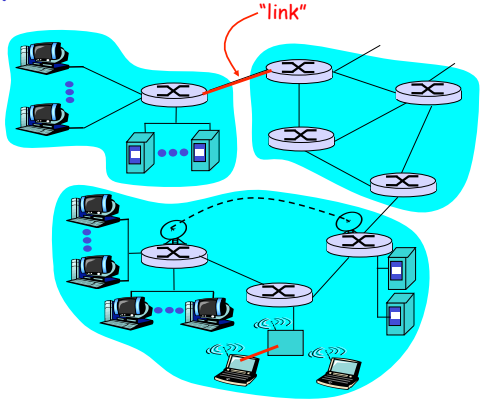
Introduction to the Link Layer, Chapter 4

Smith College, CSC 249
October 27, 2014

Link Layer Services & Protocols

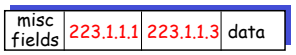
- Link layer services?
- Types of connections?
- Principles for multiple access protocols?
- Categories of multiple access protocols?
- Example of link layer technology
  - Ethernet & CSMA/CD

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

Delivering a datagram: Single Subnet

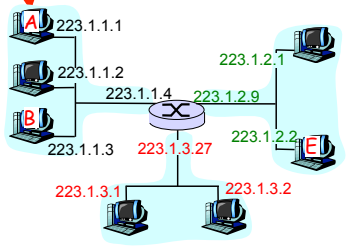


routing table in A

Dest. Net.	next router	Nhops
223.1.1		1
223.1.2	223.1.1.4	2
223.1.3	223.1.1.4	2

Starting at A, given IP datagram addressed to B:

- look up IP address of B
- find B is on same subnet as A
- link layer will send datagram directly to B inside link-layer frame
  - B and A are directly connected
- Remember definition of SUBNET?

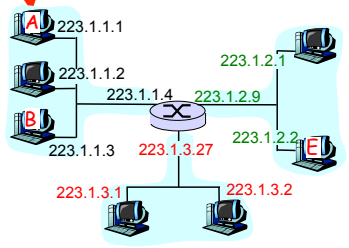


Delivering a datagram: Different Subnet

misc fields	223.1.1.1	223.1.2.2	data

routing table in A

Dest. Net.	next router	Nhops
223.1.1		1
223.1.2	223.1.1.4	2
223.1.3	223.1.1.4	2



Starting at A, dest. E:

- look up network address of E
- E on *different* subnet
  - A, E not directly attached
- routing table: next hop router to E is 223.1.1.4
- link layer sends datagram to router 223.1.1.4 inside link-layer frame
- datagram arrives at 223.1.1.4
- continued.....

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

Link Layer Services

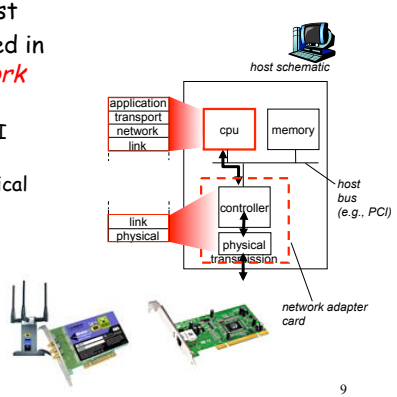
1. Framing, link access:
   - Encapsulate datagram into frame, adding header, trailer (with MAC addresses)
   - Coordinate access to the communication channel, if it is a shared medium
2. Reliable delivery between adjacent nodes
   - Seldom used on low bit error link (fiber, some twisted pair)
   - Wireless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

Link Layer Services (more)

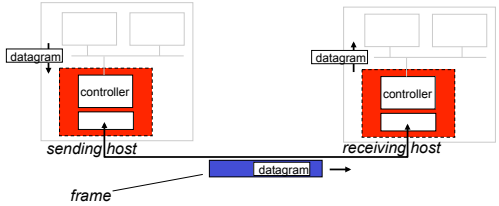
3. *Error Detection*:
   - errors caused by signal attenuation, noise.
   - receiver detects presence of errors:
     - signals sender for retransmission or drops frame
4. *Error Correction:*
   - receiver identifies *and corrects* bit error(s) without resorting to retransmission
5. *Half-duplex and 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

Where is the link layer implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC)
  - Ethernet card, PCMCI card, 802.11 card
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



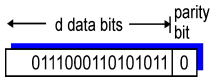
Adaptors Communicating



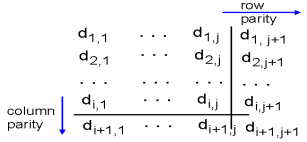
- sending side:
  - encapsulates datagram in frame
  - adds error checking bits, rdt, flow control, etc.
- receiving side
  - looks for errors, rdt, flow control, etc
  - extracts datagram, passes to upper layer at receiving side

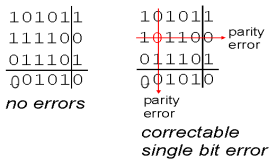
Error Detection: Parity

Single Bit Parity:
Detect single bit errors



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





Parity Problem

- Suppose a packet contains 1010101010101011
- An even parity scheme is used
- 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	

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	

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

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)

Multiple Access protocols

Problem: Single shared broadcast channel

- 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 a shared broadcast channel
- Establish rules for dealing with collisions

Ideal Multiple Access Protocol

Principles for a broadcast channel of rate R

1. When one node wants to transmit, it can send at rate R.
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

MAC Protocols: Three Categories

- Channel Partitioning
  - divide channel into smaller "pieces" (time slots, frequency, code)
  - allocate piece to node for exclusive use
- Random Access
  - channel not divided, allow collisions
  - "recover" from collisions
- "Taking turns"
  - Nodes take turns, but nodes with more to send can take longer turns

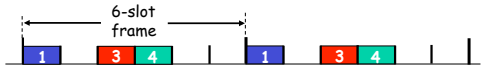
MAC Protocols: Three Types

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

Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

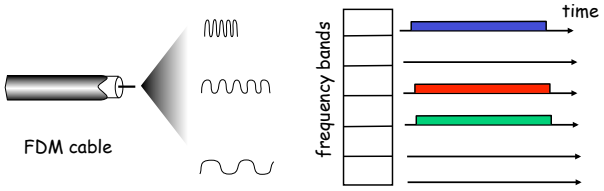
- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



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 have pkt, frequency bands 2,5,6 idle



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 ➜ "collision"
- 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

CSMA (Carrier Sense Multiple Access)

CSMA: listen before transmitting:

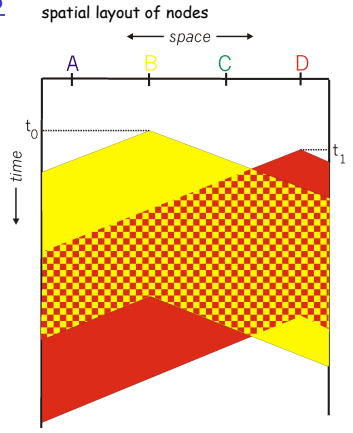
- If channel is sensed to be idle, transmit entire frame
  - Sense the voltage level on the cable or fiber
- If channel is sensed to be busy, defer transmission

CSMA collisions

collisions *can* still occur:
propagation delay means two nodes may not hear each other's transmission

collision:
entire packet transmission time wasted

note:
role of distance & propagation delay in determining collision probability



CSMA/CD (Collision Detection)

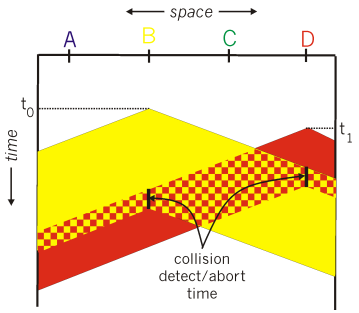
CSMA/CD: carrier sensing, deferral as in CSMA

- 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

CSMA/CD collision detection



"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

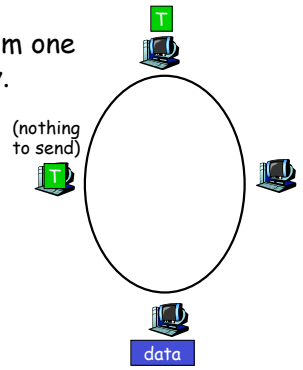
Polling Protocols

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

"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)



Summary

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