Today’s lecture

- Performance metrics
- Data link layer introduction

Performance Metrics

- Bandwidth: physical property of link
- Throughput: actual data transmitted per time unit
  - notation
    - KB = 2^10 bytes
    - Mbps = 10^6 bits per second
- Latency (delay)
  - time to send message from point A to point B
  - one-way versus round-trip time (RTT)
    - Latency = Propagation + Transmit
    - Propagation = Distance / Speed (of light)
    - Transmit = Size / Bandwidth
- Delays on Internet much greater (queueing)
**Bandwidth versus Latency**

- Relative importance
- Assume propagation delay is 100 ms
- Transfer 1 Kb, bw 1 Mbps
  - Latency: 100 + 1 (transmission delay) = 101 ms

- Transfer 1 Mb
  - Latency: 100 + 1000 (transmission delay) = 1100 ms


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**Physical layer**

- Signal encoding and synchronization

  - NNRZ
  - Clock
  - Manchester
  - NRZI


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**Role of data link layer**

- Service offered by layer 1: a stream of bits
- Service to layer 3: sending & receiving frames
- To achieve this layer 2 does
  - Framing
  - Error detection (rarely error correction)
  - Multiplexing
    - Media access control
    - Addressing (multiple access links)
Framing 1 – sentinel approach

- Used by Point-to-Point-Protocol (PPP)
- Special characters for start and end of frame
- Use “byte stuffing” if they appear in body

```
8 8 8 16 16 8
Flag Address Control Protocol Payload Checksum Flag
```

Framing 2 – byte counting approach

- Used by DECNET’s DDCMP
- Instead of “end of frame” character uses frame length field

```
8 8 8 14 42 16
SYN DSYN Count Header Body CRC
```

Framing 3 – bit oriented

- Frames delimited by special bit patterns
- HDLC uses “01111110”
- If “011111” occurs in body, sender inserts “0”

```
8 16 16 8
Beginning sequence Header Body CRC Ending sequence
```
Framing 4 – clock based framing

- Used by protocols from the phone network
- Fixed size frames
- No escape codes