NETWORKING FOR AVL TECHNICIANS

CFI Networking 101

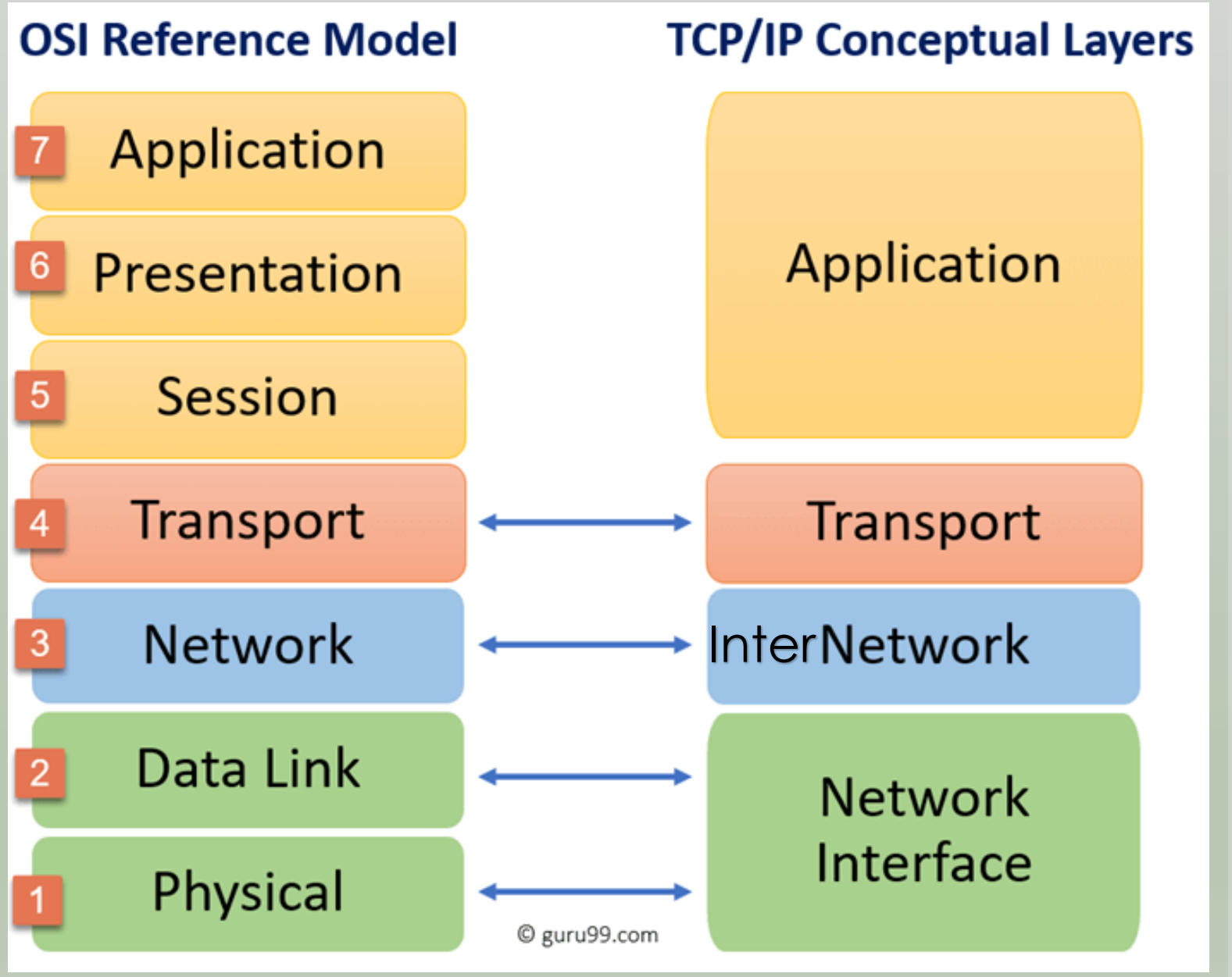
What is a network?

- A network consists of two or more computers or devices that are linked in order to share resources, exchange files or allow electronic communication. The network devices (nodes) may be connected via cables (fiber optic or category) or wirelessly to a network switch.
- Types of Networks:
  - LAN – Local Area Network
  - WLAN – Wireless Local Area Network
  - WAN – Wide Area Network
- Examples of AVL networks (LANs) are:
  - Control Network
    - Audio mixer control
    - Video router control
    - Power amplifier control
  - Dedicated Media network
    - Dante network
    - sACN (Streaming ACN), ArtNet, and RDM for lighting
    - Video Streaming – Extron NAV, Crestron NVX, QSYS NV
    - Comms – Clearcom Helixnet

OSI Model

Layer 7 – Application	(HTTP, FTP, SMTP, DNS)
Layer 6 – Presentation	(JPEG, MPEG)
Layer 5 – Session	(NFS, SMB)
Layer 4 – Transport	(TCP, UDP)
Layer 3 – Network	(IPv4, IPv6)
Layer 2 – Data Link	(ARP, CDP, STP)
Layer 1 – Physical	(100Base-TX, 1000Base-T)

The OSI Model
(Open Systems Interconnection Model)
is a conceptual framework used to describe the functions of a networking system. The OSI model characterizes computing functions into a universal set of rules and requirements in order to support interoperability between different products and software.



OSI vs. TCP/IP models

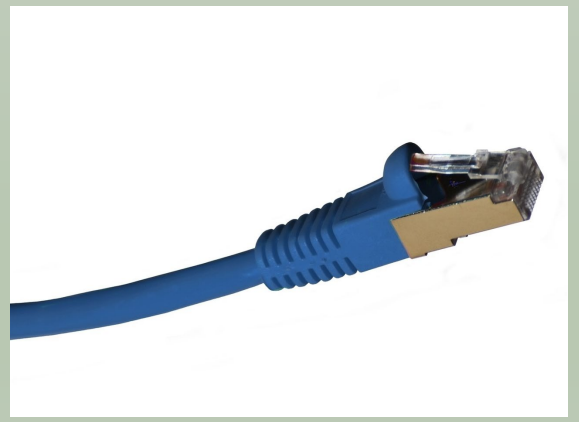
- Physical and Data Link layers combined in TCP/IP model
- Session Presentation and Application Layers combined in TCP/IP model

Layer 1 – Physical Layer

- Category Cable (UTP, STP)
  - 5e – up to 100 MHz, 100Mbps up to 1Gbps
  - 6 – up to 250Mhz, 1Gbps (10Gbps supported but only to 55 meters, 180 feet)
  - 6a – up to 500 Mhz, 10Gbps
  - 7a – up to 1000Mhz, 10Gbps - (screen shielded SSTP or screen foil shielded SFTP)
  - 8 – up to 2000 Mhz , 40 – 100Gbps (limit of 30 meters, 98 feet)
- **100 meters (330 feet)**
- Connector – 8P8C "RJ45"
- POE (Power over Ethernet) - up to 12.95W
- POE+ up to 30W
- POE++ Type 3 up to 60W, Type 4 up to 100W
- **Use STP for digital snake connections – AES50, SLink, DX, GigaAce**
- UTP is fine to use with Dante

Category Cables and Connectors

UTP Cable
Unshielded twisted pair



STP Cable
Shielded Twisted Pair

Ethercon Connector

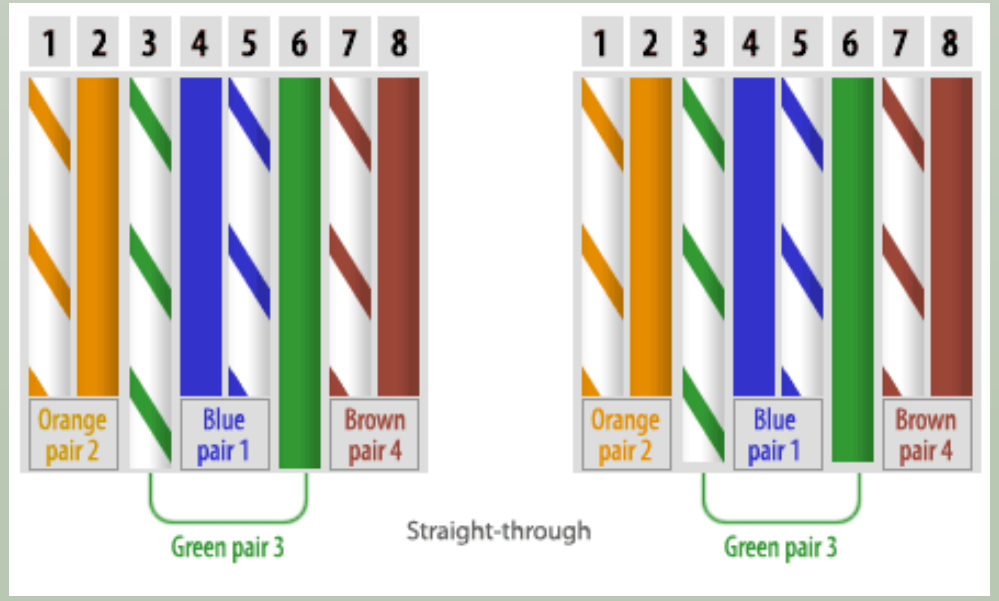
- Either UTP or STP cable
- Use STP Ethercon cables for digital snakes
- Locking connector XLR shell
- Remove tab on RJ45

Layer 1 – Physical Layer

Category Cable Wiring

- TIA/EIA 568B
- Standard in most places
- 568A swaps orange and green pairs
- 568A – 568B cable considered "crossover" cables
- 4 balanced pairs

568B wiring scheme



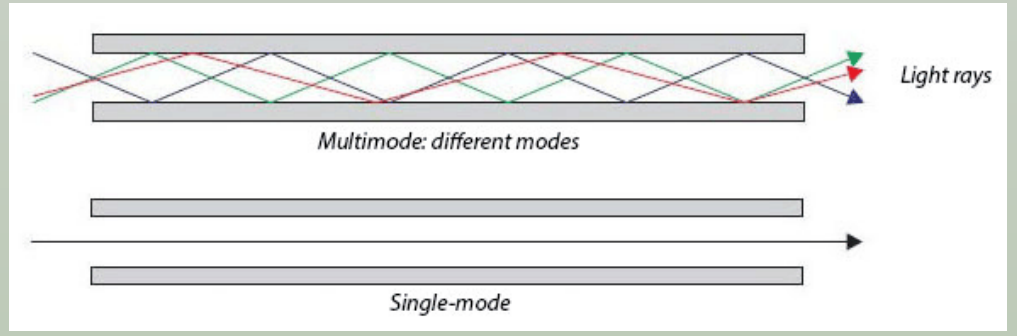
Tips for Category Cable

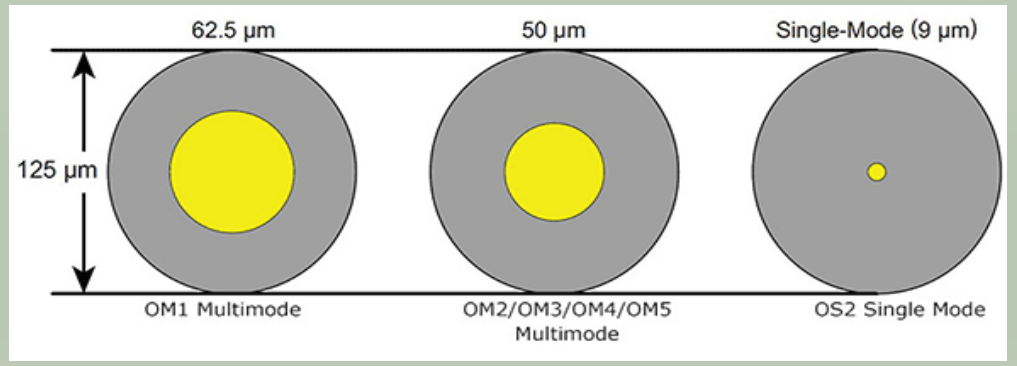
- Use strain relief
- Do not exceed bend radius of cable (4X diameter) it will cause signal attenuation or loss
- Be sure to remove the “tab” on the 8P8C “RJ45” connector that is used with an ethercon shell.
- Make sure wires reach end of 8P8C “RJ45” connector
- Test each cable for pin-to-pin continuity and bandwidth if test equipment allows
- Use stranded cable for patch cables and solid core for fixed wiring
- Remember cable length restrictions (330 ft) add a switch if you need to run a longer distance

Layer 1 – Physical Layer

Fiber Optic Cable

- Multimode
  - short range (400 meters – 1312 feet)
  - Inexpensive LED transmitters
  - Orange – 62.5 Micron (OM1)
  - Teal – 50 Micron (OM2,OM3, OM4)
  - Wavelengths 850 and 1300 nm
- Single Mode
  - long range (10 km – 32,080 feet)
  - Laser transmitters
  - Yellow (OS1, OS2)
  - Wavelengths 1310, 1383, 1550 nm





Multimode OM1

Multimode OM3

Singlemode OS2

Layer 1 – Physical Layer

Common Fiber Connector Types

- LC – Lucent Connector aka "little connector" used for neutrik opticalcon connectors
- SC – Subscriber Connector aka "Standard Connector" or "Square Connector"
- ST – Straight Tip Connector with bayonet style plug , think BNC

opticalcon

LC Connector

SC Connector

ST Connector

Common Fiber Interface Types

- GBIC – Gigabit Interface Converter
- SFP – short form-factor pluggable aka "mini GBIC"
- SFP+ - up to 10Gbps

GBIC SFP

Single or Multimode?

SFP

SFP+

Single or Multimode?

Tips for Fiber:

- Use strain relief
- Save the fiber connector caps and patch bay covers to re-use
- Don’t store a fiber cable or SFP+ without the caps
  - Dust can disrupt a fiber connection
- Invest in an easy-to-use cleaner and fiber “wipes”
- NEVER look into a fiber connector that is connected to a device
  - The wavelengths are not visible to the human eye but are harmful.
- If testing a fiber connection with an led light, use your camera phone to “look” at the connector.
- Do not exceed the bend radius of fiber. (20x diameter) It will break or cause loss of signal
- Be careful when handling broken fiber, the glass core is very sharp
- Buy armored cable for use in the field

Layer 2 – Data Link Layer

- Switches and Nodes
  - Network Nodes communicate by sending ethernet frames to another port on the switch or to a port on another switch within the same network (VLAN)
- MAC Addresses
  - 48 bit unique identifier for network card (NIC) and switchports
  - 6 groups of hexadecimal digits (base 16 – 0-9 and A-F)
  - B4-0E-DE-68-E1-92 (this laptops wifi NIC mac address)
  - B40E.DE68.E192 (another format of mac address – used by switches)
  - 1st 24 bits are manufacturer ID (OUI) , last 24 bits are unique to NIC
  - ARP Command
    - arp-a command on PC displays current ip and mac address associations
    - Show arp command on switch shows what mac is associated with the specified IP address – 192.168.1.253
  - Show Mac address-table command on switch shows which port the mac address ending in 8d5f is plugged into. Gigabit port 4 on the 3rd switch in the switchstack.

B4-0E-DE-68-E1-92

Intel Inc - NIC ID

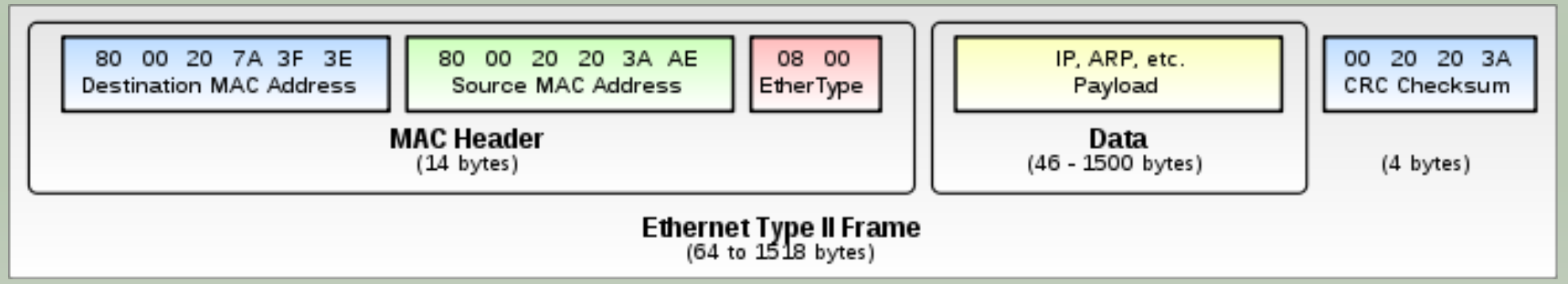
```
C:\Users\Chris Moody>arp -a

Interface: 192.168.1.131 --- 0x12
  Internet Address      Physical Address      Type
  192.168.1.1           60-38-e0-85-4e-e3     dynamic
  192.168.1.109         a0-6a-44-d6-27-24     dynamic
  192.168.1.255         ff-ff-ff-ff-ff-ff     static
```

```
FPL-9500-SV#show arp | i 192.168.1.253
Internet  192.168.1.253           7   a4bb.6d48.8d5f  ARPA
```

```
9200-Stk#show mac address-table | i 8d5f
a4bb.6d48.8d5f    DYNAMIC     Gi3/0/4
```

Layer 2 – Data Link Layer

- Ethernet Frames
  - Container for communication between network nodes
  - Contain Source and Destination MAC Addresses
  - Data Payload from further up the OSI Model (IP, etc.)
  - Frame Check Sequence (CRC) error check
  - IEEE 802.1Q tag, if present, is placed between the Source Address and the EtherType or Length fields.
    - The tag indicates if the frame is tagged or untagged as well as the QoS priority.
    - Tagged frames are "trunk" frames and indicate a switchport that passes traffic for multiple vlans (interswitch links)
    - Untagged "access" frames indicate a switchport that passes only traffic from a single vlan



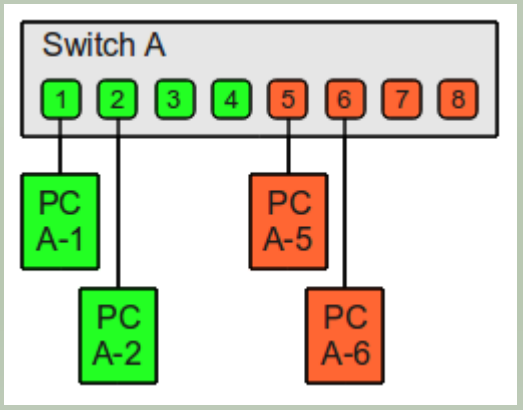
Layer 2 – Data Link Layer

- Intra and Inter Switch Communication (within 1 network)
- Network nodes communicate with 1 network at a time
- VLANs – logical grouping of network nodes even if not connected to the same switch
  - Vlans allow ports in a switch to be subdivided into a logical network for ease of administration
  - Vlans cannot communicate data between each other natively
  - Trunk ports "tagged" ports keep vlan data separate
  - Trunk ports are typically used between switches
  - Access ports are typically used by network nodes (hosts)

In Switch A

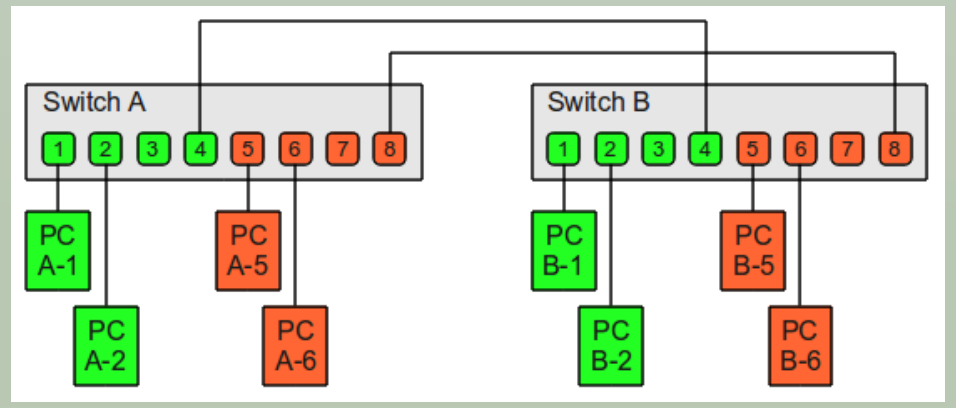
Ports 1-4 are untagged access ports and part of a vlan
Ports 5-8 are untagged access ports and part of a different vlan

PC A-1 cannot communicate with PC A-5 at Layer 2. They are logically separated and can't communicate by Layer 2 protocols.

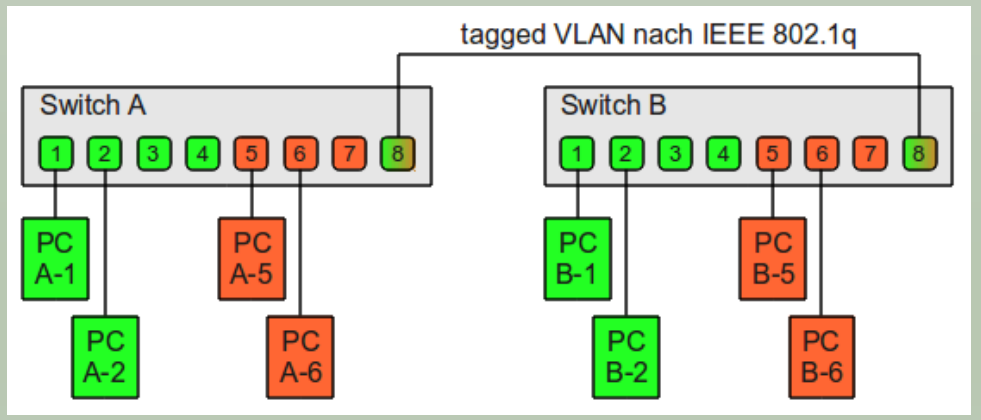


Layer 2 – Data Link Layer

Switch A and B only have access ports. Communication on the green VLAN occurs on port 4 between the switches. Similarly, port 8 connects the orange VLAN on each switch. PC A-1 can talk to PC B-1 via port 4 on the switches. PCA-1 cannot talk to PC B-5

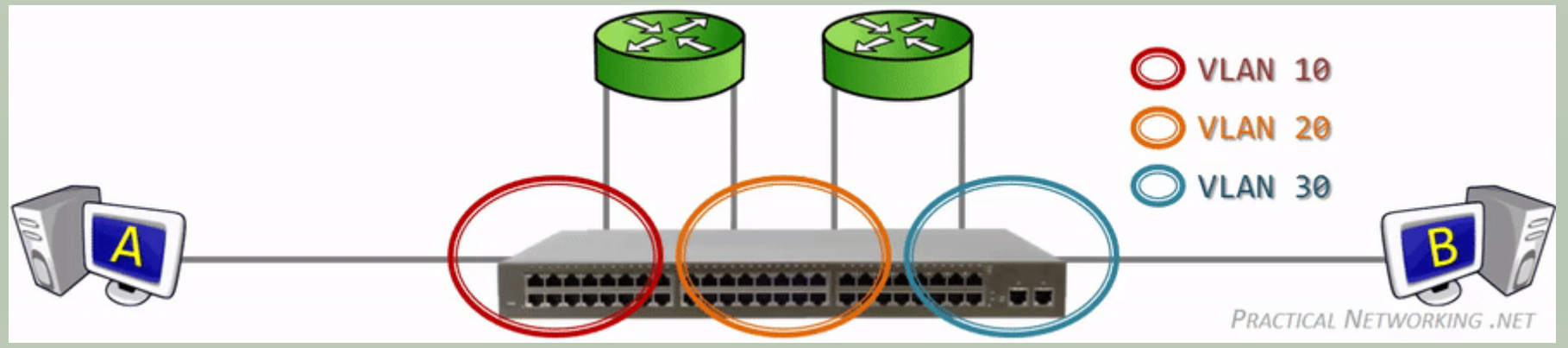


Switches A and B have a "tagged" trunk port that allows vlan data to travel between the switches on port 8 but still keeps the green and orange vlan traffic separate. PCA-1 can talk to PC-B1 via port 8 on the switches. PC A-1 cannot talk to PC B-5



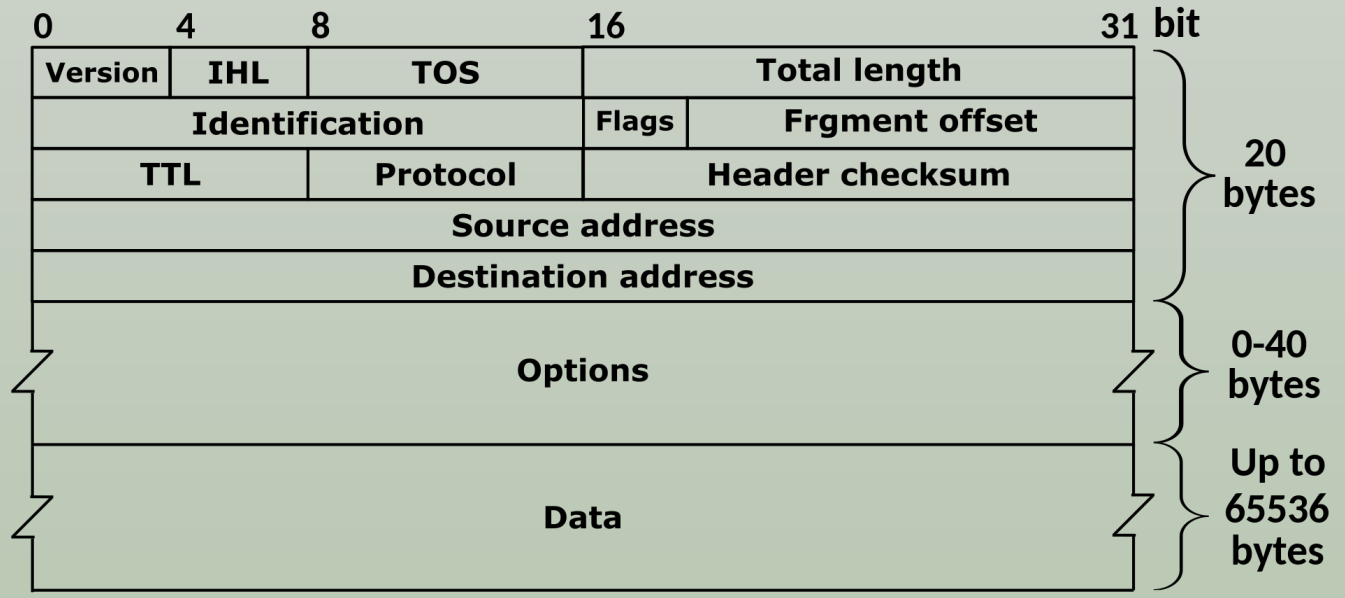
Layer 3 – Network Layer

- IP Protocol
  - Network layer communications protocol in the Internet protocol suite for relaying datagrams across network boundaries. Its routing function enables internetworking, and essentially establishes the Internet
  - Routing – between physical networks or subnets
  - Each network segment has a subnet with an IP range associated with it and a Gateway (router) address
  - A subnetwork or subnet is a logical subdivision of an IP network



Layer 3 – Network Layer

- IP Datagram (Packet)



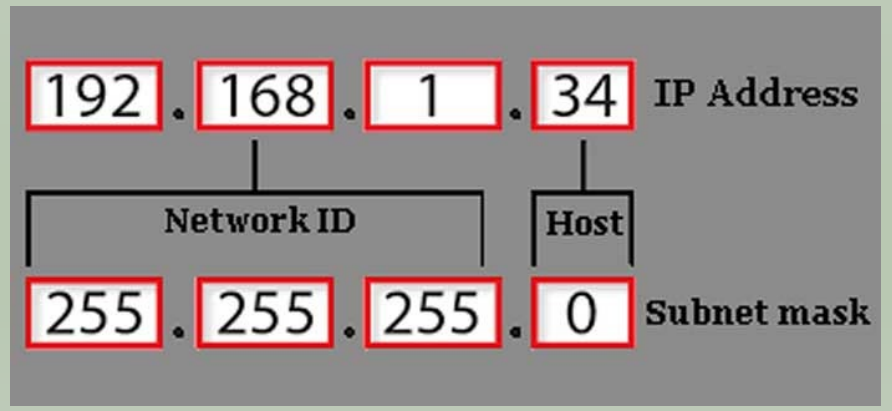
Layer 3 – Network Layer

- IPv4 Addressing
  - Host IP Address
    - A unique address that identifies a device on the internet or a local network
    - 32 bit address in 4 octets. Each octet can be 1-254
    - 0 is reserved for the network address
    - 255 is reserved for the broadcast address
    - 192.168.1.131 (this laptop)
  - Subnet Mask
    - Divides network and host addresses
    - 255.255.255.0
    - 255.255.255 represents the network ID
    - 0 represents the available host addresses
    - 192.168.1.34 with subnet mask 255.255.255.0
    - 192.168.1 is the network ID
    - 1-254 is the available IP addresses for hosts
    - .34 is the specific host
    - CIDR notation 192.168.1.0/24

Network Connection Details

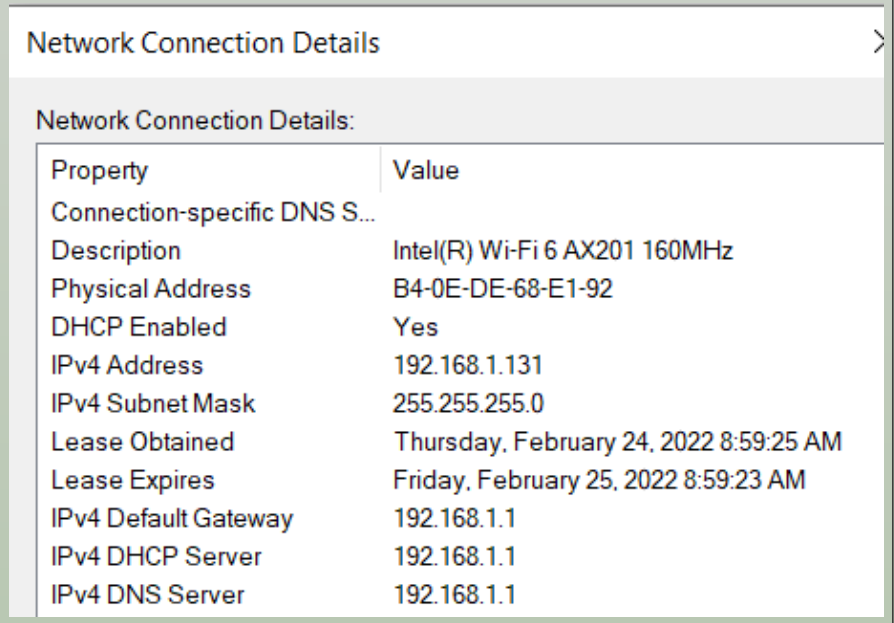
Network Connection Details:

Property	Value
Connection-specific DNS S...	
Description	Intel(R) Wi-Fi 6 AX201 160MHz
Physical Address	B4-0E-DE-68-E1-92
DHCP Enabled	Yes
IPv4 Address	192.168.1.131
IPv4 Subnet Mask	255.255.255.0
Lease Obtained	Thursday, February 24, 2022 8:59:25 AM
Lease Expires	Friday, February 25, 2022 8:59:23 AM
IPv4 Default Gateway	192.168.1.1
IPv4 DHCP Server	192.168.1.1
IPv4 DNS Server	192.168.1.1



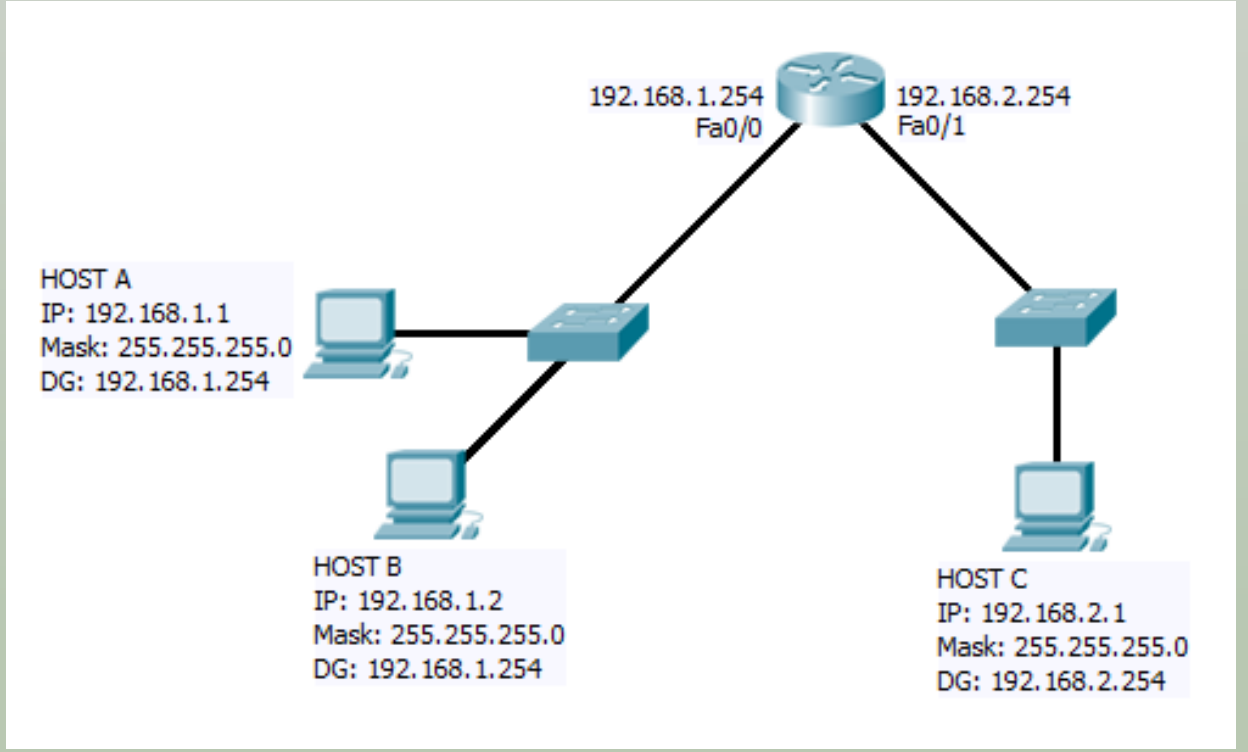
Layer 3 – Network Layer

- IP communication between hosts on a network occurs between hosts on the same network segment from host to host.
- If 2 hosts are on different network segments, then communications flows through the default gateway to bridge the networks together.
- Default Gateway:
- The node in a computer network using the Internet protocol suite that serves as the forwarding host (router) to other networks when no other route specification matches the destination IP address of a packet.



Layer 3 – Network Layer

Hosts A and B can communicate with each other directly, however communication to Host C from either A or B must flow through the Default Gateway (router) at 192.168.1.254



Layer 3 – Network Layer

Public and Private addresses

- Ip addresses are divided into 2 types, public and private.
- Public IP addresses can be routed throughout the internet
- Private IP addresses cannot cross a router boundary.
  - 10.0.0.0 to 10.255.255.255 (Class A private addresses)
  - 172.16.0.0 to 172.31.255.255 (Class B private addresses)
  - 192.168.0.0 to 192.168.255.255 (Class C private addresses)

- Hosts with private ip addresses communicate with the internet by using NAT
  - NAT - Network Address Translation – maps a private ip to a public ip for communication
  - Usually happens at network boundary by firewall or router.
  - Home Internet routers offer services such as NAT, DHCP and Firewall services.

Layer 3 – Network Layer

Unicast, Multicast, and Broadcast

- Unicast connections send IP packets to a specific host on the network
  - Unicast requires bandwidth from sending host for each data stream
- Multicast sends IP packets to a group of hosts on the network that has subscribed to the multicast
  - Multicast only requires bandwidth of host to send one group of packets to group. Network switch sends copies of packets to all subscribers
  - Most often used to send video data because of size of data stream
  - Recommended for Dante data streams to 3 or more destinations
- Broadcast sends IP packets to all hosts on the network
  - DHCP and WOL are examples of broadcasts
  - Broadcasts are dropped at router border (non-routable)

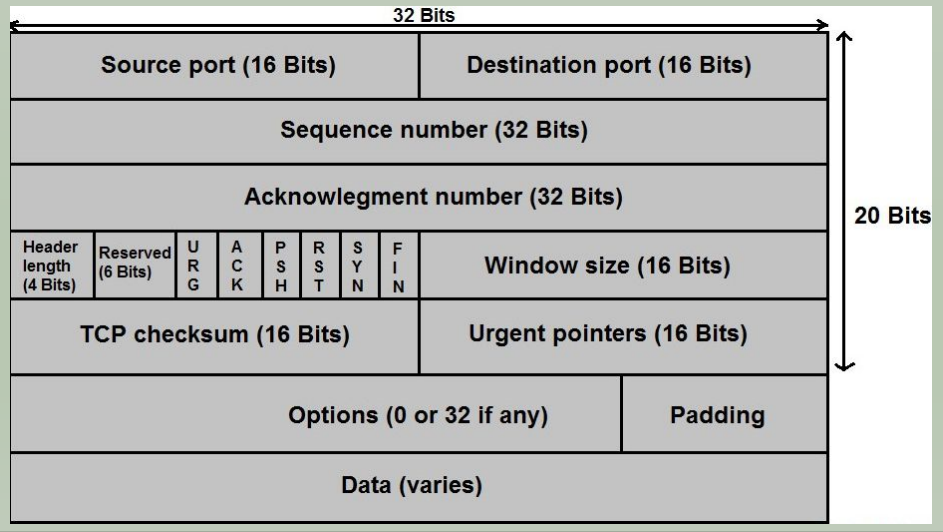
Layer 4 – Transport Layer

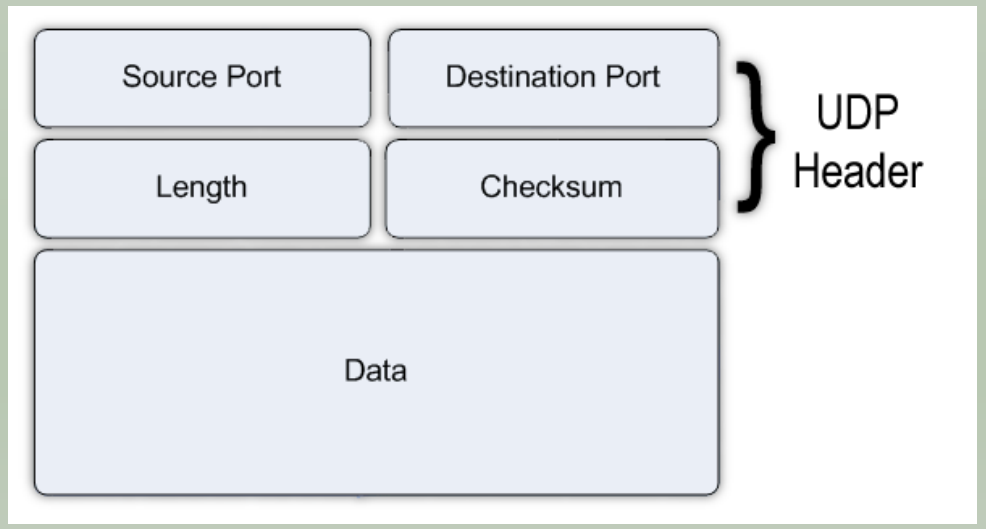
TCP – Transmission Control Protocol

- Connection based
- Reliable, Ordered and Error Checked
- TCP Datagrams called Packets
- HTTP, FTP, SSH, SMTP

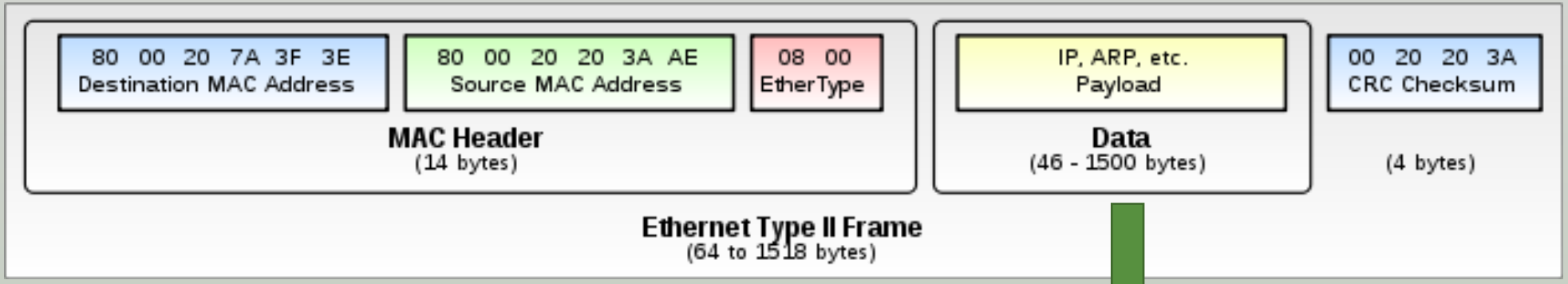
UDP – User Datagram Protocol

- Connectionless
- Fast – no error checking
- UDP Datagrams called Packets
- NTP, DHCP, VOIP, Media Transmission – (Dante Audio)



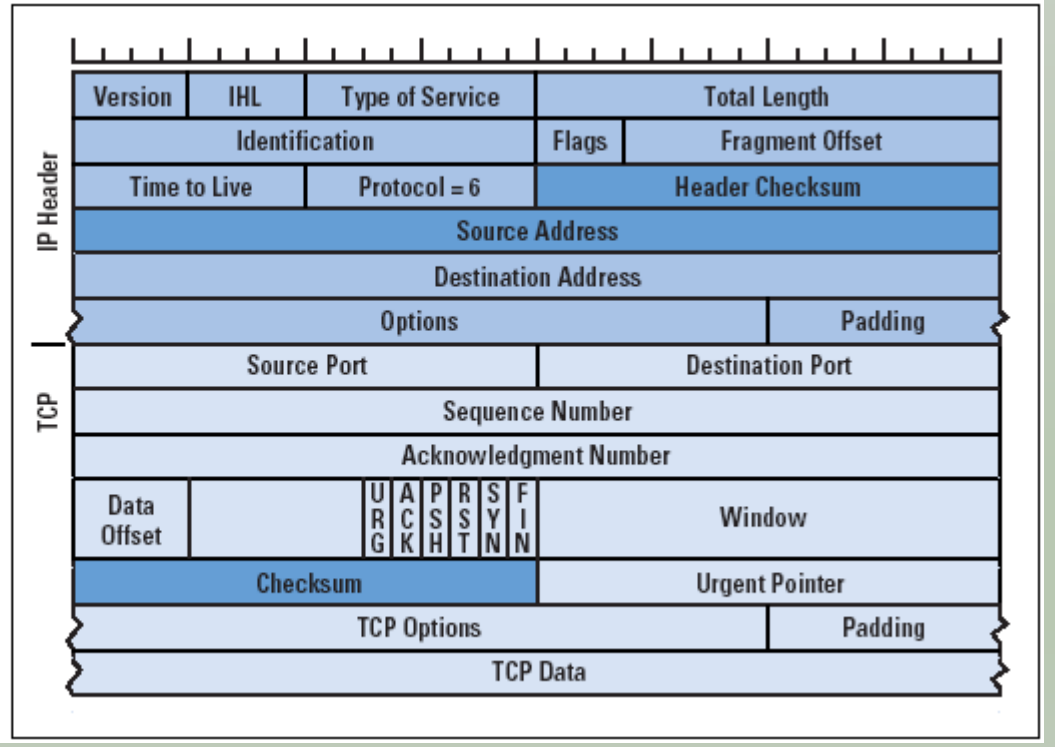


Ethernet Frame



IP Packet

Figure 1: TCP/IP Header Fields Altered by NATs (Outgoing Packet)



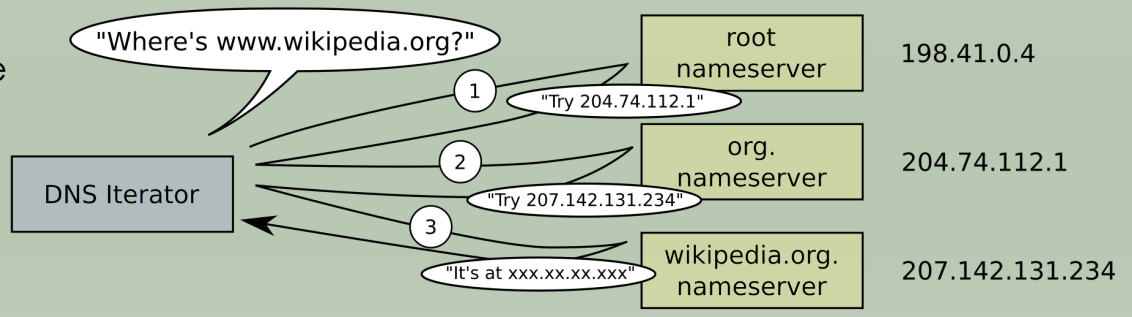
Layer 4 – Transport Layer

Packet Sizes

- MTU – Maximum Transmission Unit (Packet or Frame Size)
  - 1500 bytes – Standard Frame
  - 9000 bytes - Jumbo Frame
    - iSCSI – SANs –
    - If using jumbo frames all equipment must be configured to use them, (NICs, Switches, and SANs)

Common Protocols

- DHCP – Dynamic Host Configuration Protocol
  - Assigns an IP address to a host at startup of host
  - When a host joins the network it sends a broadcast to its network subnet asking for an IP address from a DHCP server.
  - Broadcasts are not routable so broadcasts stay within a particular network segment or subnet
  - DHCP servers allow for reservations to be made associating a mac address to a particular IP, so the host will always receive the same IP.
  - DHCP servers assign IPs for a range of time called the DHCP lease time
- DNS – Domain Name System
  - Translates IP addresses into human readable addresses
  - 198.61.250.137 = www.faylib.org
  - DNS names are resolved iteratively in reverse order of name
    - First stop is root DNS servers or "."
    - Second is org DNS servers (or com, co, us, gov, etc)
    - Third is Wikipedia DNS server
    - Fourth is webserver hosting www record for wikipedia



Common Protocols

- mDNS – multicast Domain Name System
  - Similar to DNS
  - Resolves IPs to hostnames
  - Local level vs. DNS global level
  - Used in Bonjour, Dante (without Dante Domain Manager), and Clearcom Helixnet
- Zeroconf (zero configuration networking)
  - Uses 169.254.0.0 /16 (169.254.0.0 through 169.254.255.255)
  - Link-local address
  - Within a broadcast domain (network segment) – not routable
  - automatic private IP addressing (APIPA)
  - Used in newer OS, and in Dante devices

Common Protocols

- EEE
  - Energy Efficient Ethernet
  - Reduces power consumption during periods of “low” activity
  - AKA Green Ethernet
  - Don’t use with media applications (Dante, Video, Comms)

Quality of Service

- QoS is the ability of the network to prioritize certain types of network traffic to provide better service and lower latency
  - QoS Queues only take effect when there is network congestion
  - DSCP (Differentiated Services Code Point) (DiffServ = differentiated services)

Dante DSCP Values for QoS

Priority	Usage	DSCP Label	Hex	Decimal	Binary
High	Time critical PTP events	CS7	0x38	56	111000
Medium	Audio, PTP	EF	0x2E	46	101110
Low	(reserved)	CS1	0x08	8	001000
None	Other traffic	BestEffort	0x00	0	000000

Tips

- Separate networks where useful or required by AVL technology specifications
  - Dante doesn't work on same network with Clearcom Helixnet
  - Audinate recommends not using wireless on same network as Dante devices
  - If sending multicast video, the traffic will be quite large and may require separate network from data or voice
    - Extron NAV 1G Codecs ~ 800Mbps per multicast stream
  - Audinate recommends using separate dedicated switch for Dante Secondary redundancy and not VLANs
- Use minimum number of networks necessary – don't overburden yourself with too many networks
- Separation of AVL control data is recommended from AVL media data
  - Separation of control network from media networks is recommended
  - Connect control network to wireless network for wireless control of mixers, etc
  - ETC does not recommend connecting lighting network (ETCNet) to other networks, but can have advantages

Links

- https://pro.focusrite.com/configuring-a-switch-for-dante
- https://www.audinate.com/learning/cisco-switch-configuration-guide
- https://www.clearcom.com/DownloadCenter/technicaldocs/HelixNet_IP_Networking_Guide.pdf
- https://support.etcconnect.com/ETC/Networking/General/Network_Design
- https://www.audinate.com/learning/training-certification/dante-certification-program
- https://www.smpte.org/smpte-st-2110-faq
- https://www.ndi.tv/
- https://avnu.org/

Thanks for joining us!

- Chris Moody
  - Director, IT/AV and Innovation
  - cmoody@faylib.org

Find more classes and information about the Center for Innovation at:
www.faylib.org/innovation

Download this slideshow from the CFI's resource page at:
www.faylib.org/center-for-innovation-resources