MOREnet

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Networking Essentials

Josh Noble

MOREnet Network Consulting

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Quickly --- About Me

- Hello! I am Josh Noble
- I have 20 years in IT
- Started career at an ISP and working at a school district that was also a MOREnet member!
- Been at MOREnet for 5 years
- Loves pinball, playing, fixing, staring at, dreaming about…
- Enjoys Halloween, mostly for the GM Monster Cereal!
- josh@more.net

What We're Doing This Morning

- High level overview of many networking subjects, including some tips and tricks
- If you have questions, we will have time at the end of each section
- Any super crazy advanced questions, find me or one of the other MOREnet Network Consultants during the Tech Summit
- Audience participation is highly encouraged and will be rewarded!
- Yes, we will most certainly have a break

Shameless MOREnet Network Consulting Plug

- What we do?
- How we do it?
- How to reach us?
  - help@more.net
  - 573-884-8694
  - Put case in on MyMOREnet
- Who can work with us from your organization?
- How often can you work with us in Network Consulting?

Networking Protocols

- What is a protocol?
  - Simply put, it is a set of rules that defines something
- How does this apply to networks?
  - Set of rules that defines how data is transmitted over a network
- Example Protocols
  - TCP, UDP, IP, HTTP, DNS, FTP
- What is your favorite protocol?

Why Do We Need Protocols?

- Establish and terminate connections
- Define what format data is transmitted
- Helps determine what to do if errors take place and what to do if data gets lost
- Allows us (humans) to see the data

Why Do We Need Protocols?

Network Devices

- Switches
  - Layer 2 are most common
  - Layer 3 if you need routing on the switch
- Access Points
  - Layer 2
- Routers
  - Layer 3
- Firewalls
  - Layer 3

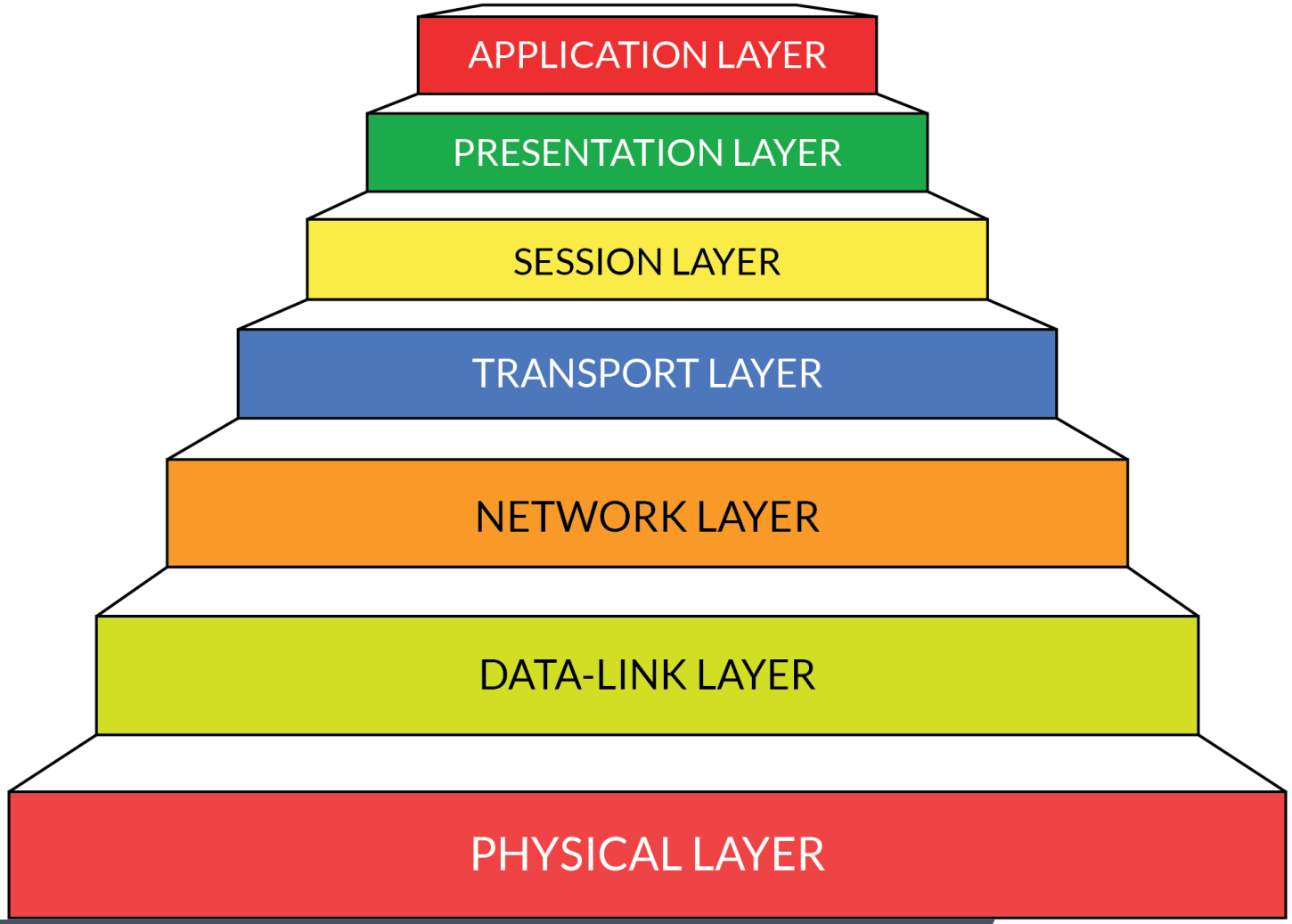
Networking Models

- OSI Model
  - Open Systems Interconnection
- What is it?
  - A standardized and layered way to describe the flow of network data
- Why do we need it?
  - Helps us troubleshoot network issues and understand how networks work. Most troubleshooting occurs in layers 1-4

OSI Model Layers – In a Nutshell

- 7 Different Layers
  - Application – Allows access to network resources
  - Presentation – Translates, encrypts and compresses data
  - Session – Establish, manage and terminate sessions
  - Transport – Provides reliable data delivery
  - Network – Move packets from source to destination
  - Data Link – Organizes bits into frames
  - Physical – Transmits bits and physical connections

OSI Model



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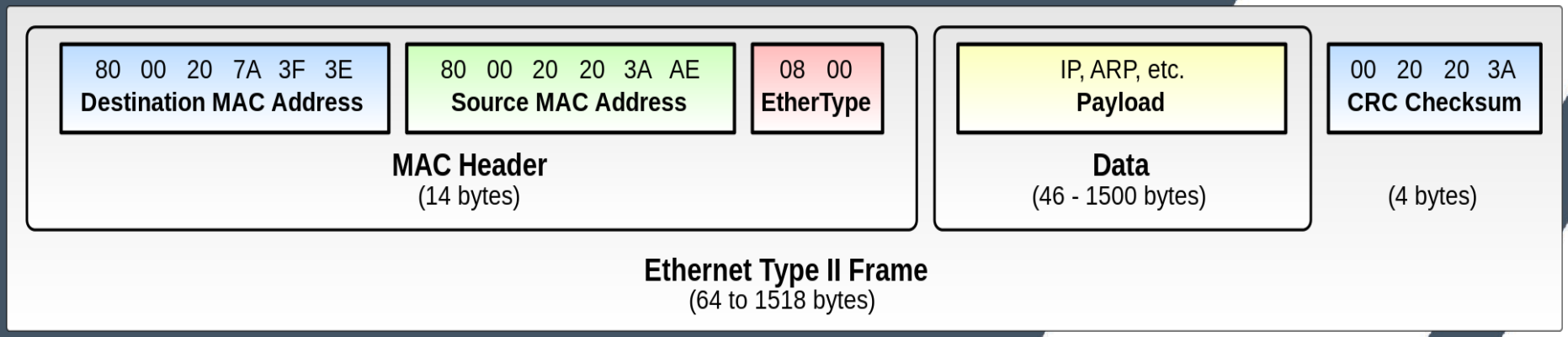
Layer 1 - Physical Layer

- Bits and Bytes live here
- Network Interface Card (NIC)
- Electrical signals are sent. Charge is a 1, no charge is a 0
- We start simple, the network cabling. Is your device plugged in? Is your cable good?
- This is often overlooked as we typically assume our cables are good, but they do indeed go bad. Keep spares handy!
- MAC address vendor lookup tool https://www.wireshark.org/tools/oui-lookup.html

Layer 2 – Data Link

- MAC Addresses
  - Unique hardware address that every network interface card (NIC) has
- Ethernet Frames live here https://en.wikipedia.org/wiki/Ethernet_frame
- Most switches are layer 2
- Access Points
- Troubleshooting? Device plugged in, good cable, but still can't see other devices on the network? Look for link lights on NIC and switch that it is plugged into.
- *arp - a* from a command prompt shows arp cache on a Windows device



Layer 3 - Network

- Routing occurs here
- IP addresses (we will go more in depth on them later)
- Layer 3 switches (switches that can do routing)
- Packets live here https://en.wikipedia.org/wiki/Network_packet
- Troubleshooting? Do you have an IP address (*ipconfig*)? Can you PING another device?
- *Nslookup* to translate hostname to IP address

Layer 4 – Transport

- TCP and UDP
- TCP is a connection-oriented protocol. Cares about data getting to destination and retransmits if any data is lost
- UDP is connectionless. Cares about getting there quickly
- Both use certain ports for certain applications that we will talk about later
- Our packets get organized (segmentation,) and reassembled here

Layer 5 - Session

- How your computer/device handles multiple applications using the network at the same time
- Termination of connections

- *netstat –a* can show you sessions from a command prompt!

Layer 6 - Presentation

- Data Conversion and formatting
- Some encryption
- Compression
- Presents to the Application Layer
- JPEG, MIDI, GIF, etc

Layer 7 - Application

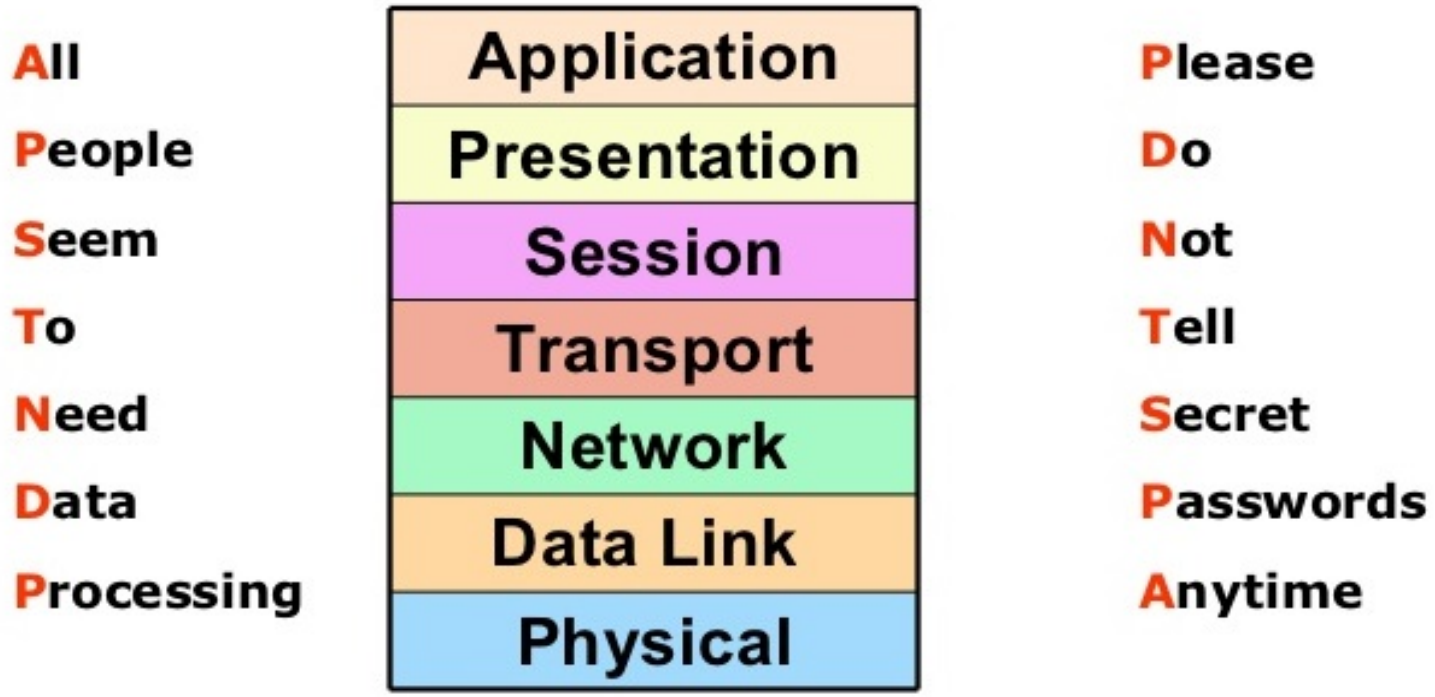
- The most visible part of the network for end users
- Email applications, web browsers etc.
- Buzzword time! *Layer 7 Firewall*. Firewall that can sort traffic based on applications

For Fun – Layer 8 – The User Layer

- Problem that exists between the keyboard and the chair
- Can't get to Facebook, so internet must be down
- Is not sure why their computer is soooo slow
- Once brought in home router, plugged in, and brought down the entire network…

Remembering the Layers

- Here are a couple of mnemonics to help



Troubleshooting with OSI

Which layer does each step belong to?

- Is it plugged in?
- Is there a link light?
- Do you have an IP address?
- Can you ping your gateway?
- Can you ping your DNS server?
- Can you ping the hostname of your website?
- Can you open the website in another browser?

OSI MODEL QUIZ TIME!!!!

- Hope you paid attention!
- We need a 90% or better to get lunch!
- http://www.gocertify.com/quizzes/osi/osi-1.html

OSI Model Links

- OSI in action http://www.rebeladmin.com/2014/06/osi-in-action/
- Layers of OSI Model Explained https://www.guru99.com/layers-of-osi-model.html

OSI Conclusion

- Unless you plan to take a network certification test, I would recommend focusing on the first 4 layers to aid in troubleshooting
- Any questions on OSI?

IP Addressing

- IP addresses are a 32 bit sequence of 1s and 0s
- It is a way to identify devices on a network
- Each group of 8 bits is called an octet
- Examples –
  - 192.168.1.150
  - 150.199.8.1
  - 8.8.8.8
  - 11000000.10101000.00000001.11001000
- IP to binary calculator https://miniwebtool.com/ip-address-to-binary-converter/

How Does Your Network Use IP Addressing?

- Do you have static IP addresses on your network? (Do you have to manually assign an address every time you get a new computer)?
- Do you have a DHCP server that handles all of your IP addresses? This is usually a Windows server or your firewall (Do you simply plug a new computer into your network and it can get to the internet)?
- Do you know your IP scheme and subnet mask?
- We can help you determine this if you aren't sure
- Subnet Calculator - https://www.calculator.net/ip-subnet-calculator.html

Dynamic Host Configuration Protocol (DHCP) Server

- One of the most important roles on your network
- DHCP server enables computer to request IP address and other parameters (DNS, Gateway, lease time, etc.)
- Typically resides on server, firewall, or router
- Uses Bootstrap Protocol (BOOTP)
- DORA – Discovery, Offer, Request, Acknowledgement
- https://en.wikipedia.org/wiki/Dynamic_Host_Configuration_Protocol

Public vs Private

- Public IP addresses are limited. There are about 4.3 billion that can be used
- There are about 7.8 billion people in the world
- Private IPs are what most of us use on our local area networks
- IPv6 give us many more public addresses, but is not widely used yet by smaller networks. **340** undecillion IP addresses. 340,000,000,000,000,000,000,000,000,000,000,000,000
- Find out what your public IP address is https://www.ipchicken.com/

IP Troubleshooting

- Make sure your device is getting an IP? Use ipconfig to verify.
- Can you ping other devices on the network? Use PING
- Can you ping the gateway?
- Can you tracert to host?
- Commands for troubleshooting – ipconfig /all – ipconfig /flushdns - ping 8.8.8.8 - tracert amazon.com and then amazon.co.uk to compare
- WHOIS IP Lookup - https://www.ultratools.com/tools/ipWhoisLookup
- Angry IP Scanner – Scans specified subnet to show what IP addresses are taken https://angryip.org/

Troubleshooting Example

Will the PC be able to reach the server?

Server IP – 192.168.0.250
Subnet – 255.255.252.0
Gateway – 192.168.1.254

PC IP – 192.168.2.100
Subnet – 255.255.255.0
Gateway – 192.168.1.254

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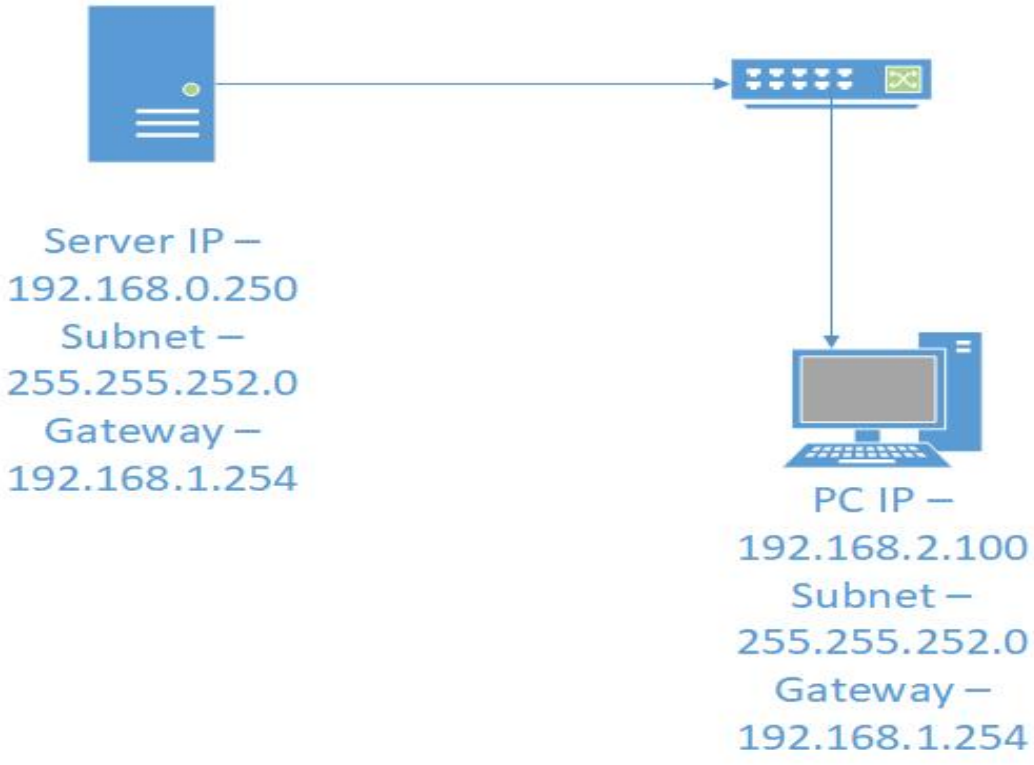
Troubleshooting Example

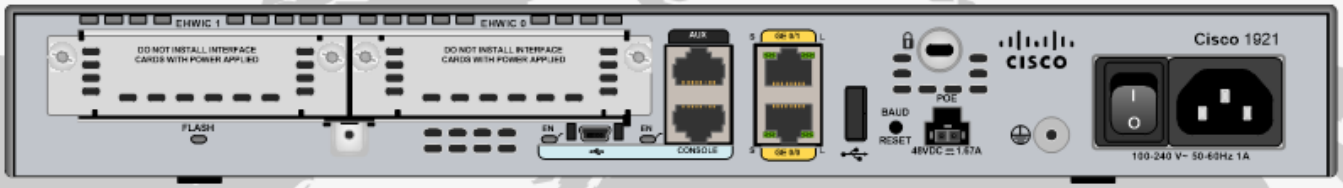
Now will the PC be able to reach the server?



Network Address Translation (NAT)

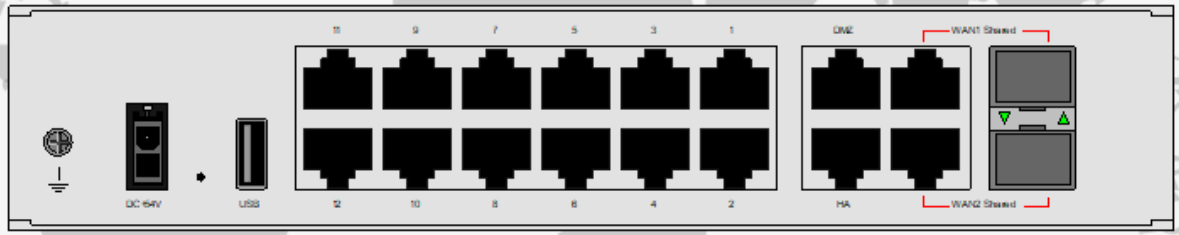
- In order to allow us all to get on the public internet, most of us use NAT
- NAT allows you to only use one public IP address for ALL of your devices
- NAT'ing is typically done on your firewall
- PAT (Port Address Translation) is used to gain access to servers etc from outside your network

EXAMPLE OF TYPICAL NAT



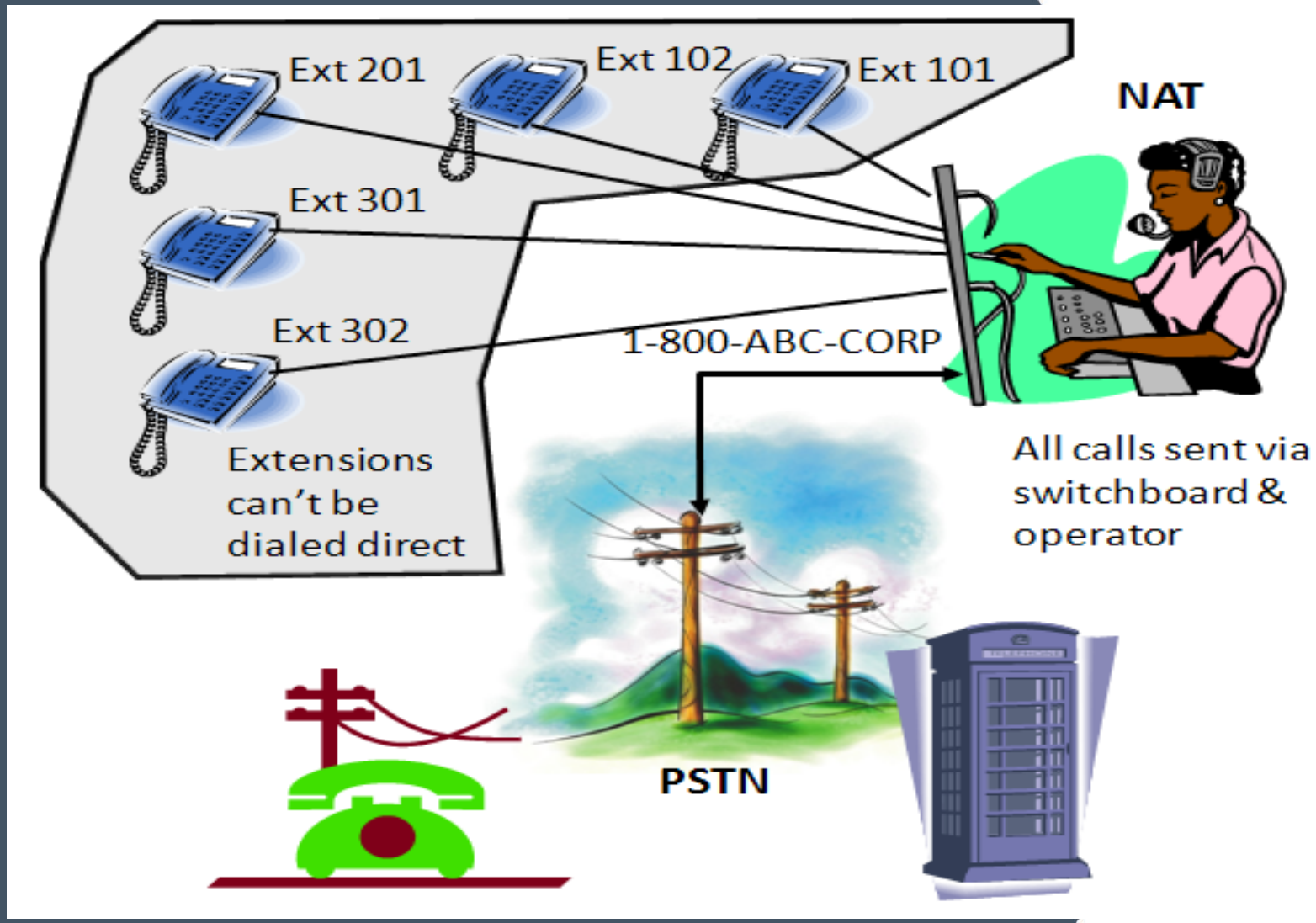
MOREnet Router – 150.199.8.254

Library Firewall Outside (Public IP address)– 150.199.8.253



Library Firewall Inside (Private IP Address using NAT) 192.168.1.254

Library switch


Ext 201
Ext 102
Ext 101
NAT
Ext 301
Ext 302
1-800-ABC-CORP
Extensions can't be dialed direct
All calls sent via switchboard & operator
PSTN

IP or NAT Questions?

TCP and UDP Ports

- Certain network protocols used certain TCP/UDP ports
- Important for firewall troubleshooting
- 65535 possible TCP and UDP ports
- 0-1023 are well known ports
- Example – https://www.google.com:***443***

Common TCP/UDP Ports

Here are some worthy TCP ports to remember!

- HTTP – 80
- HTTPS – 443
- SSH - 22
- SMTP – 25

UDP Ports to remember:

- DNS – 53
- NTP – 123
- https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers
- Anyone have any unique ports that they have had to open up for certain education testing or other websites?

QUIZ TIME!

- TCP/UDP Port Quiz
- Let's see how we do
- 82% or better for free lunch, otherwise organizations that start with the letter "C" will be buying!
- https://www.examcompass.com/comptia-network-plus-certification-exam-n10-007-tcp-and-udp-ports-quiz

Any Other Questions?

- Any additional questions or challenges that you are facing?
- Any good TCP/IP stories?

Wireless Networking

- 802.11 is a standard that defines how wireless devices connect and how to secure the connection
- IEEE sets these standards
- Are you familiar with all the different types? 802.11a/b/n/g/ac/ax?
- Wi-Fi numbers now correspond with each 802.11 standard to make it easier for average users to understand

Wi-Fi Versions

- Wi-Fi 1 = 802.11b - 1999
- Wi-Fi 2 = 802.11a - 1999
- Wi-Fi 3 = 802.11g - 2003
- Wi-Fi 4 = 802.11n - 2009
- Wi-Fi 5 = 802.11ac - 2013
- Wi-Fi 6 = 802.11ax - 2019

Wireless Frequency

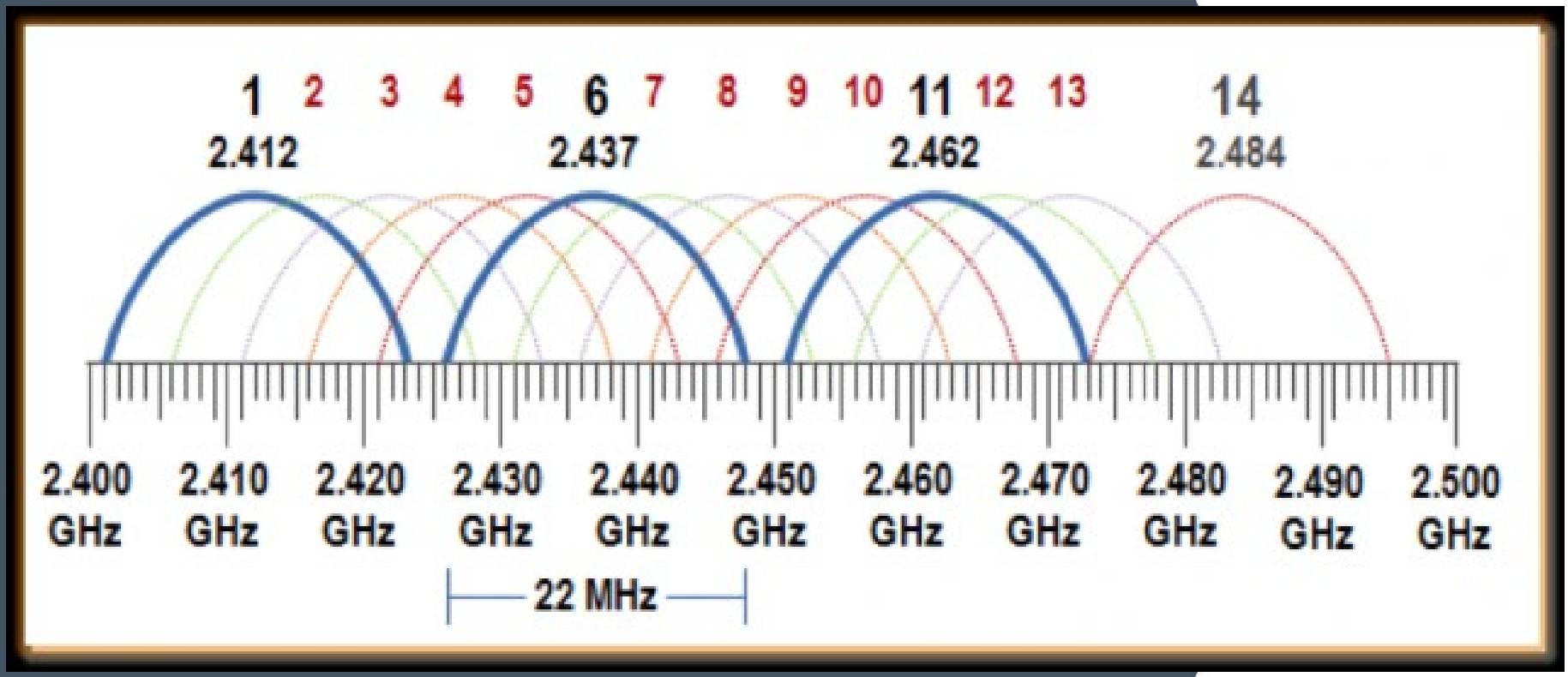
- There are two frequencies that wireless networks run on – 2.4GHz and 5Ghz
- Do you know what frequency your wireless network is running on?
- Do you know what advantages and disadvantages there are for both?

2.4GHz vs 5GHz

2.4 GHz Advantages/Disadvantages

- Only 3 usable channels available for Wi-Fi
  - 1, 6, and 11
- Other devices can interfere
  - Microwaves, cordless phones, garage doors etc
- Speeds not as fast
- May need to turn off 2.4 radios in densely deployed areas
- Can penetrate walls/objects

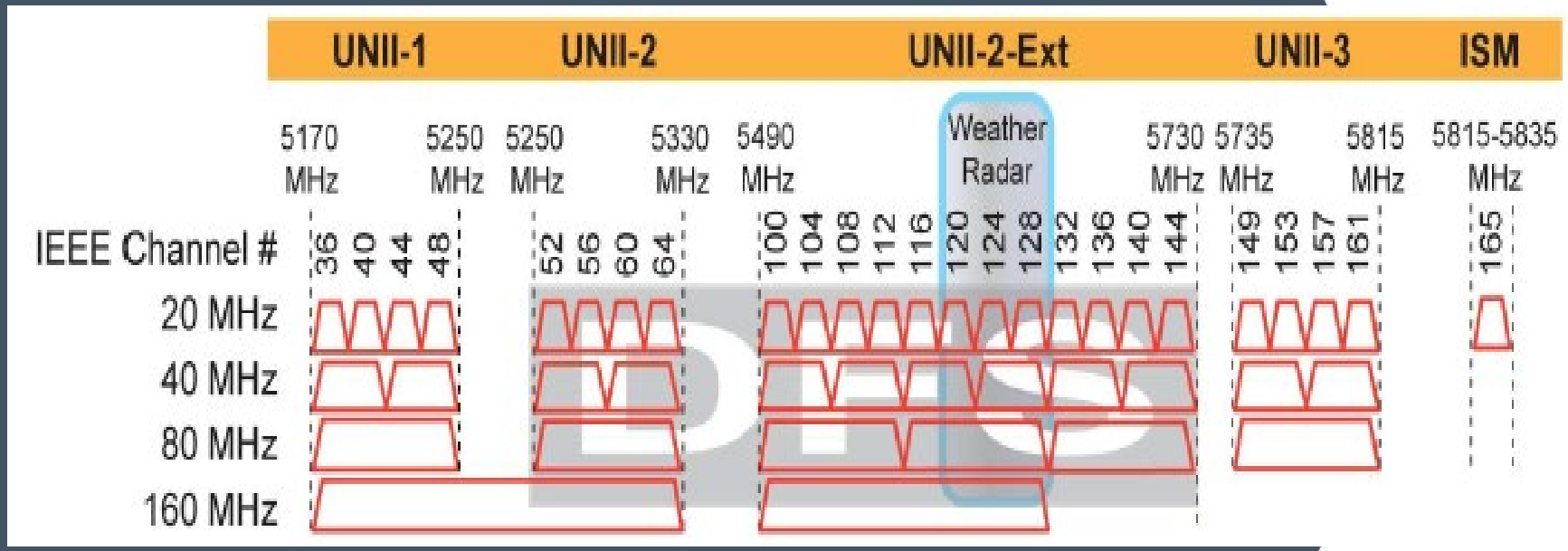
2.4 GHz Channels



5Ghz Advantages/Disadvantages

- Instead of the 3 available non-overlapping channels that 2.4 offers, 5GHz gives us 23
- With all those channels we can start bonding, so we can combine up to 8 channels for faster speeds (don't do this!!!)
- Does not travel as far as 2.4GHz
- Attenuation is greater on 5Ghz (does not penetrate walls as well)

5GHz Channels



Dynamic Frequency Selection (DFS) Channels

- Channels 52-144 are DFS Channels
- These channels are shared with radars and may or may not be available to use
- Your APs and wireless controller will detect if these are used and if not, you can use them
- If channels are in use, your AP can move to another channel automatically (kicks clients off)
- You will probably need to go to the settings on your controller and enable "Use DFS Channels"
- Tons of info on DFS here http://wifinigel.blogspot.com/2018/05/the-5ghz-problem-for-wi-fi-networks-dfs.html
- List of WLAN channels - https://en.wikipedia.org/wiki/List_of_WLAN_channels
- FCC Info - https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?switch=P&id=27155

Wireless Interference

- When more than one AP use the same channel as another one in close proximity, it can cause interference
- Interference can cause major slowness on your wireless network
- If using 2.4 band, make sure to come up with a channel plan
- Most wireless controllers can do the channel planning and power settings automatically, even with that, we often still see interference in densely deployed areas

Wireless Interference cont.

- Let's take a look at what kind of wireless APs we can see from here.
- There are many free Wi-Fi Analyzers. We are going to use Acrylic's free version.
- https://www.acrylicwifi.com/en/downloads-free-license-wifi-wireless-network-software-tools/

Wireless Controllers

- Can handle the configuration of your access points
- Can adjust channels and power to detect and avoid interference
- Can be hardware or cloud-based

Wireless Security

- There are a few different types of wireless authentication that we run into
- Open System Authentication
- PSK (Pre-Shared Key) is the most common
- PPSK – Private Pre-Shared Key
- MAC address Filtering
- 802.1x – Uses RADIUS, transparent to users

Proper Installation of APs

- How are you installing your access points?
- There are ceiling and sometimes wall mounts available for enterprise grade access points
- Will you have one in each classroom?

Wireless and Building Materials

- Did you know that the material that your walls/ceilings/floor are made out of can drastically affect your wireless coverage?
- Concrete and metal are the worse for your wireless signal
- Drywall won't absorb too much
- 2.4GHz won't have as many issues penetrating building material

Using a Wireless Planning Map

- Most wireless controllers come with an option to create a planning map
- You will need a floorplan that is to scale
- Let's look at the MOREnet office and play around with our Extreme/Aerohive controller

Wireless Site Survey

- Can be useful if you have dead zones or areas where you suspect there is a lot of interference.
- MOREnet offers these as a for fee service. We have a NetScout (Fluke) Optiview XG.
- If you just have a small area and want a free DIY option, look at Ekahau HeatMapper
- https://www.ekahau.com/products/heatmapper/overview/

Useful Wireless Terms

- MIMO – Multiple Input, Multiple Output
- MU-MIMO – Multi Users, Multiple Input, Multiple Output
- Spatial Stream – Independent and separately coded stream
- 2x2, 3x3, 4x4 – Number of antenna supporting number of spatial streams
- RSSI – Received Signal Strength Indicator – Your wireless signal strength. Strive for -67dBm or better
- SNR – Signal-to-Noise Ratio – Difference between received wireless signal and noise floor
- There will be links at the end for each of these terms!

Powering our Access Points

- How do we power those properly mounted access points that are in the ceiling?
- We need either a Power Over Ethernet (PoE) enabled switch, or wireless power injectors
- PoE switch is the preferred method

Power Over Ethernet

- Enables your network cables to carry low voltage power
- You only need one cable for data and power
- Can power your access points, VOIP phones, cameras etc.
- 802.3af is standard Type 1 PoE
- 802.3at is Type 2 and is often referred as PoE+
- Can transmit up to 100 meters (328 ft)

PoE Tips

- When purchasing a PoE switch make note of how much power will be used by all of your devices, this is noted as PoE power budget
- Your switches power budget is the maximum amount of power that can be dispersed to your switch ports
- Check specs on your access points and the switch itself
- 802.3af PoE can give you about 15 Watts per port
- 802.3at PoE+ can give you 30Watts per port
- PoE Calculator http://poe-world.com/Calculator/
- HP/Aruba command example for budget
- https://techhub.hpe.com/eginfolib/networking/docs/switches/WB/15-18/5998-8162_wb_2920_mcg/content/ch03s05.html

Questions?

- Any questions on wireless and PoE?
- Any interference or other horror stories to share?

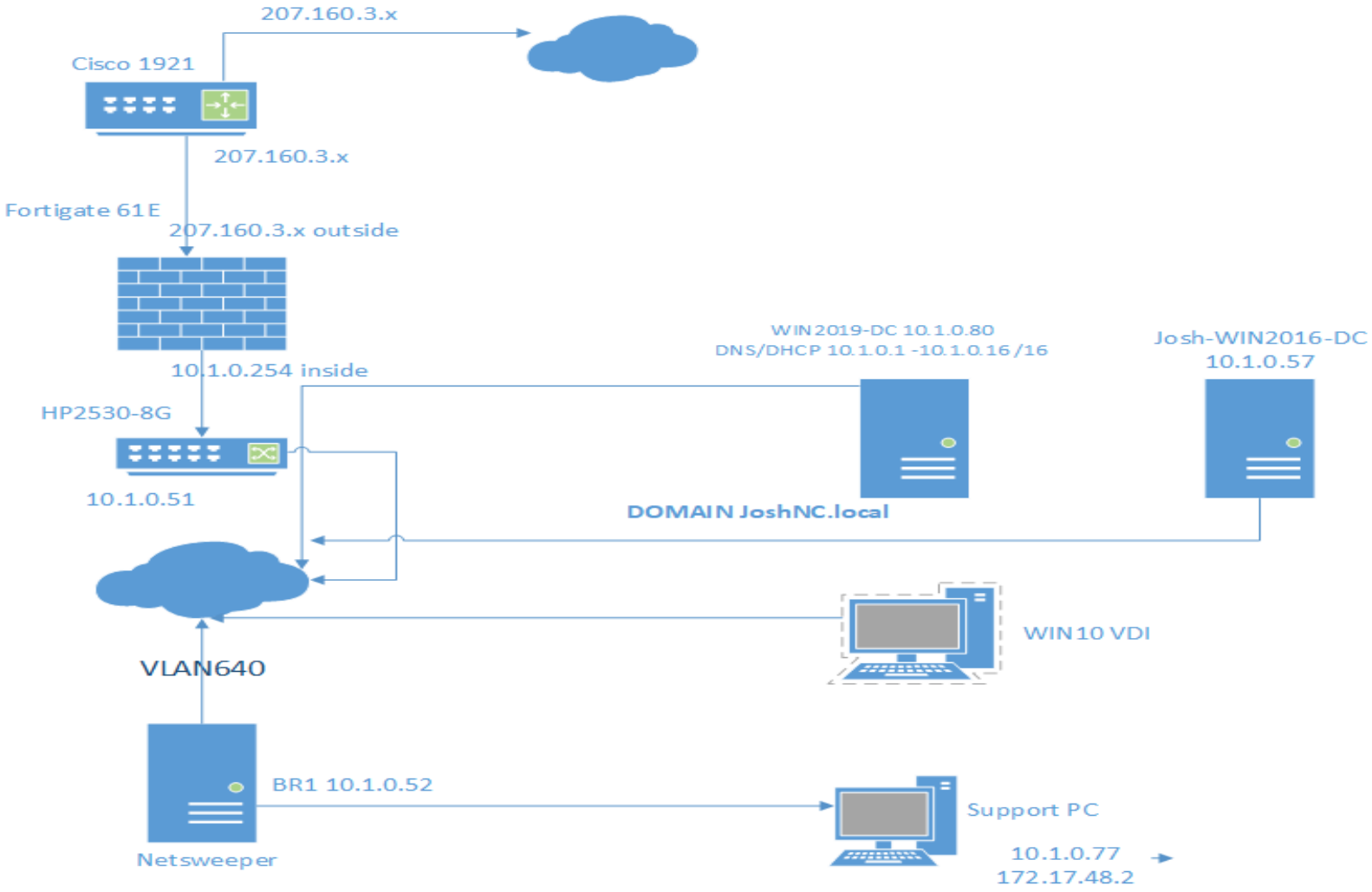
Wireless Links

- Spatial Streams Explained https://www.digitalairwireless.com/articles/blog/wi-fi-spatial-streaming-explained
- MIMO and MU-MIMOhttps://www.pcworld.com/article/2928725/how-mu-mimo-wi-fi-works.html
- SNR and RSSI - https://community.arubanetworks.com/t5/Controller-Based-WLANs/What-is-the-relationship-between-data-rate-SNR-and-RSSI/ta-p/178312

Network Documentation

- Do you have documentation on your network?
- What things are you documenting?
- We will discuss items that are helpful to have and will expedite your troubleshooting efforts

Network Diagrams



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Network Diagrams cont.

- Document major devices and IP addresses etc.
- Servers and their roles
- Microsoft Visio most common

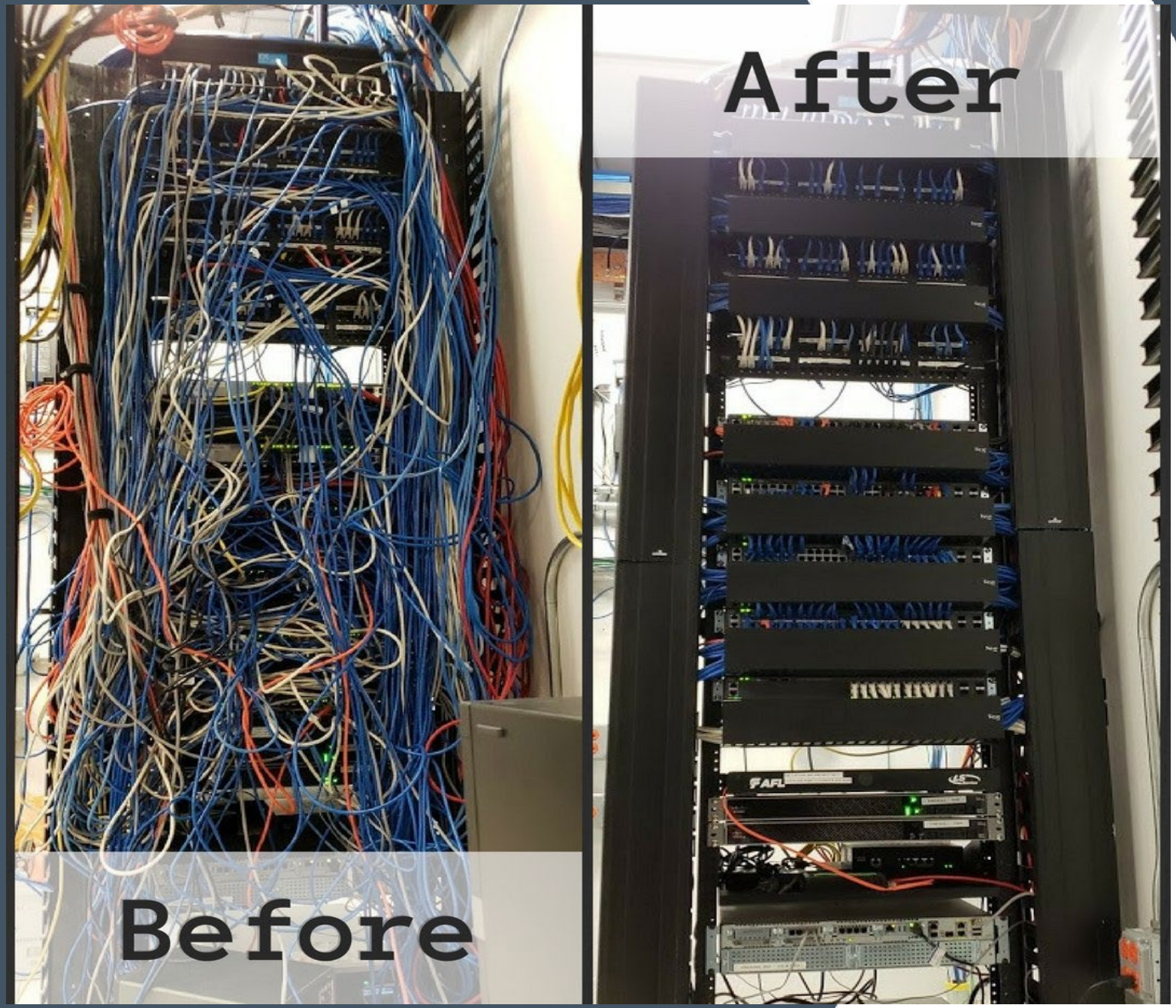
- Two free options
- https://cloud.smartdraw.com/
- https://draw.io

Helpful Documents

- Have all static IP addresses documented, both public and private
- Label and document all network drops and switch ports
- Document when licenses expire as well as when support contracts are due
- Keep this up to date!

How Organized is Your Network?

- Are you a before or an after?



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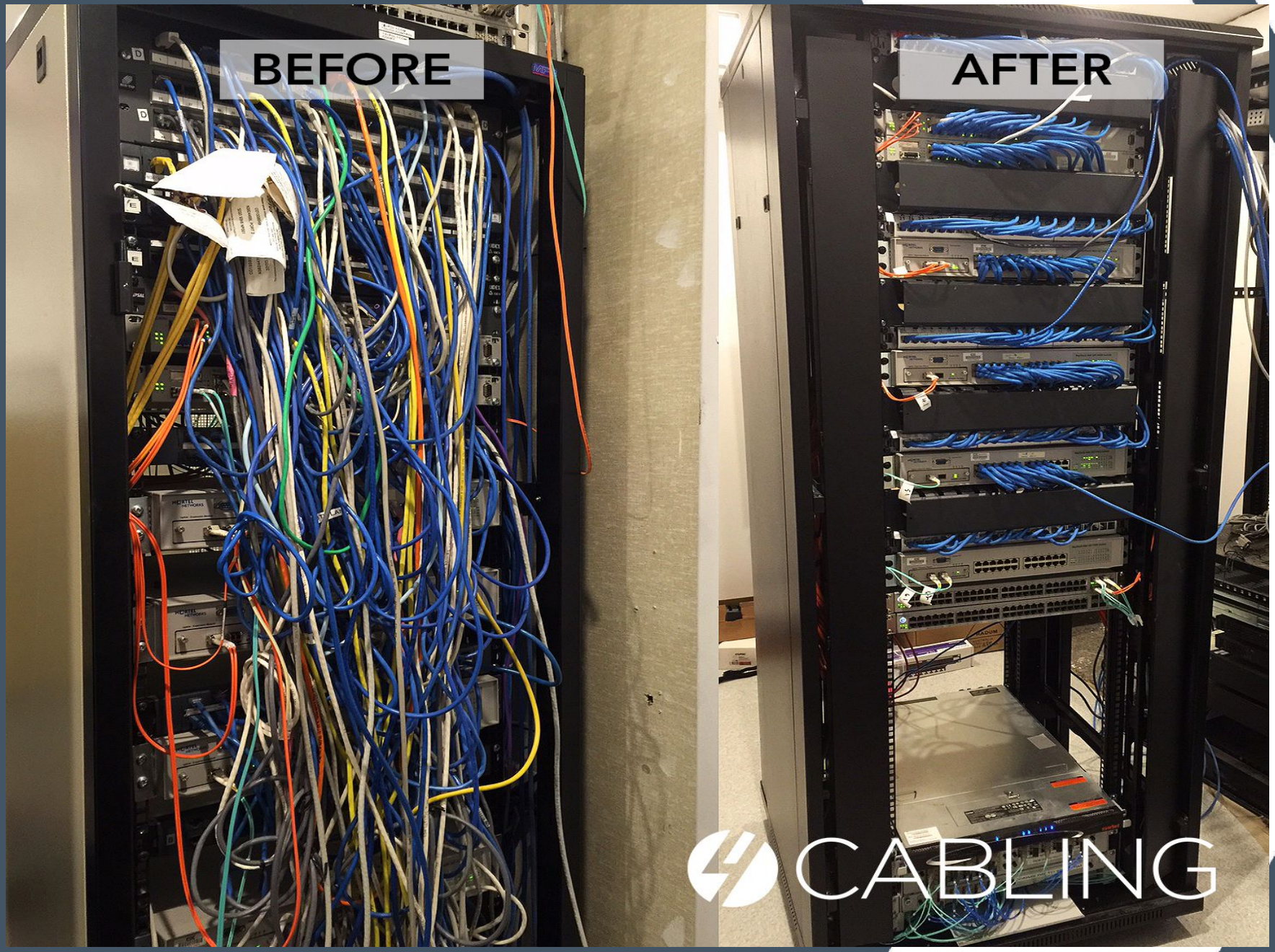

CABLING

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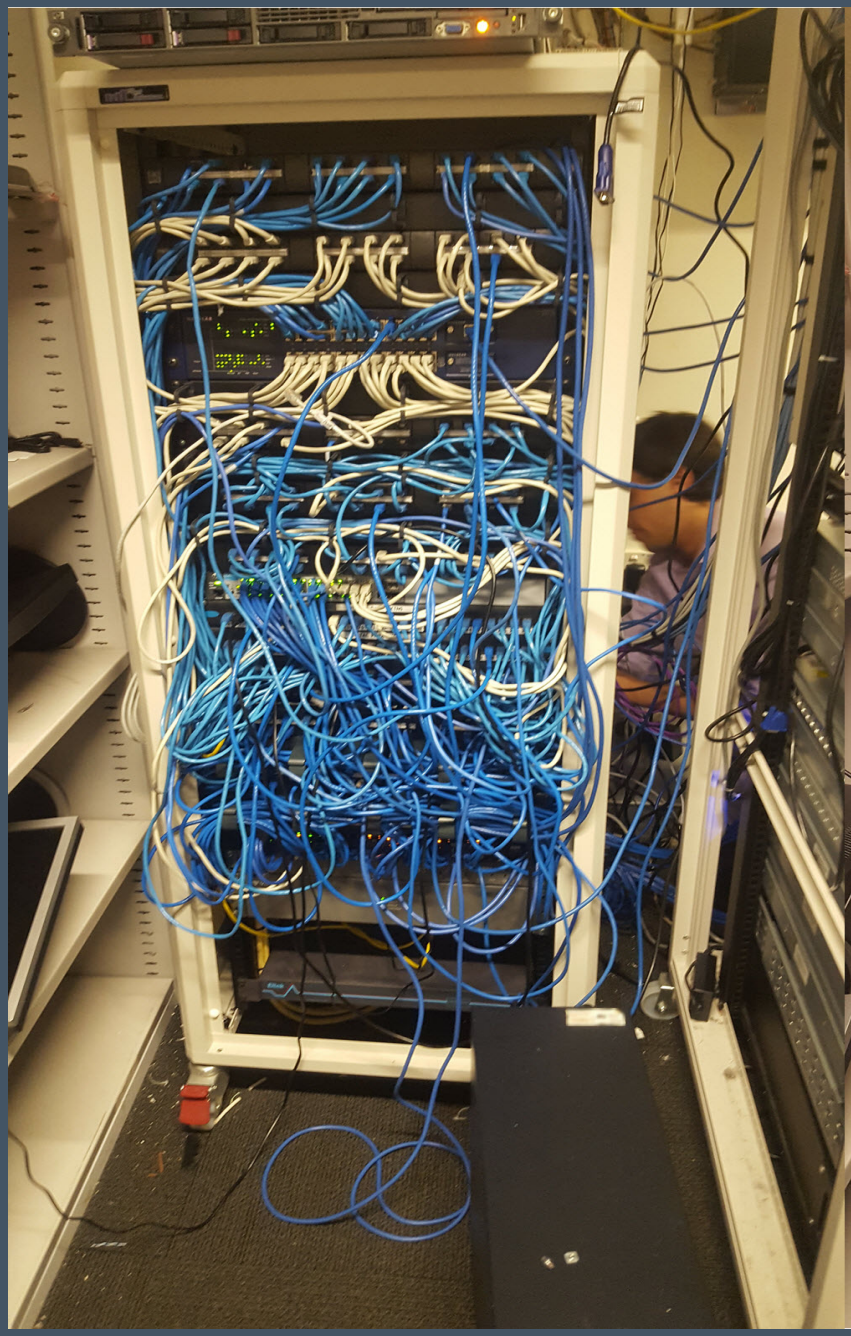

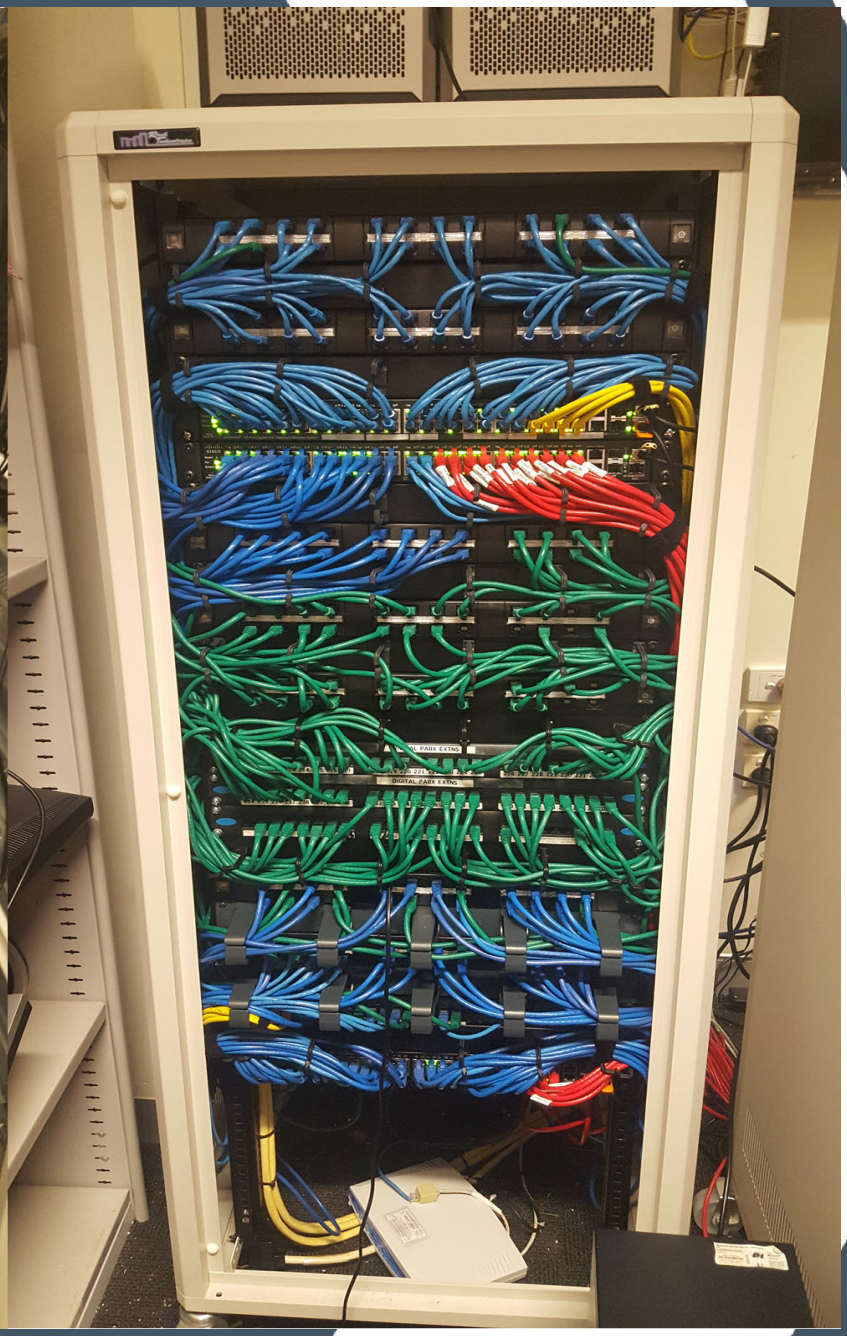

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Network Organization

- Hopefully your network is more like the “after” in examples
- Do you have a rack or racks for your network gear?
- Do you have vertical and horizontal cable management?
- If you answered no to either of these, please consider adding to your budget
- If someone else manages the network, consider having them strive towards our “after” examples

Data Center, NOC, Server Room Best Practices

- Whatever you call it…it needs certain items to be "happy"
- Do you have separate A/C for your room?
- Do you have adequate power and use UPS's?
- Who has access to your room?
- Any sensors to detect overheating or water?

Group Discussion -How Are You Doing Content Filtering?

- Let's discuss different ways of doing your web/content filtering
- Do you have a dedicated filter, or a NGFW (Next Gen Firewall?)
- Are you filtering devices that go offsite?
- What vendors have been the best? How about the worst?
- Are you filtering HTTPS? How are you dealing with certificates?

Thanks for your time!

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