"METHODS": * "COMMON SENSE" + "KNOWING DEFINITIONS"
* "PROBABILISTIC" CALCULATIONS
  - EXPECTED # OF TRIALS UNTIL SUCCESS
  - AVERAGE NUMBER OF TRIALS
* "LTI SYSTEMS" AND EWMA
* LITTLE'S LAW

**Ex. 1 (COMMON SENSE + DEF)**

\[
\text{BOTTLENECK RATE} = B \\
\text{PACKET SIZE} = P \\
\text{ACK SIZE} = A \\
\text{PROCESSING TIME + DELAY} = T \\
\text{NO LOSS ASSUMPTION, NO QUEUE, Etc.}
\]

"STOP & WAIT" THROUGHPUT

\[
= \frac{P}{B + T + \frac{A}{B}}
\]

**Ex. 2 (C.S. + DEF) + LITTLE'S LAW**

\[
\text{BOTTLENECK RATE} = B \\
\text{PACK. SIZE} = P \\
\text{WINDOW SIZE} = W \\
\text{RTT} = T \\
\text{NO LOSS}
\]

PACK. TRANSM. RATE = \( \frac{W}{T} \) (L.L)

\[
\text{TRANSM. RATE} = \frac{PW}{T} \\
\text{UTILIZATION} = \frac{PW}{BT}
\]

**Ex. 3 (C.S)**

\[
\# \text{ CLIENTS} = N \\
\text{RTT} = T \\
\text{ACK SIZE} = A
\]

SERVER'S OUTGOING BANDWIDTH

\[
\geq \frac{N \cdot A}{T}
\]
Ex. 4

\[
\begin{align*}
\text{RTT} &= \tau \\
\text{TIMEOUT} &= T \\
\text{SINGLE PACKET SUCCESS PROB.} &= p
\end{align*}
\]

\[
\text{EXPECTED TIME TO ACK} : \quad \tau - T + \frac{T}{p}
\]

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In a sequence of independent "trials", each with \( P(\text{success}) = p \), expected number of trials until success is \( 1/p \).

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**Derivation:**

\[
\begin{align*}
\frac{1}{p} &\rightarrow 1 \\
\text{Expected Time} &\rightarrow \text{Expected Time} + 1
\end{align*}
\]

\[
X = p \cdot 1 + (1-p) \cdot (X+1) \\
X = \frac{1}{p}
\]

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Ex. 5 (C.S. + DEF + L.L)

**Bandwidth** = B

**RTT** = T

**Packet Size** = P

**Min. Window Size**

\[
W = \frac{(B/p)}{T}
\]

"Queue Size" / "Rate" / "Dwelling Time" ("Packet Rate")

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Ex. 6 (C.S. + DEF)

**Bandwidth** = B (Bottleneck)

**RTT with Queue** = \( T_q \)

**RTT (no Queue)** = \( T_o \)

**Queue Size**

\[
Q = B \cdot (T_q - T_o)
\]
Ex. 7 (LTI for EWMA)

\[ s_n = a \Gamma_n + (1-a) s_{n-1} \quad (a \in (0,1) : \text{EWMA}) \]

\text{TIMEOUT} = 3 \Gamma_n

\text{RTT's} (\Gamma_n) \text{ jump from } \Gamma_n < \text{T} \text{ to } \Gamma_n = \text{T}

\text{How soon} \quad "\text{NO SPURIOUS RETRANSMISSIONS}" ?

i.e.

\[ \begin{align*}
    s_0 &= 0 \\
    s_n &= a + (T-a) s_{n-1} \\
    \text{How soon } s_n &\approx \frac{T}{3} ?
\end{align*} \]

\[ T - s_{n+1} = (1-a) (T - s_n) \]

\text{CONVERGENCE RATE}

\[ \Rightarrow \text{SOLVE FOR} \quad (1-a)^n \leq \frac{2}{3} ! \]

Ex. 8

\[ \text{E (SINGLE ACK)} = T_0 \]

\[ \text{E (n. ACK)} = n T_0 \quad \Rightarrow \quad \frac{\text{E(n. ACK)}}{n} = T_0 \]

\[ \text{E (# of ACK in T)} \quad \text{in} \quad \frac{T}{T} = ? \]

\text{WHEN T SMALL, SOMETHING} \quad \leq \frac{1}{T_0}

\text{AS } T \to \infty : \text{APPROACHES} \quad \frac{1}{T_0} \]