

ECE 435 – Network Engineering

Lecture 20

Vince Weaver

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

`vincent.weaver@maine.edu`

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Announcements

- HW#8 due tomorrow



Ethernet History

- Proposed by Bob Metcalfe in 1973
(went on to found 3Com)
2022 Turing Award
- Metcalfe, Boggs, Thacker, and Lampson listed on patent
- Inspired by ALOHAnet, a wireless network in Hawaii, allow users on various islands to connect to server on Oahu
- Various competing local networks, Ethernet won in the end



Token Ring (Ethernet Competitor)

- Guaranteed Deterministic Delivery
(vs Ethernet: best effort)
- Dates to 1970s
- Standardized by IBM, 1984, IEEE 802.5 (note, not RFC)
- 4Mbps, eventually shielded twisted pair, eventually 16Mbps, 100Mbps and 1Gbps
- 3-byte frame passed around gives permission to transmit
- More complex, no crossover cable (direct connect two machines),



- Supports multiple identical MAC addresses (?)
- Deterministic time to get to transmit
- Frames can have different access priorities
- Empty token passed around. If data to transmit, put in. Then passes around until it gets to receiver, removed, and back to passing empty token. When gets back to originator it knows it has been received.
- Token Bus, GM, IEEE802.4 (withdrawn) like ring, but virtual ring. Needed to know neighbors to pass token. Guaranteed worst case transmit time.



Why did Ethernet win?

- Other competitors: FDDI, ATM, DQDB (?)
- Why did it win? Simpler and thus cheaper.
- Why simpler?
No priority mechanism, no QoS, no central control
- Could use cheaper twisted pair cable
- Token ring cards generally a lot more expensive than Ethernet



The Ethernet Progression

- Low speed (3Mbps) → High speed (400Gbps)
- Shared media → dedicated media
- LAN → WAN



Early Ethernet History

- 1972 – experimental 3Mbps (Xerox Alto)
- 1981 – DIX (DEC/Intel/Xerox) ver 1 (10Mbps)
- Standardized in 1981
- 1982 – DIX ver 2



Ethernet Naming

- Naming: Speed/BROAD, BASE, PASS/PHY
- Almost all is baseband (narrow frequency, vs broadband).
- PHY originally was distance could travel (in 100m) but now medium type.



Thick Ethernet

- 1983 – IEEE 802.3/10BASE5
- “Thick Ethernet”, up to 500m often yellow or orange (standard suggests yellow)
- Looks like garden hose.
- Vampire Tap, AUI connector, drill into cable, at 2.5m intervals (to avoid reflections)
- Terminated on each end, one bad connection could ruin for all



Thin Ethernet

- 1985 – 10BASE2
- “thin net”, thinner connections, BNC connectors, T connectors (185m, rounded up to 200m)
- 50 ohm terminator
- Issues with grounding loops (one and only one must be tied to ground, otherwise can get current flow in shielding)
- How to detect network problem? Send pulse, look for echo



10BASE-T

- 1990
- 10BASE-T – twisted pair (Cat3) , needed hub
- 1993 – 10BASE-F – fiber



Faster Ethernet

- We will talk about this in more detail later
- 1995 – 100BASE-T, 100BASE-TX 4B5B MLT-3 cat5
two twisted pairs
- 1997 – Full-duplex
- 1998/1999 – 1000BASE-TX PAM-5, four twisted pairs,
can transfer in both directions on one pair using
DSP/echo cancellation
- 2006 – 10GBASE-T
- 2010 – 40G and 100G



- 2017 – 400GB



“Classic” Ethernet Overview

- Not really used anymore, but a classic example of what a relatively easy-to-understand link-level interface is like



Ethernet MAC

- CSMA/CD “Carrier sense multiple access with collision detection”
- First senses cable (how? – see later)
- If busy, waits
- Sends. If collision, jams the cable aborts transmission, waits random back off time before retrying.
- Exponential backoff. Randomly choose time from 0 to



$2^k - 1$ where k is number of tries (capping at 10). Time slot is 512 bits for 10/100, 4096 for 1Gbs

- on newer full-duplex links no need for carrier sense and collision detection not needed



Ethernet Collisions

- In order to work properly, twice round-trip time needs to be less than time needed to transmit minimal (64-byte) frame, otherwise not possible to notice collision in time and frame loss
- This limits network size to collision domain
- Bits wasted is not bad, collision often caught in the preamble



NRZ/NRZI Encoding

NRZ is just 0 low, 1 high

NRZI (NRZ Inverted) (1 flip, 0 same)

```
  1  0  1  1  0  0  1
--  !  ---  !  !  --
  |  !  |  |  !  !  |
  ---!---  !---!---!---
      !      !  !
```



Encoding

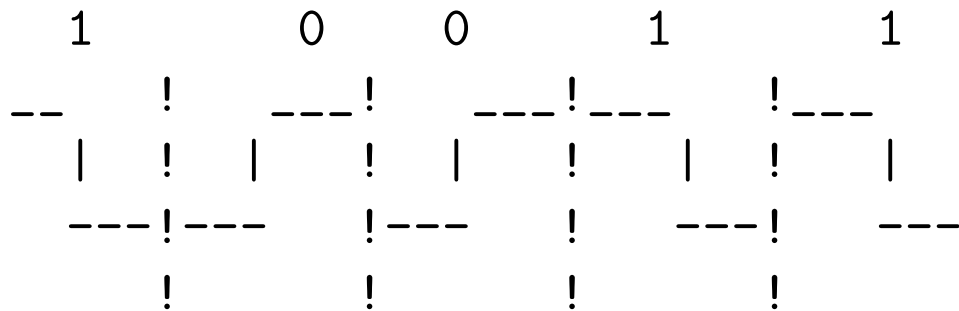
- Does not use 0V for 0 and 5V for 1.
Why? Idle is 0, so how can you tell how many zeros at beginning of signal?
- Could use $+1V/-1V$, but still would need way to sync signal on long runs of 0 or 1



Manchester Encoding (Ethernet)

- 1 is high to low transition.
- 0 is low to high transition.
- Always a transition in the middle of an interval.
- Disadvantage, need twice as much bandwidth

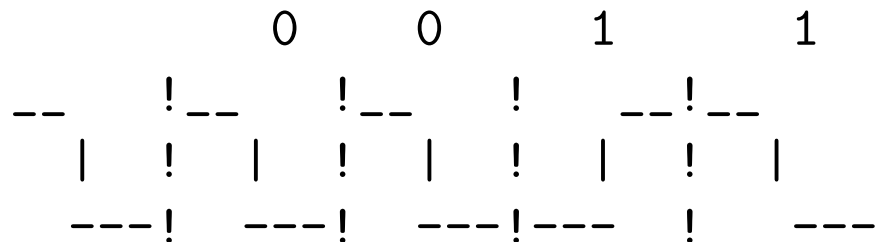
Manchester (10BASET Ethernet)



Differential Manchester (Token Ring)

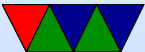
- transition at start of interval means 0
- lack of transition means 1
- Still transition in the middle
- More complex but better noise handling

Differential Manchester (Token Ring)



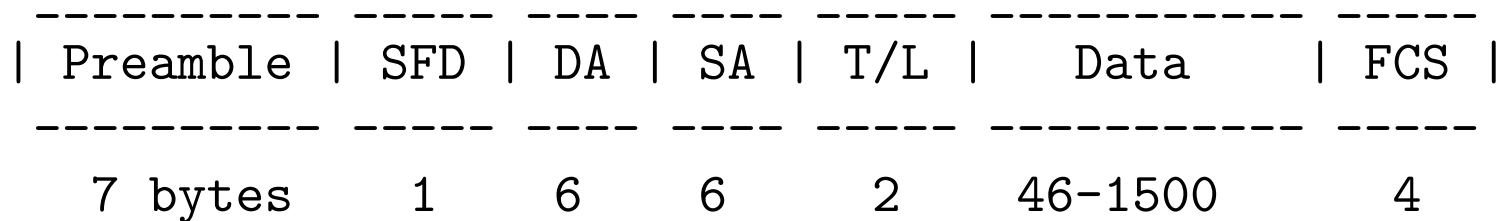
Ethernet on the Wire

- Manchester Encoding
- High 0.85V and low -0.85V



Ethernet Frame layout

This is Ethernet II/DIX standard, the most common



Frame size is variable. Often first two fields are excluded and said that Ethernet frames are between 64 and 1518 bytes long



Ethernet Frame Preamble

- Fixed 1010...1010 in transmission order (LSB, least significant bit first)
- On original Ethernet this was 10MHz 6.4us pulse used to synch clocks
- PHY might do other things (100BASE-X uses 4B/5B stuff, so different pattern)



Ethernet Start Frame Delimiter (SFD)

- SFD - indicates the start of the frame
- value 10101011 in transmission order
- Original Ethernet declared 8 bytes of same pattern, but on modern first 7 bytes might be different



Ethernet MAC addresses

- DA = 48 bit destination MAC address
- SA = 48 bit source MAC address
 - First 3 bytes the OUI (organization unique identifier)
 - Next 3 bytes supposed to be a unique ID
- Ethernet packets put on the wire least-significant bit first (as if shifted right out of a shift register)
- Multicast if the “first” bit (meaning 0x1, not 0x80) is set in the first octet (e.g. 01-80-C2-00-00-00)
- Broadcast if all bits set ff:ff:ff:ff:ff:ff



Ethernet Type/Length Field

- Originally type field
- 802.3 makes it length of *data* (not length of frame)
- In 1997 802.3 approved as type too, so dual meaning
- How tell difference?
 - Max len 1500, value bigger than 0x600 (1536) is type
 - 0x0800 = IPv4, 0x86dd = IPv6, 0x0806 = ARP
 - How tell length if type? Detect end of signal or inter-frame gap, or valid checksum (this is most common usage)



- How tell type if length? Will have 802.2 header?



Ethernet Frame – Data

- Data – data from 46 to 1500 bytes
- Why limit 1500B? because RAM was expensive in 1978.
- If smaller than 46 bytes padded. Makes sure checksum works.
- Also if too short, could be done transmitting before a collision can be detected (light travel to furthest node and back)



Ethernet Frame Check Sequence (FCS)

- FCS – a 32-bit CRC code.
- Somewhat complicated, magic number at end 0xc704dd7b
 - Hard to get a clear description of what it looks like w/o a lot of math
 - You can implement with linear feedback shift register (shift register with xors)
 - Possibly CRC calculated MSB first rather than LSB
- If incorrect FCS, silently drops



End of Frame / Inter Packet Gap

- At end of frame, drop carrier
- More modern Ethernet might signal this with a symbol
- Inter-packet gap, 96 bits (12 bytes) of idle before sending next frame
- Gives receiver time to handle frame before next starts

