1) Text Problem 3 1000 KB file $= 1000(1024)$ B

$= 1000(1024)(8)$ bits

1 RTT = 50 ms

packet size 1024 B $= 1024(8) = 8192$ bits

$2 \times$ RTT = 100 ms for handshake

a) BW = 1.5 Mbps send continuous

Total file size = 8,192,000 bits

transmit time $= 8{,}192{,}000 / 1.5\times10^6 = 5.461\overline{3}$ seconds

propagation delay $= \frac{1}{2}$ RTT = 25 ms

Total time $= \underbrace{2\,RTT}_{\text{handshake}} + \underbrace{\tfrac{1}{2}RTT}_{\text{prop delay}} +$ transmit time

$= 125\text{ms} + 5.461\overline{3} = \boxed{5.5863 \text{ seconds}}$

b) BW = 1.5 mbps. wait 1 RTT after sending one packet.

$\#\text{packets} = \dfrac{8{,}192{,}000}{1024(8)} = 1000$ packets

transmit time still the same $5.461\overline{3}$ sec.

handshake - same 100 mS

prop delay for last packet 25 ms

P1
1RTT → P2
1RTT → P3

# of waits of 1RTT = # packets − 1 = 999

= 999 (50 ms)

= 49.95 sec

∴ Total Time $= 49.95 + 0.025 + 0.1 + 5.461\overline{3}$

= 55.536 seconds

1 Cont c) BW = ∞ ⇒ Transmit time is 0, but send 20 packets/RTT

have to send 50 groups of packets

2 RTT for handshake

$\frac{1}{2}$ RTT for prop delay of last ~~Ac~~ Group of PKTS.

49 RTT for transmission of 20 packet groups

Total Time = 51.5 RTT = $\boxed{2.575 \text{ seconds}}$

d) BW = ∞

n = 1st xmit $2^{n-1} = 1$ packets in 1 RTT

n = 2 xmit $2^{2-1} = 2$ packets in 1 RTT

n = 3 xmit $2^{3-1} = 4$ packets in 1 RTT

n = 4 ⇒ 8 n = 5 ⇒ 16 n = 6 ⇒ 32 n = 7 ⇒ 64 n = 8 ⇒ 128

n = 9 ⇒ 256 n = 10 ⇒ 512

So 10 transmissions required so we must wait 9 RTT to make all transmissions

Total time = $9 + 2 + \frac{1}{2}$ = 11.5 RTT = $\boxed{0.575 \text{ sec}}$

2) Text #16

latency - 1^{st} bit sent to last bit Received

a) 100 Mbps BW packet = 12,000 bits

1 store and forward switch (Receive all before xmit)

link prop delay = 10 μs

A —10 μs— [S] —10 μs— B

Packet xmit time $\frac{12{,}000}{100 \times 10^6} = 120\,\mu s$

Since 120 μs > 10 μs Time to get from A TO S

is 120 μs + 10 μs = 130 μs

Same to go from S TO B.

∴ $\boxed{\text{latency} = 260\,\mu s}$

b) same as a with 3 switches

A — S1 — S2 — S3 — B

4 links @ 130 μs/link = $\boxed{520\,\mu s}$

c) same as a with cut through switching after 200 bits received

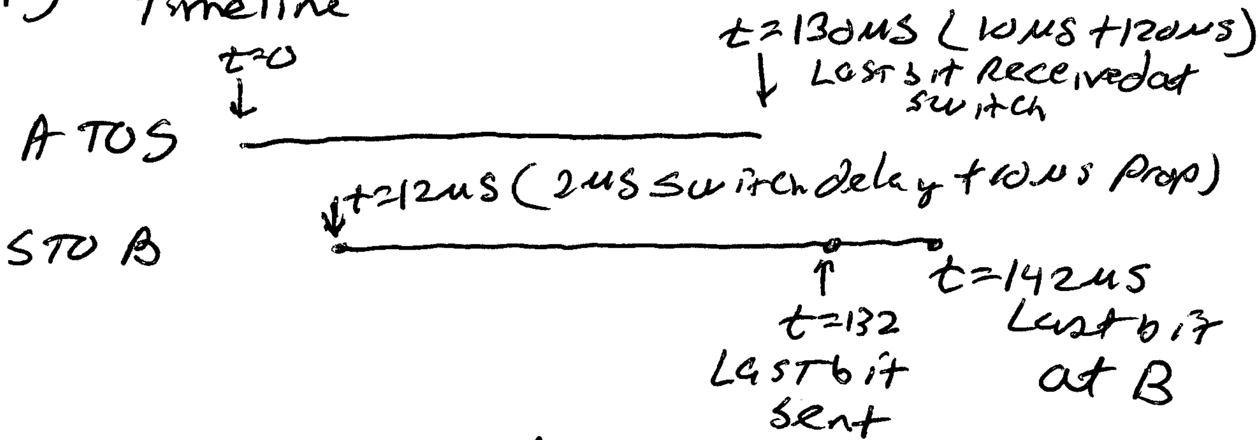
$\frac{200}{100 \times 10^6} = 2\,\mu s$

$\boxed{\text{Answer } 142\,\mu s}$

it takes 130 μs for packet to Reach switch. 2 μs the last bit of the packet is being transmitted to B. In 10 μs B receives last bit

$\boxed{142\,\mu s}$

2 cont)
e) timeline



3) text 19 - calculate delay x BW product
use delay based on first bit sent to first bit Received

a) 100 Mbps   delay = 10 uS

100×10^6 bps (10 uS) = $\boxed{1000 \text{ bits} = 125 \text{ bytes}}$

b) 100 mbps   1 store and forward switch
10 uS prop delay / link
12000 bit packet

A —— S —— B

Xmit time = 120 uS

first bit arrives at B at t = 140 uS
120 uS to Xmit A to S and 10 uS of delay from A to S and 10 more for S to B.

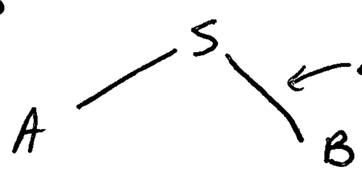
$100 \times 10^6 (140 \times 10^{-6}) = \boxed{14{,}000 \text{ bits} = 1750 \text{ Bytes}}$

(See next page)

c) 1.5Mbps with delay of 50 ms

$1.5\times10^6(0.05) = \boxed{75{,}000 \text{ bits} = 9375 \text{ Bytes}}$

d) 1.5MBps



← delay/link $= \dfrac{35{,}900{,}000 \text{ meters}}{3\times10^8 \text{ m/s}} = 119.\bar{6}$ ms

total delay $= 2(119.\bar{6}\text{ ms}) = 0.23933\bar{3}$ seconds

$1.5\times10^6(0.23933\bar{3}) = \boxed{359{,}000 \text{ bits}} = 44{,}875 \text{ Bytes}$

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other possibilities for b

first bit received

b - 3 stations until first bit received

A — S — S — S — B 4 delays at 10 µs each
3 xmits at 120 µs each

latency = 400 µs

$100\times10^6(400\times10^{-6}) = 40{,}000$ bits = 5000 Bytes

1 station delay until last bit received

A — S — B 2 delays at 10 µs each
2 xmit times of 120 µs each

delay = 260 µs ⇒ 26,000 bits = $\boxed{3250 \text{ Bytes}}$

3 stations delay until last bit received

A — S — S — S — B 4 delays @ 10 µs each
4 xmits @ 120 µs each

delay = 520 µs ⇒ $\boxed{52000 \text{ bits} = 6500 \text{ Bytes}}$

4) text #20   A — S — B   Prop delay = 20 µs/link

Switch is store and forward with 35 µs delay after receiving packet

send 10,000 bits

100 Mbps links

a) send 10,000 bits as one packet

$$\text{Xmit time} = \frac{10{,}000}{100 \times 10^6} = 100\,\mu s$$

A TO S

$t = 20\,\mu s$ 1st bit arrives $120\,\mu s$ last bit arrives

S TO B

$t = 155\,\mu s$ first bit sent $175\,\mu s$ first bit arrives $275\,\mu s$ last bit arrives

$\boxed{275\,\mu s}$

b) 2 - 5000 bit packets (5000 bits Xmit in 50 µs)

Packet 1: A TO S 1st packet arrives after 70 µs, switch transmits to B at time $t = 105\,\mu s$ and
S TO B packet received at B at $t = 175\,\mu s$

Packet 2 A TO S starts at $t = 50\,\mu s$, arrives at switch at $t = 120\,\mu s$. ready for transmission at $t = 155\,\mu s$

$\boxed{\text{answer } 225\,\mu s}$

S TO B switch transmits packet 1 until $t = 155\,\mu s$

∴ packet 2 immediately follows packet 1

$t = 155 + 50 + 20 = \boxed{225\,\mu s}$

5) text problem 24

a) $BW = 100\ \text{mbps}$ Prop. $= 2\times10^8\ m/s$

1500 Byte Packet = 12,000 bits

No delay in stations

$\frac{12{,}000}{100\times10^6} = 120\mu s$ to xmit

in $120\mu s$ we can travel $120\times10^{-6}(2\times10^8\ m/s)$

$= \boxed{24{,}000 \text{ meters}}$

b) station every 100 meters

each station has 10 bits of delay

to go 100 meters it takes $\frac{100\ m}{2\times10^8} = 0.5\mu s$

in $0.5\mu s$ we xmit 50 bits

so a station plus link to next station takes 60 bits. we have 12,000 bits

$\therefore$ # of stations $= \frac{12{,}000}{60} = 200$ stations

@100m/station

$\Rightarrow \boxed{20{,}000 \text{ meters}}$

also 60 bits/100 meters is stored in the ring

$\frac{12{,}000 \text{ bits}}{60 \text{ bits}/100m} = 20{,}000$ meters