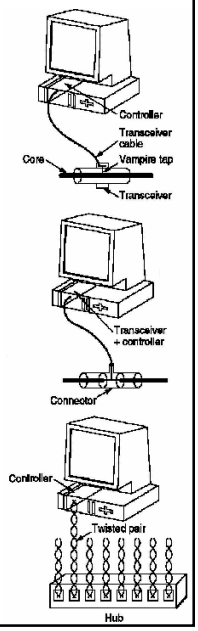
Ethernet

- IEEE standard 802.3
  - CSMA / CD

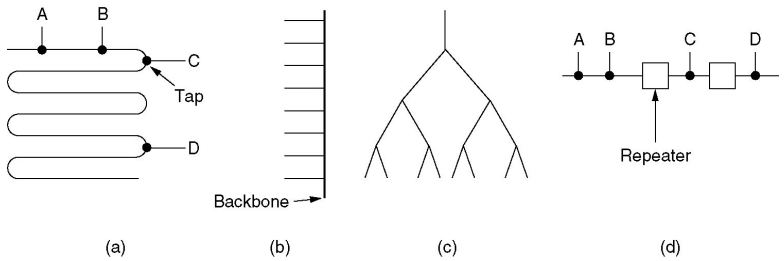
Ethernet Cabling

- 10Base-5: operates at 10 Mbps, using baseband signaling, running over (70 ohm) coaxial cable that can support segments up to 500m
  - Connected using vampire taps
  - Up to 100 allowed per segment
- 10Base-2: Thin-wire Ethernet
  - Uses a thinner, lower quality cable which can bend easily,
  - Connected using BNC connectors
  - Up to 30 allowed per segment
- 10Base-T: 10Mbps running over twisted pair
  - Runs to a central hub. Only 100-200m of cable from hub allowed (200m if CAT5 cable)
  - Up to 1024 stations allowed within 200m
- 10Base-F: 10Mbps Ethernet running over fiber-optic cabling,
  - Typically a hub/star topology
  - Max segment 2km, Up to 1024 stations per segment



Cable Topologies

- Linear: A linear topology simply has all stations connected to a single wire,
- Spine: A spine is typically used as a backbone for smaller segments,
- Tree: The tree topology is the most general topology as it potentially provides the shortest routes between stations without allowing multiple routes,
- Repeaters: Whenever multiple segments are connected together we need to use a repeater – which receives, amplifies and retransmits signals in both directions.

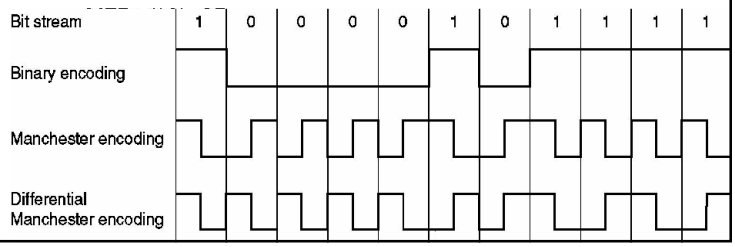


Encoding

- Considering a stream of bits to be transmitted and received we must address a number of issues:
  - How to distinguish idle from 0?
    - Solution: Use positive voltage for 1 and negative voltage for 0
  - How can we avoid having an average D.C. voltage?
    - Solution: Use differential codes – which indicate ones and zeros by transitions
  - How can we be sure that we sample the signal correctly?
    - Solution: Incorporate clock somehow into the signal.

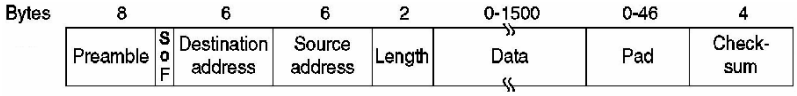
Manchester Encoding

- Manchester
  - 1 represented as a high to low transition in the middle of the bit period,
  - 0 represented as a low to high transition.
- Differential Manchester
  - 1 represented as no transition at the start of an interval,
  - 0 represented as a transition at the start of an interval.



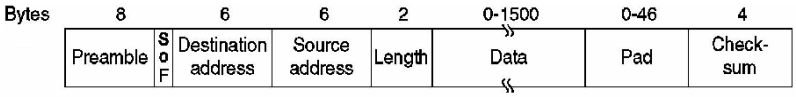
MAC Sublayer protocol

- A preamble is sent in order to allow sender and receiver to get synchronized,
  - This consists of 7 bytes of 10101010, producing a 10MHz square wave for 5.6 μsecs.
  - This is followed by a SOF byte: Start of Frame
- Destination & Source Addresses are
  - Either 2 or 6 bytes long
  - High order bit (Destination Bit 47) is
    - 0 for ordinary addresses,
    - 1 for group addresses – sending to a group of stations is called multicast,
    - 111…111 for all stations – this is referred to as broadcast
  - Destination Bit 46 indicates whether an address is local or global



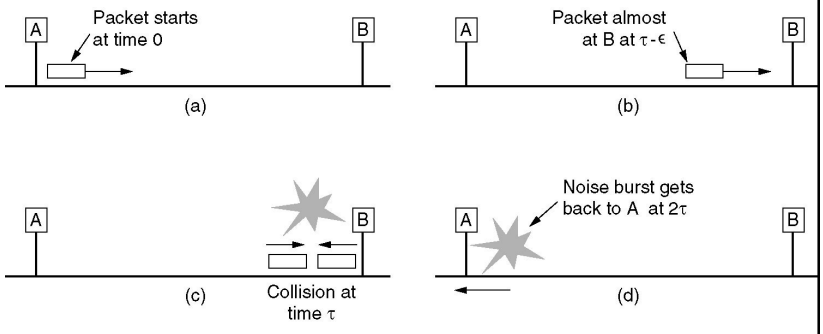
MAC Sublayer protocol

- Length / Type is interpreted differently…
  - <= 1500 interpreted as the number of bytes of data,
  - > 1500 interpreted as the packet type encapsulated by the frame.
- Data & PAD
  - Data + PAD >= 46 bytes as ethernet requires a minimum frame size of 64 bytes,
- Checksum is a 32 bit CRC



Detecting Collision

- Assume stations A and B are at extremes of the LAN



- Time $_{\text{Simultaneous transmission}}$ **At τ, B transmits as the frame arrives**
- Time $_{\text{Collision Detection}}$ **It takes 2τ for the collision to be detected by A**
- Worst Case: **Round trip delay is 50μsec, which is based on a maximum distance of 2.5 km with 4 repeaters. This equates to 500 bits which rounded up gives 512bits = 64bytes**

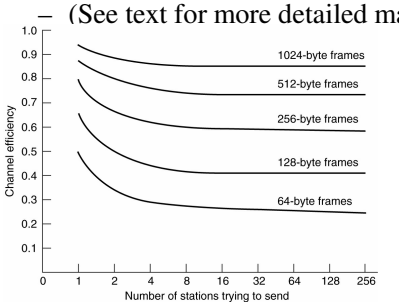
Binary Exponential Backoff

- After a collision, time is divided into discrete time slots
  - Length of time slot: worst case round trip propagation time (51.2 μsec)
- After collisions 1-9: wait a random number of slots between 0 and $2^i - 1$ (i is the number of collisions)
- After collisions 10-15: wait a random number of time slots between 0 and $2^{10} - 1 = 1023$
- After collision 16: just give up

- Performance:
  - Small number of stations colliding: reasonable performance, wail for a small number slots
  - Large number colliding: graceful degradation but it can still be successful.

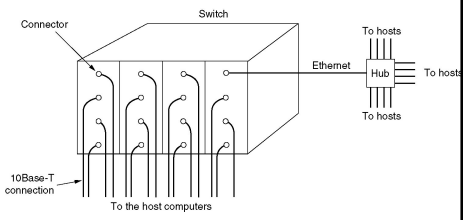
Performance

- Under high load to increase efficiency:
  - Decrease B -- bandwidth
  - Decrease L -- max cable length, the longer the cable, the longer the contention interval,
  - Increase F – frame length. From chart, the bigger the frame size, the more efficient the channel usage.
  - Note: **Channel efficiency = 1 / (1 + 2.B.L.e/c.F)**
  - (See text for more detailed mathematics).



Switched Ethernet

- Eventually Ethernet will become saturated with traffic
- One approach to solving this is use a type of switch. This contains …
  - Cards : A switch can contain between 4 and 32 cards
  - Connectors: Each card has between 1 and 8 connectors
  - High speed backbone
- Card operation:
  - On-card LAN so that each card acts as a local collision domain
  - Buffering can be used to avoid collisions completely



Fast Ethernet

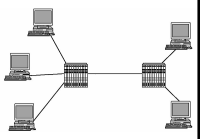
- 802.3u: standard based on 802.3, was chosen to make ethernet faster,
- Selected by IEEE because
  - Compatibility: Need for backward compatibility,
  - Fear: A new protocol would have new problems,
  - Speed: Needed to get standard out quickly before industry did it.
- No changes were made to the frame formats, interfaces and procedural rules.
- Changes were made…
  - 10Base-T: physical layout based on 10BaseT, uses hubs and switches,
  - Wiring: No longer allows multidrop cables with vampire taps or BNC.

Fast Ethernet Wiring

- **100Base-T4 Uses Cat 3 UTP cabling. Max segment length is 100m.**
  - Cabling & Speed: Requires 4 twisted pairs to achieve 100Mbps.
  - Cable organisation: 1 pair is always to the hub and the other is always away from the hub. The other 2 are always switchable to the current transmission direction.
  - Encoding: Not Manchester. Clock rate is upped to 25MHz and ternary signals are used (3 levels)
    - 8B/6T: Each data byte is compared to the values in the 8B6T table. Every possible byte has a unique 6T code, a set of 6 tri-state symbols.
- **100Base-TX: Uses Cat 5 UTP cabling at 125MHz. Max segment length is 100m.**
  - Cabling & Speed: Requires 2 twisted pairs per station, full-duplex operation at 100Mbps.
  - Cable organisation: 1 Twisted Pair to the hub and one from it
  - Encoding: Uses 4B/5B encoding
    - 4B/5B 4 bits are converted to 5 by a lookup table
- **100Base-FX: Uses Multimode fiber. Max distance from hub is 2km.**
  - Cabling & Speed: Uses 2 fibers to provide full-duplex transmission.

Gigabit Ethernet

- 802.3z: The protocol has to support 1000Mbps
  - Compatibility: Yet, it still had to remain backwards compatible
  - Protocol: Had to use the same addressing scheme, frame format, including min and max frame sizes.
- Point-to-point connections only
- Two modes of operation supported:
  - Full duplex – where only switches are used.
    - No possibility of contention
    - Max cable length now determined by signal strength, not by round-trip-time.
  - Half duplex – where hubs are used, which connect all lines internally – effectively simulating the multidrop situation.
    - Standard CSMA/CD used but the data rate is 100 times faster, so in theory max length should be 100 times less, i.e.:25m.
    - Max length maintained by:
      - Carrier Extension: Extends normal frames up to 512bytes
      - Frame bursting: Sends multiple frames as one – similar to piggybacking

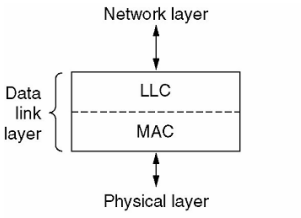


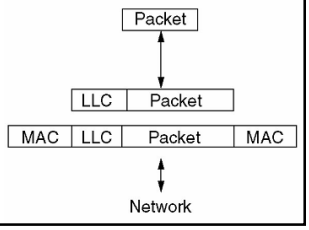
Gigabit Ethernet Wiring

- Wiring Options:
  - 1000Base-SX Fiber optics (multimode) with max segment of 550m.
  - 1000Base-LX Fiber optics (single) with max segment of 5000m.
  - 1000Base-CX 2 pairs of shielded twisted pair with max segment of 25m
  - 1000Base-T 4 pairs of Cat5 UTP with a max segment of 100m
- Encoding (fiber)
  - 8B/10B: This implies 1GHz clock rate
  - 4 identical bits: never in a row in any codeword
  - Six 0s or six 1s: no codeword has more than 6 0s or 1s
- Encoding (1000Base-T) is done using 5 voltage levels per clock cycle (00, 01, 10, 11 or control) at a clock rate of 125MHz
- Flow control is also supported, a receiver can ask a sender to pause
- 802.3ae IEEE standardized 802.3ae, 10Gbps ethernet

Logical Link Control

- Data Link Layer is in theory capable of supporting reliable communication on an unreliable line…
- LLC Logical Link Control, provides a single format and interface to the network layer
  - Service Options
    1. Unreliable datagram service
    2. Acknowledged datagram service
    3. Connection oriented datagram service
  - Header: prepended to the network layer packet
  - It contains:
    - Access points: destination access point, source access point
    - Control field: Seq and Ack Id.





Why Ethernet?

- Competition: No major competitors
- Reliability: Once vampire taps were removed, failures became very rare
- Simple: Thin ethernet, Twisted Pair cables and interfaces are cheap. Switches and hubs are the only expensive components.
- Maintenance: Easy. No software to install, only device drivers. Easy to plug a host in.
- TCP/IP: Interfaces easily with TCP/IP
- Stability: Has evolved in terms of speed but managed not to require that the software drivers be changed.