Computer Networks

Overview of the Physical Layer

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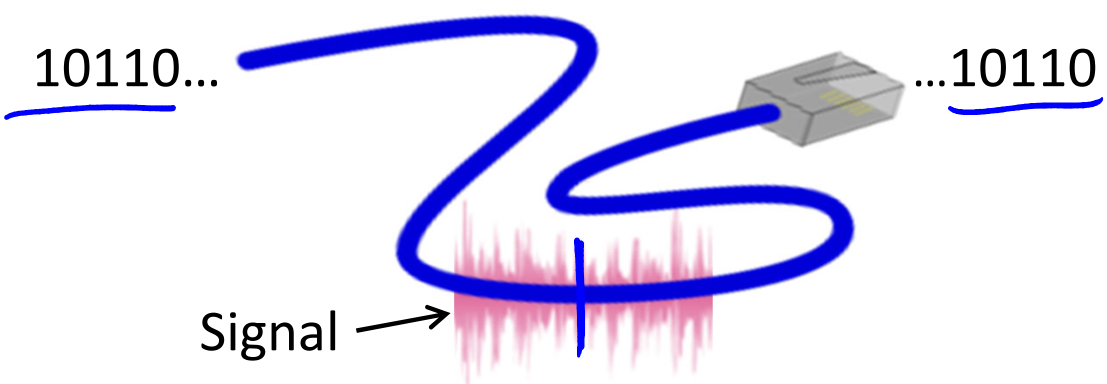
Where we are in the Course

- Beginning to work our way up starting with the Physical layer

Application
Transport
Network
Link
Physical

Scope of the Physical Layer

- Concerns how signals are used to transfer message bits over a link
  - Wires etc. carry analog signals
  - We want to send digital bits

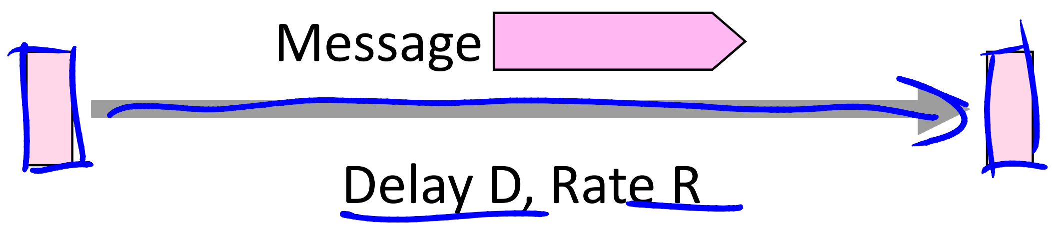


Topics

1. Properties of media
   – Wires, fiber optics, wireless
2. Simple signal propagation
   – Bandwidth, attenuation, noise
3. Modulation schemes
   – Representing bits, noise
4. Fundamental limits
   – Nyquist, Shannon

Simple Link Model

- We'll end with an abstraction of a physical channel
  - Rate (or bandwidth, capacity, speed) in bits/second
  - Delay in seconds, related to length



- Other important properties:
  - Whether the channel is broadcast, and its error rate

Message Latency

- Latency is the delay to send a message over a link
  - Transmission delay: time to put M-bit message "on the wire"

    M/R

  - Propagation delay: time for bits to propagate across the wire

    $\text{Length} / \frac{2}{3}c = D$

  - Combining the two terms we have: $L = M/R + D$

Message Latency (2)

- Latency is the delay to send a message over a link
  - Transmission delay: time to put M-bit message "on the wire"

    T-delay = M (bits) / Rate (bits/sec) = M/R seconds

  - Propagation delay: time for bits to propagate across the wire

    P-delay = Length / speed of signals = Length / ⅔c = D seconds

  - Combining the two terms we have: $\boxed{L = M/R + D}$

Metric Units

- The main prefixes we use:

Prefix	Exp.	prefix	exp.
K(ilo)	10^3	m(illi)	10^{-3}
M(ega)	10^6	μ(micro)	10^{-6}
G(iga)	10^9	n(ano)	10^{-9}

- Use powers of 10 for rates, 2 for storage
  - 1 Mbps = 1,000,000 bps, 1 KB = 2^{10} bytes
- "B" is for bytes, "b" is for bits

1024

Latency Examples

- "Dialup" with a telephone modem:
  - D = 5 ms, R = 56 kbps, M = 1250 bytes

$L = 5\,ms + 1250 \cdot 8 / 56 \cdot 10^3$

$= 184\,ms$

- Broadband cross-country link:
  - D = 50 ms, R = 10 Mbps, M = 1250 bytes

$L = 50\,ms + 1250 \cdot 8 / 10 \cdot 10^6$

$= 50 + 10^4 / 10^{7}$

$= 51\,ms$

Latency Examples (2)

- "Dialup" with a telephone modem:

  D = 5 ms, R = 56 kbps, M = 1250 bytes

  $L = 5 \text{ ms} + (1250 \times 8)/(56 \times 10^3) \text{ sec} = 184 \text{ ms!}$

- Broadband cross-country link:

  D = 50 ms, R = 10 Mbps, M = 1250 bytes

  $L = 50 \text{ ms} + (1250 \times 8) / (10 \times 10^6) \text{ sec} = 51 \text{ ms}$

- A long link or a slow rate means high latency
  - Often, one delay component dominates

Bandwidth-Delay Product

- Messages take space on the wire!

- The amount of data in flight is the <u>bandwidth-delay (BD) product</u>

$$\boxed{BD = R \times D}$$

  - Measure in bits, or in messages
  - Small for LANs, big for "long fat" pipes

Bandwidth-Delay Example

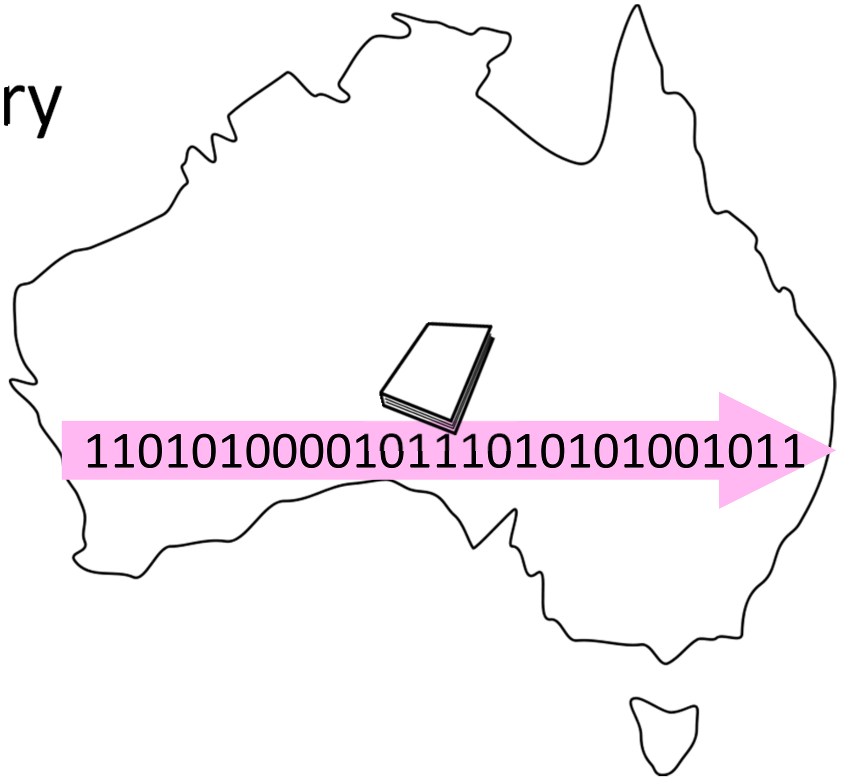
- Fiber at home, cross-country

R=40 Mbps, D=50 ms

$BD = 40 \cdot 10^{6} \cdot 50 \cdot 10^{-3}$

$= 2000 \times 10^{3}$

$= 250$ KB



Bandwidth-Delay Example (2)

- Fiber at home, cross-country

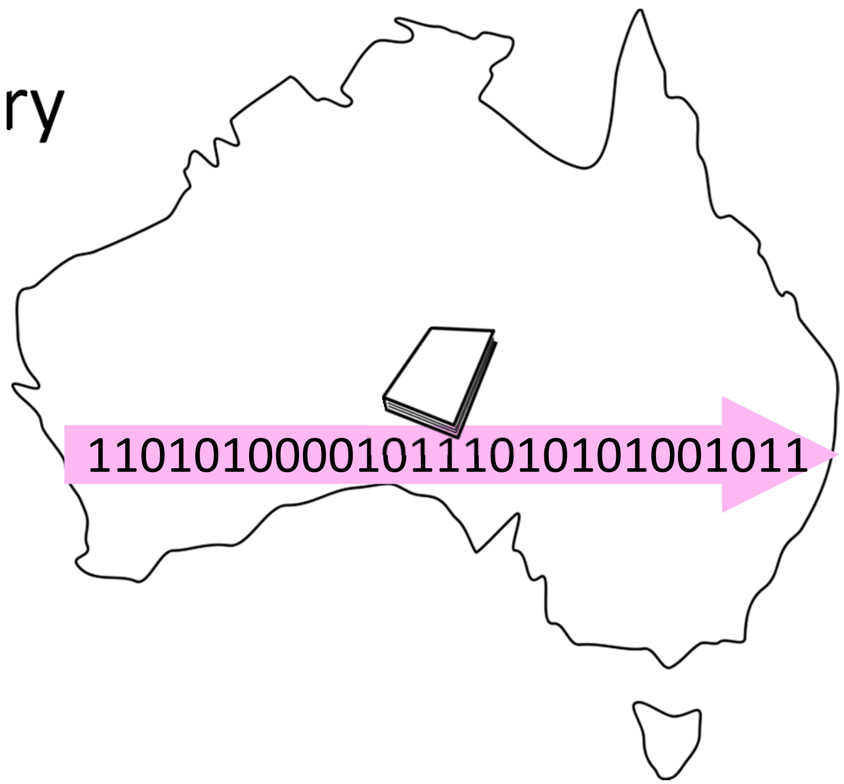
  R=40 Mbps, D=50 ms

  BD $= 40 \times 10^6 \times 50 \times 10^{-3}$ bits

  $= 2000$ Kbit

  $= 250$ KB

- That's quite a lot of data "in the network"!



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