CS-331 Computer Networks

Tutorial-1

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1)

$$(A) \longleftrightarrow (B)$$

Distance = 'm' meters.

Link Rate = 'R' bps.

Propogation speed = 'S' m/s

Size of Packet = 'L' bits. [From A to B].

a) if we ignore processing & queuing delays.

then

$$\text{Total delay} = T_{\text{transmission}} + T_{\text{propogation}}$$

$T_{\text{transmission}}$ [d_{trans}] — Time to send all bits into the link

$T_{\text{propogation}}$ [d_{prop}] — Time for a bit to travel through the link

$$\Rightarrow d_{\text{end-to-end}} = \left(\frac{L}{R} + \frac{m}{S}\right) \text{ sec.}$$

(Ans).

b) At $t = d_{trans}$,

Host A has just finished transmitting the last bit into the link. Since the propogation delay d_{prop} hasn't elapsed yet, the last bit is still at Host A [just entering the link].

(Ans)

c) $d_{prop} > d_{trans}$ & $t = d_{trans}$

The first bit is still in transit and hasn't reached the Host B yet. It is somewhere in the middle of the link.

$$\text{Distance} = s \times d_{trans} = \frac{sL}{R} \text{ meters.}$$

So, first bit is on the link, $\frac{sL}{R}$ meters away from Host A and yet to reach Host B.

(Ans)

d) $d_{prop} < d_{trans}$ & $t = d_{trans}$

The first bit has already arrived at Host B. Since, $d_{prop} < d_{trans}$, the first bit reaches Host B before the last bit is even transmitted.

(Ans).

e) $S = 2.5 \times 10^8$ m/s.

$L = 120$ bits

$R = 56$ kbps

for $d_{prop} = d_{trans}$,

$$\frac{m}{S} = \frac{L}{R}$$

$$\Rightarrow m = S \times \frac{L}{R}$$

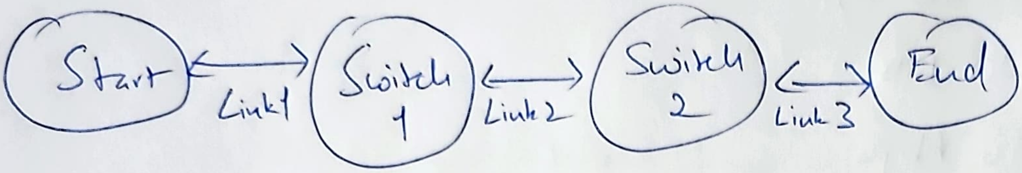
$$\Rightarrow m = \frac{2.5 \times 10^8 \cancel{m/s} \times 120 \cancel{bits}}{56 \times 10^3 \cancel{bps}}$$

$$\Rightarrow m = \frac{300 \times 10^5}{56} \text{ m}$$

$$\Rightarrow m \approx 5.357 \times 10^5 \text{ m}$$

$$\Rightarrow m \approx \underline{\underline{535.71 \text{ km}}}$$ (Ans).

2)



d_i = length of link i

S_i = propagation speed of link i

R_i = transmission rate of link i

L = Length of Packet.

d_{proc} = delay for each packet by switch.

No queuing delays.

$\therefore$

$$\text{End to End delay} = \left[\text{delay for } 1^{st} \text{ Link}\right] + d_{proc} + \left[\text{delay for } 2^{nd} \text{ Link}\right] + d_{proc} + \left[\text{delay for } 3^{rd} \text{ Link}\right]$$

$$= \left[\text{delay for } i^{th} \text{ Link}\right]_{\text{for } i = 1,2,3} + 2 \times d_{proc}$$

$$= \left[(d_{trans})_i + (d_{prop})_i\right]_{\text{for } i=1,2,3} + 2 \times d_{proc}$$

$$= \left[\frac{L}{R_i} + \frac{d_i}{S_i}\right]_{\text{for } i=1,2,3} + 2 \times d_{proc}$$

$$= \underline{\sum_{i=1}^{3} \left(\frac{L}{R_i} + \frac{d_i}{S_i}\right) + 2 d_{proc}} \quad \text{(Ans)}.$$

Given values :-

$$L = 1500 \text{ bytes}$$

$$R_1 = R_2 = R_3 = R = 2 \text{ Mbps}$$

$$S_1 = S_2 = S_3 = S = 2.5 \times 10^8 \text{ m/s}$$

$$d_1 = 6000 \text{ km}$$

$$d_2 = 3000 \text{ km}$$

$$d_3 = 1000 \text{ km}$$

$$(d_{proc}) = 3 \text{ ms}$$

Putting it in eq^n, we get

$$\text{end-to-end delay} = \left[\frac{1500 \times 8}{2 \times 10^6} + \frac{6000 \times 10^3}{2.5 \times 10^8}\right] + 3 \text{ ms}$$

$$+ \left[\frac{1500 \times 8}{2 \times 10^6} + \frac{3000 \times 10^3}{2.5 \times 10^8}\right] + 3 \text{ ms}$$

$$+ \left[\frac{1500 \times 8}{2 \times 10^6} + \frac{1000 \times 10^3}{2.5 \times 10^8}\right]$$

$$= (6 \text{ ms} + 24 \text{ ms}) + (3 \text{ ms})$$

$$+ (6 \text{ ms} + 12 \text{ ms}) + (3 \text{ ms})$$

$$+ (6 \text{ ms} + 4 \text{ ms})$$

$$= \underline{\underline{64 \text{ ms}}} \quad \text{(Ans)}$$

3) If the switches do not store and forward the entire packet but immediately transmit each bit as soon as it is received,

the the transmission delays are no longer additive. The total transmission delay is just for one link.

Also, given $R_1 = R_2 = R_3 = R$.

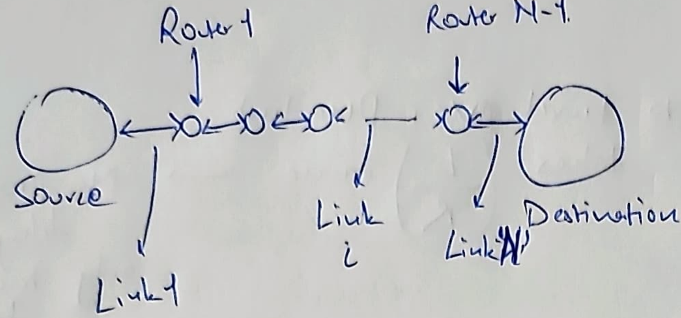
& $d_{proc} = 0$.

$\therefore$ End to End delay $= d_{prop}$ for 1st link $+ d_{trans}$ for 1st link $+ d_{prop}$ for 2nd link $+ d_{prop}$ for 3rd link $+ \cancel{2 \times d_{proc}} \to 0$

$$= \sum_{i=1}^{3} \left(\frac{d_i}{s_i} \right) + \frac{L}{R}$$

(Ans).

4)



$\boxed{\text{All Routers}} \rightarrow$ Store & forward.

$\Rightarrow$ No propogation delay.

Packet size = 'L' bits.

Transmission Rate = 'R' bps.

$\therefore$ End to end delay $= \text{Delay}_{(\text{Link }1)} + \text{Delay}_{(\text{Link }1)} + \cdots \text{Delay}_{(\text{Link }N)}$

$$= \sum_{i=1}^{N} \left(\cancelto{0}{d_{prop}} + d_{trans}\right)_{\text{Link } i}$$

$$= \sum_{i=1}^{N} \left(d_{trans}\right)_{\text{Link } i}$$

$$= \underbrace{\left(\frac{L}{R} + \frac{L}{R} \cdots \cdots + \frac{L}{R}\right)}_{N \text{ times for 'N' links}}$$

$$= \frac{N \times L}{R}$$

$$= \frac{NL}{R} \text{ sec. (Ans)}$$

Now, For 'P' packets.

For any packet to travel over One link, it takes $\left(\frac{L}{R}\right)$ time → No propogation delay only transmission delay.

So, when

At time $= \frac{NL}{R}$, first packet will reach destination

& second packet will be at $(N-1)^{th}$ router

& 3^{rd} will be at $(N-2)^{th}$ router & so on.

∴ At destination,

after $\left(\frac{NL}{R}\right)$ time, each new packet will arrive in every $\left(\frac{L}{R}\right)$ time.

∴ Total end-to end delay $= \underbrace{\frac{NL}{R}}_{\text{for first packet}} + \underbrace{\frac{L}{R}}_{\text{for 2nd packet}} + \cdots + \underbrace{\frac{L}{R}}_{\text{for } p^{th} \text{ packet}}$

$$= \frac{NL}{R} + (P-1)\frac{L}{R}$$

$$= \frac{(N+P-1)L}{R} \text{ sec}$$

(Ans).

5)

Little's formula,

$$N = a \times d$$

$N \Rightarrow$ average no. of packet in system (buffer + the packet being transmitted)

$a \rightarrow$ Average arrival rate of packets (pps)

$d \rightarrow$ Average total delay per packet [queuing + transmission delay].

Here, $N = \underbrace{10}_{\text{buffer}} + \underbrace{1}_{\text{being transmitted}}$

$= 11$ packets

$$d = \underbrace{10\text{ ms}}_{\text{Avg. Queuing delay for 1 packet}} + \underbrace{\frac{1\text{ packet}}{100\text{ packet/s}}}_{\text{Avg. transmission delay for 1 packet}} = 10\text{ ms} + 10\text{ ms} = 20\text{ ms}$$

Assuming no packet loss

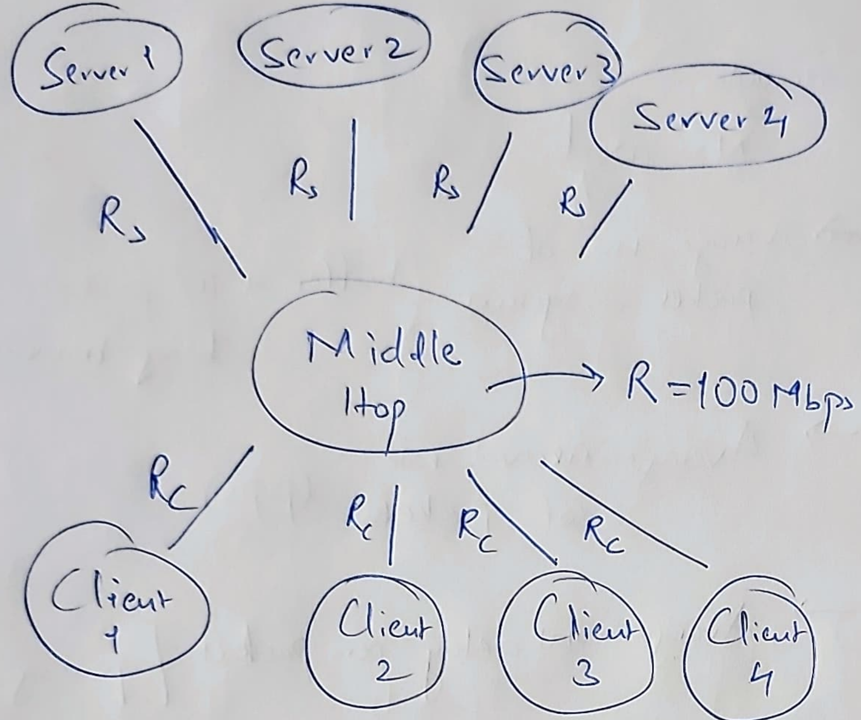
$\therefore$ avg packet arrival rate $= a = \dfrac{N}{d}$

$= \dfrac{11\text{ packet}}{20\text{ ms}}$

$= 550$ packets/second

(Ans)

6)



Transmission Capacity ~~Of~~ ~~Each~~ server to middle hop link	$R_s = 80$ Mbps.
Transmission capacity of middle hop to each client link	$R_c = 50$ Mbps.

Transmission Capacity of middle hop link	$R = 100$ Mbps

Middle link is fairly shared

∴ Transmission capacity of shared link for one client-server pair $R_e = \frac{100}{4}$

$\Rightarrow R_e = 25$ Mbps

Now,

a) Maximum achievable end-to-end throughput for each client-server pair $= \text{Min}(R_s, R_c, R_e)$

$= 25$ Mbps (Ans)

b) 'R' link is the bottleneck because
each client link can handle 50 Mbps of data
& each server link can handle 80 Mbps of data
but due to limited 100 Mbps of shared link,
only 25 Mbps of data transfer is possible
b/w one client-server pair.
(Ans).

c)
$$\text{Server link Utilisation} = \frac{\text{Actual throughput}}{\text{Link Capacity}}$$
$$= \frac{25\text{ Mbps}}{80\text{ Mbps}} = 0.3125$$
$$= 31.25\%$$ (Ans)

d)
$$\text{Client link Utilisation} = \frac{\text{Actual throughput}}{\text{Link Capacity}}$$
$$= \frac{25\text{ Mbps}}{50\text{ Mbps}} = 0.5$$
$$= 50\%$$ (Ans)

e)
$$\text{Shared link Utilisation} = \frac{\text{Throughput}}{\text{Link Capacity}}$$
Total traffic is 4 times that of each server-client pair.
$$= \frac{4 \times 25\text{ Mbps}}{100\text{ Mbps}} = 1$$
$$= 100\%$$ (Ans)

7) A) 'N' packets arrive simultaneously

Each Packet Length = 'L'

Transmission Rate = 'R'.

Queuing delay for 1^{st} packet = 0.

Queuing delay for 2^{nd} packet $= \sum_{i=1}^{2-1} \left[\left(\text{Transmission time} \right)_i \right]$

$= L/R.$

Queuing delay for 3^{rd} packet $= \sum_{i=1}^{3-1} \left[\left(\text{Transmission time} \right)_i \right]$

$= \frac{2L}{R}$

Similarly,

Queuing delay for N^{th} packet $= \sum_{i=1}^{N-1} \left[\left(\text{Transmission time} \right)_i \right]$

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

$\therefore$ Avg Queuing delay $= \frac{\text{Total delay(queueing) for all packets}}{N}$

$$= \frac{0 + \frac{L}{R} + \frac{2L}{R} + \cdots \frac{(N-1)L}{R}}{N}$$

$$= \frac{\frac{L}{R}\left[\frac{(N-1)N}{2}\right]}{N} = \frac{(N-1)L}{2R} \text{ sec.}$$

(Ans)

B)

Now,

Queuing delay for n^{th} packet $= \frac{(N-1)L}{R}$ [for Part A]

Transmission delay for n^{th} packet $= \frac{L}{R}$

$\therefore$ Total delay for N^{th} packet $= \frac{NL}{R}$

$\therefore$ At time $= \frac{NL}{R}$ (and its integral multiple), N^{th} packet will get transmitted

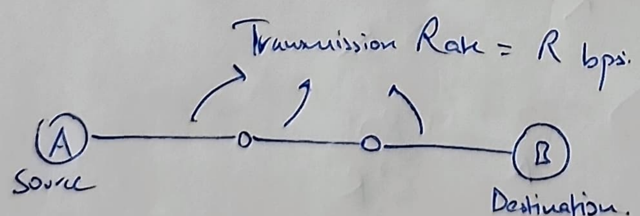
So for the new incoming N packets wont face any additional ~~delay~~ queuing delay due to previous packets.

$\therefore$ Average queuing delay will remain same

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

(Ans)

8)



File $\Rightarrow$ 'F' size, large $\}$ $\rightarrow$ Divided into Segments of 'S' bits.

- 80 headers adde. to each segment
- No queuing delay.

From solution of Question 4,

$$\text{Total delay} = \underbrace{(N}_{\text{No. of Links}} + \underbrace{P}_{\text{No. of Packets}} - 1)\frac{\overbrace{L}^{\text{Packet size}}}{\underbrace{R}_{\text{Transmission rate}}}$$

∴ Here,

$$\text{total delay} = \left(3 + \frac{F}{S} - 1\right)\frac{(S+80)}{R}$$

$$= \left(2 + \frac{F}{S}\right)\left(\frac{S+80}{R}\right)$$

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

$$\therefore f(S) = \frac{F+160}{R} + \frac{2S+160}{R} + \frac{80F}{SR}$$

For minimizing delay,
we differentiate wrt 'S', and equating to zero.

$$\therefore f'(S) = \frac{2}{R} + (-1)\frac{80F}{S^2R} = 0$$

$$\Rightarrow \frac{2}{R} = \frac{80F}{S^2R}$$

$$\Rightarrow S^2 = 80F$$

$$\Rightarrow S = \sqrt{40F} \text{ bits (Ans)}$$

∴ The optimal value of 'S' is closest integer to $\sqrt{40F}$ bits for minimizing delay. (Ans)

9)

Local Resolver $\xrightarrow{.in?}$ Root DNS Server (.) $\boxed{\text{1st Query}}$

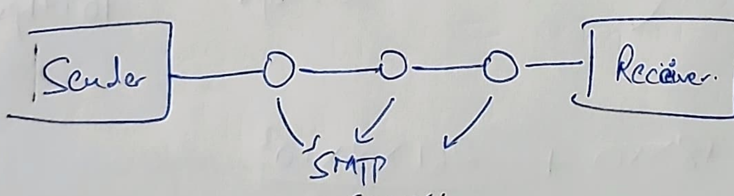
$\xrightarrow{.ac.in?}$ TLD DNS Server (.in) $\boxed{\text{2nd Query}}$

$\xrightarrow{.iitgn.ac.in?}$ Auth DNS Server (.ac.in) $\boxed{\text{3rd Query}}$

$\xrightarrow{www}$ iitgn.acin server $\boxed{\text{4th Query}}$

Total = 4 Queries (Ans)

10)



→ processing delay (d_{proc}) = 30ms.

Propagation delay (d_{prop}) for each link = 20ms.

∴ Total delay = $\underbrace{3 \times d_{proc}}_{\text{3 servers}} + \underbrace{4 \times d_{prop}}_{\text{4 links}}$

$= 3 \times 30 + 4 \times 20$

$= 170ms$ (Ans)

11)

1 HTML $\rightarrow$ 5 KB

3 CSS $\rightarrow$ 2 KB each

5 images $\rightarrow$ 50 KB each

RTT b/w server & client = 50 ms

A) HTTP/1.1 without persistent connection.

1 for TCP handshake & 1 for HTTP request & response.

$$\text{Total page loading Time} = \left[2 \times RTT * \text{Time for data transfer}\right] \text{ for each file}$$

every file will be downloaded sequentially one by one

$$= \sum_{i=1}^{9} \left[2 \times RTT + \text{Time for data transfer}\right]$$

$$= \left(18 \times RTT + \frac{1 \times 5KB}{10\,Mbps} + \frac{3 \times 2\,KB}{10\,Mbps} + \frac{5 \times 50KB}{10\,Mbps}\right)$$

$$= 18 \times 50 + \frac{261 \times 8 \times 10^3}{10 \times 10^6}$$

$$= \underline{\underline{1108.80 \text{ ms}}} \quad \text{(Ans)}.$$

B) HTTP/2 with Multiplexing

↳ All files will be sent parallely over a single connection.

∴ Total page loading time $= 2 \times RTT + $ Transmission time for all files together

$2 \times RTT$: 1 for TCP handshake + 1 for HTTP request & response

$= 2 \times 50 + \frac{261 \times 8 \times 10^3}{10 \times 10^6}$

$= 308.82\,ms$ (Ans)

HTTP/2 with multiplexing is faster than HTTP/1.1 without persistent connection

by $\frac{1108.80}{308.80} \approx 3.6$ times

12)

Local DNS with single level Cache,

Cache hit rate = 80%

Cache lookup time = 1 ms.

if Cache misses

Root server: RTT = 50 ms.

TLD server: RTT = 70 ms.

Auth. server : RTT = 100 ms.

Also, 10% of all DNS queries are invalid,

Bypass Cache, Return error after 10 ms.

Remaining 90% are valid.

i) Avg DNS resolution time = Invalid Queries time + Valid Queries time

= (10%) × 10 ms + Valid Queries time

= 1 ms + [Cache hit time + Cache miss time]

$$= 1\,ms + (\underbrace{90\%}_{\text{Valid Queries}} \times \underbrace{80\%}_{\text{Cache hit rate}} \times \underbrace{1\,ms}_{\text{Cache Check}}) + (\underbrace{90\%}_{\text{Valid Queries}} \times \underbrace{20\%}_{\text{Cache miss rate}} \times [\overset{\text{Cache Check}}{1\,ms} + \underbrace{50\,ms}_{\text{root RTT}} + \underbrace{70\,ms}_{\text{TLD RTT}} + \underbrace{100\,ms}_{\text{Auth RTT}}])$$

= 1 ms + 0.72 ms + 39.78 ms

= 41.5 ms (Ans).

ii) New cache hit rate = 95%

∴ New Avg DNS resolution time = Invalid Queries time + Valid Queries time

$$= (10\%) \times 10\,ms + \left(\text{Cache hit time} + \text{Cache miss time}\right)$$

$$= 1ms + \left[\left(90\% \times \underbrace{95\%}_{\text{New Cache hit rate}} \times 1\,ms\right) + \left(90\% \times \underbrace{5\%}_{\text{New Cache miss rate}} \times \left(1ms + 50ms + 70\,ms + 100\,ms\right)\right)\right]$$

$$= 1ms + 0.855\,ms + 9.945\,ms$$

$$= \underline{\underline{11.8\,ms}}$$

∴ Percentage Faster $= (\text{Speedup} - 1) \times 100$

$$= \left(\frac{\text{time of old}}{\text{time of new}} - 1\right) \times 100$$

$$= \left(\frac{41.5}{11.8} - 1\right) \times 100 = \underline{\underline{251.64\%}}$$

(Ans)

New DNS resolution would be 251.64% faster than before.

13)

RTT with DNS cache = 1 ms

RTT with second DNS = 47 ms.

RTT with webserver = 72 ms.

i) Time req. for loading web page = (DNS cache check) + (Second DNS) + Webserver

$$= RTT_{\text{Cache DNS}} + RTT_{\text{Second DNS}} + \underbrace{RTT_{\text{Webserver}} \times 2}_{\substack{\text{1 for TCP handshake} \\ \text{1 for HTTP requests}}}$$

$$= 1 + 47 + 2 \times 72 \text{ ms}$$

$$= 192 \text{ ms}$$ (Ans)

ii) Time for loading 7 small Objects with non-persistent connection = Time for loading objects + Time for loading webpage

$$= \left[2 \times RTT_{\text{Webserver}} \times 7\right] + 192 \text{ ms}$$

b/cuz non-persistent connection ← Individually for each

$$= 2 \times 72 \times 7 + 192 \text{ ms}$$

$$= 1008 + 192 \text{ ms}$$

$$= 1200 \text{ ms}$$ (Ans)

iii) Time Req. with 5 parallel Connections = Time for 7 objects + Time for webpage

$$= [2 \times RTT_{webser} \times 2] + 192\ ms$$

Only 2 trips are required b/c 5 parallel connection and 7 objects

$$= 2 \times 72 \times 2 + 192\ ms$$

$$= 288 + 192\ ms$$

$$= 480\ ms$$ (Ans)

iv) Time Req. with 5 parallel connection & persistant connection = Time for webpage + Time for loading objects

$$= 192\ ms + [2 \times RTT_{webserver}]$$

Since persistante connection, we only need 1 RTT each for 2 trips of 5 objects & then 2 object.

$$= 192\ ms + 144\ ms$$

$$= 336\ ms$$ (Ans)

v) Fastest method is persistant - parallel (Ans)

14) Avg. obj size = 850000 bits

Avg. request rate = 16 requests per second.

Avg. response time b/w link = 3 seconds

B = 15 Mbps.

A)

avg time to send an object 'Δ' = $\frac{850000 \text{ bits}}{B} = \frac{850000 \text{ bits}}{15 \times 10^6 \text{ bps}}$

= 0.0567 seconds

traffic intensity '$\Delta\beta$' = (16 requests/sec) $\times$ (0.0567 sec/request)

= 0.9072

$\therefore$ Avg. access delay = $\frac{\Delta}{1-\Delta\beta} = \frac{0.0567 \text{ s}}{1-0.9072} = 0.611$ sec.

$\therefore$ Total avg. response time = 0.611 sec + 3 sec

Avg. response time b/w links

= 3.61 sec

(Ans)

B)

Cache hit rate = 0.6

$\therefore$ We only send request 0.4 of the original with cache.

Assumption → Cache hit time = 0 seconds

$\therefore$ Total avg. requests = 0.4×16 request/s.

= 6.4 requests/s.

$\therefore$ $\Delta\beta = 6.4 \times 0.0567 = \underline{0.36288}$

$\Delta = 0.0567$ seconds

$\therefore$ Avg. access delay $= \dfrac{\Delta}{1-\Delta\beta} = \dfrac{0.0567}{1-0.3688} = \underline{0.089\,s}$

$\therefore$ Total delay = $0.089 + \underbrace{3\,sec}_{\text{Avg Response time}}$

= $\underline{3.089}$. → which takes place for 40% Cache miss

$\therefore$ Total average time = $\underbrace{0.6}_{\text{Cache hit rate}} \times \underbrace{0s}_{\text{Cache hit time}} + \underbrace{0.4}_{\text{Cache miss rate}} \times \underbrace{3.089}_{\text{Cache miss time}}$

= $\underline{1.2356 \text{ seconds}}$ (Ans)

15)

IP address for URL is not cached. → DNS lookup req.

DNS lookup time → n DNS servers.

↓

$RTT_1, RTT_2, RTT_3 \cdots RTT_n$.

Exactly one object → small HTML text

transmission time = 0 s.

RTT → RTT b/w local host & server.

∴ Total time elapsed = $2 \times RTT$ + time to get IP address

[1 for TCP handshake + 1 for HTTP request]

$= 2 \times RTT + [RTT_1 + RTT_2 + RTT_3 + \cdots - RTT_n]$

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

(Ans).