5.3. Maximum data throughput = $\frac{d}{b \times R} \times b = \frac{d}{R}$

6. For Simplex positive acknowledgement with retransmission (PAR) protocol: -
   6.1. Maximum channel utilization and throughput is similar to stop-and-wait protocol when the effect of errors is ignored.
7. For *Sliding Window Protocols* with window size of **w**,
   7.1. Go-Back-N,
      7.1.1. Channel utilization, u

$$= \begin{cases} \frac{1-p}{1+2ap}, & if\ window\ fills\ the\ pipe\ i.e., w \geq 2a+1 \\ \frac{w(1-p)}{(1+2a)(1-p+wp)}, & if\ window\ does\ not\ fills\ the\ pipe\ i.e., w < 2a+1 \end{cases}$$

   7.2. Selective reject,
      7.2.1. Channel utilization ,u $= \begin{cases} (1-p), & if\ window\ fills\ the\ pipe\ i.e., w \geq 2a+1 \\ \frac{w(1-p)}{(1+2a)}, & if\ window\ does\ not\ fills\ the\ pipe\ i.e., w < 2a+1 \end{cases}$
   7.3. Condition for maximum utilization or throughput is:
   $[Time\ to\ transmit\ \boldsymbol{w}\ frames] \geq [Round\ Trip\ Time]$

Throughput Calculations:

Throughput = Channel Utilization × Channel Bandwidth

Signal and Noise Calculations:

1. *Signal to Noise Ratio* (in decibels, **dB**) = $10\log_{10}\frac{S}{N}$,
   a. where S= Signal strength and N = noise strength.
2. *Signal Attenuation* (in decibels, **dB**) = $10\log_{10}\frac{Transmitted\ Power}{Received\ Power}$,

Data Rate and Channel Capacity Calculations:

1. *Nyquist Theorem*: Maximum data rate = $2H\log_2 V$ bits/sec, where H is bandwidth in hertz (Hz) and V is number of levels.
2. *Shannon's theorem*: Channel capacity = $H\log_2\left(1+\frac{S}{N}\right)$ bits/sec, where H is bandwidth in hertz (Hz). (Note: here $\frac{S}{N}$ is **not** in decibels).

Baud rate: A baud is the number of changes per second in the signal.

- For Manchester encoding, **baud rate = 2 × bit-rate**

MAC Sub layer:

Static channel allocation in LANs and MANs.

If C = channel capacity in bps

λ = arrival rate of frames (frames/sec)

$\frac{1}{\mu}$ = no. of bits per frame, then