

# ECE 435 – Network Engineering

## Lecture 7

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# Announcements

- HW#2 is graded
- HW#3 will be posted



# HW#2 Review

- Server Code
  - just a loop
  - how to compare strings?
  - be careful with fgets
  - how to make uppercase
  - Why port 31337? What is loopback?
- tcpdump
- Questions



1. Satellite over fiber:  
no need to run cables everywhere  
Can broadcast over greater area
2. Fiber over satellite:  
less secure (easier to tap)  
longer latency  
Cost? Which is more expensive?
3. FCC won't let me be  
Though they only regulate consumer, federal govt (like military, FAA, etc, NTIA National Telecommunications



and Information Administration)  
4.3GHz airport/radio navigation



# Questions From Last Time

- Manchester encoding



# Full Duplex MAC

- Early Ethernet was coaxial in a bus
- Twisted pair has replaced this, usually in a hub/or switch star topology
- 10BASE-T and 100BASE-TX pair for transmit or receive
- inefficient. Since point to point, why do you need arbitration?
- Full-duplex introduced in 1997. Must be able to



transmit/receive w/o interference, and be point to point.

- Full duplex effectively doubles how much bandwidth between. Also it lifts the distance limit imposed by collision detection





# Ethernet Flow Control

- Flow control is optional
- In half duplex a receiver can transmit a “false carrier” of 1010..10 until it can take more.
- Congested receiver can also force a collision, causing a backoff and resend. Sometimes called force collision
- Above schemes called “back pressure”
- For full duplex can send a PAUSE frame that specifies how much time to wait.



# Fast Ethernet (100MB)

- 802.3u 1995
- 10BASE-TX most common
- Decided to keep everything same, just faster. bit time from 100nsec to 10nsec
- Uses twisted pair/switches, no coax
- To use cat3 100BASE-T4 wiring needed 4 twisted pair and complex encoding



- To use cat5 wiring 100BASE-TX. Two twisted pair, one to hub, one from. 4B/5B encoding used. Full duplex
- Most hubs (story) support mix of 10/100 and half/full duplex
- Often split between MAC (media access controller) and PHY (physical interface). Card configures the PHY via the MII (media independent interface)  
Goal was you could have same card but interchangeable PHY (twisted pair, fiber, etc). 4bit bus  
Interface requires 18 signals, only two can be shared if



multiple PHY

So RMII (reduced) was designed. Clock doubled, only 2-bit bus. Fewer signal wires.

- 100BASE-TX:

2 pairs. One pair 100MB each direction, full duplex, 100m distance

Raw bits (4 bits wide at 25MHz at MII) go through 4B5B encoding clocked at 125MHz. (DC equalization and spectrum shaping) Then NRZI encoding (transition at clock if 1, none if 0). TX then goes through MLT-3 encoding (-1,0,+1,0. Transition means 1, no transition



means 0) 31.25MHz, much like FDDI



# Router vs Hub vs switch

- Hub all frames are broadcast to all others  
Bandwidth is shared (only say 100MB for all)
- Switch – direct connection, no broadcast. Has to be intelligent. Each point to point connection full bandwidth.  
no collisions
- Direct Ethernet connection. Need a special cable?
- Router will move frames from one network to another
- Lights. How many ports? Uplink ports?



# Gigabit Ethernet

- Two task forces working in 1998/1999
- 802.3z 1998 (fiber), 802.3ab 1999 (copper)
- Problem was the CSMA/CD restriction. About 200m for 100Mbps. For Gb would have been 20m which is not very far.
- To handle this, there are extension bits at the end to extend to be longer than the collision time



- Better solution is just use full duplex
- Point-to-point (direct or need switch)
- 1000BASE-T:  
8B/10B encoding, 4 pairs, 125MHz, simultaneous transmission in both directions with adaptive equalization (using DSPs), 5-level pulse-level modulation (PAM-5) [technically 100BASE-TX is PAM-3].  
Diagram? looks sort of like a sine wave as cycle through the voltages. four-dimensional trellis coded modulation (TCM) 6dB coding gain across the four pairs





Autonegotiation of speed. Only uses two pairs for this, can be trouble if pairs missing.

- Fast enough that computers at time had trouble saturating such a connection
- Jumbo Frames? 9000 byte?



# Even Faster Ethernet

- Misquote: Not sure what the network will be like in 30 years, but they will call it Ethernet.
- 2.5Gb: 802.3bz (Sep 2016?)  
Like 10Gb but slower. Can't run 10Gb over Cat5e  
Power over Ethernet (for using on wireless access points)  
Power with signal overlaid on top.  
2.5Gb on Cat 5e, 5Gb on Cat6
- 10Gb: 802.3ae-2002. Full duplex, switches only



Need Cat6a or Cat7 for links up to 100m

Expensive. Lots of kind. 10GBASE-T, 802.3an-2006

100m over cat6a, 55m Cat6

additional encoding overhead, higher latency

Tomlinson-Harashin precoding (THP), PAM15 in two-dimensional checkerboard DSQ128 at 800Msymbol/s

- 25Gb, 802.3by. 25GBASE-T, 50GBASE-T. Available, if copper only a few meters
- 40GB, 100GB. 802.3ba-2010, 802.3bg-2011, 802.3bj-2014, 802.3bm-2015



40GBASE-T twisted pair 40GBit/s 30m. QFSP+ connectors, like infiniband

- Terabit? still under discussion



# What does your machine have

- skylake machine:

```
[ 18.240021] e1000e: eth0 NIC Link is Up 1000
```

- Raspberry Pi:

```
[ 77.110505] smsc95xx 1-1.1:1.0 eth0: link up
```

- Haswell machine:



```
[ 3.907651] tg3 0000:03:00.0 eth0: Tigon3 [p
[ 3.919115] tg3 0000:03:00.0 eth0: attached
[ 3.929838] tg3 0000:03:00.0 eth0: RXcsu[1
[ 3.938174] tg3 0000:03:00.0 eth0: dma_rwctr
[ 13.758613] IPv6: ADDRCONF(NETDEV_UP): eth0:
[ 15.404905] tg3 0000:03:00.0 eth0: Link is u
[ 15.411479] tg3 0000:03:00.0 eth0: Flow cont
```



# Linux OS Support

- When frame comes in, interrupt comes in
- Allocates `sk_buff` copies in
- Old: `net_if_rx()` interrupt, `net_rx_action()`  
interrupt/polling
- `net_if_receive_skb()`
- passes it to proper net level (`ip_rcv()`,  
`ip_ipvs6_rcv()`, `arp_rcv()`)



- for send
- `net_tx_action()`  
`dev_queue_xmit()` and then deallocate `sk_buff`
- `qdisc_run()` selects next frame to transmit and calls `dequeue_skb()`





# Wireless



# Why Wireless?

- Pros
  - Use anywhere
  - No wires
- Cons
  - Less reliability, noise
  - Less power availability
  - Less security



# Wireless LAN

- What does WiFi mean? Nothing really.
- 802.11. Started in 1990, no standard until 1997
- originally infrared, direct-sequence spread spectrum (DSSS) and freq-hopping spread spectrum (FHSS)  
FHSS – 79 channels, each 1MHz wide starting at 2.4GHz  
pseudo-random hop between freqs, both need to start with same seed. Dwell time is adjustable but less than 400ms. Low bandwidth.



DSSS similar to CDMA.

After 2002 rule that ISM band usage had to be spread-spectrum dropped.

- All of the various 802.11 have been sort of merged together, but people use the old letters out of habit
- 802.11b (1999) extends DSSS to 5.5Mbps and 11Mbps HR-DSSS (High Rate Direct Sequence Spread Spectrum) actually was popular before a.  
In the 2.4GHz frequency band, no licensing  
Various channels, but 22MHz wide. Not all available in



all countries. Some overlap.

- 802.11a (1999) not compatible with B, 54Mbps in 5GHz band  
5GHz less crowded, but signal doesn't go as far  
48 data channels 4 sync OFDM (Orthogonal Frequency Division Multiplexing)
- 802.11g 54Mbps, 2003. 2.4GHz but uses OFDM.  
Backward compatible with b, which slows it down
- 802.11n – MIMO (multiple input/multiple output antennas)



Can do spatial multiplexing, two antennas broadcast on same frequency by aiming signal

- 802.11ad – 60GHz range?
- 802.11af – white wi-fi, super wi-fi, operates in vacant UHF/VHF TV bands. Receiver uses GPS to find out where it is and what channels are free
- Many more

