Introduction to the Link Layer, Chapter 4

Smith College, CSC 249
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Link Layer (all wired and wireless lines below)

"link"

"link" has responsibility of transferring a frame from one node to an adjacent node over a link

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

Delivering a datagram: Single Subnet

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**

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
- Parity:
  - Data: 0110001101011100
  - Parity bit: 0

Two Dimensional Bit Parity:
- Detect and correct single bit errors
- Parity:
  - Data: 1010101010101011
  - Parity: 101010101010101011
  - Error: 0
  - Correctable:

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?

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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

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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

### 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

### 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

![6-slot frame diagram]
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

"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