The Link Layer: Framing, Error Detection, Channel Access

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Plan

• Multiplexing links using a switch
  • Circuit switching (TDM) and packet switching (statistical multiplexing)

• Today: Best-effort networks and layering
  • Delays, losses, reordering: properties of a best-effort packet-switched network

• Link-layer: Framing, error detection, channel access

• Network layer: forwarding, routing

• End-to-end (transport) layer: reliable delivery
Link Layer Framing

- Q: What if “SOF/END” appears in payload?
  - One solution: bit stuffing
  - A common SOF/END is 01111110
  - At sender: If 5 ones in a row, insert 0
  - At receiver: If 111110abc, decode as 11111abc, stripping out 0 following 5 ones
  - If receiver gets 0111111, then:
    - If next bit = 0, SOF/END, else some corruption
  - Drawbacks?
    - Worst case frame size could be quite large
    - What happens if there are bit errors?

Using Length to Frame

- No need for bit-stuffing with explicit length
- But what happens when there are bit errors?
- With errors, both bit-stuffing and explicit length may cause
  - Truncated frames
  - Dropped frames
- Remedy: Protect headers with separate CRC
Error Detection

- Use checksum or cyclic redundancy check (CRC)
  - In lab: checksum using block parity
- Discard frame if checksum/CRC fails?
- To improve performance, could retransmit missing frame
  - Also called Automatic Repeat reQuest (ARQ)
  - How many times should link layer retransmit before giving up?
    - End-to-end argument: not too many times!
    - When should link layer retransmit?

Channel Access

- Broadcast networks: assume everyone can hear everyone else
- Examples of broadcast networks:
  - Most wireless networks incl. WiFi (802.11)
  - Ethernet (but not 1 Gbit/s or higher)
- Goal: Want to share channel efficiently
What does “efficiently” mean?

- Want high channel throughput (utilization)
  - Throughput = Useful data rate
  - Utilization = Throughput/Channel Rate

- Easy to achieve: just allow one person to send all the time

- So... want fairness also
  - All nodes with data to send should get equal share over some time (this is a simplification...)

- These goals are common to many networks

Many Solutions

- Channel access or multiple access protocols
- Time Division Multiple Access (TDMA)
  - Analogous to TDM for circuit switching
  - Used in some cellular networks, Bluetooth
- Carrier Sense Multiple Access (CSMA)
  - Aloha: Precursor to (and inspiration for) CSMA
  - CSMA used in Ethernet, WiFi, etc.
  - Numerous optimizations
- Channel reservation schemes
The Aloha Protocol

- Context: Norm Abramson, U. Hawaii
- Developed scheme to connect islands via satellite network

The Aloha Protocol is Really Simple!

- Sender: Just sends
- Receiver: if received successfully, send ACK
- Sender: If no ACK in time T, try later
  - In a variant, try immediately with some probability, else try later
  - A lot depends on what “later” means
  - A good “later” uses exponential backoff
    - We’ll revisit retransmissions in a few lectures from now
    - For now, assume no retransmissions

- How can this protocol possibly work?
Collisions

- A collision occurs when multiple transmissions overlap in time

Throughput = uncollided packets per second

Calculating Throughput

- Channel throughput depends on both arrival rate and how packets arrive
- Analysis is tractable for certain random arrival processes
- Example: exponentially distributed arrivals (Poisson process)
- $P(\text{one arrival in } t, t+\Delta t) = \lambda \Delta t$
- Distribution is memoryless (past doesn’t matter, prob. indep. of time)
- Assume that total offered load is Poisson with rate $\lambda$ (superposition)
  - $N$ transmitters, assume $N$ is large, each sending at a (low) Poisson rate such that total rate is $\lambda$
Calculating Throughput (cont.)

- Suppose a packet A is sent at time \( t \).
- Then, any packet whose transmission starts in the interval \((t-\tau, t+\tau)\) will collide with P.

- What is \( P(\text{no other packet in time } 2\tau) \)?
  - Answer: \( \exp(-\lambda(2\tau)) \) [Why?]

Throughput v. Offered Load

- Throughput \( = \lambda \exp(-2\lambda \tau) \)

Throughput (for \( \tau = 1 \) vs. Offered load, \( \lambda \))
Improving on Aloha

- **Slotting**
  - Divide time into slots of duration = frame time, transmit only at start of slot

- **Carrier sense: Listen before transmit**
  - If busy, defer; else, send

- **Ethernet: Carrier sense + collision detect**
  - Wired broadcast medium allows detection (if your transmission got corrupted, then collision)

- **WiFi: Carrier sense (not always that good) + collision avoidance heuristics**

Summary

- **Link layer has three functions:**
  - Framing, error detection, channel access

- **Framing using bit stuffing, explicit length setting**

- **Channel access using Aloha contention protocol**
  - Analysis of Aloha

- **Lab: simple link layer for Aloha + performance study**