ECE 435 – Network Engineering
Lecture 33

Vince Weaver

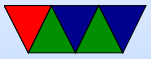
https://web.eece.maine.edu/~vweaver

vincent.weaver@maine.edu

20 April 2026

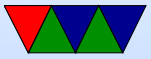
Announcements

- HW#11 was posted (last one)
- Title II warning
  Possibly all notes on the website might go away as of April 24th
- Don't forget course reviews
- Will send out preliminary project presentation schedule
  Everyone wants to present Monday, unusual
- Trying to catch up on grading homeworks



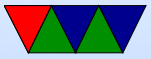
Connecting switches together

- Can chain switches together (TODO: diagram)
- Why? Because large-number of ports expensive?
  Redundancy?
  Bonding (combine connections for more bandwidth)
- What happens if loop?



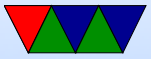
Spanning Tree Protocol

- Invented by Radia Perlman at DEC
- Can have problems if cause a loop in the topology. Frames can circulate loop forever
- Why have a loop then? Redundancy.
- https://spectrum.ieee.org/how-dec-engineers-saved-ethernet

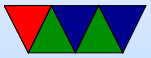


Spanning Tree Protocol – 802.1D

- (aside, case matters in IEEE specs, uppercase 802.1D means standalone, lowercase like 802.11b means update)
- Each switch and port assigned an ID with priority
- Each link assigned a cost, inversely proportional to link speed
- The lowest ID gets to act as root (there is a protocol on how to elect the root)
- Each LAN connected to upstream port in active topology, called the dedicated port. Receives from root port

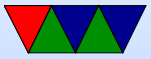


- Config info comes from root as bridge protocol data unit (BPDU) on reserved multicast address 01:80:c2:00:00:00
- Switch may configure itself based on BPDU.
- BDPU sent every 2 seconds
- Can take 30-50s to notice failure



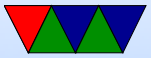
Rapid Spanning Tree Protocol – 802.1w

- Modern replacement
- Can detect failure in milliseconds



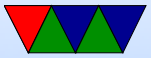
Bridging 802.11 to 802.3

- Your wifi router probably does that
- Need to strip off one header, put new one on
- Need to put fields in as needed, recalc checksum, etc
- What if bridging faster net to slower one
- What if maximum frame size different on different LANs? Can't always fragment
- What if one has encryption and one doesn't
- What of quality of service?



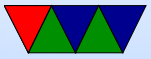
Splitting up LANs

- In a small lab / house / apartment might be OK for everyone to be on same LAN
- What about in large organizations / companies / universities?

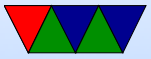


Why might you want to split up LANs

- Bandwidth concerns
- Different groups, privacy/security
  Even if a switch, can sometimes still leak traffic (broadcast, multicast, traffic before self-learning kicks in)
- Security: put not-trusted devices (IoT, guest network, externally visible servers) on a separate network (DMZ) from your core critical internal machines
- Equipment costs

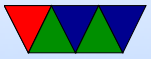


- Distance
- Reliability (equipment failure)
- Load – two groups, one not happy if other group takes up all bandwidth
- Broadcasting – when asks for a connection, broadcasts to all broadcast storms – entire LAN brought down with all machines broadcasting



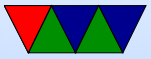
Configuring LANs (in the old days)

- All ethernet sockets in building come into "wiring closet"
- Each line terminated in a patch panel which has rj45 connector + and hopefully a label
- Wiring closet also have racks of routers, one for each LAN
- Often not all sockets wired up by default
- Could make request to IT to wire socket to specific network
- I had a job in grad school where I had to go to wiring



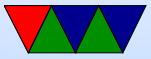
closet, find a patch cable, and “patch” the right socket to the correct router

- Could this all be done in software instead?



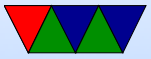
VLAN

- How to switch machines between networks? Request? Someone in wiring closet?
- Physical LAN
- What if want to partition a switch so some nodes are on one and one on another (virtual LANs)
- Ideally get fancy VLAN-equipped routers and have each socket wired to a port in a router
- Which port on which LAN configured remotely through a management (web?) interface



802.1Q

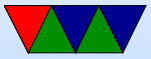
- IEEE 802.1Q (dot1Q)(?)
- can have priority
- link aggregation, combine two links for higher bandwidth
- how to bridge VLANs?
  - special VLAN field in Ethernet frame
  - priority, CDI (makes connectionless interface have some manner of connection)
  - Changes Ethernet frame, but only between bridges. Endpoints don't see modified frames



- Adds 32-bit field between SRC and Ethertype.

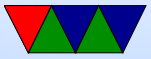
16 bits	3	1	2
TPID	TCI		
	PCP	DEI	VID

- Tag Protocol Identifier – 0x8100, same location as ethertype so it tells that it's special VLAN frame
- PCP – priority code point
- DEI – drop eligible indicator (OK to drop frame)
- VID – VLAN Identifier



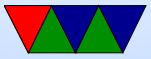
What about VPNs?

- Virtual Private Networks
- Let you encapsulate traffic on local network and have it tunnel to another network
- Can happen at either level2 or level3
  - Level2 – Ethernet frames from local network tunnel to remote and appear as if on same Ethernet
  - Level3 – IP traffic on local network appear as if local on another network



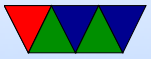
Why have a VPN

- Join two networks if actual connection not possible (usually due to distance)
- Security, access remote networks purely internally, besides the encrypted tunnel packets not visible to outside world
- Censorship avoidance, let you browse the web as if from a different country
- Content block avoidance, view movies/streams not available in your area



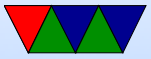
Cellphones

- Today most people's interactions with computer networks are through cellphones
- Have gotten increasingly complex
- What was life like before cellphones?
- Hard to keep up as things are constantly changing

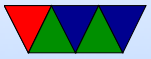


Cellphone Hardware

- RF hardware
  - Antennas – possibly many on modern phone
    1-2 Wifi, 1 bluetooth, 1 for GPS, 1-4 for 4G LTE
  - DSP
  - Baseband processor, with own RAM, running RTOS
- Application Processor
  - Separate from the RF side, for both security and regulatory reasons, don't want rogue code having access to transmitter

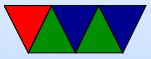


  - These days powerful ARM processor running apps and such
  - Running OS, ios, on Android it's Linux
  - TODO: which is wifi/bluetooth hooked up to?
- Other: camera, battery, etc.



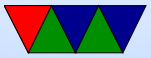
Cellphone SIMs

- Holds info on your account/phone, including phone number, company, billing, etc, encryption keys
- Has room for 8-256k of data, in old days could hold things like contacts and texts (these days, not as much)
- Different sizes, mini, micro, nano
- Some phones can support multiple (two numbers / accounts with one phone)

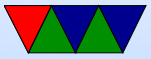


Cellphone eSIMs

- To save space, have permanent SIM soldered to motherboard, programmable via software?
- `https://arstechnica.com/gadgets/2023/04/isim-vs`
- Benefits of eSim
  - No card to lose
  - Hard to damage
  - Smaller
- Downsides
  - Cannot change w/o tech support

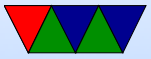


- If broken phone can't just swap to new one
- Have to wipe before sell phone



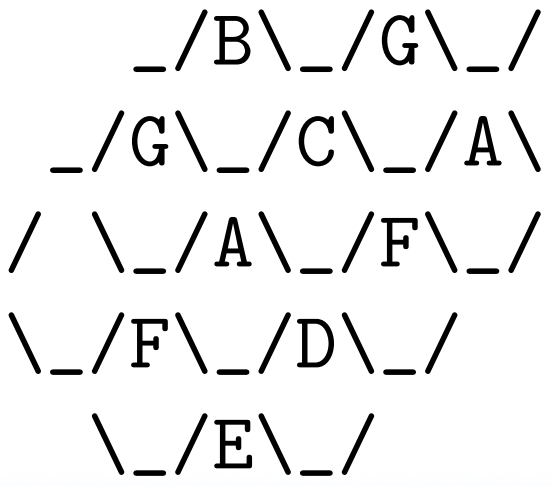
Phone Numbers

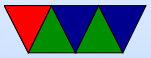
- How do you identify phone? Unique ID?
- Phone number history
  - 5 digits (old fashioned KL5-1234)
  - 7 digits
  - 10 digits with area codes
  - Number portability confuses this all
  - Other countries might be a bit different. Country codes. US is just 1



Cellphones – Cells

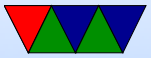
- Geographic area split up into cells
- Each cell uses a frequency different than neighbors
- Smaller cells, lower power more users





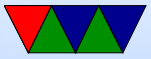
Cellphones – Infrastructure

- Center of each cell is base station
- Maybe seen them. Tower, 3 vertically parallel bars
- Hilltops? Giant towers? Fake Trees? Churches? Side of student union
- Transmitter/Receiver
- Connected to MSC (mobile switching center) or MTSO (Mobile Telephone Switching Office)
- Backup diesel generators



Cellphones – Handoff

- Need to transparently handle moving between cells without dropping call (or noticeable glitch)
- Tricky
- How they do it has changed with newer versions
- soft handoff: connects to new before switching off old. no loss, but needs to be able to receive two freq
- hard handoff, old drops before new. If something goes wrong, lose connection.



Cellphones – Types of Channels

- Control (base to phone)
- Paging (base to phone) alerts phone for incoming call
- Access (bidirectional) call setup and channel assign
- Data (bidirection) carry data/voice