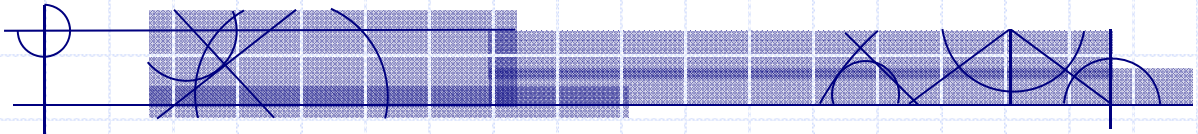
Basic IP for Radio Technicians

A Technician's Guide to the Technology



2019 IWCE Conference

College of Technology

Las Vegas, Nevada

Goals for this class

- Provide basic introduction to IP networking
- Provide hands on experience
- Provide tools for some basic troubleshooting and network information.

Where is it all going?

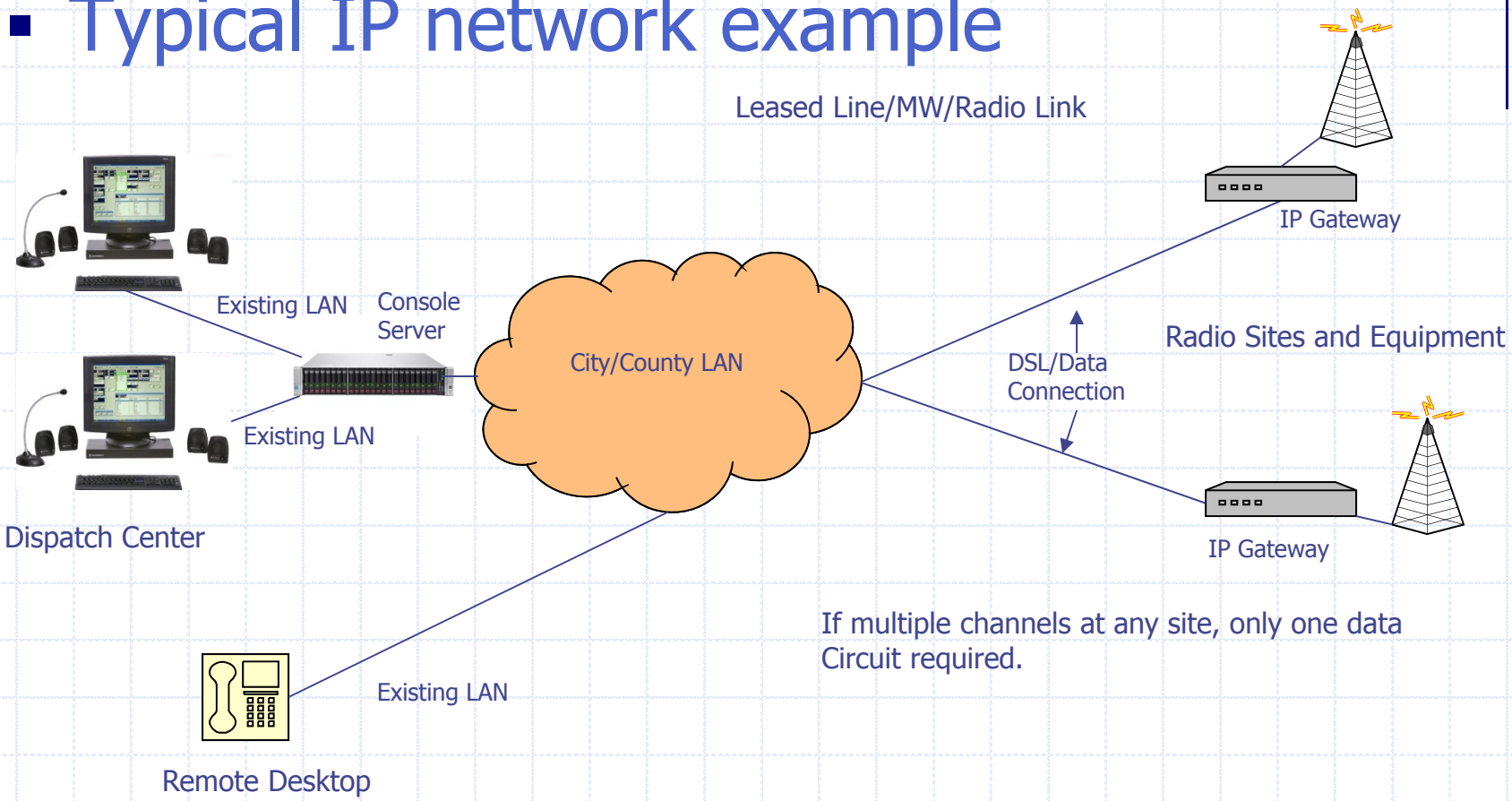
- Voice and data have become one.
  - Transport is all data.
  - Analog voice only at the human interface.
  - Data and voice indistinguishable in the network.
- Digital interfaces are easy and cheap to design.
- Data networks require higher bandwidths for mixed traffic.
- When will this occur? It already has!
- Greater interconnectivity between devices using IP network technology, Machine-to-machine (M2M), Internet of Things (IOT)

No more butt sets or TIMS

- Maintenance is more complex.
  - Good news is no level setting, bad news is no level setting!
- Often no set path for data or voice. Bits are bits
- Requires detailed knowledge of the protocols and network design
- Specialized tools and software
- Often IT people do not have this level of expertise

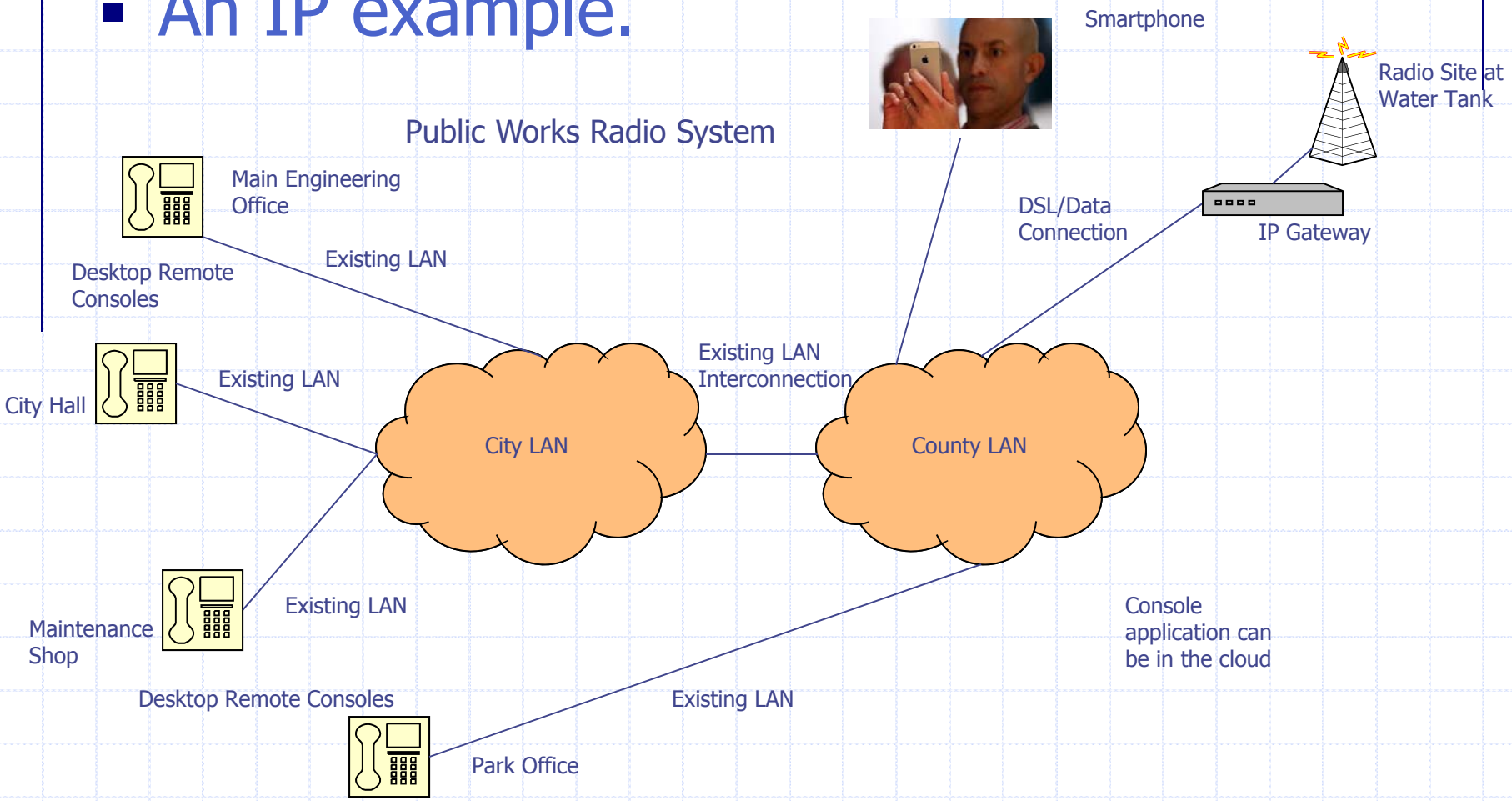
Why IP?

- Typical IP network example



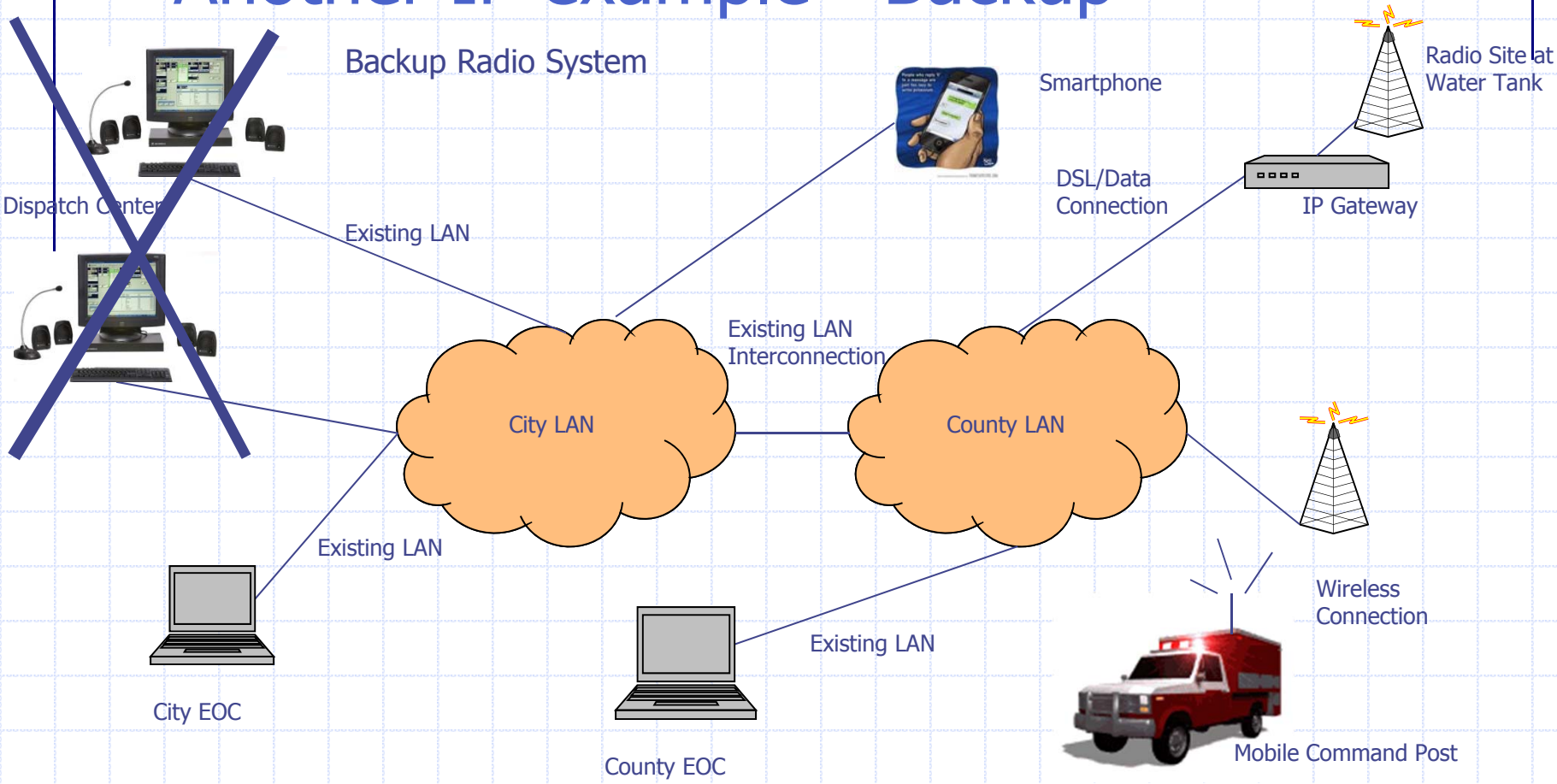
Why IP?

- An IP example.



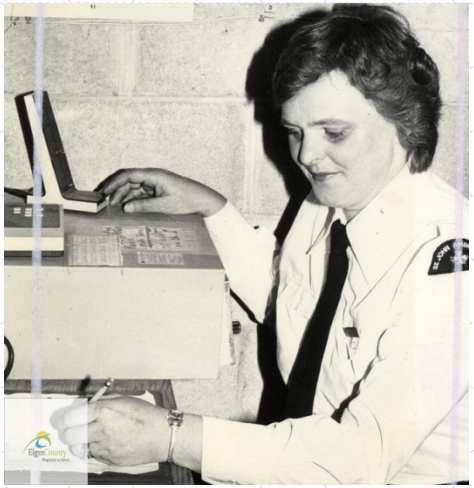
Why IP?

- Another IP example - Backup



How can IP be used for radio?

- It is a method of interconnecting consoles, radios, telephones, and other devices
- It is not transmitted over-the-air to the user radios (Mostly true)
- IP ≠ P25
- Uses standard Internet Protocols (IP)
  - TCP/IP – Most reliable format because provides guaranteed delivery but not generally used for voice because of bandwidth
  - UDP/IP – Uses less bandwidth but may be less reliable because no guaranteed delivery
  - Uses many of the standards and protocols available in most data networks but not necessarily allowed by the network manager

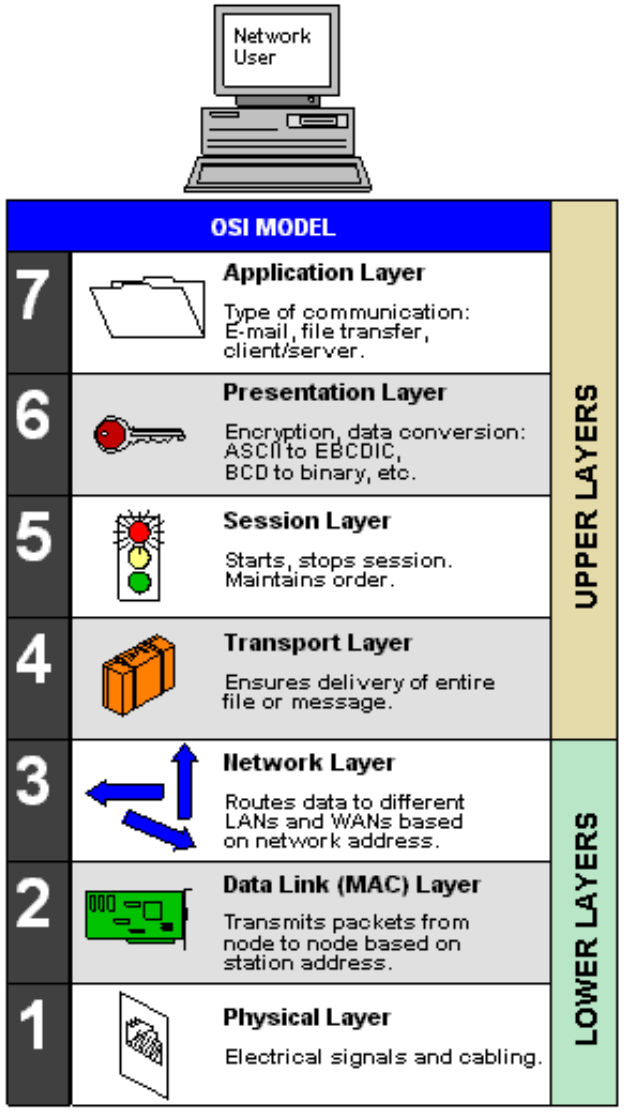


The Promise of IP

- Reduces costs because existing data networks can be used
- Easy to use, interconnects many different brands of equipment
- Control consoles can be located anywhere there is a data network and a simple laptop can be used
- Reduces costs because standard computer hardware can be used
- Great for disaster recovery and back up because IP data networks are often more resilient than voice or dedicated facilities
- Reduces costs because one data circuit can handle multiple base stations
- Interconnects many different kinds of equipment such as cell phones, 2-way radio, Internet Phones, VoIP phones, etc.
- Plug and Play

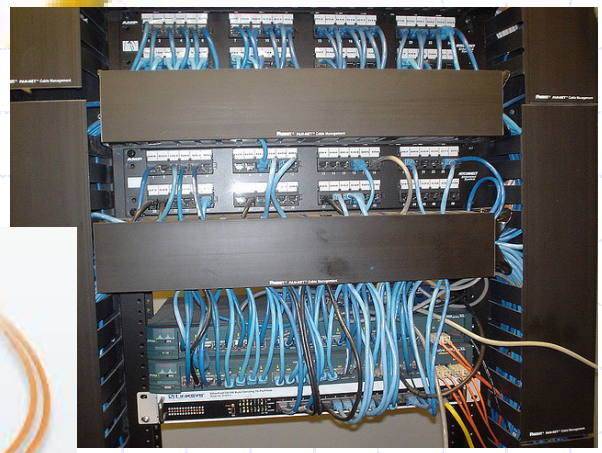
OSI Model

- Open System Interconnection
- Seems esoteric but is important to understand how various network components work.
- Released in 1983



OSI Model

- Layer 1 – Physical Link
  - Voltage
  - Number of wires
  - Pin outs
  - CAT5, CAT6, Fiber

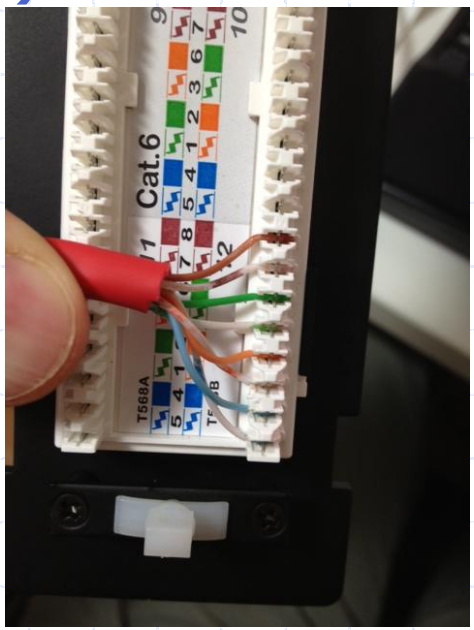


Layer 1 Cable Categories

Frequency Bandwidth	***TIA (Components)***	***TIA (Cabling)***	***ISO (Components)***	***ISO (Cabling)***
1 - 100 MHz	Category 5e	Category 5e	Category 5e	Class D
1 - 250 MHz	Category 6	Category 6	Category 6	Class E
1 - 500 MHz	Category 6A	Category 6A	Category 6A	Class EA
1 - 600 MHz	n/a	n/a	Category 7	Class F
1 - 1000 MHz	n/a	n/a	Category 7A	Class FA

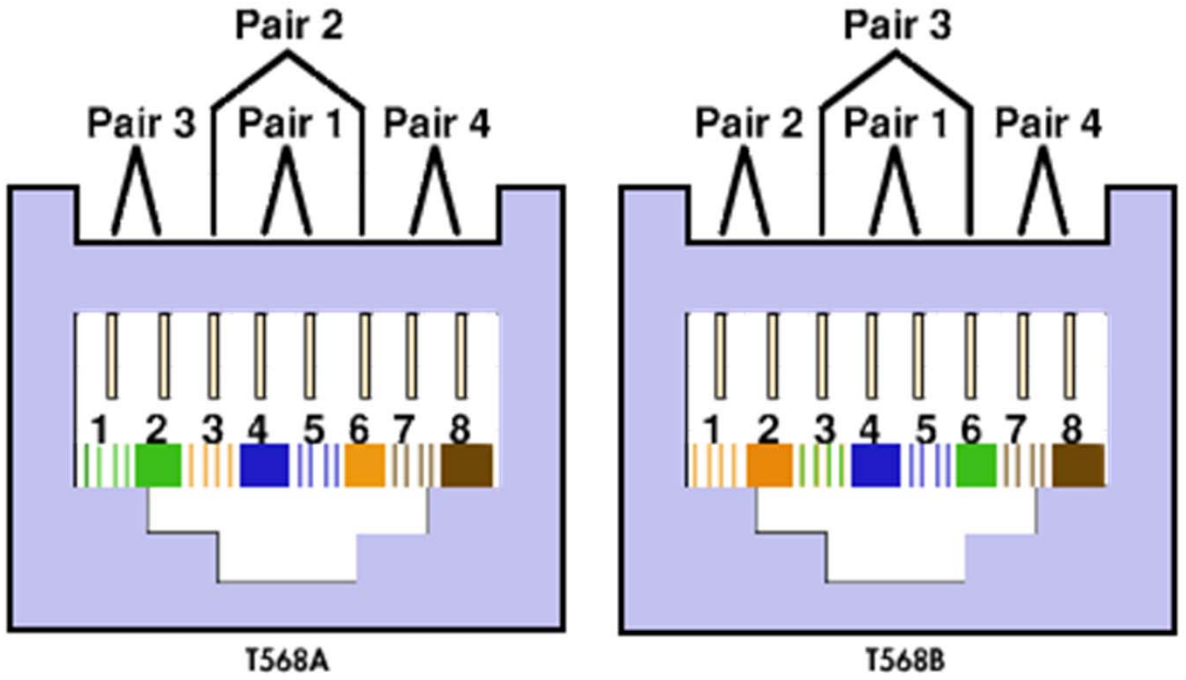
Layer 1 Wiring

- Layer 1 Wiring standards
- Connector 8P8C (not really RJ45)
  - TIA 568A
    - Recommended for general use
    - Compatible with T1 USOC RJ-48C
    - Recommended for home networks TIA 570
    - Compatible with voice telephone line RJ11 type connections
  - TIA 568B
    - Most common in commercial applications
    - Legacy "Bell System" wiring (Merlin systems)

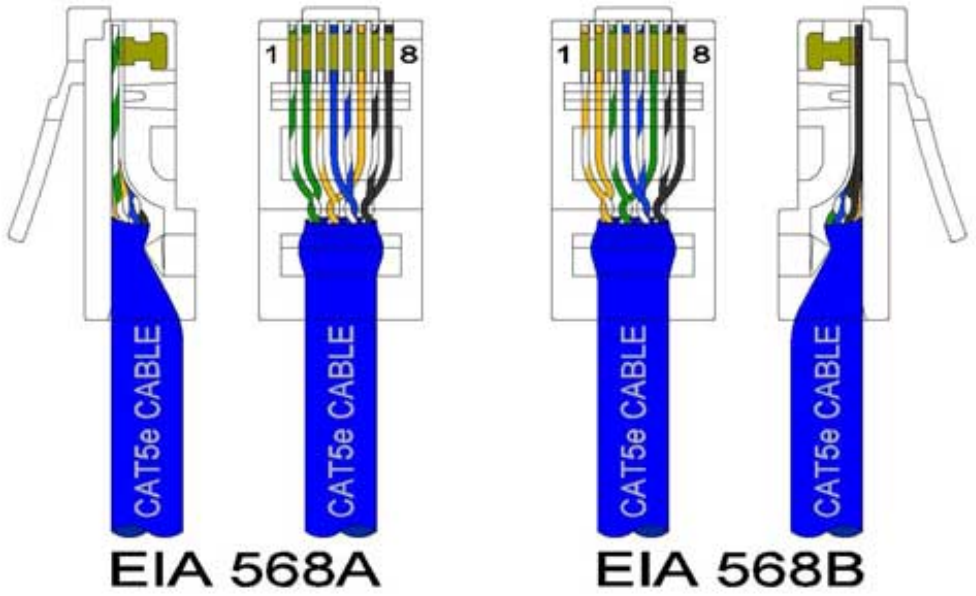


Layer 1 Wiring

- TIA 568 Pin outs



Layer 1 Wiring



EIA 568A

Pin #	Wire Color Legend	Signal
1	White/Green	TX+
2	Green	TX-
3	White/Orange	RX+
4	Blue	TRD2+
5	White/Blue	TRD2-
6	Orange	RX-
7	White/Brown	TRD3+
8	Brown	TRD3-

EIA 568B

Pin #	Wire Color Legend	Signal
1	White/Orange	TX+
2	Orange	TX-
3	White/Greege	RX+
4	Blue	TRD2+
5	White/Blue	TRD2-
6	Green	RX-
7	White/Brown	TRD3+
8	Brown	TRD3-

Power over Ethernet (POE)

- There are different standards
- 15.4 and 25.5 watts of power are standard
- Some vendors supply up to 51 watts
- Watch total power in large cable bundles!
- National Electrical Code applies

POE Pin Use

802.3af Standards A and B from the power sourcing equipment perspective

Pins at switch	T568A color	T568B color	10/100 mode B, DC on spares		10/100 mode A, mixed DC & data		1000 (1 gigabit) mode B, DC & bi-data		1000 (1 gigabit) mode A, DC & bi-data	
Pin 1	White/green stripe	White/orange stripe	Rx +		Rx +	DC +	TxRx A +		TxRx A +	DC +
Pin 2	Green solid	Orange solid	Rx –		Rx –	DC +	TxRx A –		TxRx A –	DC +
Pin 3	White/orange stripe	White/green stripe	Tx +		Tx +	DC –	TxRx B +		TxRx B +	DC –
Pin 4	Blue solid	Blue solid		DC +	Unused		TxRx C +	DC +	TxRx C +	
Pin 5	White/blue stripe	White/blue stripe		DC +	Unused		TxRx C –	DC +	TxRx C –	
Pin 6	Orange solid	Green solid	Tx –		Tx –	DC –	TxRx B –		TxRx B –	DC –
Pin 7	White/brown stripe	White/brown stripe		DC –	Unused		TxRx D +	DC –	TxRx D +	
Pin 8	Brown solid	Brown solid		DC –	Unused		TxRx D –	DC –	TxRx D –	

Fiber Interconnection

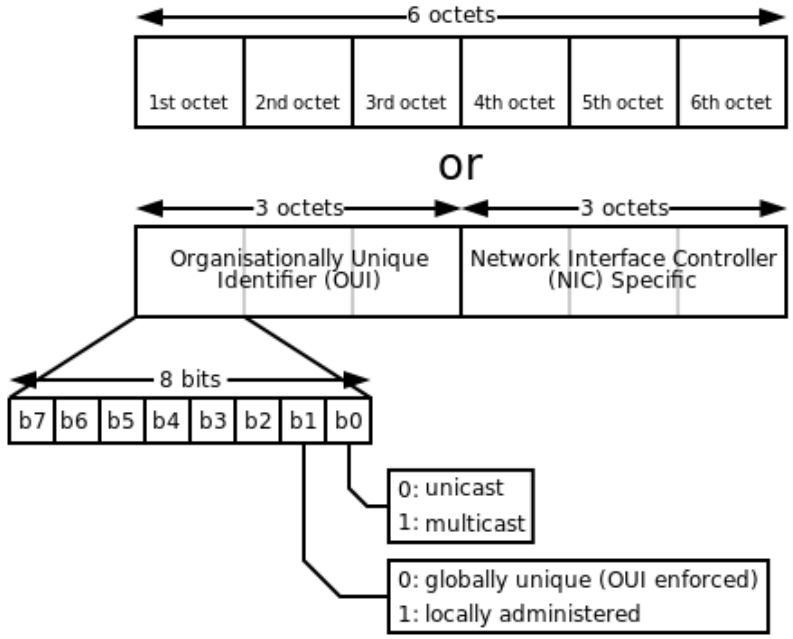
- Multimode fiber for short distances up to maybe 2 km but less expensive
- Single mode fiber for long distances starting at 1 km to 10s of km but more expensive
- Variety of connectors
- Field assembly can be difficult
- Buy pre-made jumpers for patch panels
- Wire for short distances is cheaper

OSI Model

- Layer 2 – Data Link
  - Media Access Control (MAC) Addresses
  - Ethernet, Token Ring, Frame Relay, ATM
  - Data "Switches" usually work at this level
  - LAN Cards – Usually Layer 2 depending on card
  - Ethernet uses Carrier Sense Multiple Access with Collision Detection (CSMA-CD)

MAC Address

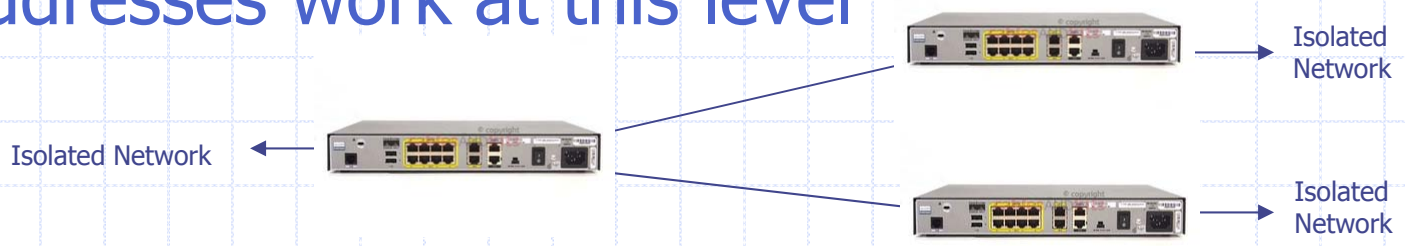
- Media Access Control address
- Unique identifier to network interfaces
- "Ethernet" address
- My laptop MAC
  - 5C-26-0A-4F-9E-B0
  - 5C-26-0A – Dell
- https://macvendors.com



OSI Model

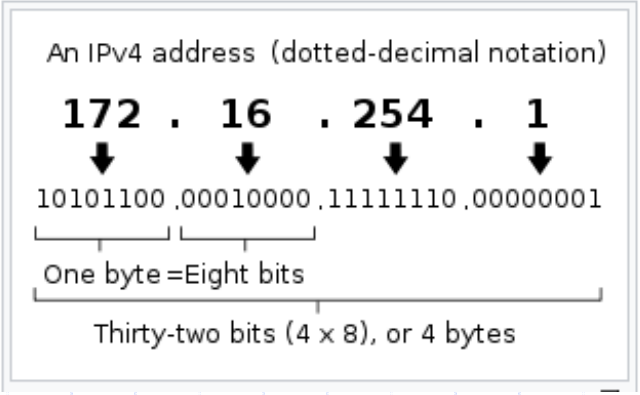
- Layer 3 – Network Layer
  - Higher level addressing
  - Handles communications between network switching points.
  - Routers generally operate at this level
  - IP, SNA, Apple Talk
  - IP addresses work at this level

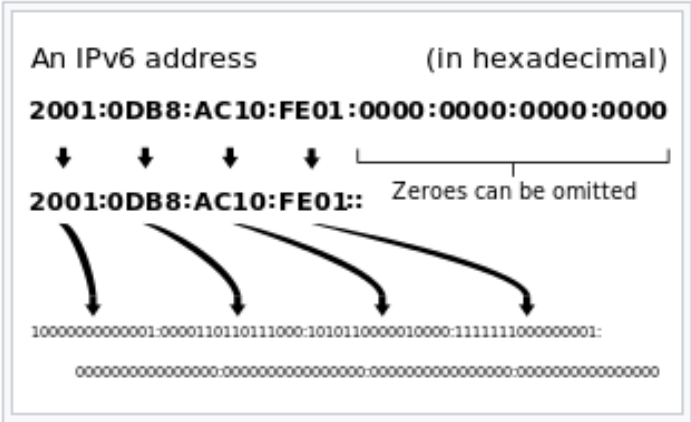
Router



IP Addresses

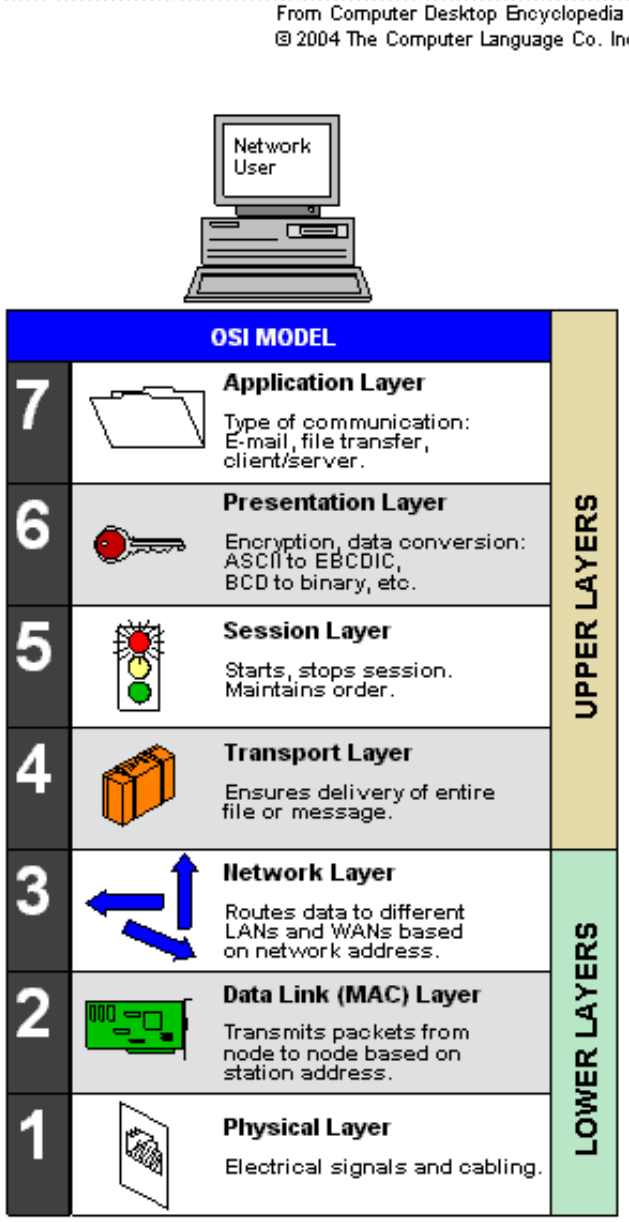
- How the Internet is addressed
- IP Version 4 is the legacy addressing approach – 32 bits
- IP V4 addresses are essentially used up
- IP Version 6 is the new system – 128 bits
- In addition to addresses, there are 65,000 ports associated with each address



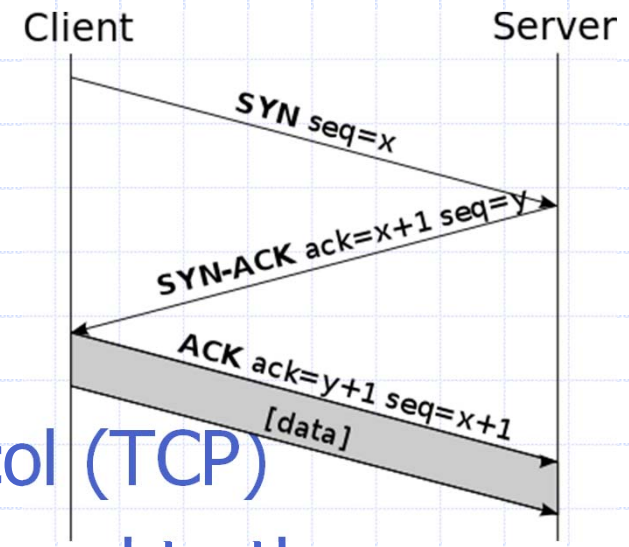


OSI Model

- Lower Layers
  - Layer 1 - Cables, etc.
  - Layer 2 - Ethernet
  - Layer 3 - IP

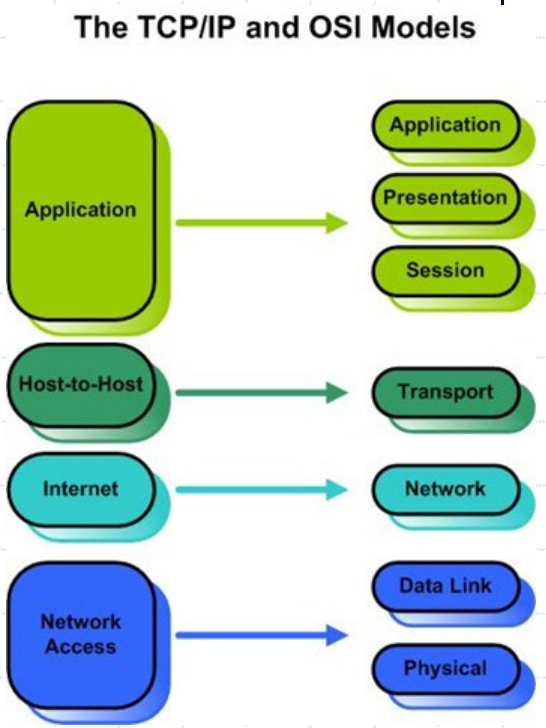


OSI Model



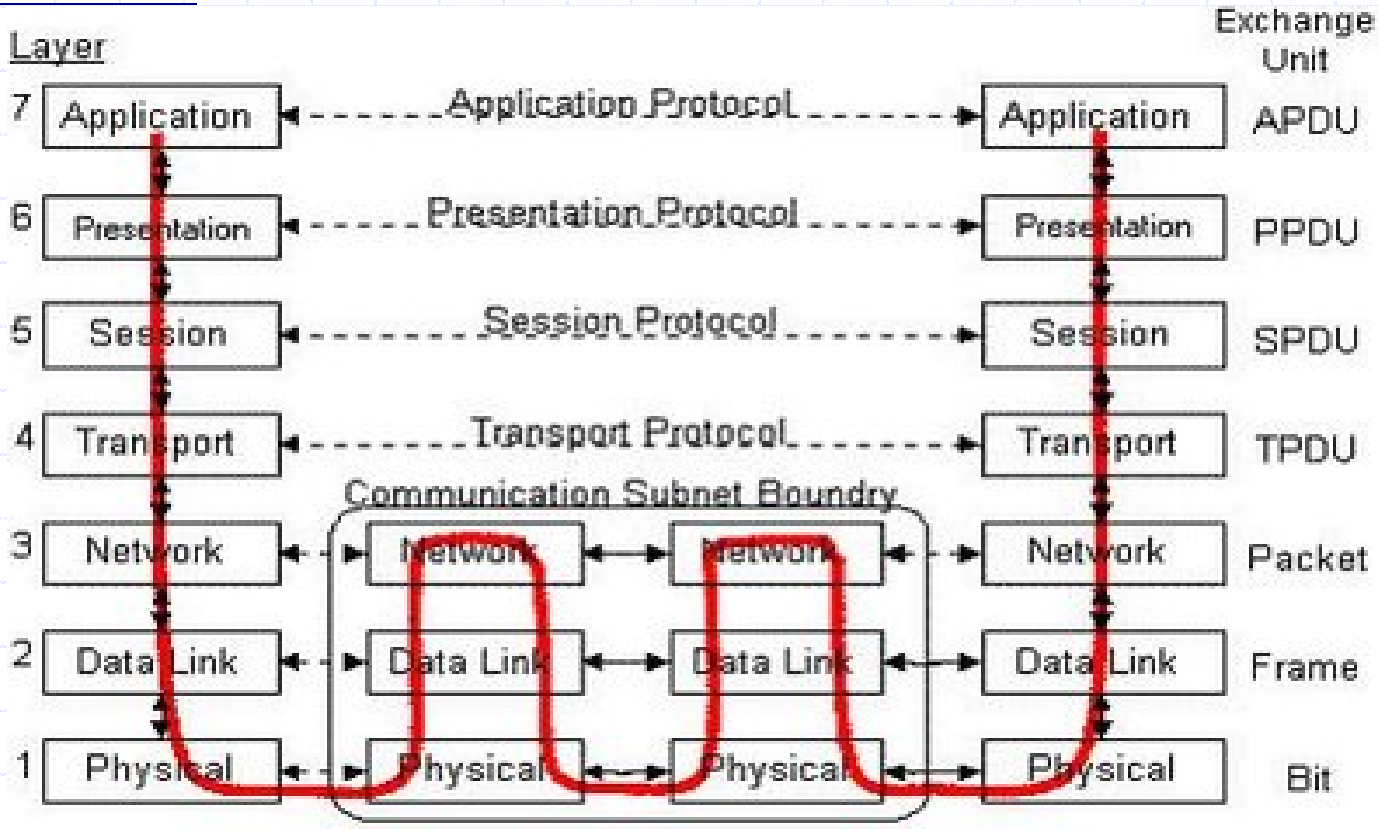
- Layer 4 Transport Layer
  - Transmission Control Protocol (TCP)
  - Ensures data gets from one end to the other.
  - Counts packets, etc.
  - Part of the TCP/IP "Internet" protocol
  - Sometimes contains parts of Layer 5

OSI Model



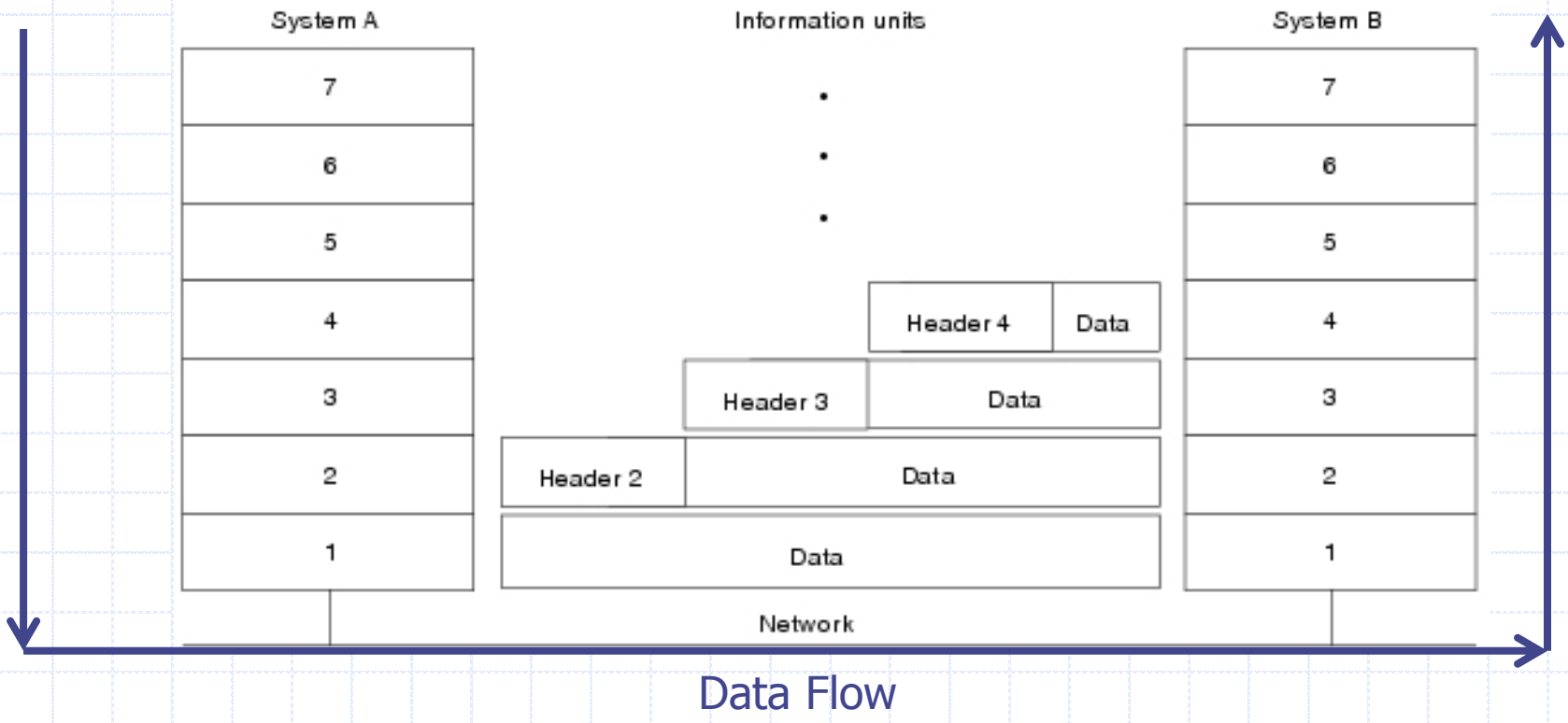
- Layer 5 – Session Layer
  - Manages two-way or one-way transmission
  - Provides communications coordination
  - Often incorporated in Layer 4
  - SIP operates at this layer
- Layer 6 – Presentation Layer
  - Use has changed over time
  - Generally used for encryption now.
- Layer 7 – Application Layer
  - Used to manage the applications such as file transfers, etc.
- Layers 5, 6, and 7 are often merged together in the operating system or applications in modern computers.

Network Data Flow



Network Data Flow

- Data flows through the OSI model elements.



Networking Equipment

- Hub
  - Layer 1 device
  - Network wire nut
  - All traffic flows to all ports
  - Inexpensive switches have replaced hubs
  - Hubs maybe required for network monitoring

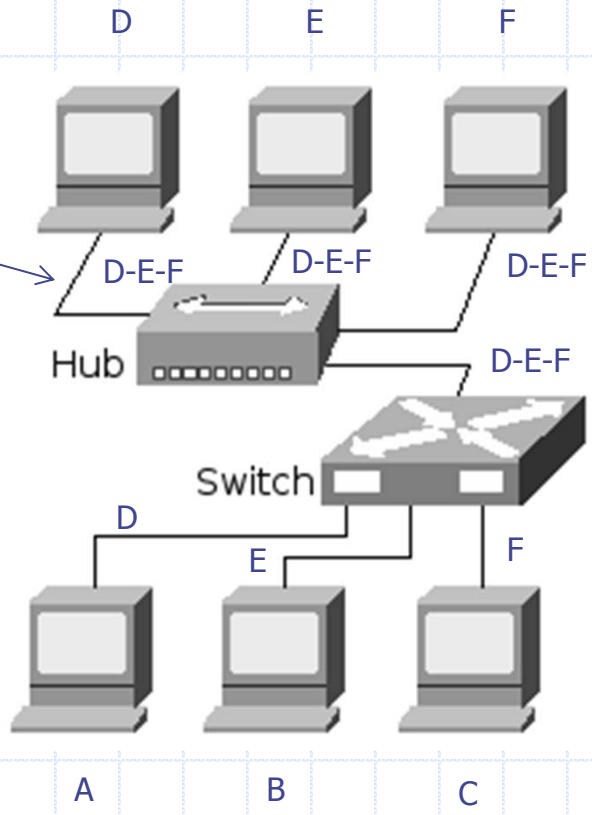
Network Equipment

- Switch
  - Layer 2 Device
  - Routes traffic to the network segment with the destination device
  - Reduces traffic and collisions on the network
  - Smart switches can provide enhanced switching and limited "Layer 3" functions
  - Cannot monitor network traffic unless using a "mirrored" port
  - Switch bandwidth should match network

Switch and Hub Example

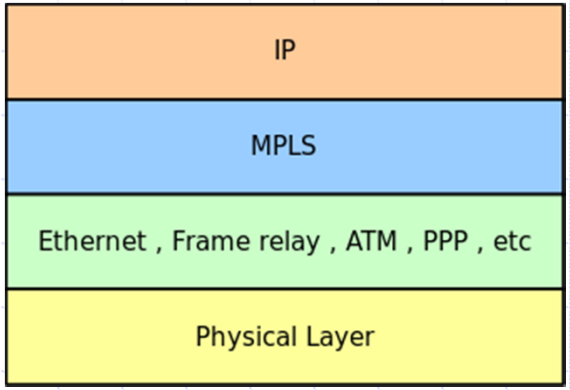
All data flows to all devices regardless.

Only the data destined for the end device flows in the LAN segment.



MultiProtocol Label Switching(MPLS)

- "Layer 2.5"
- Data agnostic
- Switching decisions made on the basis of labels assigned when the data enters the network
- Connection oriented protocol as opposed to IP which is connectionless
- Allows for faster transport of data and applying different rules for different labels



Networking Equipment

- Routers
  - Layer 3 Device
  - Connects one network to another
  - Usually provides transport conversion
  - Makes "intelligent" decisions about how to route data
  - Bandwidth should match the network

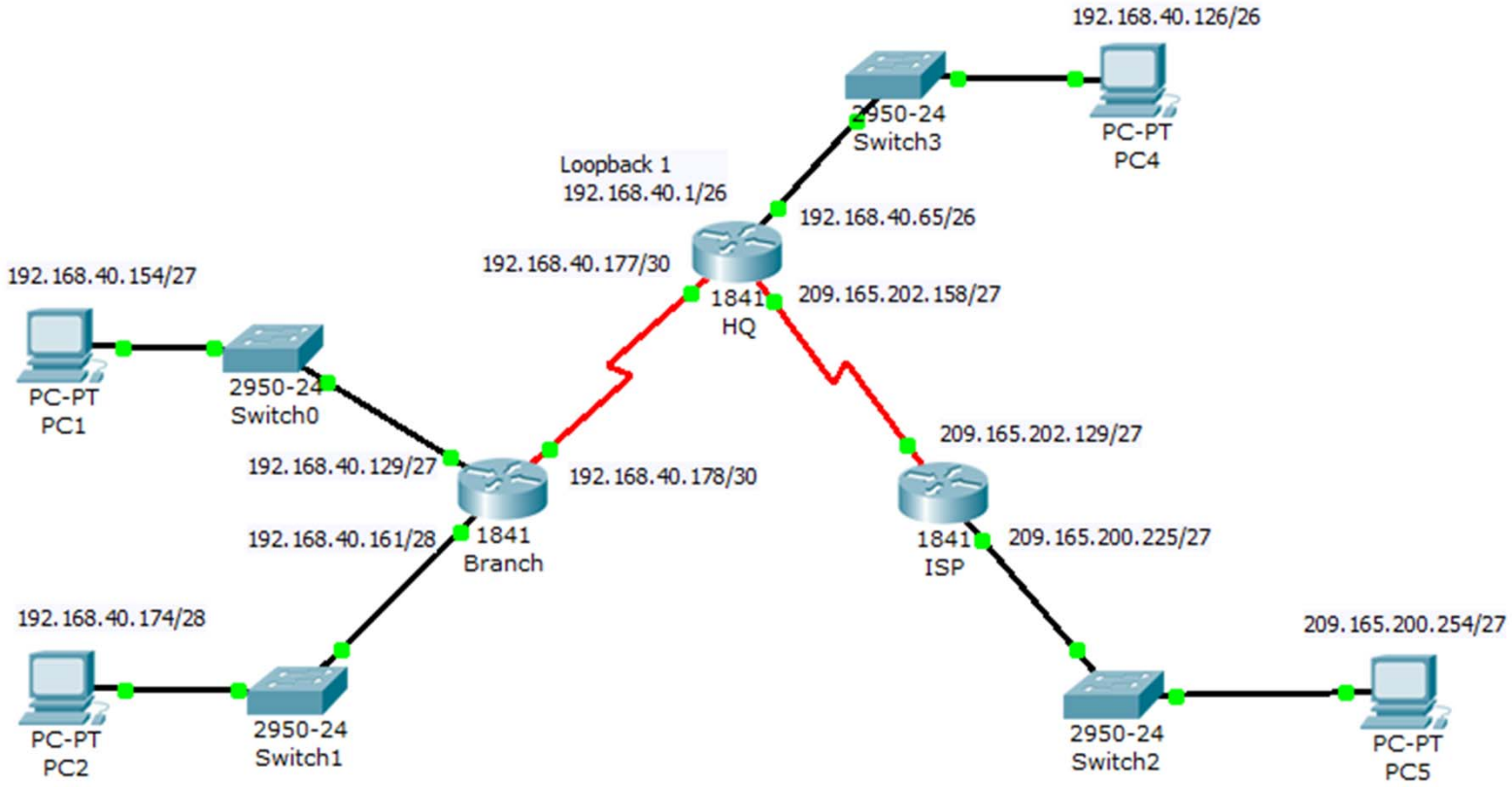
Router

Equipment Requirements

≠

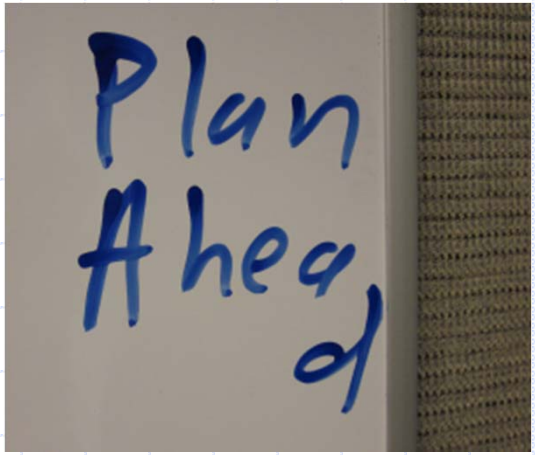
- Router bandwidth defines total throughput
- Having four 1 Gb interfaces does not mean the maximum bandwidth is 4 Gbps
- The Netgear router above has a bandwidth of 450 Mbs and the Cisco up to 4 Gbps

Putting it all together



Initial Considerations

- Shared or dedicated network
- Shared network should support
  - Multicast – Transmits to multiple points simultaneously
  - Bandwidth – Depends on vocoding assume 50k per voice channel worst case
  - Fixed IP addresses
  - Dedicated bandwidth or Quality of Service
  - Virtual LAN's do not guarantee bandwidth
  - Delay must be controlled
  - Router/Firewall programming control
  - Security and virus protection

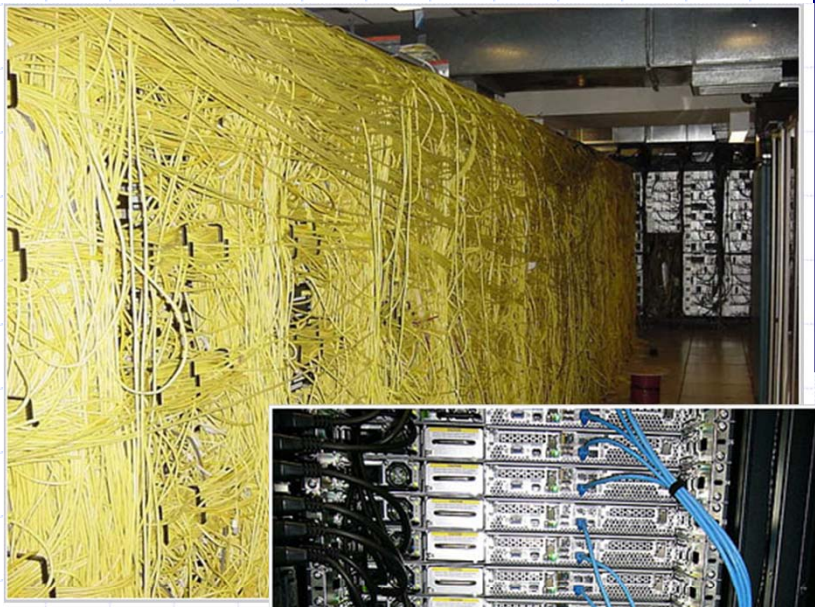


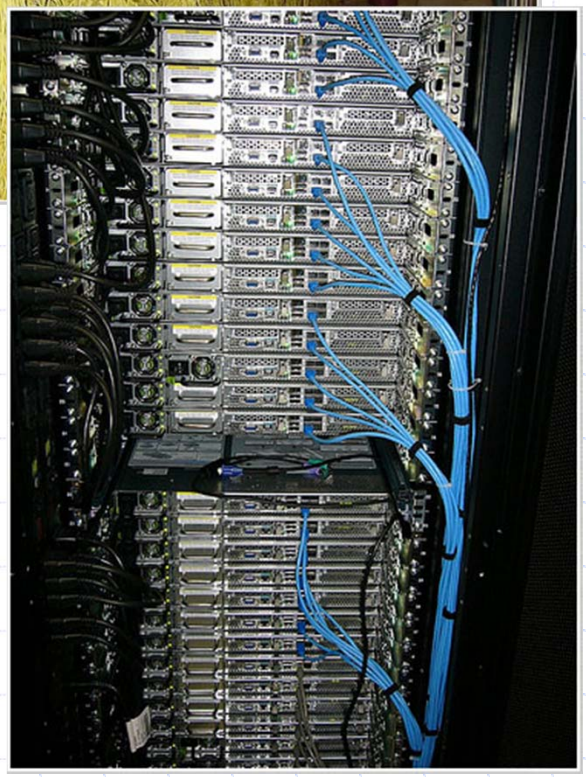
Technical Details

- Data Networking
  - Common use:
    - TCP/IP for control signals – More reliable
    - UDP/IP for voice data – Less bandwidth
    - Multicast – Routing data to multiple points
    - Fixed IP addresses
    - Be careful with any network assumptions as different vendors have implemented network interfaces differently.
  - Quality of service is generally required to ensure delivery of audio packets. (Remember they are UDP/IP.)
  - Multiple ports may need to be opened in firewalls, etc. for proper operation.
  - Virtual LANs do not guarantee bandwidth.
  - Network security must be managed.

Implementing IP

- Document your network!
- Workmanship does make a difference
- Details, details, details, pay attention to the details

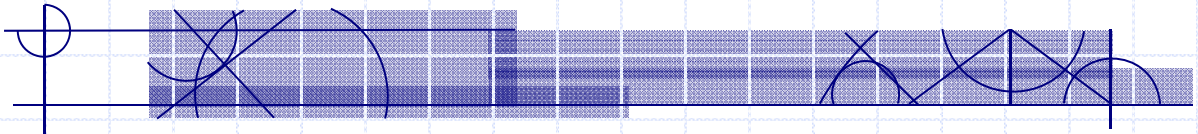




IP – The Future is Now

- Good news
  - Can be a very cost effective solution in some situations
  - If limitations are not a problem, costs can be reduced
  - This technology will eventually become the dominate method for radio system interconnection because most communications are moving to an IP type network
  - Improvements in the interfaces are being made all the time
  - Some issues are resolved if implemented on a dedicated data network but that raises costs

Questions?



Thank you!

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