

The Link Layer

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May 5, 2008

1 Administrivia

Announcements

Assignment

Read 6.1–6.3.

Projects due Wednesday. Not accepted after Friday at 2:30 pm.

From Last Time

Routing.

Outline

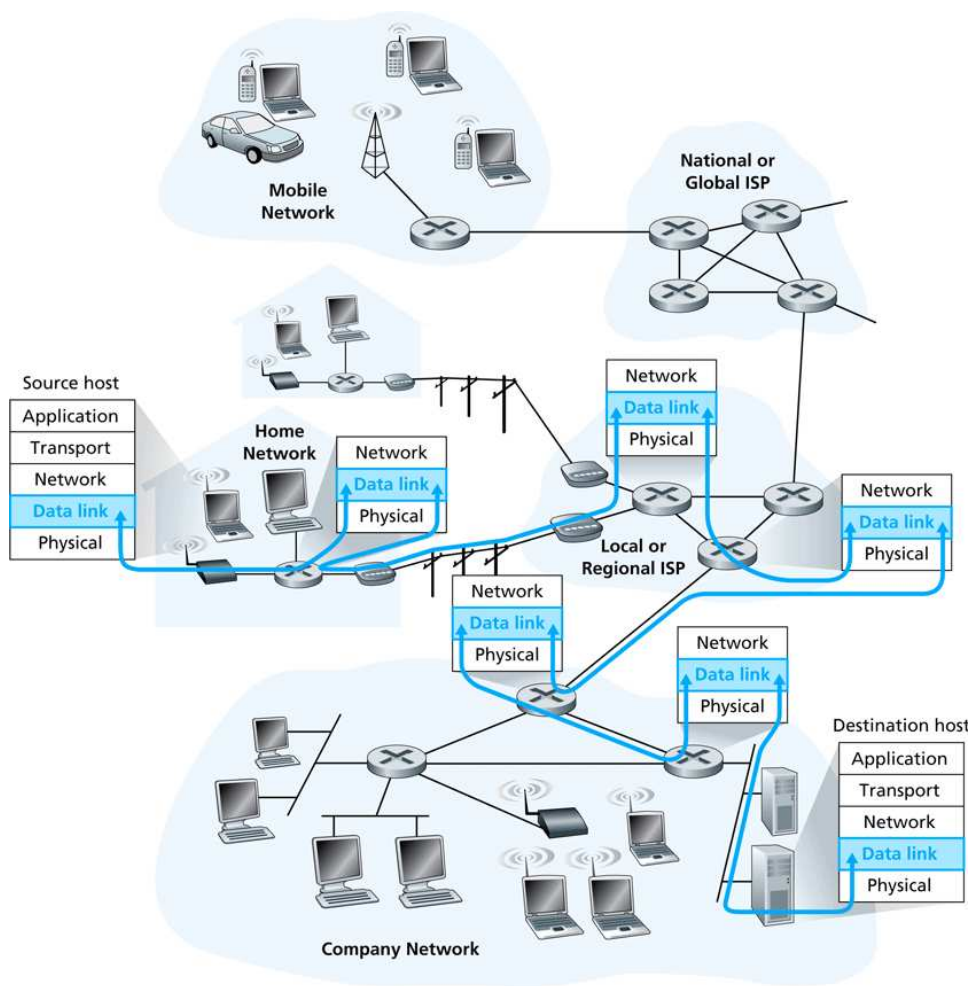
1. Introduction.
2. Multiple Access protocol — CSMA/CD.
3. Link layer addressing.
4. Ethernet.
5. Link layer switches.

Coming Up

Wireless networking.

2 Introduction

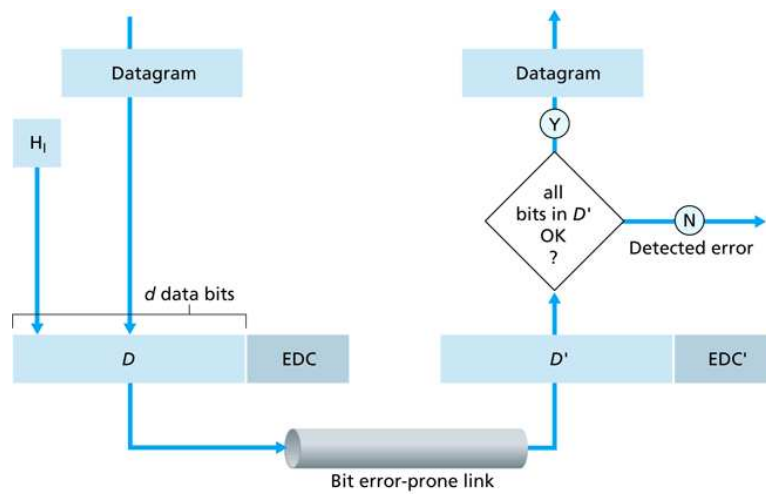
Link layer exists between hosts on either side of a *single* link:



Unit of exchange is a packet/frame/datagram. Physical layer exchanges individual bits.

Example technologies: Ethernet, ATM, 802.11.

Error detection/correction codes appended frame:

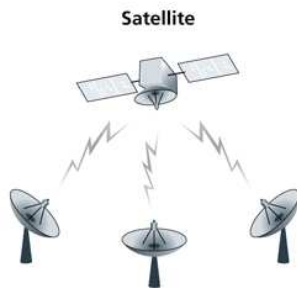
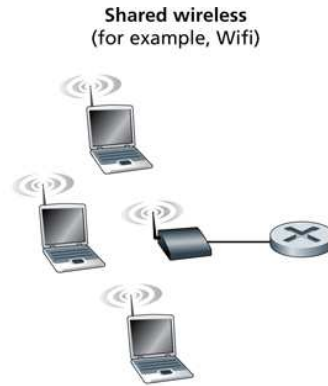
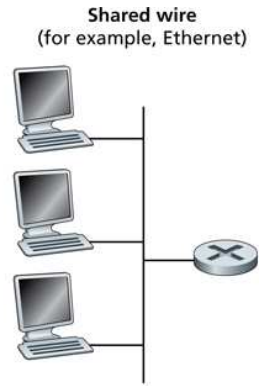


Link layer services:

1. Framing — encapsulation.
2. Link access — protocols for shared access links.
3. Reliable delivery — important for media with high error rates (802.11).
Error detection/correction.
4. Flow control.
5. Duplex — half or full?

3 Multiple Access Protocol — CSMA/CD

How do you control transmission in a shared access medium?:



A number of possible ideas:

1. Take turns: fixed intervals, or a request protocol.

Time division multiplexing.

2. Partition the bandwidth.

Frequency division multiplexing.

3. Code division multiplexing.

4. Random access protocols:

- (a) Listen. If no stations sending, begin to send.

If a station is sending, wait a random amount of time, then listen again.

- (b) Possible for two senders to begin sending. Action upon detection of collision?

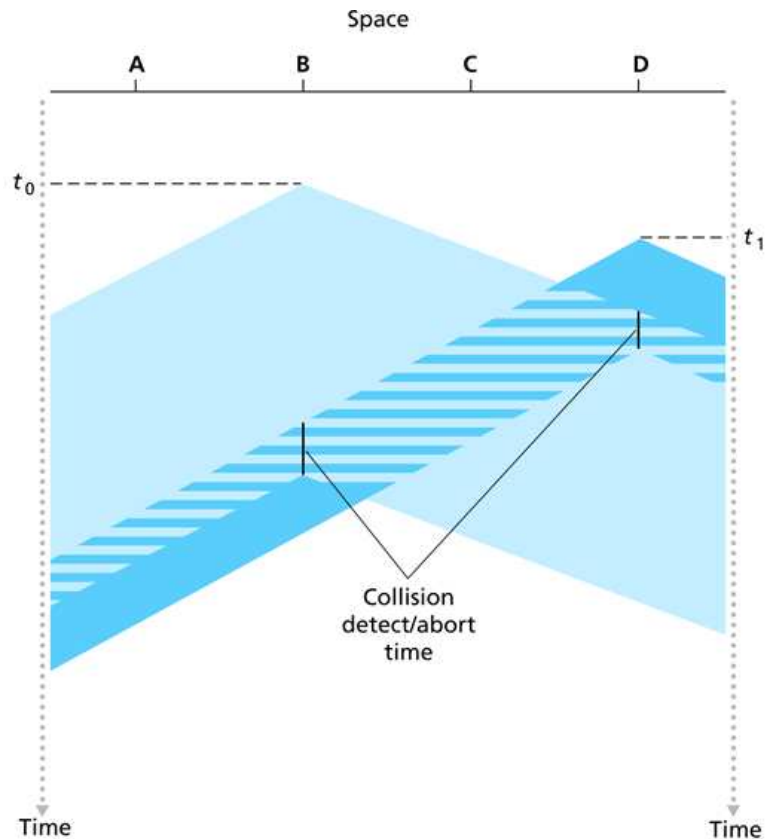
Is it always possible to detect a sending collision?

5. CSMA/CD — Carrier Sense Multiple Access/Collision Detection:

(a) Sense media for idle state. If idle, begin transmitting.

If media isn't idle, backoff for a randomly chosen unit of time.

(b) How can collisions occur?



4 Link Layer Addressing

1. Each network adapter has an eight byte MAC address:

```
bluebird:~/Class/Cs325/Lectures
% ifconfig eth0
eth0      Link encap:Ethernet  HWaddr 00:1A:A0:16:65:8B
          inet addr:10.67.1.26  Bcast:10.67.1.255  Mask:255.255.255.0
          inet6 addr: fe80::21a:a0ff:fe16:658b/64  Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
```

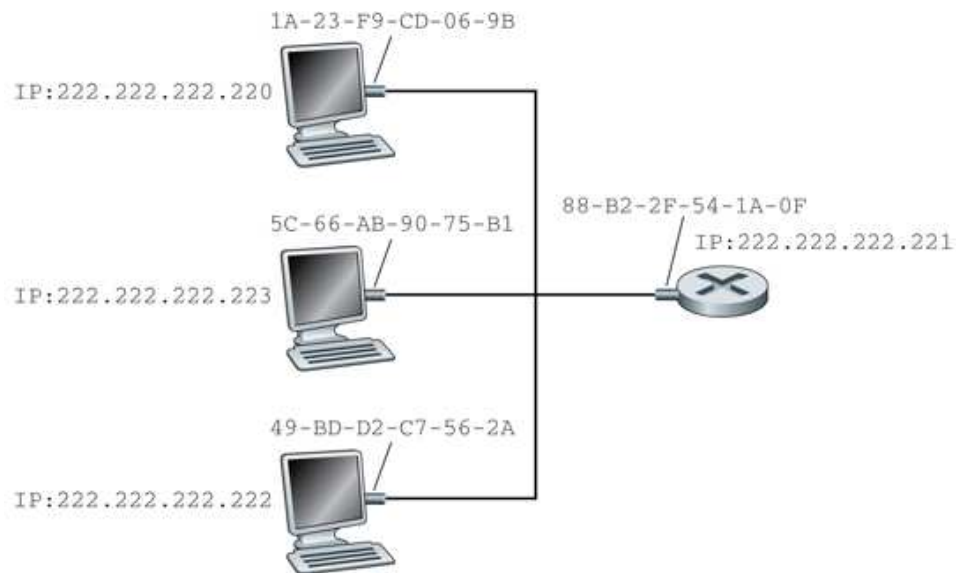
```

RX packets:295533 errors:0 dropped:0 overruns:0 frame:0
TX packets:173558 errors:0 dropped:0 overruns:0 carrier:0
collisions:0 txqueuelen:1000
RX bytes:139988511 (133.5 MiB) TX bytes:31578020 (30.1 MiB)
Interrupt:177

```

MAC addresses are “unique.”

- Each host on a network has an IP address and a MAC address:



Why both?

MAC addresses are not hierarchical, beyond vendor/adaptor number designation.

- So you want to send a datagram to IP address w.x.y.z. At the link layer, you really need the MAC address. How do we get that?

Use ARP!!

An ARP cache:

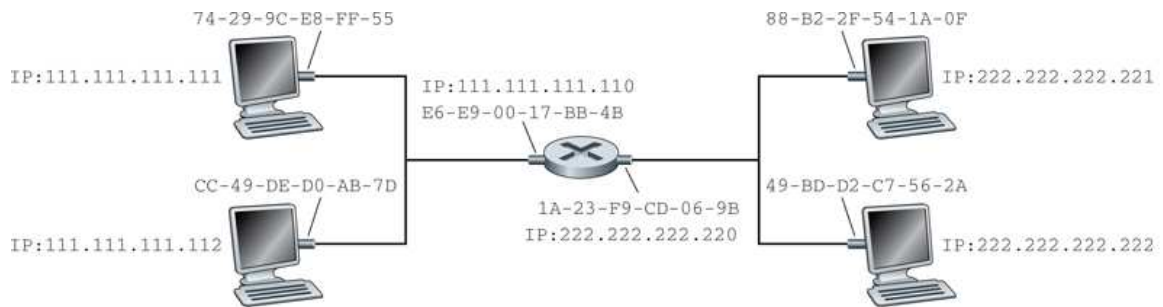
```
bluebird:~/Class/Cs325/Lectures
```

```
% arp
```

Address	HWtype	HWaddress	Flags	Mask	Iface
10.67.1.1	ether	00:13:5F:C4:B8:0A	C		eth0
shrike.goucher.edu	ether	00:08:74:92:71:6B	C		eth0
goldfinch.goucher.edu	ether	00:0B:DB:A7:EC:2A	C		eth0

ARP protocol screen capture. (On web site.) Ping of kingfisher from bluebird. Note multiple protocols:

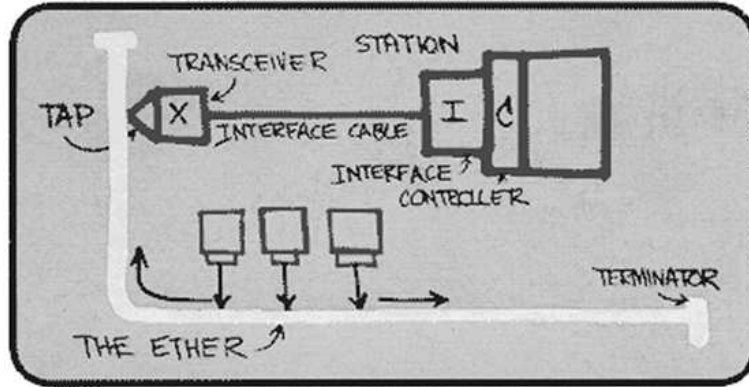
- (a) DNS — A record lookup.
 - (b) ARP — broadcast request, single destination response.
 - (c) DNS — PTR record lookup.
 - (d) ICMP — echo request/reply.
4. Trace an IP datagram from one network to the next:



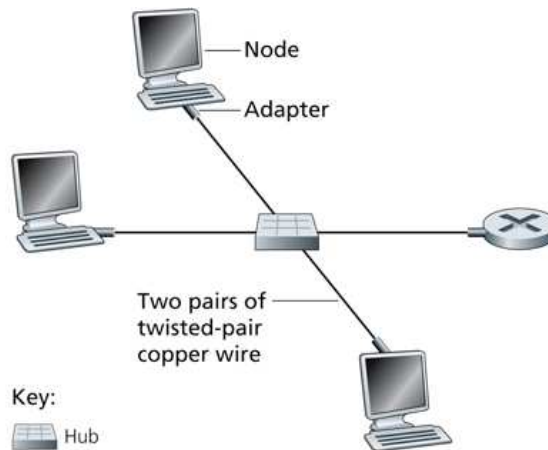
Example: Send an HTTP request to a server on another subnet. (Resolver target on same subnet.)

5 Ethernet

1. Originally, Ethernet was a shared access medium using thinwire (10B2) or thickwire (10B5) coaxial cabling:

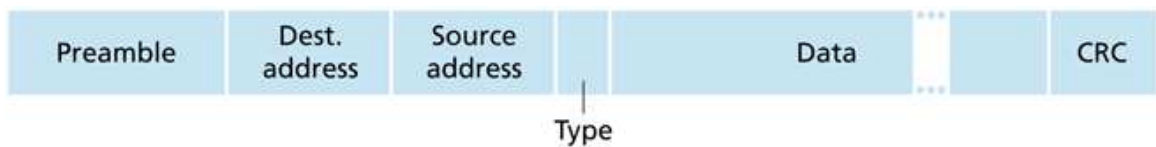


2. Then, we moved on to twisted-pair and hubs in a star topology:



Hubs are physical layer devices (re-generate and broadcast) — still a shared medium.

3. Ethernet frame fields:



(a) Preamble (8 bytes): Used to synchronize receiver clocks with send clock.

(Ethernet is asynchronous.)

(b) Type (2 bytes): Indicates which network layer protocol is contained in the frame's payload.

(c) Data: 46 to 1,500 bytes. Short frames are padded to 46 bytes. Padded bytes passed onto network layer.

(IP uses datagram length to ignore padding.)

(d) CRC (4 bytes): error detection.

4. Ethernet's CSMA/CD uses exponential backoff and random choice after back-to-back collisions:

(a) After 1st collision, wait $\{0, 1\} \times 512$ bit times.

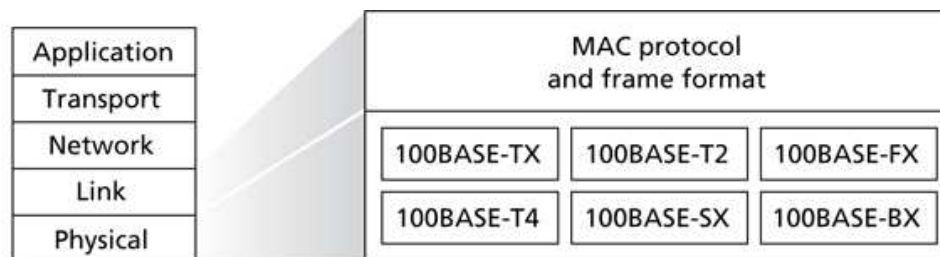
(b) After 2nd, wait $\{0, 1, 2, 3\} \times 512$ bit times.

(c) After 3rd, wait $\{0, 1, \dots, 7\} \times 512$ bit times.

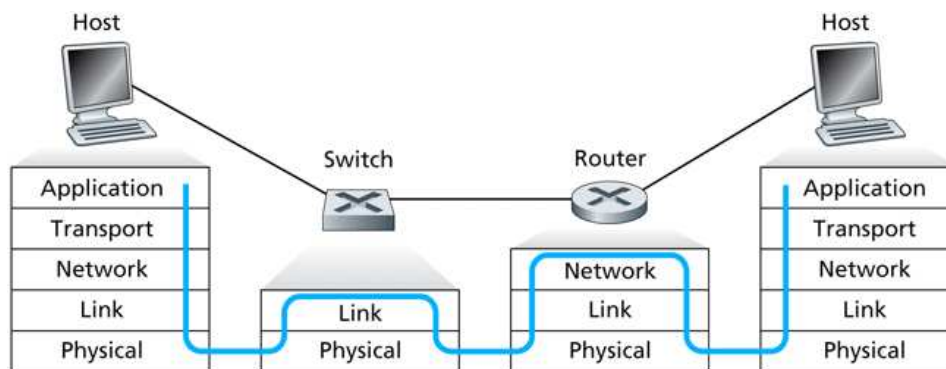
(d) ...

(e) Maximum is $\{0, 1, \dots, 1023\} \times 512$ bit times.

5. Ethernet standards exist at both link and physical layers:



6 Link Layer Switches



1. Switches are intelligent, link layer devices.
Store & forward.
Eliminate collisions.
Heterogeneous link speeds.
2. Are transparent — hosts aren't aware they're there.
Don't have MAC addresses.
3. Learn about the network, to eliminate broadcasting frames meant for one host.
 - (a) When a host first sends a frame, switch notes the source MAC address.
 - (b) Switch stores (MAC address, interface, timestamp) n -tuples in a table.
Essentially, a small forwarding table.
Multiple MAC addresses may be associated with the same interface. Why?
 - (c) On receipt of a frame, lookup the destination MAC address in the table.
 - If found, send the frame to the indicated interface.
 - Otherwise, broadcast the frame.
 - (d) Timestamp used to purge stale entries.