EE:450 – Computer Networks

Discussion Session #3

Some Terminology

- **Bit (b)**
  - Basic unit of information in computers
  - Binary : 0 or 1
- **Byte (B)**
  - 8 bits in one byte
- **Bit Rate**
  - Number of bits transmitted in a time unit
  - Typical unit is **bits-per-second (bps)**
  - Used to measure transmission speed in digital transmissions

Terminology continued…

- 1K Bytes = 1000 Bytes = 8000 bits
- Similarly, 1M Bytes = 1,000,000 Bytes

However,

- 1 Kbps ≠ 2^{10} bps

  1 Kbps = 1000 bps
- Similarly, 1 Mbps = 10^6 bps

<u>In this course, the approximation 1KB ~ 1000 Bytes is always allowed</u>

Terminology

- Delay/Latency: Time it takes a message to travel from one end of a link to another
- It is a very important performance parameter
- End to End delay consists of several components
  - Transmission time
  - Propagation delay
  - Nodal Processing time
  - Queuing delay

Transmission time

- How long does it take to transmit a message (usually in KB) over a link with bit rate (usually in Mbps)?
- Steps:
  - <u>1. Convert message size to bits</u>
    - 1KB = 1000 bytes
    - 1MB = 1,000,000 bytes
    - 1 Byte = 8 bits
    - <u>Key is the difference between "**B**" and "**b**"</u>

Transmission time ctd.

- 2. To obtain the transmission time, divide the message size (in bits) by the bit rate a.k.a. bandwidth (in bps)

Transmission time = Message size/Bit rate

Transmission time example

Ex: How long does it take to transmit a 4KB file over a link with 1Mbps bandwidth?

Solution:

- Step 1: Convert the file size to bits

  4 KB = 4 x 1000 Bytes = 4000 Bytes

  = 32000 bits

1Mbps = 10^6 bps

- Step 2: Transmission Time = file size / bandwidth

  t_{trans} = 32000 bits / 10^6 bps

  = 32ms

Propagation delay

- Propagation delay: The time it takes for a bit to traverse from one end of the link to the other end

$$t_{prop} = \text{Link length (m)} / V_{prop} \text{ (m/s)}$$

Where V_{prop} is the speed with which the bit travels in the medium - same as the speed of light in the given medium

Propagation delay example

Ex: What is the propagation time of a message in a link of 2.5 Km long? The speed of light in the cable is 2.3×10^8 m/s.

Solution:

t_{prop} = Link length/ V_{prop}

= 2500 m / 2.3×10^8 m/s

= 10.9 µs

Attention: t_{prop} is independent of message size and bit rate of the link.

Message Transfer Time

- **Message transfer time (t_{xfr})** : Time taken from the point when the sender starts transmitting the message till the receiver receives the entire message. Also known as end – to – end delay

$$\mathbf{t_{xfr}} = t_{hs} + t_{trans} + t_{prop} + t_{queuing/processing}$$

Where:

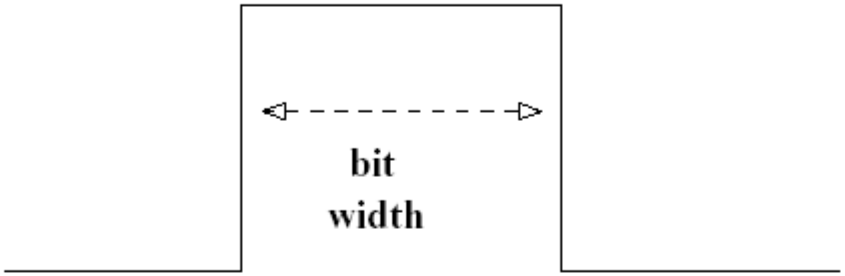
- t_{hs} is the handshake time (time it takes for the initial connection establishment phase)
- $t_{queuing/processing}$ is the queuing and processing delay in the network.
- We will assume the latter as zero most of the time.

Round Trip Time (RTT)

- Round Trip Time: The time to send a message from a sender to the receiver and receive a response back
- Depends on the message size, length of link, direction of propagation, propagation velocity (speed), node processing delay, network traffic load etc.
- We will assume **RTT = 2 x t_{prop}**
  - May not be true if the message and the response choose different links to traverse
  - The other delay components are ignored here.

Bit Duration

- **<u>Bit Duration</u>**: duration (in time) of a pulse representing a bit – depends on bit rate (bandwidth) of the link.
- Bit Duration= 1 / Bandwidth
  - A bit is 1 μs wide in a 1 Mbps channel
    $1/(10^6 \text{ bps}) = (1 \times 10^{-6})$ seconds per bit
  - A bit is 0.5 μs wide in a 2 Mbps channel



Bit Length(bit Width)

- **Bit length**: The length occupied by a bit on a transmission link

- Bit length = Bit durationx Prop. Speed
  = (sec) x (meters/sec)
  = (meters)

Bandwidth Delay Product

- Product of Bandwidth and link latency (propagation delay)
- Represents the maximum number of bits present in the link at given time
- Analogy
  - **A Pipe**: delay is the length
    : bandwidth is the width
  - Bandwidth Delay product gives the volume

Example #1

Ex: A terminal sends a 1 MB file to another computer through a link of 10 Mbps. The distance between the two terminals is 2000 Km and the propagation speed in the cable is 2×10^8 m/s.

a) What is the RTT?

b) What is the Bandwidth Delay Product? (Use RTT as the delay)

c) What is the bit duration?

d) Assume a handshake period of 2 RTT's and no processing/queuing delay, what is the total transfer time of the file?

Example contd…

a) **RTT** = 2 t_{prop}

t_{prop} = 2 x 10^6 m **/** 2 x 10^8 m/s

= 10 msec.

Therefore, <u>RTT = 20 msec</u>

b) **Bandwidth X Delay**

= 10 Mbps x 20 ms

= 200000 bits

~ 25000 Bytes = <u>25 KB</u>

Example contd…

c) **Bit duration** = 1 / Bandwidth

= 1 / (10 Mbps)

= 10^{-7} sec./bit = <u>0.1μs/bit</u>

d) $t_{xfr} = t_{hs} + t_{trans} + t_{prop}$

t_{trans} = 1 MB / (10 Mbps)

= 8 Mb / (10 Mbps) = 800 msec

t_{hs} = 2RTT = 40 msec

t_{prop} = 10 msec

$\mathbf{t_{xfr}}$ = 40 + 800 + 10 = <u>850 msec</u>

Example #2: Bandwith or Delay Sensitive?

- For each of the Following operations on a remote file server, discuss whether they are more likely to be delay-sensitive or bandwidth-sensitive:
  - Open a file
  - Read the contents of a file
  - List the contents of a directory
  - Display the attributes of a file

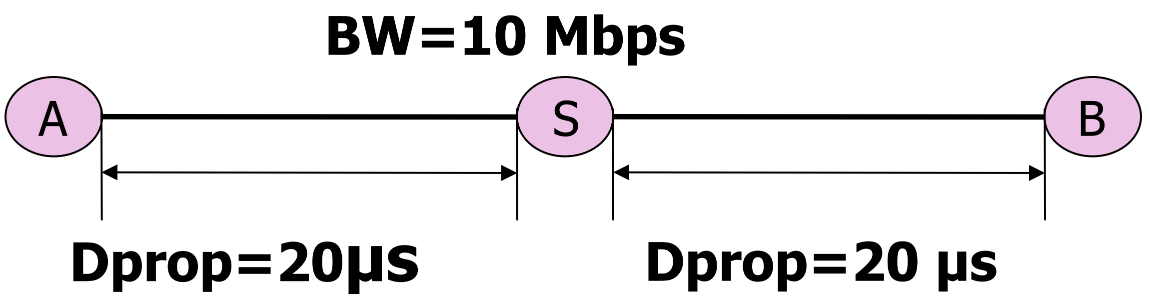
Solution

- Delay-sensitive; the messages exchanged are short.
- Bandwidth-sensitive, particularly for large files. (Technically this does presume that the underlying protocol uses a large message size or window size; stop-and-wait transmission (as in Section 2.5 of the text) with a small message size would be delay-sensitive.)
- Delay-sensitive; directories are typically of modest size.
- Delay-sensitive; a file's attributes are typically much smaller than the file itself (even on NT file systems).

Example #3

- Hosts A and B are each connected to a switch via 10 Mbps links as shown in the figure. The propagation delay on each link is 20μs. S is a store and forward device; it begins transmitting a received packet 35μs after it has finished receiving it. Calculate the total time required to transmit 10,000 bits from A to B
  - As a single packet
  - As 2 5000-bit packets sent one right after another

Solution



(a) Per-link transmission delay is 10^4 bits / 10^7 bits/sec = 1000 μs. Total transfer time = 2 × 1000 + 2 × 20 + 35 = 2075 μs.

Solution continued

(b) When sending as two packets, here is a table of times for various events:

T=0 start T=500 A finishes sending packet 1, starts packet 2
T=520 packet 1 finishes arriving at S
T=555 packet 1 departs for B
T=1000 A finishes sending packet 2
T=1055 packet 2 departs for B
T=1075 bit 1 of packet 2 arrives at B
T=1575 last bit of packet 2 arrives at B

Expressed algebraically, we now have a total of one switch delay and two link propagation delays; transmission delay is now 500µs:
$3 \times 500 + 2 \times 20 + 1 \times 35 = 1575$ µs.

Sending smaller packets is faster, here.