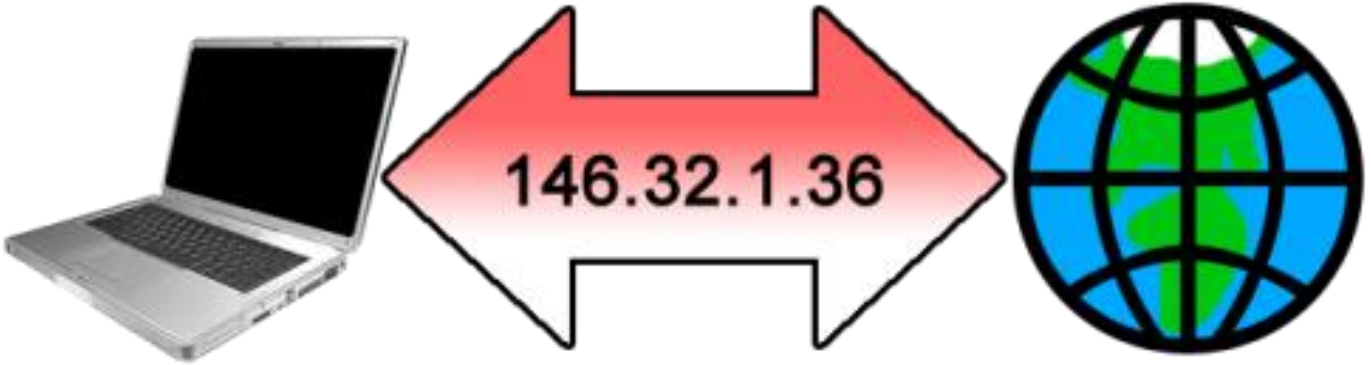
Local Addresses

Addresses that can only talk on private networks

Network Size	Private Network	Address Range
Class A (large)	10.0.0.0	10.0.0.1 - 10.255.255.254
Class B (medium)	172.16-31.0.0	172.16.0.1 - 172.31.255.254
Class C (small)	192.168.0.0	192.168.0.1 - 192.168.255.254

Global Addresses

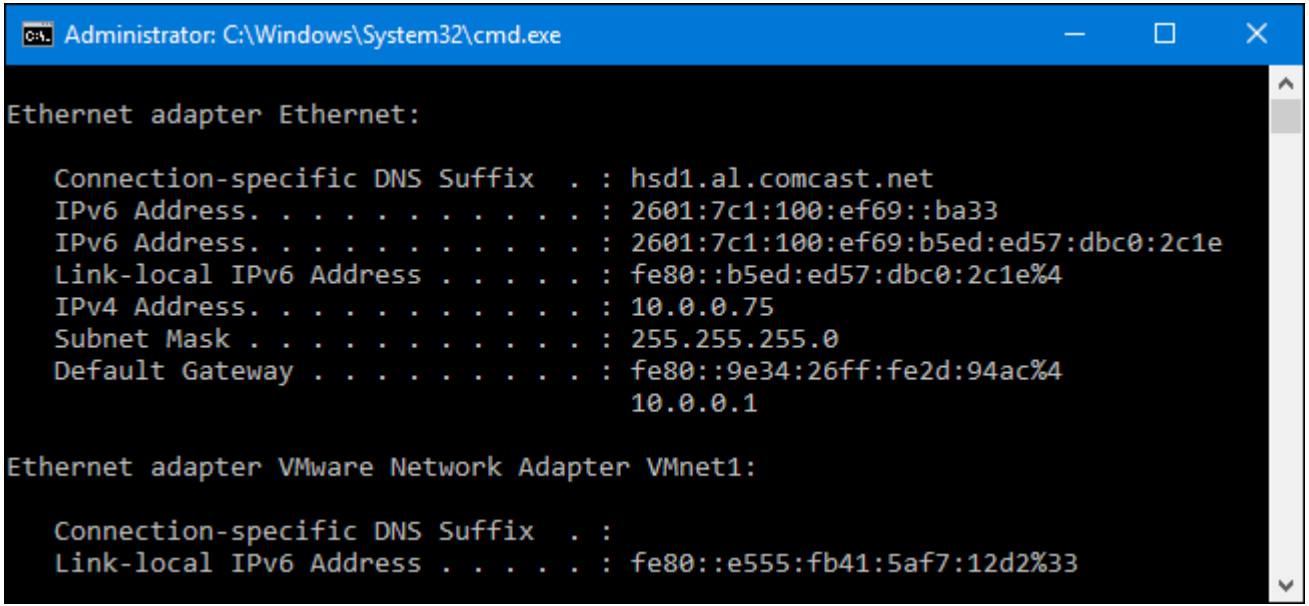
- Addresses that can access the Internet
- Range: Anything that is not local or reserved



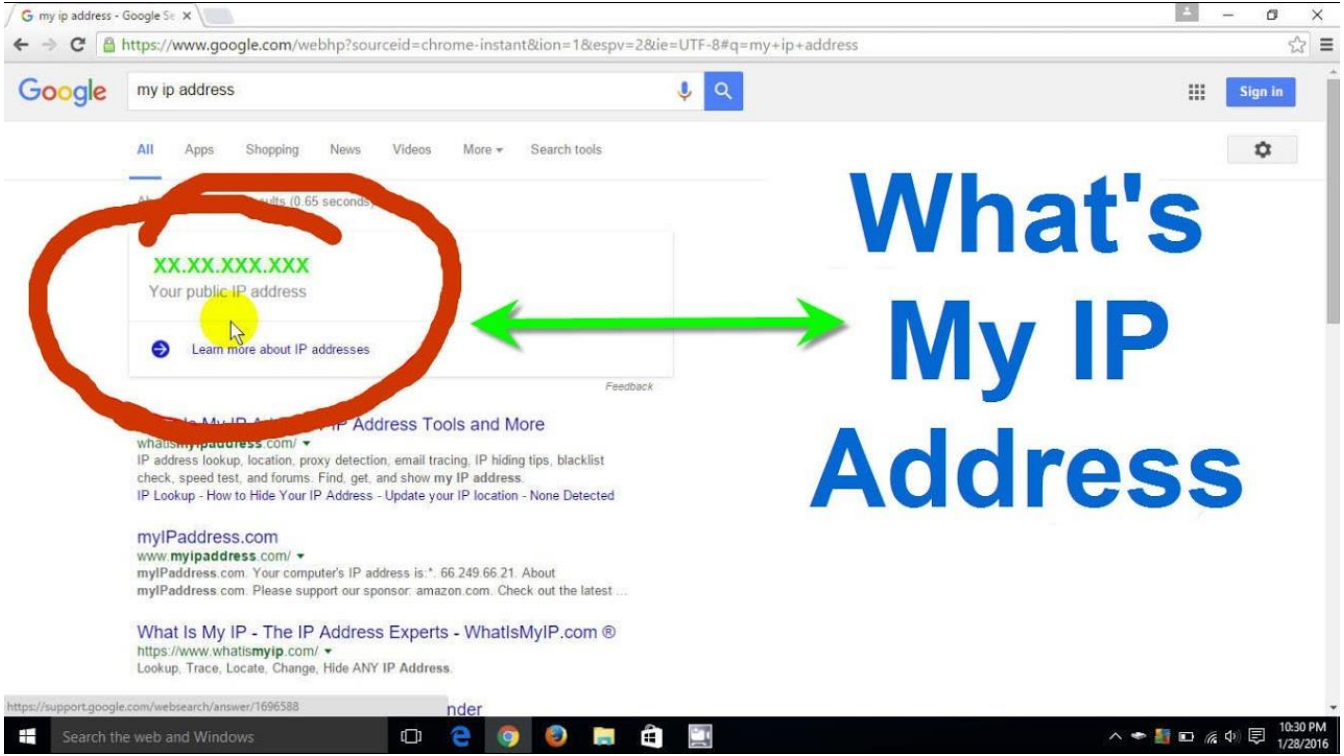
Network Address Translation

- Lets locally addressed devices access the Internet
- Replaces local address with global address at the gateway

Local address

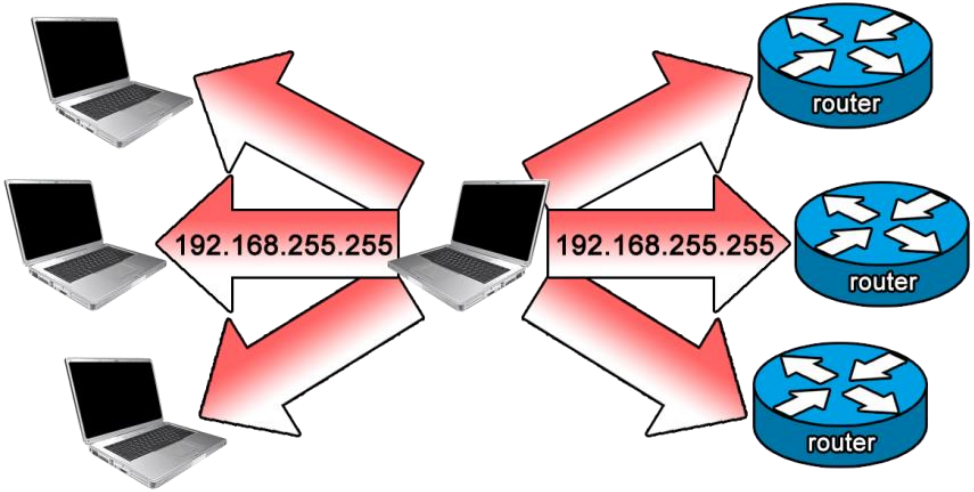


Global address



Broadcast Address

- All 1s in the host bits
- Sends announcements to every device in the same subnet/LAN



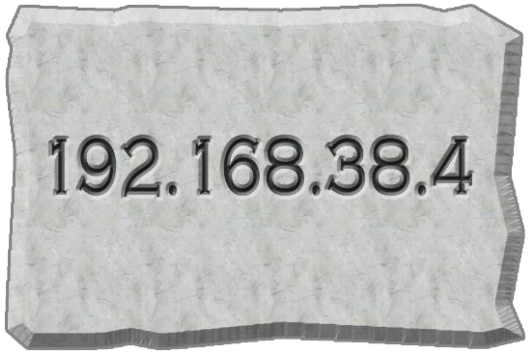
Static and Dynamic Addressing

- Static – permanently assigned
- Dynamic – loaned an address from a server

Ch 6 – Pg 129-130

Static Addresses

- You need:
  - MAC address
  - IP address
  - Subnet mask
- IP address/subnet will come from IT



Manufacturer / Model #	Software	Firmware	MAC Address	IP Address	Subnet Mask	Gateway IP Address
ProjectTech 4000ZT	v. 8.0	v. 11.4.5	78:ab:0f:23:32:89	192.168.38.4	255.255.255.000	192.168.38.1
…	…	…	…	…	…	…

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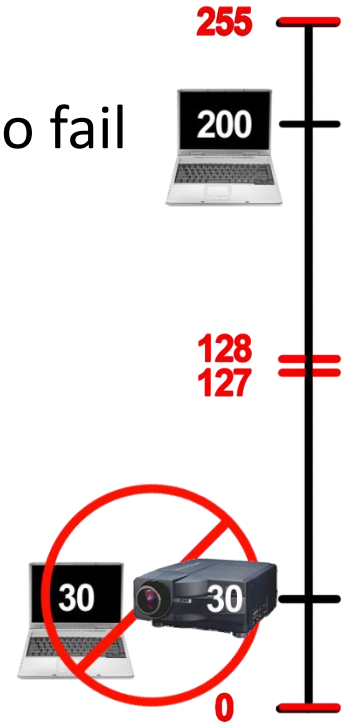
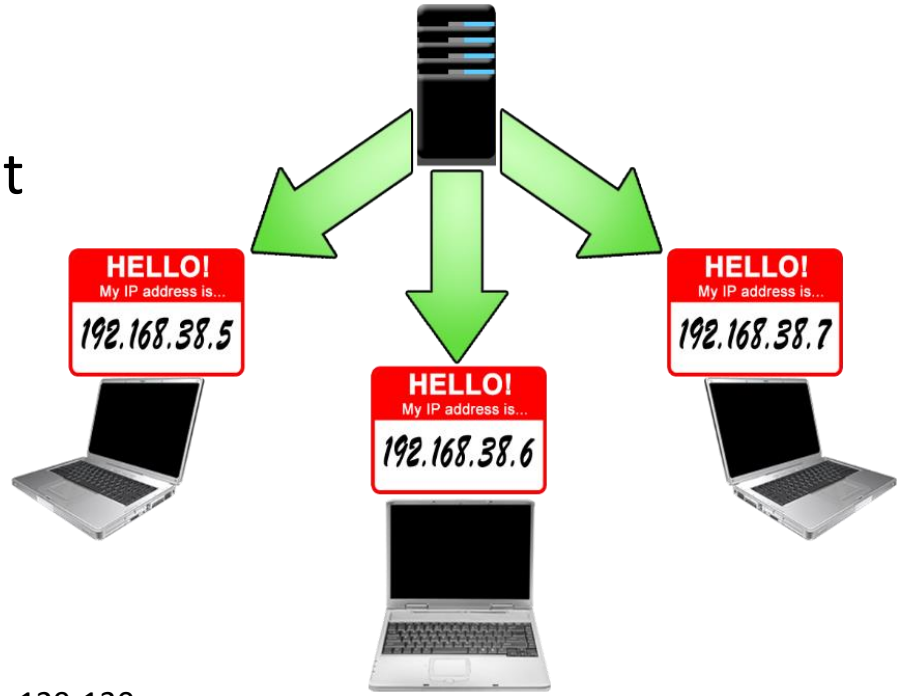
How Static Addressing Works

- Manually entered into the device
- Duplicate addresses cause both connections to fail
- Difficult to track/time-consuming to manage



Dynamic Host Configuration Protocol (DHCP)

- Devices get addresses automatically
- Addresses are loaned for a preset time period
- IP address may change (this is a problem for Av equipment)



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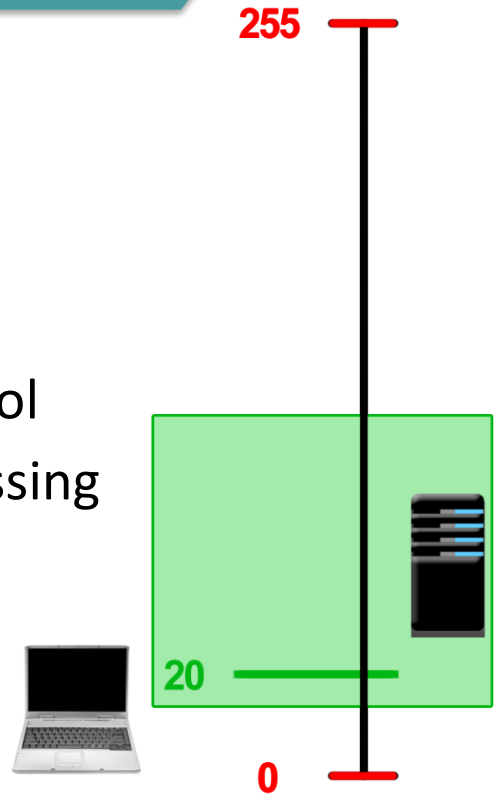
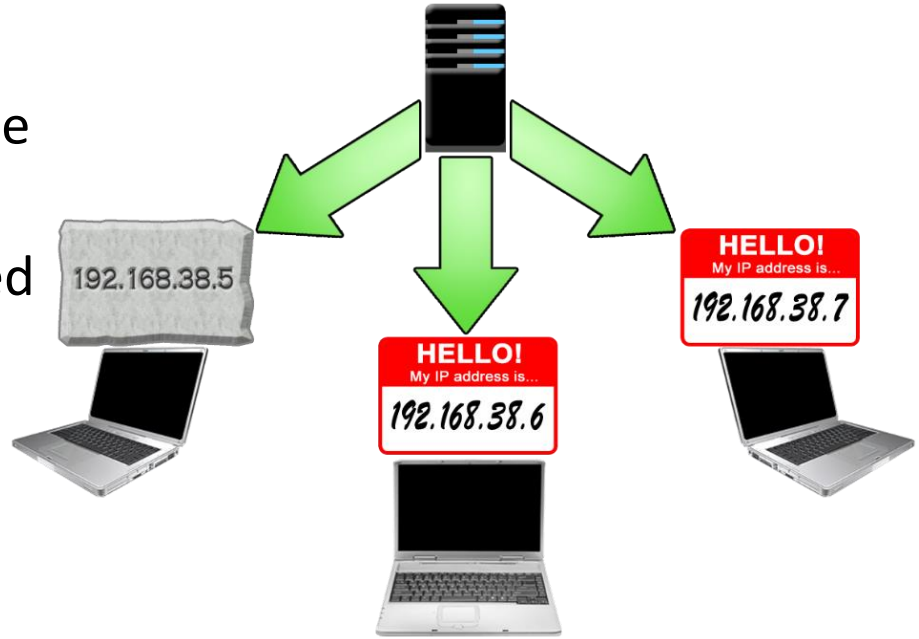
How DHCP Works

- "Slots" are reserved by the DHCP server
- Lease time varies by application
  - Airport: 15 minutes
  - Office: 10 – 24 hours
- A device requesting an address gets one from the pool
- Hosts above and below are available for static addressing



Reserve DHCP

- Static addresses are reserved on the DHCP server
- DHCP gives those addresses only to the associated MAC
- Allows static and dynamic to be tracked by a single system



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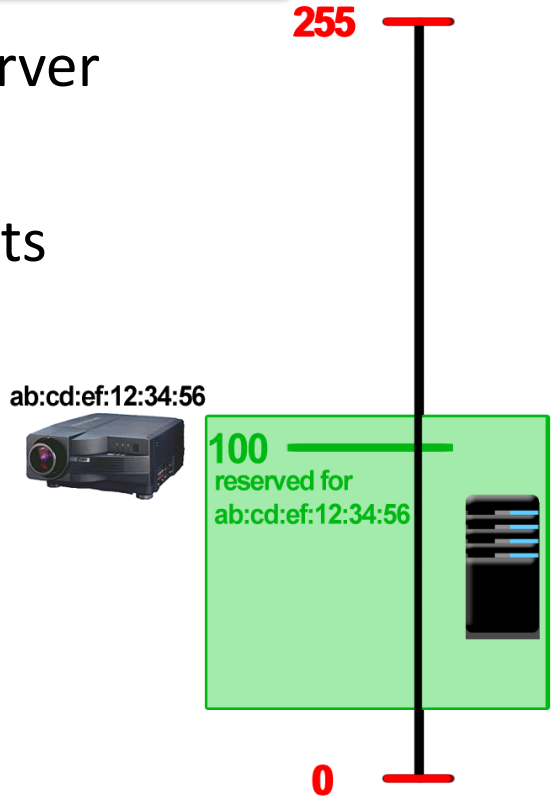
How Reserve DHCP Works

- Address is reserved by MAC on the DCHP server
- Device is set to obtain address via DHCP
- Every time the device with that MAC requests an address, it gets the same one



Automatic Private IP Addressing (APIPA)

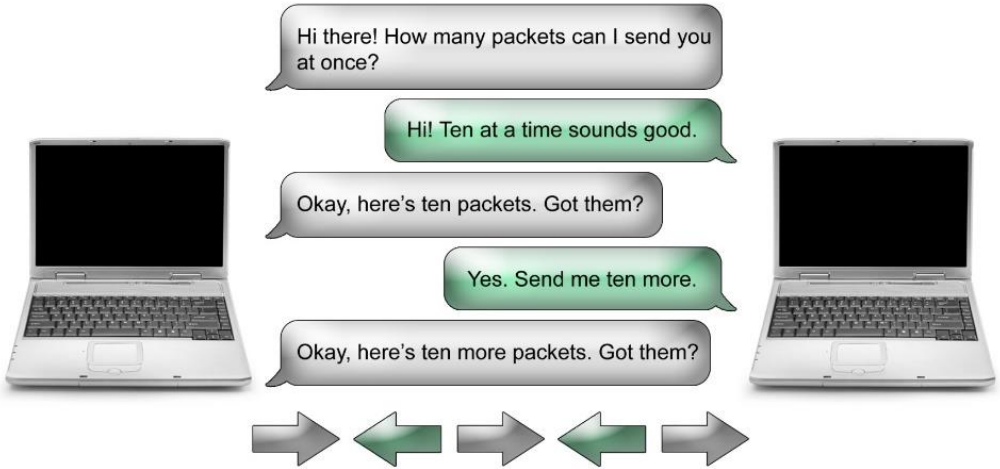
- Also called Zero configuration, link-local
- Kicks in when DHCP fails
- Range: 169.254.0.1 169.254.255.254
- Allows communication with other APIPA-enabled devices on the same subnet/LAN

Domain Name System (DNS)

- Naming services - identify devices by names instead of numbers
- DNS - most popular naming service (e.g. web addresses)
- Dynamic DNS (DDNS) - assigns permanent names to dynamically addressed devices

TCP Transport

- Connection-oriented
- Reliable
- Resends any lost packets



UDP Transport

- Connectionless - no "handshake"
- Delivery is not guaranteed
- Reliability may be tracked by a higher layer protocol
- Used for streaming media
- Used to exchange small pieces of data

TCP Versus UDP

TCP Segment Header Format

Bit #	0 – 7	8 – 15	16 – 23	24 – 31
0	Source Port		Destination Port	
32	Sequence Number			
64	Acknowledgment Number			
96	Data Offset	Res	Flags	Window Size
128	Header and Data Checksum		Urgent Pointer	
160...	Options			

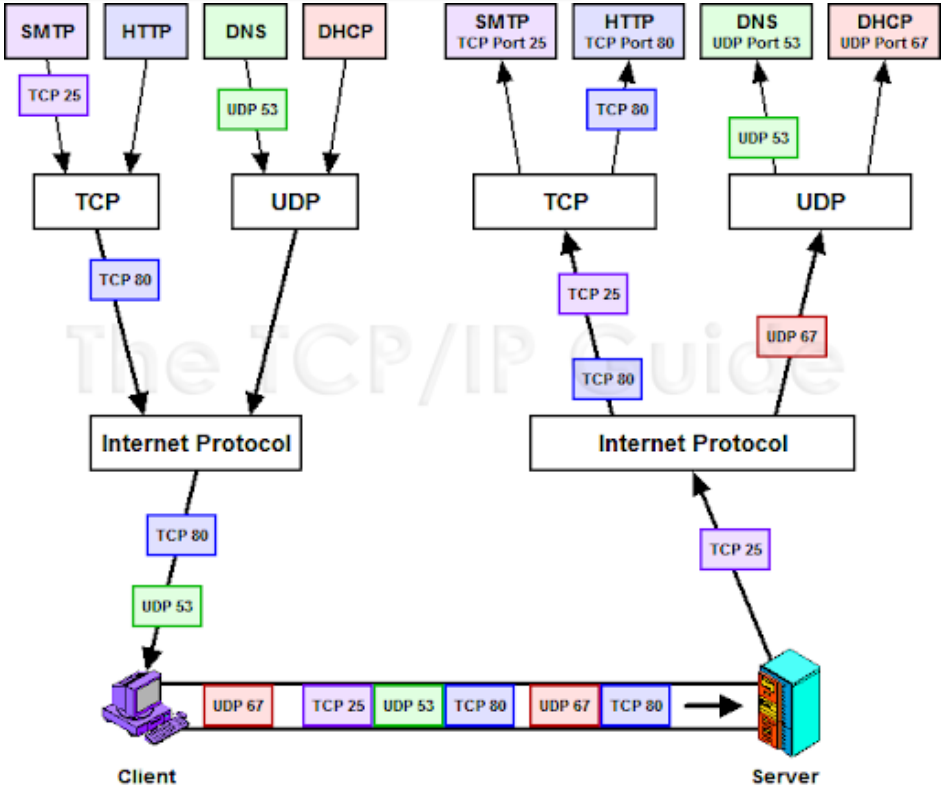
UDP Datagram Header Format

Bit #	0 – 7	8 – 15	16 – 23	24 – 31
0	Source Port		Destination Port	
32	Length		Header and Data Checksum	

Ports

Ports

- Not physical, but logical
- Multiplexing
- They are a communication tool

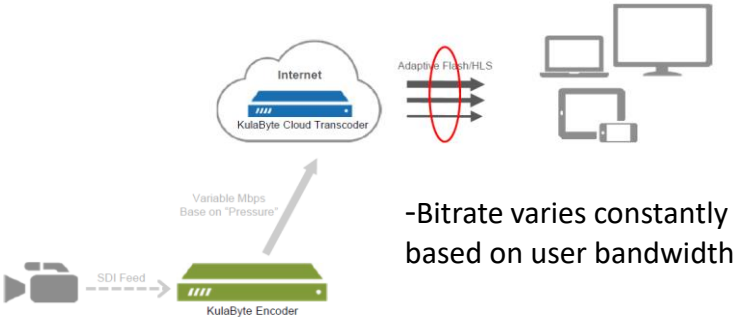


*AV over IP – Transport Protocols

- RTP – Real Time Transport Protocol
  - RTCP - Real Time Control Protocol
  - RTSP – Real Time Streaming Protocol
  - RTMP – Real Time Messaging Protocol
- SMPTE (Society of Motion Picture and Television Engineers) 2022.x(1-9)
- TSN – Time sensitive Networking; AVB – Audio Video Bridging 802.1BA, AS, Qat Qav/IEEE 1722(AVTP)

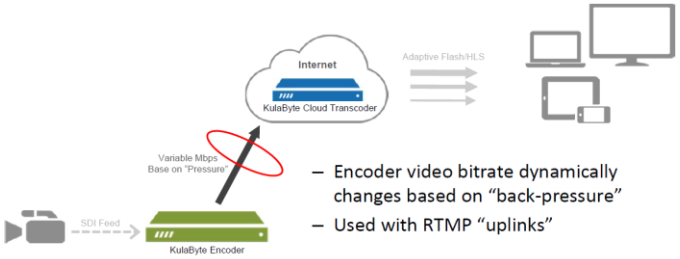
*AV over IP - Streaming

Adaptive Bit Rate Streaming (ABR)



-Bitrate varies constantly based on user bandwidth

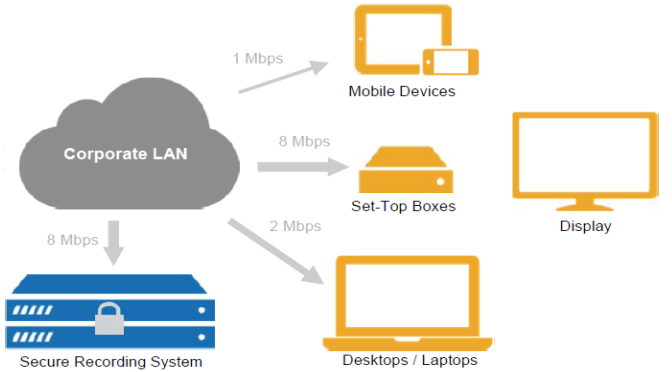
Dynamic Stream Shaping (DSS)



- Encoder video bitrate dynamically changes based on "back-pressure"
- Used with RTMP "uplinks"

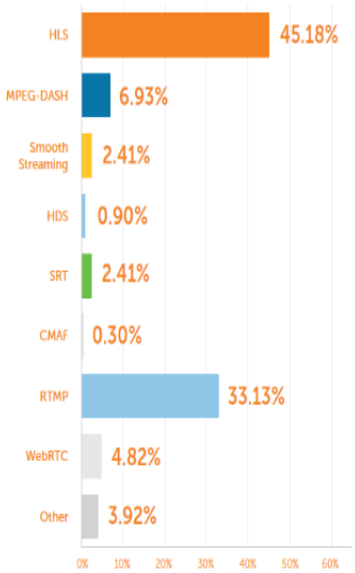
Multi Bit Rate Streaming (MBR)

-Multiple Bitrates defined and set



*AV over IP – Transport Protocols

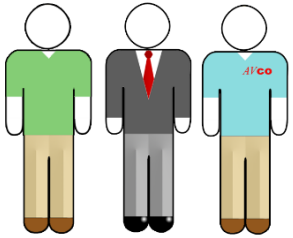
- Streaming- content streamed directly or sent to a CDN(content Delivery network) to be streamed on demand
  - –HLS – HTTP Live Streaming (most popular)
  - –HDS – HTTP Dynamic Streaming (based on Adobe Flash)
  - –MPEG-DASH – Dynamic Adaptive Streaming over HTTP (the future?)
  - –Streaming Techniques
    - ABR – Adaptive Bit Rate Streaming
    - DSS - Dynamic Rate Shaping
    - MBR – MultiBit Rate Streaming

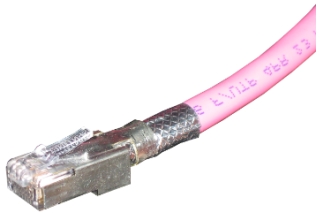


Streaming video latency report 2019 WoWZA

Network Access Control (NAC)

- Network access based on “least privilege”
- NAC: who you are determines what you can do
- “Who you are” may include:
  - User login
  - Endpoint security
  - Type of connection





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Access Control Lists (ACL)

- Configured on network routers
- Control what traffic may pass through the router
- May filter based on:
  - Source IP
  - Destination IP
  - Traffic type
  - User

Ch 6 – Pg 132-134

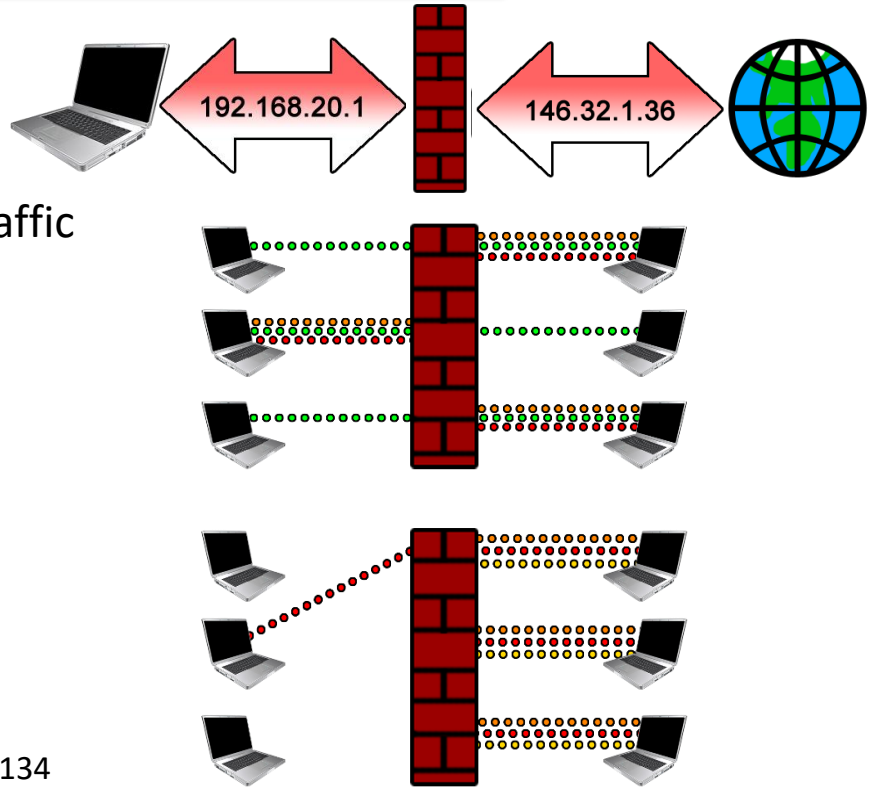
Firewalls

- Any technology that protects the network from intrusion
- Located at borders and within the private network
- **Default allow** – all ports allowed unless forbidden
- **Default deny** – all ports forbidden unless allowed

Ch 6 – Pg 132-134

Firewall Technologies

- Network address translation (NAT)
- Packet Filtering
  - Sets up rules forbidding or allowing certain traffic
- Port Forwarding
  - Combines NAT and packet filtering
  - Traffic from the right device is let through



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Questions?

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