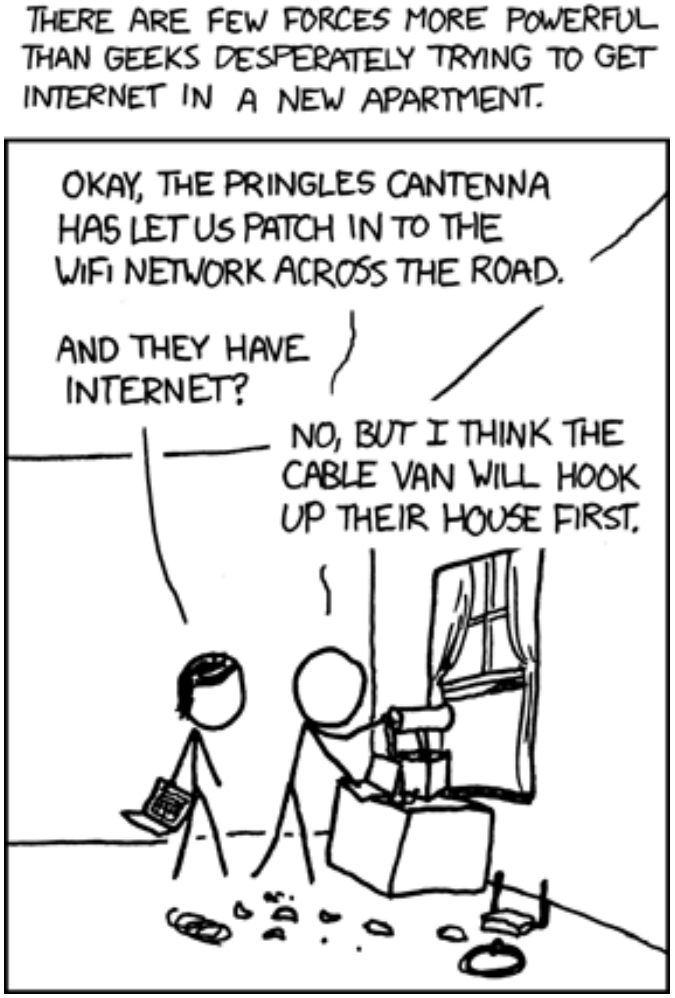
Ethernet and WiFi



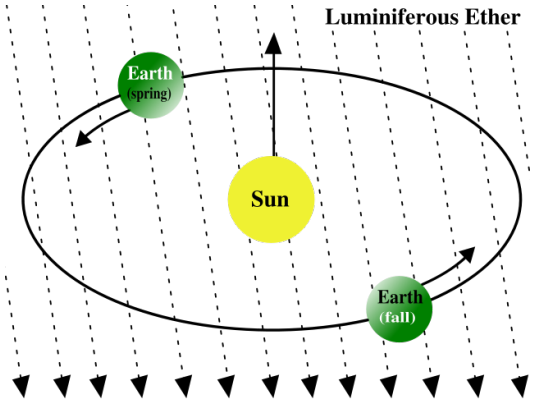
http://xkcd.com/466/

Overview

- Multiple access networks
  - Ethernet
    - Long history
    - Dominant wired technology
  - 802.11
    - Dominant wireless technology

Classic Ethernet

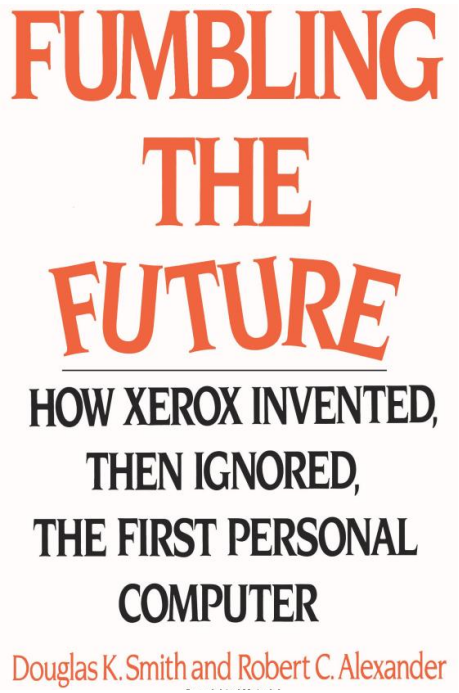
- Ethernet
  - luminferous ether through which electromagnetic radiation once thought to propagate
  - Carrier Sense, Multiple Access with Collision Detection (CSMA/CD)
  - IEEE 802.3



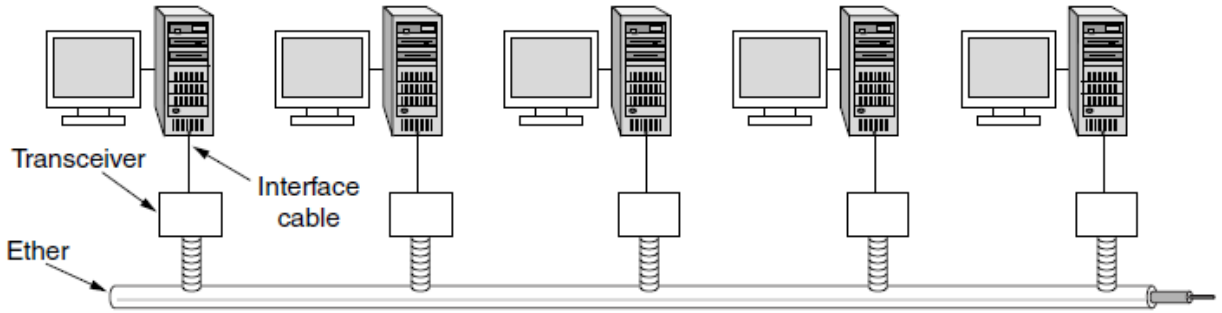
Robert Metcalfe, co-inventor of Ethernet

Classic Ethernet

- Ethernet
  - Xerox Ethernet standardized as IEEE 802.3 in 1983
  - Xerox not interested in commercializing
  - Metcalfe leaves and forms 3Com



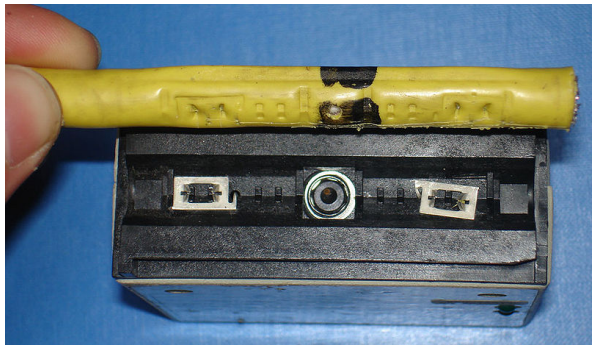
Ethernet connectivity



- Shared medium
  - All hosts hear all traffic on cable
  - Hosts tapped the cable
  - 2500m maximum length
  - May include repeaters amplifying signal
  - 10 Mbps bandwidth

Classic Ethernet cabling

Thick Ethernet cable (yellow), 10BASE-5 transceivers, cable tapping tool (orange), 500m maximum length.

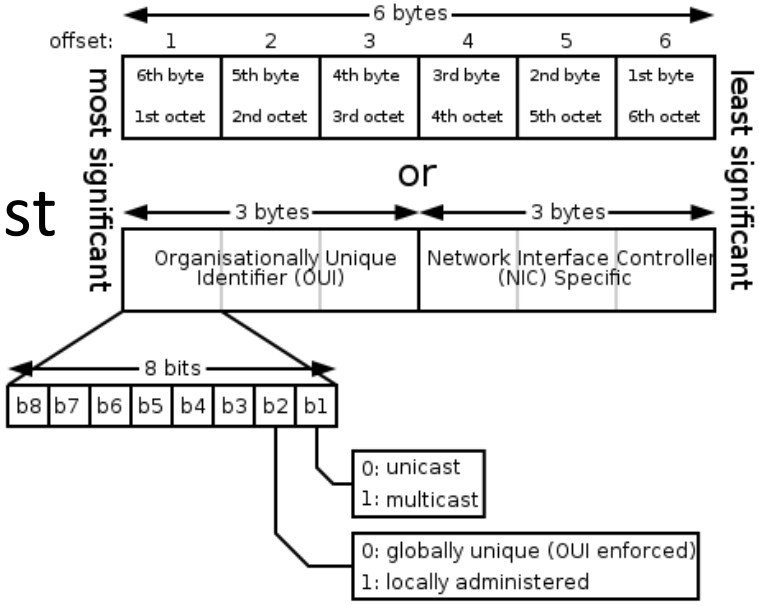


Cable after being "vampire" tapped.

Thin Ethernet cable (10BASE2) with BNC T-connector, 185m maximum length.

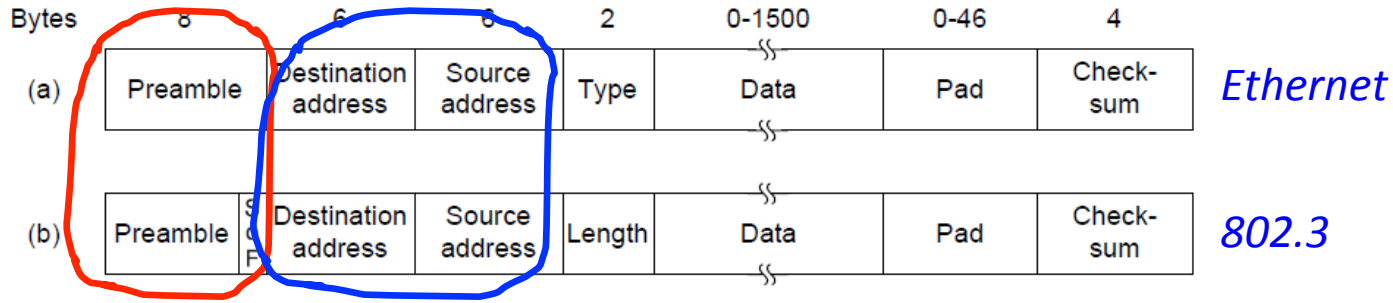
Ethernet addressing

- Media Access Control address (MAC)
  - 48-bit globally unique address
    - 281,474,976,710,656 possible addresses
    - Should last till 2100
    - e.g. 01:23:45:67:89:ab
  - Address of all 1's is broadcast
    - FF:FF:FF:FF:FF:FF



Ethernet frame format

- Frame format
  - Manchester encoded
  - Preamble products 10-Mhz square wave
    - Allows clock synch between sender & receiver
  - Pad to at least 64-bytes (collision detection)



Ethernet receivers

- Hosts listens to medium
  - Deliver to host:
    - Any frame with host's MAC address
    - All broadcast frames (all 1's)
    - Multicast frames (if subscribed to)
    - Or all frames if in promiscuous mode

MAC sublayer

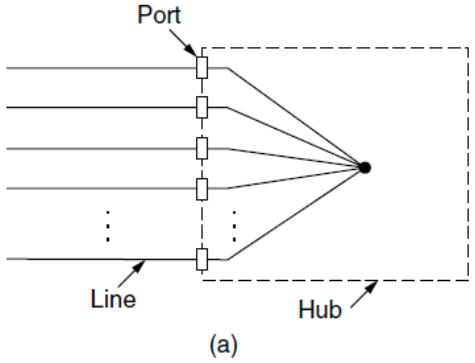
- Media Access Control (MAC) sublayer
  - Who goes next on a shared medium
  - Ethernet hosts can sense if medium in use
  - Algorithm for sending data:
    1. Is medium idle? If not, wait.
    2. Start transmitting data, listen for collision.
    3. If collision detected, transmit 32-bit jamming sequence. Stop transmitting and go to backoff procedure.

Backoff procedure

- Binary exponential backoff
  - First collision
    - Wait 0-1 timeslots (chosen at random)
  - Second collision
    - Wait 0-3 timeslots
  - In general, i^{th} collision
    - Wait a random number of timeslots between 0 and 2^i - 1 (max of 1023 slots)
  - Give up after 16 or so retries
  - Timeslot = 51.2 μs

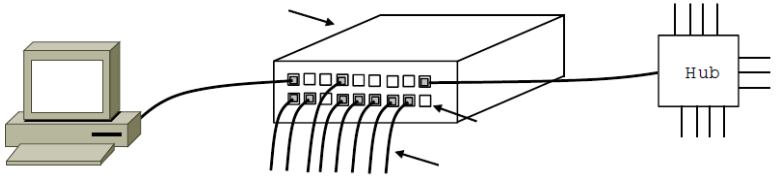
Switched Ethernet

- Long single cable
  - Hard to find breaks or loose connections
- Different wiring pattern
  - Each host wired straight to hub
  - Hub simply connected all wires together
  - Using existing office twisted pair phone lines

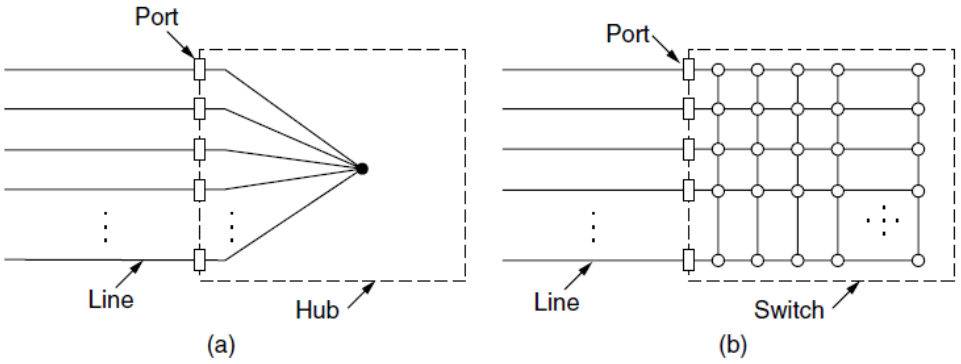


(a)

Switched Ethernet



- Hubs
  - Made network easier to manage
  - But did not address capacity problem
- Switches
  - High-speed backplane connecting all ports
  - Only output frame to destination port
  - Isolates traffic, no collisions, better security



Fast Ethernet

- Fast Ethernet
  - IEEE 802.3u
  - Keep all the classic Ethernet frame formats, etc.
  - Reduce the bit time from 100 nsec to 10nsec
  - 100 Mbps
  - No more multidrop cables or vampire taps

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps (Cat 5 UTP)
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

Gigabit Ethernet

- Gigabit Ethernet
  - IEEE 802.3ab
  - 1000 Mbps
  - Unacknowledged datagram service
  - Addition of flow control
  - Unofficial support for jumbo frames
    - Up to 9KB (instead of limit of 1500 bytes)

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

Even faster

- 10-Gigabit Ethernet
  - 1000x faster than original Ethernet
  - Inside data centers, long haul trunks

Name	Cable	Max. segment	Advantages
10GBase-SR	Fiber optics	Up to 300 m	Multimode fiber (0.85μ)
10GBase-LR	Fiber optics	10 km	Single-mode fiber (1.3μ)
10GBase-ER	Fiber optics	40 km	Single-mode fiber (1.5μ)
10GBase-CX4	4 Pairs of twinax	15 m	Twinaxial copper
10GBase-T	4 Pairs of UTP	100 m	Category 6a UTP

- 40 and 100-Gigabit Ethernet
  - Recently ratified and starting to be deployed

Ethernet retrospective

- Why so popular?
  - Easy to administer, no routing or config tables
  - Cheap hardware and wiring
  - Plays nice with TCP/IP
    - Ethernet and IP are connectionless protocols
    - Alternates like ATM were not
  - Speed increased by order of magnitude periodically without throwing away existing infrastructure
  - Borrowed good ideas from other (failed) networking technologies (FDDI, Fiber Channel)

Wireless

- Shared medium using wireless
  - Bit errors more prevalent than wired
  - Limits on transmit power
    - Battery life, government regulation
  - Difficult to transmit and listen for collisions
  - Undirected signal
    - Interference
    - Security

Wireless technologies

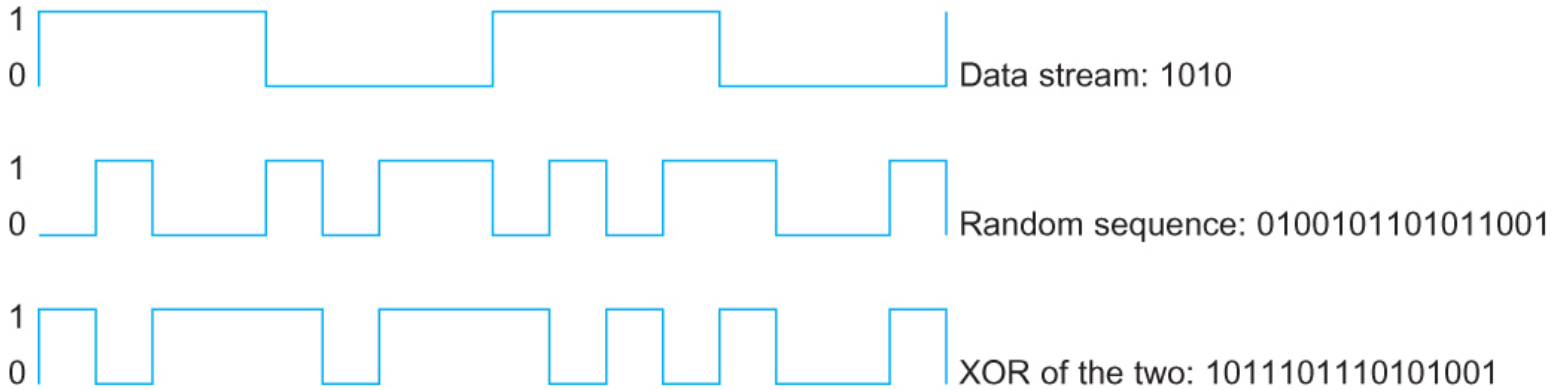
	Link length	Data rate	Uses
RFID	10 m	Very low	Smart cards, pet implants, passports, library books
Bluetooth 802.15.1	10 m	2 Mbps	Link peripheral to computer (e.g. headset, mouse, keyboard).
Wi-Fi 802.11	100 m	11-600 Mbps	Link computer to a wired base station.
3G Cellular	10 km	Hundreds of kbps (per connection)	Link mobile device to wired tower.
Wi-MAX 802.16	50 km	144 Mbps	Last-mile broadband to home. Mobile broadband.

Wireless transmission

- Spread spectrum
  - A way to share the medium
    - Support varying numbers of users
    - Support bursty traffic (e.g. web surfing)
  - Frequency hopping
    - Original military's attempt to avoid jamming
    - Pseudorandom sequence of frequencies
    - Unlikely two transmitters using same sequence

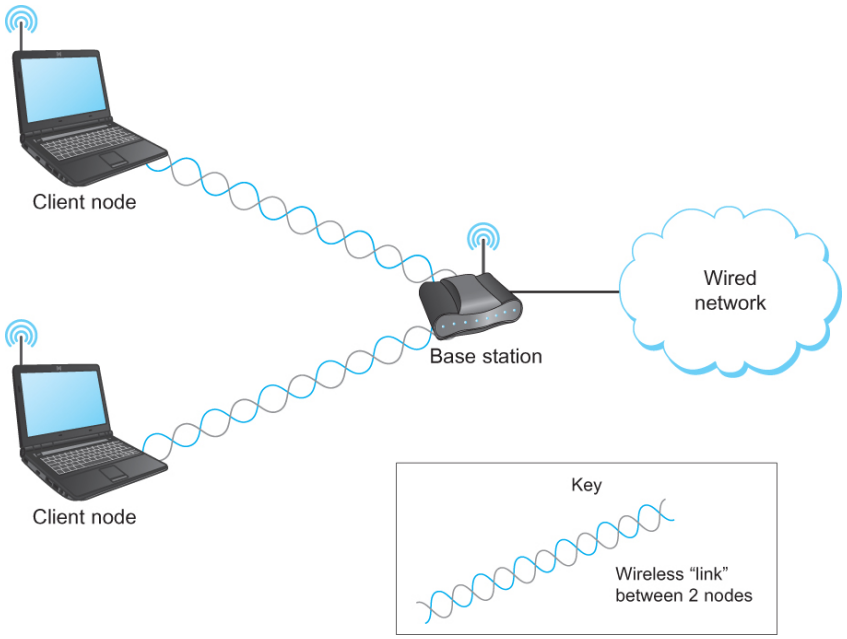
Wireless transmission

- Spread spectrum
  - Direct sequence
    - Transmit same bit on *n* different frequencies
    - Spread signal across *n* times wider frequency band
    - XOR signal bit with *n* pseudorandom bits



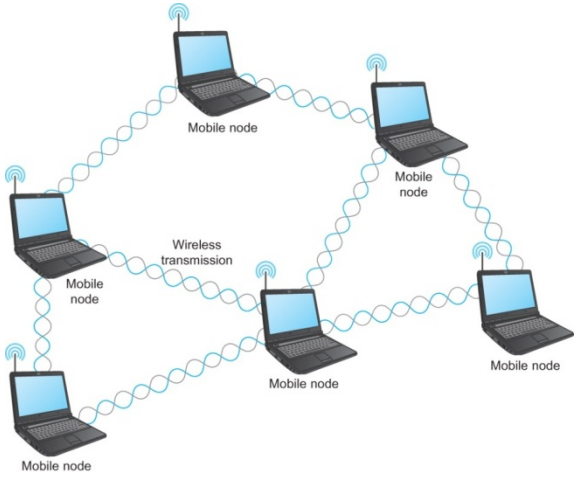
Wireless topology

- Base station topology
  - Typically all clients talk to base station
  - No direct communication between clients



Wireless topology

- Ad hoc / mesh topology
  - Nodes are peers
  - No special base station
  - Advantages:
    - More fault tolerant
    - Extends range
  - Disadvantages:
    - Nodes are more complex
    - Nodes may be asked to expend limited resources (e.g. power)



One Laptop per Child, uses 802.11s mesh draft standard.

802.11 Wi-Fi

Standard	Released	Max bit rate (shared)	Frequency band	Indoor range
802.11	1997	2 Mbps	2.4 GHz	20 m
802.11a	1999	54 Mbps	5 GHz	35 m
802.11b	1999	11 Mbps	2.4 GHz	38 m
802.11g	2003	54 Mbps	2.4 GHz	38 m
802.11n	2009	600 Mbps	2.4 GHz 5 GHz	70 m

- Operate in license exempt bands
- More absorption at high frequencies (5 GHz)
- All support lower bit rates
  - Switch between modulation techniques & error correction codes
- 802.11n, multiple antennas
  - MIMO (Multiple Input Multiple Output)

Summary

- Wired Ethernet
  - Long history and widely adopted
  - Used in LANs, datacenters, etc.
  - Order of magnitude bit rate increase every few years
  - Careful attention to backwards compatibility
- 802.11 Wi-Fi
  - Widely adopted short-range wireless technology
  - Typically via fixed access point
  - Also can be used ad hoc between clients