

13

THU
DEC

WK 50 • 347-018

2018



1

DECEMBER 2018						
M	T	W	T	F	S	S
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Tutorial 1 | CN-CS331 | 03 Feb 2025

Problem 1:

$$\text{Link Rate} = R \text{ bps} \quad | \quad \text{Propagation Speed} = s \text{ m/s}$$

$$\text{distance} = m \text{ meters} \quad | \quad \text{Packet size} = L \text{ bits}$$

a) End-to-end delay = Transmission delay + Propagation delay

Ignore ~~→~~ ~~Processing~~ (Processing delay, queuing delay)

$$d_{\text{trans}} = \frac{L}{R} \quad | \quad d_{\text{prop}} = \frac{m}{s}$$

$$= \frac{L}{R} + \frac{m}{s}$$

b). The last bit has just been fully transmitted but has not yet reached host B. It is just starting to propagate through the link. The last bit is just leaving host A and is at the very beginning of the link.

c). At $t = d_{\text{trans}}$, the first bit has already been propagating for d_{trans} seconds. Since propagation speed is s , the first bit will have traveled:

$$\text{distance} = s \times d_{\text{trans}} = s \times \frac{L}{R}$$

host B.

The 1st bit is at a distance $s \cdot \frac{L}{R}$ from host A, but it has not reached

JANUARY 2019						
M	T	W	T	F	S	S
1	2	3	4	5	6	
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

2

WED
DEC

19

2018 WK 51 • 353-012

d). Since $d_{prop} < d_{trans}$, the 1st bit would have reached Host B before d_{trans} is completed. The 1st bit has already arrived at host B before $t = d_{trans}$.

For store & forward = 1st bit is at host B and has been waiting there for $[d_{trans} - (d_{prop} \text{ time} + \text{time to transmit one bit})]$ seconds.

~~For each message~~

$$l), m = ? \text{ such that } d_{prop} = d_{trans} \rightarrow \frac{m}{s} = \frac{L}{R}$$

$$m = \frac{L}{R} \times s \text{ where } s = 2.5 \times 10^8 \text{ m/s, } L = 120 \text{ bits}$$

$$R = 56 \text{ kbps} = 56 \times 10^3 \text{ bps}$$

$$m = \frac{120}{56 \times 10^3} \times 2.5 \times 10^8 = \frac{120}{56} \frac{300 \times 10^8}{10^3} = \frac{300 \times 10^5}{56}$$

$$m \approx 5.36 \times 10^5 = 536 \text{ km.}$$

Problem 2.

Total delay 1. Transmission delay for each link ($d_{trans,i}$)

$$d_{trans,i} = \frac{L}{R_i}$$

20

THU
DEC

WK 51 • 354-011

2018



3

DECEMBER 2018						
M	T	W	T	F	S	S
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

⁸ Propagation delay for each link $d_{\text{prop}, i}$

$$d_{\text{prop}, i} = \frac{d_i}{R_i}$$

⁹ Processing delay at each packet switch (d_{proc}).

¹⁰ There are 2 packet switches, so the total processing delay is:

$$2 d_{\text{proc}}$$

$$\begin{aligned} \text{Total end-to-end delay} &= \sum_{i=1}^3 (d_{\text{trans}, i} + d_{\text{prop}, i}) + 2 d_{\text{proc}} \\ &= \sum_{i=1}^3 \left(\frac{L}{R_i} + \frac{d_i}{R_i} \right) + 2 d_{\text{proc}}. \end{aligned}$$

$$\text{Given } L = 1500 \text{ bytes} = 1500 \times 8 = 12,000 \text{ bits}$$

$$\text{Propagation speed} = R_1 = R_2 = R_3 = 2.5 \times 10^8 \text{ m/s.}$$

$$\text{Transmission rate} = R_1 = R_2 = R_3 = 2 \text{ Mbit/s} = 2 \times 10^6 \text{ bps}$$

$$\text{Processing delay at each switch} = d_{\text{proc}} = 3 \text{ ms.}$$

$$\text{Link length } d_1 = 800 \text{ km} = 8 \times 10^6 \text{ m}$$

$$d_2 = 300 \text{ km} = 3 \times 10^6 \text{ m}$$

$$d_3 = 100 \text{ km} = 1 \times 10^6 \text{ m}$$

JANUARY 2019

M	T	W	T	F	S	S
1	2	3	4	5	6	
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

4

FRI
DEC

14

2018

WK 50 • 348-017

$$d_{\text{trans},1} = \frac{12,000}{2 \times 10^6} = 6 \times 10^{-3} \text{ ms}$$

$$\sum d_{\text{trans},i} = 3 \times 6 = 18 \text{ ms}$$

$$d_{\text{proc},1} = \frac{d_1}{R_1} = \frac{6 \times 10^6}{2.5 \times 10^8} = 0.024 \text{ s} = 24 \text{ ms}$$

$$d_{\text{proc},2} = \frac{d_2}{R_2} = \frac{3 \times 10^6}{2.5 \times 10^8} = 12 \text{ ms}$$

$$d_{\text{proc},3} = \frac{d_3}{R_3} = 7 \text{ ms}$$

$$\sum_{i=1}^3 d_{\text{proc},i} = 24 + 12 + 7 = 43 \text{ ms}$$

$$2d_{\text{proc}} = 2 \times 3 = 6 \text{ ms}$$

$$d_{\text{end-to-end}} = \sum d_{\text{trans},i} + \sum d_{\text{proc},i} + 2d_{\text{proc}}$$

$$= 18 \text{ ms} + 43 \text{ ms} + 6 \text{ ms}$$

$$= 67 \text{ ms}$$

15

SAT
DEC

K50 • 349-016 2018



5

DECEMBER 2018						
M	T	W	T	F	S	S
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Problem 3 - Since the 1st ~~bit~~ bit does not wait for full packet transmission at each switch, the total delay consists of:

1 Transmission delay of only the 1st link:

$$d_{\text{trans}} = \frac{L}{R}$$

(Only the 1st link's transmission delay matters.)

2. Propagation delay for all 3 links:

$$d_{\text{prop, total}} = \sum_{i=1}^3 \frac{d_i}{R_i}$$

Total end-to-end delay is:

$$d_{\text{end-to-end}} = d_{\text{transf}, 1} + d_{\text{prop}, i}$$

$$= \frac{L}{R} + \frac{d_1}{R_1} + \frac{d_2}{R_2} + \frac{d_3}{R_3}$$

$$L = 1500 \text{ Bytes} = 1500 \times 8 = 12,000 \text{ bits} \quad | \quad R = 2 \text{ Mbytes} = 2 \times 10^6 \text{ bytes}$$

16 SUNDAY

$$\lambda = 2.5 \times 10^8 \text{ m/s} \quad | \quad d_1 = 6 \times 10^6 \text{ m}$$

$$d_2 = 3 \times 10^6 \text{ m}$$

$$d_3 = 1 \times 10^6 \text{ m}$$

$$d_{\text{transf}, 1} = 0.006 \text{ sec} = 6 \text{ ms} \quad | \quad d_{\text{prop}, 1} = \frac{6 \times 10^6}{2.5 \times 10^8} = 24 \text{ ms}$$

JANUARY 2019						
M	T	W	T	F	S	S
1	2	3	4	5	6	
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

6

MON
DEC

17

2018 WK 51 • 351-014

8 $d_{prop,2} = \frac{d_2}{R} = \frac{3 \times 10^6}{2.5 \times 10^8} = 12 \text{ ms}$

9 10 $d_{prop,3} = \frac{d_3}{R} = 4 \text{ ms}$

11 Total = $6 + 2 \times 4 + 12 + 4 = 40 \text{ ms}$.

12 Problem 9 - We assume :-

Packet length = L bits | No propagation delay.

1 Number of links = N

Transmission rate of each link = R bps | Store & forward switching.

Step 1.

① Transmission delay per link

The transmission delay (d_{transf}) is the time required to push the entire packet onto a link = $\frac{L}{R}$

Since the packet must be fully received before transmission

on the next link, each link contributes a delay of d_{transf} .

Step 2. The 1st link starts transmitting immediately. The second link can only start transmission after the 1st link has finished & so on.

Since there are N links, and each introduces a transmission delay,

$$d_{end-to-end} = N \times \frac{L}{R}$$

18

TUE
DEC

WK 51 • 352-013

2018



7

DECEMBER 2018						
M	T	W	T	F	S	S
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

When sending multiple packets back-to-back, the 2nd packet ⁸ experiences the full delay computed above. However, the second packet can start transmission on the 1st link immediately after the 2nd packet ~~finishes~~ finishes transmission there.

¹⁰ Thus, for P packets

¹¹ The 1st packet takes $N \times \frac{L}{R}$ seconds.

¹² Each subsequent packet leaves the 1st link every $\frac{L}{R}$ seconds, forming a pipeline effect.

$$\text{d}_{\text{total}} = (N + (P - 1)) \times \frac{L}{R}$$

Problem 5.

Little's formula: $N = \lambda \cdot d$.

⁴ $N = \text{Avg no. of packets in the system}$.

⁵ $\lambda = \text{packet arrival rate}$ | $d = \text{avg total delay per packet}$ (queuing delay + transmission delay).

$$N = 10 \quad | \quad d_{\text{queue}} = 10 \text{ ms} = 0.01 \text{ sec} \quad | \quad \text{Tr. rate} = 100 \text{ packets/sec}$$

$$d = d_{\text{queue}} + d_{\text{trans}} \quad | \quad d_{\text{trans}} = \frac{1}{\text{Tr. Rate}} = \frac{1}{100} = 0.01 \text{ sec.}$$

$$d = 0.01 + 0.01 = 0.02 \text{ sec.}$$

(8)

CARNET

Date: / /

Page No.:

$$N = a \cdot d \quad | \quad 10 = a \times 0.02 \quad | \quad a = \frac{10}{0.02} = 500 \text{ packets/sec}$$

Problem 6 Shared middle hop with total capacity

$$R = 100 \text{ Mbps}$$

Serves-to shared link capacity = $80 \text{ Mbps} = R_s$

Serves-to client link capacity = $R_c = 50 \text{ Mbps}$

Path

Server $\rightarrow R_s \rightarrow R \rightarrow R_c \rightarrow$ Client

a) Max achievable end-to-end throughput per Pass. =

$$\frac{R}{4} = \frac{100}{4} = 25 \text{ Mbps} \rightarrow$$

b) A bottleneck link is the slowest link along the path that limits throughput.

$$R_s = 80 \text{ Mbps}$$

$$R = 100 \text{ Mbps}$$

$$R_c = 50 \text{ Mbps}$$

The bottleneck is R.

$$(c) \quad \text{Utilization} = \frac{\text{Actual Data Rate}}{\text{Link Capacity}} = \frac{25}{80} = \frac{5}{16} = 0.3125$$

$$(d) \quad \text{Utilization} = \frac{25}{50} = 0.5$$

- (Q) The shared link carries four flows, each at 25 Mbps, for a total of :

Date: _____

$$4 \times 25 = 100 \text{ Mbps}$$

Since the link capacity is also 100 Mbps,

$$\therefore \text{Utilization} = \frac{100}{100} = 1$$

of R

Problem - 7

- (A). Given N packets arrive at the same time.

Length of each packet = L bits

Link transmission rate = R bps

Transmission delay per packet

$$d_{\text{trans}} = \frac{L}{R} \text{ sec}$$

1st packet experiences 0 queuing delay.

2nd packet waits for 1 transmission time before starting transmission.

3rd packet waits for 2 transmission times before starting & so on.

kth packet waits for (k-1).d_{trans}.

$$\text{Total queuing delay} = 0 + d_{\text{trans}} + 2d_{\text{trans}} + \dots + (N-1)d_{\text{trans}}$$

$$\sum = d_{\text{trans}} \times [1 + 2 + \dots + N-1]$$

$$= d_{\text{trans}} \times \frac{N(N-1)}{2}$$

For avg, divide by N .

$$= \frac{1}{R} L \times \frac{N(N-1)}{2N} = \frac{(N-1)L}{2R}$$

(B) N such packets arrive at the Link every $\frac{LN}{R}$ seconds.

Avg queuing delay will be same

$$= \frac{(N-1)L}{2R}$$

Problem 8:



File size = F bits

Segment size = S bits

Header size = 80 bits

Packet size = $(S + 80)$ bits

$$\text{Number of segments (packets)} = N = \frac{F}{S}$$

Using formulae derived in Problem 7.

$$d_{\text{total}} = [N + (P-1)] \times \frac{L}{R} = \frac{(F + 3-1)(80+S)}{R}$$

$$= \frac{160}{R} + \frac{2S}{R} + \frac{80F}{SR} + \frac{F}{R}$$

Date: _____

Taking derivative of d_{total} w.r.t. s .

$$\frac{d(d_{\text{total}})}{ds} = 0 + \frac{2}{R} - \frac{80F}{s^2 R} + 0 = 0$$

$$\frac{2}{R} = \frac{80F}{s^2 R} \Rightarrow s = \sqrt{40F}$$

Problem 9.

My computer \rightarrow Resolves.

- 2). Resolves \rightarrow Root DNS \rightarrow Response (TLD serves for .in)
2. " \rightarrow TLD DNS(.in) \rightarrow " (Authoritative servers for .ac.in)
- 3). " \rightarrow Authoritative DNS(.ac.in) \rightarrow Response (Authoritative server for www.iiitgn.ac.in)
- 4). Resolves \rightarrow Authoritative DNS(iiitgn.ac.in) \rightarrow Response (IP address of www.iiitgn.ac.in)

Total number of query-response pairs is 4.

Problem 10. Number of SMTP servers (hops) = 3

Processing delay per SMTP server = 30 ms.

Number of links = 4.

Propagation delay per link = 20 ms.

Total processing delay = $3 \times 30 \text{ ms} = 90 \text{ ms}$

" Propagation delay = $4 \times 20 \text{ ms} = 80 \text{ ms}$

Total Delay = $80 + 90 = 170 \text{ ms}$.

Date: _____

Problem 11 Given Data

$1 \text{ HTML file} = 5 \text{ KB}$	$5 \text{ images} = 50 \text{ KB each}$
$3 \text{ CSS } \rightarrow = 2 \text{ KB each}$	$\text{Total objects} = 1 + 3 + 5 = 9$
$\text{RTT time} = 50 \text{ ms} (0.05 \text{ sec})$	$\text{Bandwidth} = 10 \text{ Mbps} = 10 \times 10^6 \text{ bps}$

$$\text{Download time} = \frac{\text{File size (in bits)}}{\text{Bandwidth (in bps)}}$$

a). Each object requires:

- (1) 1 RTT for TCP connection establishment.
- (2) 1 RTT for HTTP request & 1st byte response.
- (3) Download time.

Download time for each object.

$$\begin{aligned} \text{HTML} &= 5 \text{ KB} = 50,000 \text{ bits} \rightarrow 4 \text{ ms} \\ \text{CSS (each)} &= 2 \text{ KB} = 16,000 \text{ bits} \rightarrow 1.6 \text{ ms} \\ \text{Image (each)} &= 50 \text{ KB} = 500,000 \text{ bits} \rightarrow 90 \text{ ms.} \end{aligned}$$

Each object has a delay of 2 RTT + download time.

$$\text{HTML} \quad 2 \times 0.05 + 0.004 = 0.104 \text{ s}$$

$$3 \text{ CSS Files} \quad 3 \times (2 \times 0.05 + 0.004) = 0.3048 \text{ s}$$

$$\text{Images} \quad 5 \times (2 \times 0.05 + 0.04) = 5 \times 0.14 = 0.7 \text{ s}$$

$$\text{Total} = 0.104 + 0.3048 + 0.7 = 1.1088 \text{ sec}$$

Date: _____

b). HTTP/2 with multiplexing

Single TCP connection is used.

$$\text{Total data to download} = 5 + (3 \times 7) + (5 \times 50)$$

$$= 261 \text{ KB}$$

$$\text{Total download time} = \frac{261 \times 8,000}{10,000,000} = 0.2088 \text{ sec.}$$

Adding 2 RTT (Connection) + 2 RTT (Request Response):

$$0.05 + 0.05 + 0.2088 = 0.3088 \text{ sec.}$$

Problem 12.

Cache Hit Rate = 80% Cache Lookup time = 1 ms.

Cache Miss Rate = 20%.

External resolution follows these steps:

1. Query to the root server \rightarrow RTT = 50 ms.

2. TLD server \rightarrow RTT = 70 ms

3. Authoritative server \rightarrow RTT = 100 ms.

4. Total external resolution time = $50 + 70 + 100 = 220 \text{ ms}$.

Invalid queries = 10%.

They don't go through the external resolution process.

Valid queries = 90%.

Either caching or external resolution.

14

Date: _____

$$T_{avg} = (\text{Cache Hit Rate} \times T_{cache}) + (\text{Valid Cache Miss Rate} \times T_{external}) \\ + (\text{Invalid miss rate} \times T_{invalid})$$

$$T_{avg} = 0.80 \times 2 + 0.10 \times 220 + 0.1 \times 10 \\ = 0.8 + 34.6 + 1 = 36.4 \text{ ms.}$$

$$2 \quad \text{Hit Rate} = 95\%.$$

$$T_{avg, new} = 0.95 \times 1 + 0.05 \times 220 + 0.1 \times 10 \\ = 0.95 + 11 + 1 = 12.95 \text{ ms.}$$

$$\text{Improvement in T} = \frac{(36.4 - 12.95) \times 100}{36.4} \\ = \underline{\underline{28.45}} \times 100 = 68.73\% \text{ faster.}$$

Problem 13.

1 Time for base web page (single object).

2 DNS resolution.

Client requires local DNS resolves ($RTT_0 = 1 \text{ ms}$).

If IP is not cached, the local DNS contacts the external DNS server ($RTT_1 = 47 \text{ ms}$)

$$\text{Total DNS Time} = RTT_0 + RTT_1 = 1 + 47 = 48 \text{ ms.}$$

Date: _____

$RTT_{HTTP} = 72 \text{ ms}$ $\xrightarrow{\text{For}}$ TCP 3-way handshake.

$RTT_{HTTP} = 72 \text{ ms}$ For client sends an HTTP request.

$RTT_{HTTP} = 72 \text{ ms}$ Server responds

$$\text{Total Time} = 48 + 72 + 72 = 192 \text{ ms}$$

II

1. Step from part I : 192 ms for DNS + base object
2. Each add. object requires a new TCP connection, each taking 2 RTT's.

$$7 \text{ objects} \times [2 \times RTT_{HTTP}] = 7 \times 48 = 1008 \text{ ms}$$

$$3. \text{ Total time} : 192 + 1008 = 1200 \text{ ms.}$$

III

1. DNS + Base Page = 192 ms
2. Batch 1 (5 Objects) = 144 ms.
3. Batch 2 (2 ") = 147 ms.

$$\text{Total} = 480 \text{ ms}$$

IV

1. DNS + Base Page = 192 ms.
2. Batch 1 (5 objects, 2 RTT) : 72 ms.
3. 1 2 (2 " , 2 RTT) : 72 ms.

$$192 + 72 + 72 = 336 \text{ ms.}$$

Fastest method is Persistent HTTP with Parallel connections (336 ms)

Date: _____

Problem 15. Total time accounts for all below pts.

$$2. \text{ DNS lookup time} = \sum_{i=1}^n RTT_i = RTT_1 + RTT_2 + \dots + RTT_n$$

$$2. \text{ TCP connection establishment} = 1 RTT$$

$$3. \text{ HTTP Request & Response} = 1 RTT$$

$$T_{\text{total}} = \sum_{i=1}^n RTT_i + 1 RTT + 1 RTT$$

$$= \sum_{i=1}^n RTT_i + 2 RTT$$