#7

BW = 1 Gbps , latency = 100 msec

File size = 10 MB

$TCP_{packet\ size}$ = 1KB

(a) 1st RTT → 2 KB , 2nd RTT → 4 KB = 2^2 KB

ith RTT → 2^i KB 1MB ? = 2^{10} KB

10th RTT → 2^{10} KB

$$\log_2\left(\frac{\text{send window}}{\text{segment size}}\right) = \log_2\left(\frac{1MB}{1KB}\right) = 10 \text{ RTTs}$$

(b)

time slot	Data sent	sending window (unit) segment	s. w. (send) byte
1st RTT	$2^0 \times 1KB$	$2^1 = 2$	$2^1 \times 1KB$
2nd RTT	$2^1 \times 1KB$	$2^2 = 4$	$2^2 \times 1KB$
3rd RTT	$2^2 \times 1KB$	$2^3 = 8$	$2^3 \times 1KB$
⋮			
Nth RTT	$2^n \times 1KB$	$2^n =$	$2^n \times 1KB$

$$\sum_{i=1}^{\bigcirc} 2^{i-1} \times 1KB \approx 10\ MB \text{ (file size)}$$

i = 10: $(1024 - 1) \times 1KB \cong 1MB$

	sending	
11^{th} RTT	1 MB	
12^{th} RTT	2 MB	
13^{th} RTT	4 MB	
14^{th} RTT	7MB data	8 MB sending window (bytes)

Answer: 14 RTTs to send file

(c) $Total_{time}$ = 14 RTTs

latency = 100 msec

time send file: $14 \times 100\,msec = 1.4\,sec$

Effective throughput: $\frac{File\ size}{time\ sent} = \frac{10\,MB}{1.4\,sec} = 7.1\,MBps$

$= 57.1\,Mbps$

$Utilization_{link} = \frac{Ef.\ Throput}{Bandwidth} = \frac{57.1\,Mbps}{1\,Gbps} = 5.7\%$ link bandwidth