Introduction to the Link Layer

Smith College, CSC 249
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Link Layer Services & Protocols

- Link layer services
- Principles for multiple access protocols
- Categories of multiple access protocols
- Example of link layer technology
  - Ethernet & CSMA/CD

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Link Layer Vocabulary

- Node: hosts and routers
- Link: communication channels that connect adjacent nodes
  - wired & wireless links
- Frame
  - A Layer-2 packet is a 'frame'
- "MAC" addresses
  - Media Access Control address
  - In 'frame' headers to identify source and destination
  - Different from IP address

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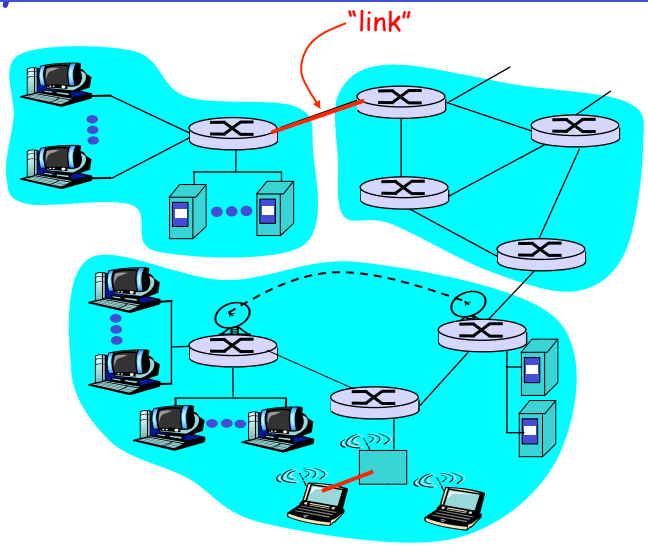
Link Layer (all wired and wireless lines below)



data-link layer has responsibility of transferring a frame from one node to an adjacent node over a link

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Link Layer Services 1

1. Framing, link access:
   - Encapsulate datagram into frame, adding header, trailer (with MAC addresses)
   - Coordinate access to the communication channel, if it is a shared medium
2. Reliable delivery between adjacent nodes
   - Seldom used on low bit-error links (fiber optic, some twisted pair)
   - But wireless links have high error rates
   - Why have both link-level and end-end reliability?

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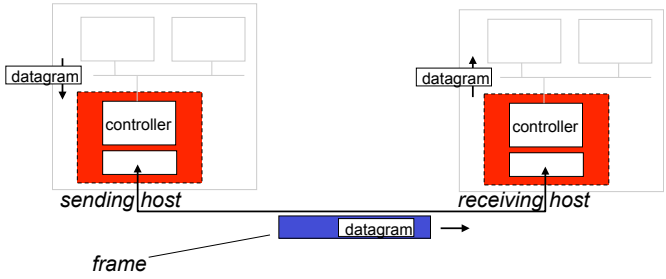
Adaptors Communicating



- Sending side:
  - Encapsulates datagram in frame
  - Adds error checking bits, flow control, etc.
- Receiving side
  - Looks for errors, flow control, etc
  - Extracts datagram, passes to upper layer at receiving side

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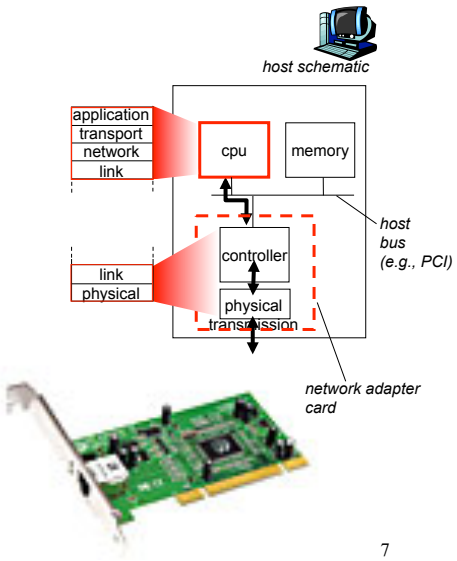
Where is the link layer implemented?

- In every host
- Link layer implemented in "adaptor," the *network interface card,* NIC
  - Ethernet card, 802.11 card
  - Implements link & physical layer
- Attaches into host's system buses
- Combination of hardware, software, firmware



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Link Layer Services 2 (more)

3. *Error Detection*:
   - errors caused by signal attenuation, noise.
   - receiver detects presence of errors:
     - signals sender for retransmission or drops frame
4. *& Error **Correction**:*
   - receiver identifies *and corrects* bit error(s) without resorting to retransmission
5. *Half-duplex and full-duplex*
   - with half duplex, nodes at both ends of link can transmit, but not at same time
6. *Flow Control:*
   - pacing between adjacent sending and receiving nodes

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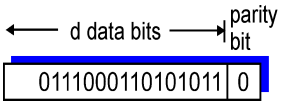
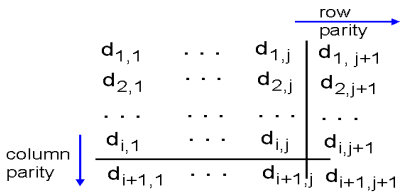
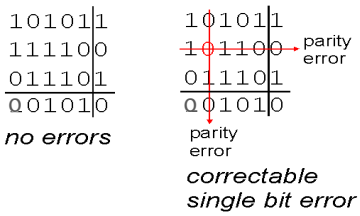
Error Detection: Parity

Single Bit Parity:
Detect single bit errors



Two Dimensional Bit Parity:
Detect *and correct* single bit errors





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Parity Problem

- Suppose a packet contains 1010101010101011
  - An even parity scheme is used, so the total number of '1' bits in the row/column is an even number
- What would the value of the field containing the parity bits be, for the case of a 2D parity scheme?

1 0 1 0	
1 0 1 0	
1 0 1 0	
1 0 1 1	

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Parity Problem

- For the previous question, show an example of
  - 1-bit error detected and corrected
  - 2-bit error detected but not corrected
    - Note row 2, columns 2 and 3

1	0	1	0	
1	1	0	0	
1	0	1	0	
1	0	1	1	

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Error Detection

- Parity – typically applied to individual bytes
- Checksum
  - Applied to a packet, a packet header…
  - Is moderately robust
- CRC can detect more errors
  - A single bit of the packet affects the CRC in a more complex manner than for checksum
    - Each bit feeds into the CRC in three places
    - Each bit then cycles through and interacts with remaining bits

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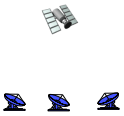
Multiple Access Links and Protocols

Two types of "links":

- point-to-point
  - point-to-point link between Ethernet switch and host
- broadcast (shared wire or medium)
  - traditional Ethernet
  - 802.11 wireless LAN

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

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Multiple Access protocols

Problem: Single shared transmission link

- All nodes receive all frames
- There is 'collision' if more than one node transmits at the same time

Solution: Multiple access protocol

- Coordinate access to the shared link
- Establish rules for dealing with collisions

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Ideal Multiple Access Protocol

Principles for a shared link of rate R

1. When one node wants to transmit, it can send at rate R (R bits/second)
2. When M nodes want to transmit, each can send at average rate R/M
3. Fully decentralized:
   - no special node to coordinate transmissions
   - no synchronization of clocks, slots
4. Simple

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MAC Protocols: Three Categories

1) Channel Partitioning
   - Divide link bandwidth into smaller "pieces" (time slots, frequency, code)
   - Allocate piece to node for exclusive use
2) Random Access (most used today)
   - The link bandwidth is not divided, allow collisions
   - "Recover" from collisions
3) "Taking turns"
   - Nodes take turns, but nodes with more to send can take longer turns

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MAC Protocols: Three Types

- Volunteers
  - To 'send' (read) text
  - To 'receive' (hear and decipher) text

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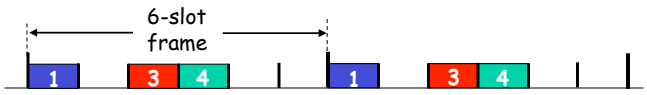
Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

- access to channel in "rounds"
- each station gets fixed length slot (length = packet transmission time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have packets, slots 2,5,6 are idle



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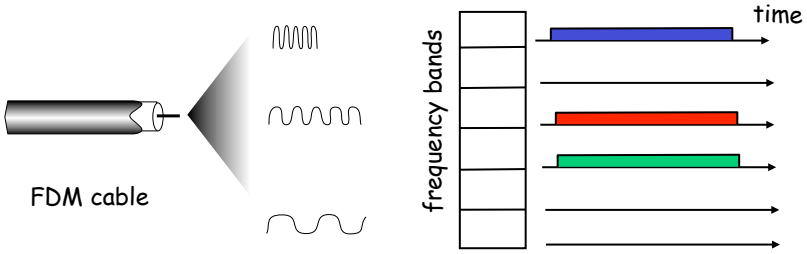
Channel Partitioning MAC protocols: FDMA

FDMA: frequency division multiple access

- Channel spectrum divided into frequency bands
- Each station assigned fixed frequency band
- Unused transmission time in frequency bands go idle
- Example: 6-station LAN, 1,3,4 bands have packets, frequency bands 2,5,6 idle



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Random Access Protocols

- When node has packet to send
  - Transmit at full channel data rate R.
  - No *a priori* coordination among nodes
- Two or more transmitting nodes "collide"
- Random access MAC protocol specifies:
  - How to detect collisions
  - How to recover from collisions (e.g., via delayed retransmissions)
- Examples of random access MAC protocols:
  - CSMA, CSMA/CD, CSMA/CA – Ethernet and 802.11 wireless protocol

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CSMA (Carrier Sense Multiple Access)

CSMA: listen before transmitting:

- If channel is sensed to be idle, transmit entire frame
  - Sense the voltage level on the cable or fiber
- If channel is sensed to be busy, delay transmission

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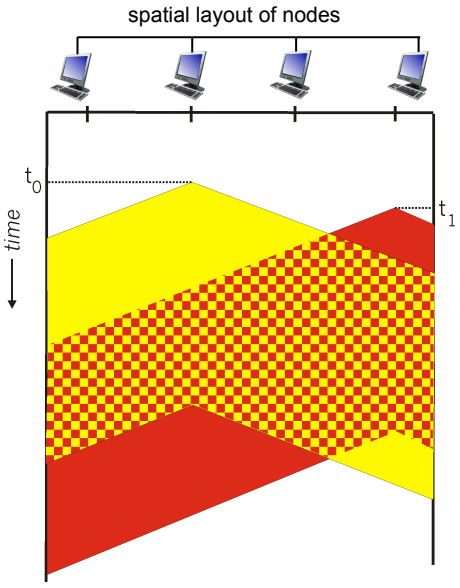
CSMA collisions

Collisions *can* occur:
Propagation delay means two nodes may not hear each other's transmission initially

Collision:
Entire packet transmission time wasted

Note the role of distance & propagation delay in determining the collision probability



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CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- Collisions *detected* within short time
- Colliding transmissions aborted, reducing channel wastage

- Collision Detection:
  - Easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - Difficult in wireless LANs: receiver shut off while transmitting
  - **csma/cd applet:**

http://wps.aw.com/aw_kurose_network_3/0,9212,1406346-,00.html

http://wps.aw.com/aw_kurose_network_5/111/28536/7305312.cw/index.html

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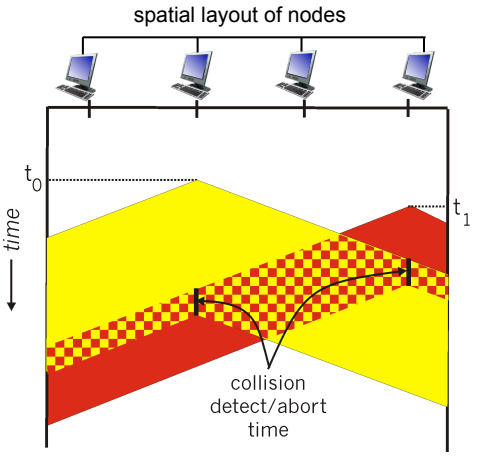
CSMA/CD collision detection



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"Taking Turns" MAC protocols

Channel partitioning MAC protocols:

- Share channel efficiently and fairly at high load
- Inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node

Random access MAC protocols

- Efficient at low load: single node can fully utilize channel
- High load: collision overhead

"Taking turns" protocols

- Polling protocols, and token ring protocols

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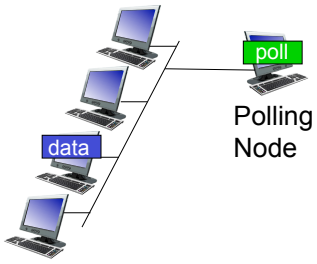
Polling Protocols

- A master node coordinates which node uses the channel
- Efficient, but…
  - Single point of failure possible
  - Polling process and latency



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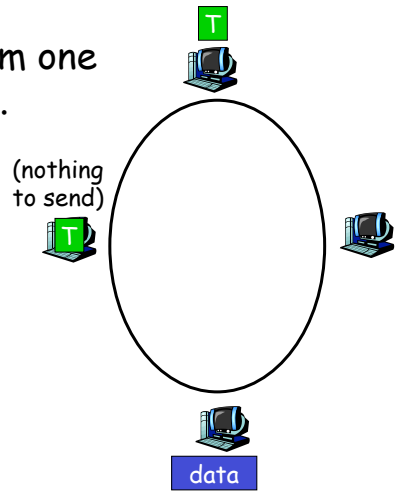
"Taking Turns" MAC protocols

Token passing:

- control **token** passed from one node to next sequentially.
- token message
- concerns:
  - token overhead
  - latency
  - single point of failure (token)



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Summary

- New link layer vocabulary
- Link layer services
  - Parity for error detection and correction
- Multiple access protocol principles
- Three categories of MAC protocols

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