LAN technologies

Data link layer so far:

m services, error detection/correction, multiple access

Next: LAN technologies

m addressing

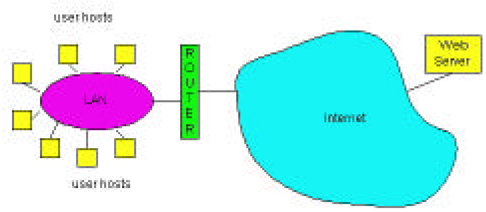
m Ethernet

m hubs, bridges, switches

m 802.11

m PPP

m ATM



5: DataLink Layer 5a-1

LAN Addresses and ARP

32-bit IP address:

r *network-layer* address

r used to get datagram to destination network (recall IP network definition)

LAN (or MAC or physical) address:

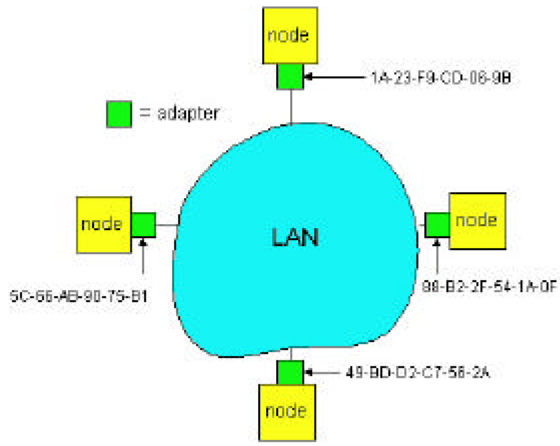
r used to get datagram from one interface to another physically-connected interface (same network)

r 48 bit MAC address (for most LANs) burned in the adapter ROM

5: DataLink Layer 5a-2

LAN Addresses and ARP

Each adapter on LAN has unique LAN address



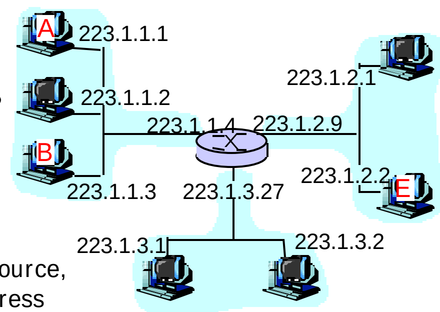
LAN Address (more)

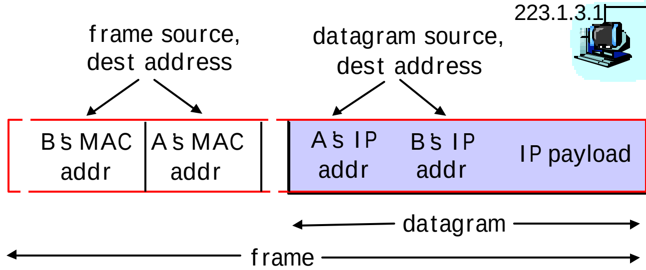
- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy:
  - (a) MAC address: like Social Security Number
  - (b) IP address: like postal address
- MAC flat address => portability
  - can move LAN card from one LAN to another
- IP hierarchical address NOT portable
  - depends on network to which one attaches

Recall earlier routing discussion

Starting at A, given IP datagram addressed to B:

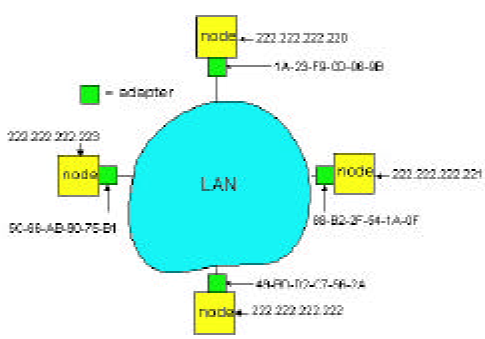
- look up net. address of B, find B on same net. as A
- link layer send datagram to B inside link-layer frame





ARP: Address Resolution Protocol

Question: how to determine MAC address of B given B's IP address?



- Each IP node (Host, Router) on LAN has ARP module, table
- ARP Table: IP/MAC address mappings for some LAN nodes

  < IP address; MAC address; TTL>

  < ………………….. >

  - TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

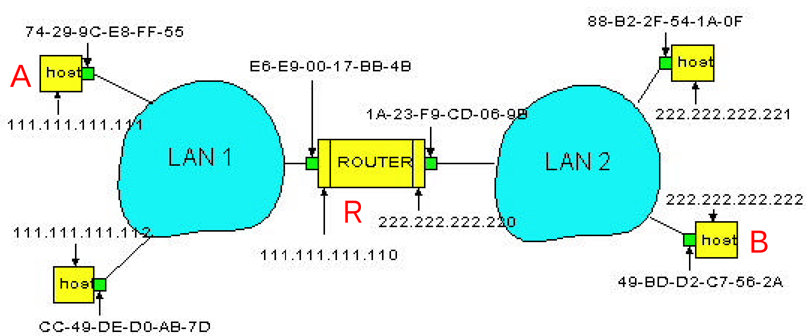
ARP protocol

- A knows B's IP address, wants to learn physical address of B
- A broadcasts ARP query pkt, containing B's IP address
  - all machines on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) physical layer address
- A caches (saves) IP-to-physical address pairs until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed

5: DataLink Layer 5a-7

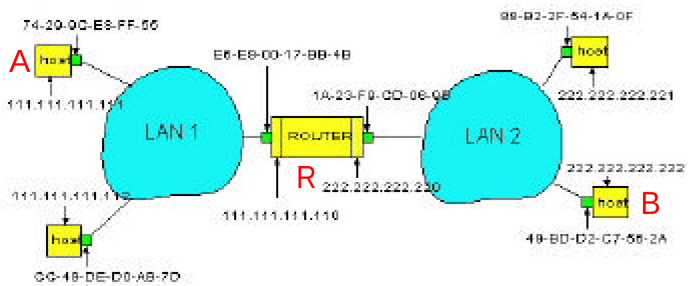
Routing to another LAN

walkthrough: routing from A to B via R



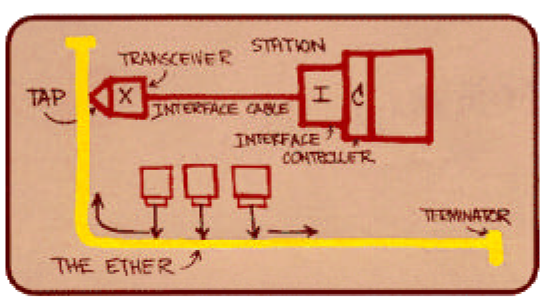
5: DataLink Layer 5a-8

- A creates IP packet with source A, destination B
- A uses ARP to get R's physical layer address for 111.111.111.110
- A creates Ethernet frame with R's physical address as dest, Ethernet frame contains A-to-B IP datagram
- A's data link layer sends Ethernet frame
- R's data link layer receives Ethernet frame
- R removes IP datagram from Ethernet frame, sees its destined to B
- R uses ARP to get B's physical layer address
- R creates frame containing A-to-B IP datagram sends to B



Ethernet

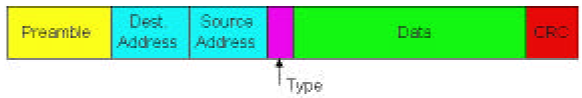
"dominant" LAN technology:
- cheap $20 for 100Mbs!
- first wildly used LAN technology
- Simpler, cheaper than token LANs and ATM
- Kept up with speed race: 10, 100, 1000 Mbps



Metcalfe's Etheret sketch

Ethernet Frame Structure

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame



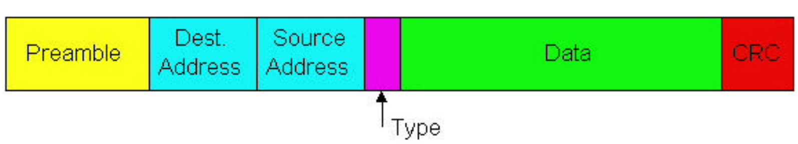
Preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- used to synchronize receiver, sender clock rates

5: DataLink Layer 5a-11

Ethernet Frame Structure (more)

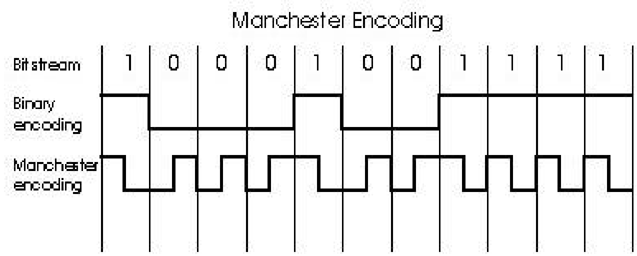
- Addresses: 6 bytes, frame is received by all adapters on a LAN and dropped if address does not match
- Type: indicates the higher layer protocol, mostly IP but others may be supported such as Novell IPX and AppleTalk)
- CRC: checked at receiver, if error is detected, the frame is simply dropped



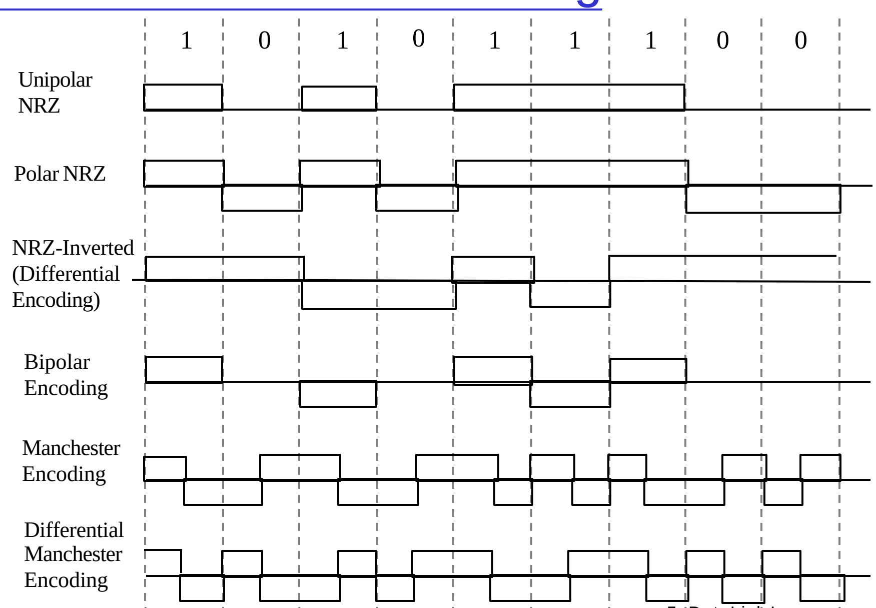
5: DataLink Layer 5a-12

Baseband Manchester Encoding

- Baseband here means that no carrier is modulated; instead bits are encoded using Manchester encoding and transmitted directly by modified voltage of a DC signal
- Manchester encoding ensures that a voltage transition occurs in each bit time which helps with receiver and sender clock synchronization



More Baseband Encoding



4B/5B Encoding

- Manchester only has 50% efficiency.
- Insert extra bits into the bit stream to break up long sequence of 0s and 1s.
- 4-bit data are encoded in a 5-bit code.
- No more than one leading 0 and no more than two trailing 0s.
- Use NRZI (non-return to zero inverted) to transmit.
- 4B/5B: 80% efficiency.
- Used in 100Mbit Ethernet.

4-Bit Data Symbol	5-Bit Code
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1110	11100
1111	11101

Ethernet: uses CSMA/CD

A: sense channel, **if** idle

```
then {
        transmit and monitor the channel;
        If detect another transmission
          then {
             abort and send jam signal;
             update # collisions;
             delay as required by exponential backoff algorithm;
             goto A
             }
         else {done with the frame; set collisions to zero}
    }
else {wait until ongoing transmission is over and goto A}
```

Ethernet's CSMA/CD (more)

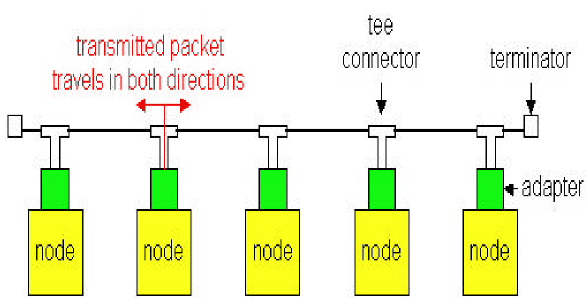
Jam Signal: make sure all other transmitters are aware of collision; 48 bits;

Exponential Backoff:

- *Goal*: adapt retransmission attemtps to estimated current load
  - heavy load: random wait will be longer
- first collision: choose K from {0,1}; delay is K x 512 bit transmission times
- after second collision: choose K from {0,1,2,3}…
- after ten or more collisions, choose K from {0,1,2,3,4,…,1023}

Ethernet Technologies: 10Base2

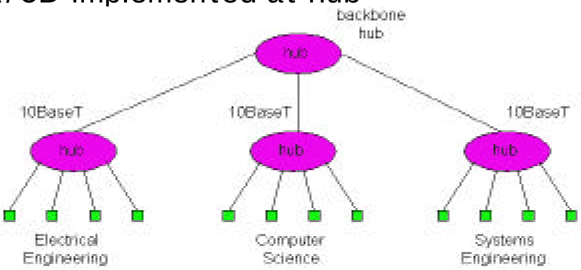
- 10: 10Mbps; 2: under 200 meters max cable length
- thin coaxial cable in a bus topology



- repeaters used to connect up to multiple segments
- repeater repeats bits it hears on one interface to its other interfaces: physical layer device only!

10BaseT and 100BaseT

- 10/100 Mbps rate; latter called “fast ethernet”
- T stands for Twisted Pair
- Hub to which nodes are connected by twisted pair, thus “star topology”
- CSMA/CD implemented at hub



10BaseT and 100BaseT (more)

- Max distance from node to Hub is 100 meters
- Hub can disconnect “jabbering adapter
- Hub can gather monitoring information, statistics for display to LAN administrators

Gbit Ethernet

- use standard Ethernet frame format
- allows for point-to-point links and shared broadcast channels
- in shared mode, CSMA/CD is used; short distances between nodes to be efficient
- uses hubs, called here "Buffered Distributors"
- Full-Duplex at 1 Gbps for point-to-point links

Token Passing: IEEE802.5 standard

- 4 Mbps
- max token holding time: 10 ms, limiting frame length

- SD, ED mark start, end of packet
- AC: access control byte:
  - token bit: value 0 means token can be seized, value 1 means data follows FC
  - priority bits: priority of packet
  - reservation bits: station can write these bits to prevent stations with lower priority packet from seizing token after token becomes free

Token Passing: IEEE802.5 standard

SD	AC	FC

SD	AC	FC	dest addr	src addr	data	checksum	ED	FS

- FC: frame control used for monitoring and maintenance
- source, destination address: 48 bit physical address, as in Ethernet
- data: packet from network layer
- checksum: CRC
- FS: frame status: set by dest., read by sender
  - set to indicate destination up, frame copied OK from ring
  - DLC-level ACKing

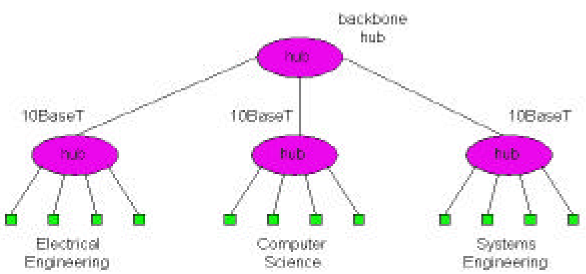
Interconnecting LANs

Q: Why not just one big LAN?

- Limited amount of supportable traffic: on single LAN, all stations must share bandwidth
- limited length: 802.3 specifies maximum cable length
- large “collision domain” (can collide with many stations)
- limited number of stations: 802.5 have token passing delays at each station

Hubs

- Physical Layer devices: essentially repeaters operating at bit levels: repeat received bits on one interface to all other interfaces
- Hubs can be arranged in a hierarchy (or multi-tier design), with backbone hub at its top



Hubs (more)

- Each connected LAN referred to as LAN **segment**
- Hubs do not isolate collision domains: node may collide with any node residing at any segment in LAN
- Hub Advantages:
  - simple, inexpensive device
  - Multi-tier provides graceful degradation: portions of the LAN continue to operate if one hub malfunctions
  - extends maximum distance between node pairs (100m per Hub)

Hub limitations

- single collision domain results in no increase in max throughput
  - multi-tier throughput same as single segment throughput
- individual LAN restrictions pose limits on number of nodes in same collision domain and on total allowed geographical coverage
- cannot connect different Ethernet types (e.g., 10BaseT and 100baseT)

5: DataLink Layer 5a-27

Bridges

- Link Layer devices: operate on Ethernet frames, examining frame header and selectively forwarding frame based on its destination
- Bridge isolates collision domains since it buffers frames
- When frame is to be forwarded on segment, bridge uses CSMA/CD to access segment and transmit

5: DataLink Layer 5a-28

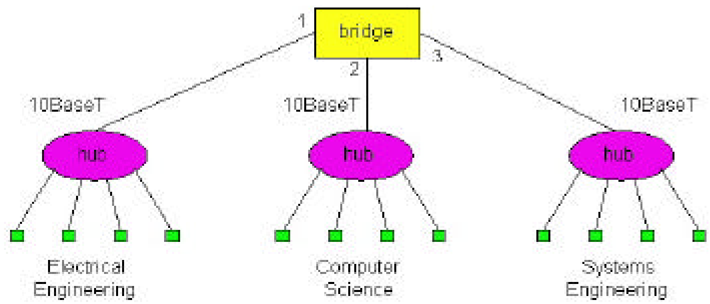
Bridges (more)

- Bridge advantages:
  - Isolates collision domains resulting in higher total max throughput, and does not limit the number of nodes nor geographical coverage
  - Can connect different type Ethernet since it is a store and forward device
  - Transparent: no need for any change to hosts LAN adapters

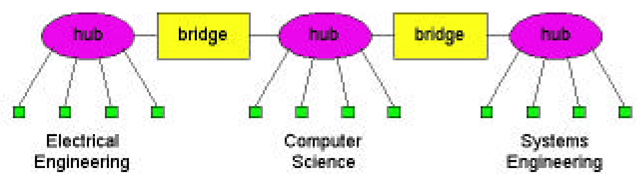
Bridges: frame filtering, forwarding

- bridges filter packets
  - same-LAN -segment frames not forwarded onto other LAN segments
- forwarding:
  - how to know which LAN segment on which to forward frame?
  - looks like a routing problem (more shortly!)

Backbone Bridge



Interconnection Without Backbone



- Not recommended for two reasons:
  - single point of failure at Computer Science hub
  - all traffic between EE and SE must path over CS segment

Bridge Filtering

- bridges *learn* which hosts can be reached through which interfaces: maintain filtering tables
  - when frame received, bridge "learns" location of sender: incoming LAN segment
  - records sender location in filtering table
- filtering table entry:
  - (Node LAN Address, Bridge Interface, Time Stamp)
  - stale entries in Filtering Table dropped (TTL can be 60 minutes)

5: DataLink Layer 5a-33

Bridge Filtering

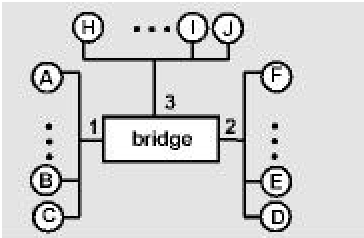
- filtering procedure:

```
if destination is on LAN on which frame was received
    then drop the frame
    else { lookup filtering table
           if entry found for destination
            then forward the frame on interface indicated;
            else flood;   /* forward on all but the interface
              on                      which the frame
              arrived*/
       }
```

5: DataLink Layer 5a-34

Bridge Learning: example

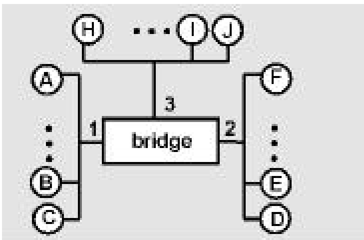
Suppose C sends frame to D and D replies back with frame to C



address	port
A	1
B	1
E	2
H	3
J	3

- C sends frame, bridge has no info about D, so floods to both LANs
  - bridge notes that C is on port 1
  - frame ignored on upper LAN
  - frame received by D

Bridge Learning: example

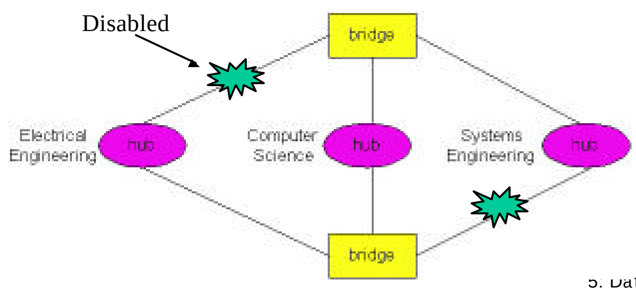


address	port
A	1
B	1
E	2
H	3
J	3

- D generates reply to C, sends
  - bridge sees frame from D
  - bridge notes that D is on interface 2
  - bridge knows C on interface 1, so *selectively* forwards frame out via interface 1

Bridges Spanning Tree

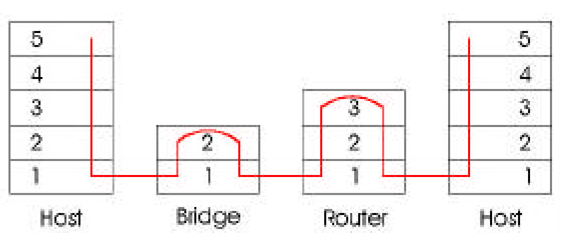
- for increased reliability, desirable to have redundant, alternate paths from source to dest
- with multiple simultaneous paths, cycles result - bridges may multiply and forward frame forever
- solution: organize bridges in a spanning tree by disabling subset of interfaces



5: DataLink Layer 5a-37

WWF Bridges vs. Routers

- both store-and-forward devices
  - routers: network layer devices (examine network layer headers)
  - bridges are Link Layer devices
- routers maintain routing tables, implement routing algorithms
- bridges maintain filtering tables, implement filtering, learning and spanning tree algorithms



5: DataLink Layer 5a-38

Routers vs. Bridges

Bridges + and -

+ Bridge operation is simpler requiring less processing bandwidth
- Topologies are restricted with bridges: a spanning tree must be built to avoid cycles
- Bridges do not offer protection from broadcast storms (endless broadcasting by a host will be forwarded by a bridge)

Routers vs. Bridges

Routers + and -

+ arbitrary topologies can be supported, cycling is limited by TTL counters (and good routing protocols)
+ provide firewall protection against broadcast storms
- require IP address configuration (not plug and play)
- require higher processing bandwidth

- bridges do well in small (few hundred hosts) while routers used in large networks (thousands of hosts)