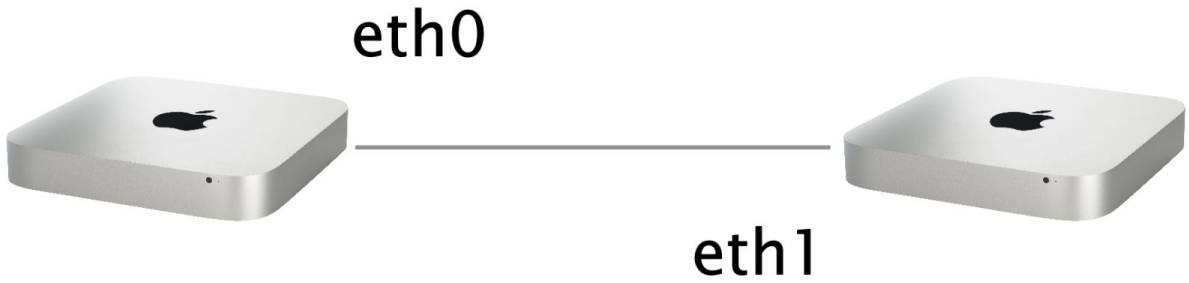
Link Layer

How do local computers communicate?



Link Layer

1. What is a link?
2. How do we share a network medium?
3. How do we identify link adapters?
4. What is Ethernet?
5. How do we interconnect segments at the link layer?

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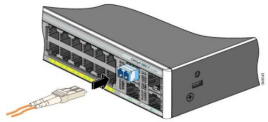
Link Layer

Link Communication medium and Network adapter

Wifi

Ethernet

Fiber



Link Layer

terminology:

- hosts and routers: **nodes**
- communication channels that connect adjacent nodes along communication path: **links**
  - wired
  - wireless
  - LANs
- layer-2 packet: *frame*, encapsulates datagram

Link layer has responsibility of transferring datagram from one node to physically adjacent node over a link

Link Layer

- datagram transferred by different link protocols over different links:
  - e.g., WiFi on first link, Ethernet on next link
- each link protocol provides different services
  - e.g., may or may not provide reliable data transfer over link

transportation analogy:

- trip from Princeton to Lausanne
  - limo: Princeton to JFK
  - plane: JFK to Geneva
  - train: Geneva to Lausanne
- tourist = datagram
- transport segment = communication link
- transportation mode = link-layer protocol
- travel agent = routing algorithm

Link Layer Services

- framing, link access:
  - encapsulate datagram into frame, adding header, trailer
  - channel access if shared medium
  - “MAC” addresses in frame headers identify source, destination

- reliable delivery between adjacent nodes
  - seldom used on low bit-error links
  - wireless links: high error rates
  - Question: why both link-level and end-end reliability?

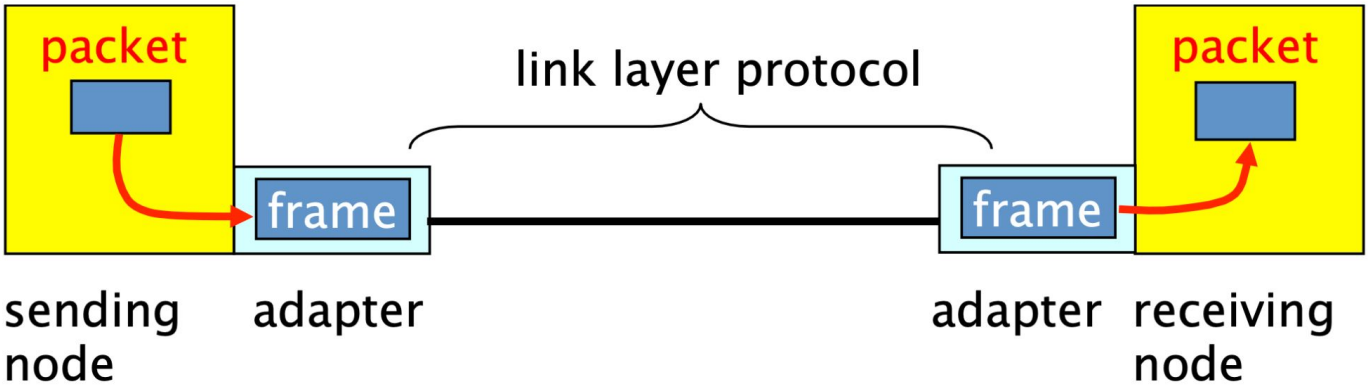
Link Layer Services

- flow control:
  - pacing between adjacent sending and receiving nodes
- error detection:
  - errors caused by signal attenuation, noise.
  - receiver detects errors, signals retransmission, or drops frame
- error correction:
  - receiver identifies and corrects bit error(s) without retransmission
- half-duplex and full-duplex:
  - with half duplex, nodes at both ends of link can transmit, but not at same time

Where is the Link Layer Implemented?

- each-and-every host
- link layer implemented in *network interface card* (NIC) or on a chip
  - Ethernet, WiFi card or chip
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware

Network Adapters Communicate via the Medium



sending side:

- encapsulates datagram in frame
- adds error checking bits, reliable data transfer, flow control, etc.

receiving side:

- looks for errors, reliable data transfer, flow control, etc.
- extracts datagram, passes to upper layer at receiving side

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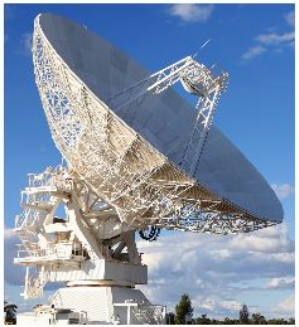
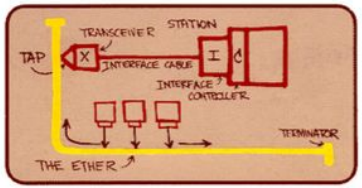
Some Mediums are Multi-Access (>1 Host can Communicate at a Time)

Wireless networks



Satellite networks



original Ethernet networks

Cellular networks

Multi-Access Problem: Collisions

Problem

collisions lead
to garbled data

Solution

distributed algorithm
for sharing the channel

When can each node transmit?

How would you handle multiple access to avoid collisions?

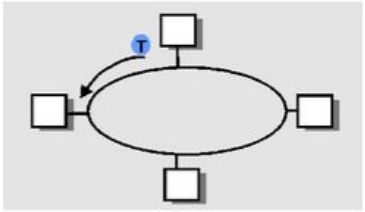
There are Effectively Three Ways to Manage Multiple Access

Divide the channel into pieces

either in time or in frequency

Take turns

pass a token for the right to transmit



Random access

allow collisions, detect them and then recover

There are Effectively Three Ways to Manage Multiple Access

channel partitioning, by time, frequency or code

- Time Division, Frequency Division

taking turns

- polling from central site, token passing
- Bluetooth, FDDI, token ring

random access (dynamic),

- ALOHA, S-ALOHA, CSMA, CSMA/CD
- carrier sensing: easy in some technologies (wire), hard in others (wireless)
- CSMA/CD used in Ethernet
- CSMA/CA used in 802.11

Carrier Sense Multiple Access

simple CSMA: listen before transmit:

- if channel sensed idle: transmit entire frame
- if channel sensed busy: defer transmission

human analogy: don’t interrupt others

See any potential problems with this?

Carrier Sense Multiple Access

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Two nodes start transmitting at some time or slightly offset: collision with lots of wasted transmission (full frames)

Carrier Sense Multiple Access

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CSMA/CD: CSMA with collision detection

- collisions detected within short time
- colliding transmissions aborted, reducing channel wastage
- collision detection easy in wired, difficult with wireless

human analogy: the polite conversationalist

Carrier Sense Multiple Access

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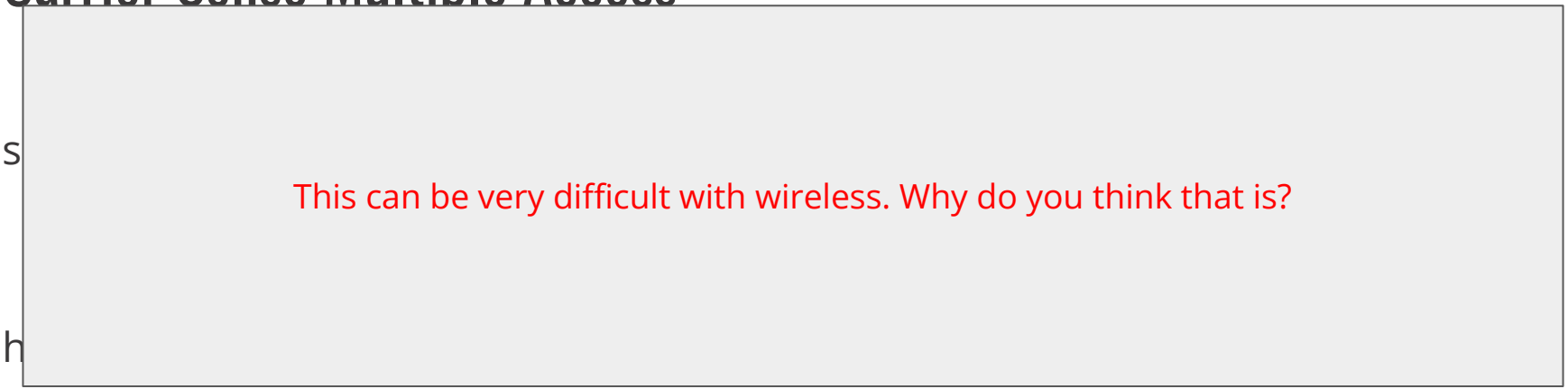

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This can be very difficult with wireless. Why do you think that is?

It’s hard to hear others over yourself without more complex (expensive) radio hardware

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