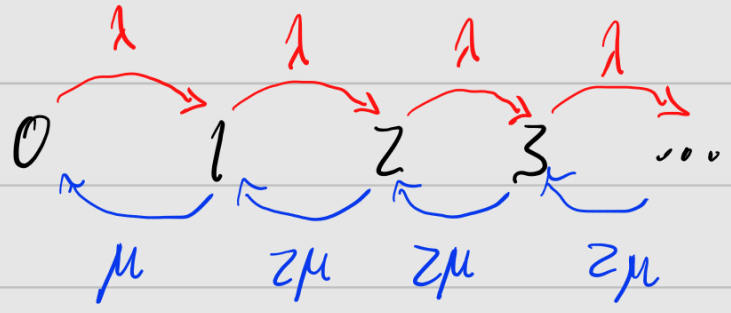
1) $\lambda = 3600 pc/min \rightarrow M$

$m = 2$

$\mu = 300 Kbps \rightarrow 1pc \equiv 4000b$

a) $M/M/2/\infty/\infty/FIFO \Rightarrow 1b \equiv 1/4000 pc$



b) $$P_0 = \frac{1}{\sum_{k=0}^{m-1} \frac{\rho^k}{k!} + \frac{\rho^m}{m!\left(1-\frac{\rho}{m}\right)}}$$

$$\rho = \frac{\lambda}{\mu} \Rightarrow \lambda = \frac{3600}{60}\frac{pc}{s} = 60 pc/s$$

$$\mu = 300 \cdot 10^3 \frac{b}{s} = 300 \cdot 10^3 \cdot \frac{1}{4000}\frac{pc}{s} \therefore \mu = 75 pc/s$$

$\therefore \rho = 0,8$

$\therefore P_0 = 0,428571$

c) $P_3 = ?$ $k \geq m \Rightarrow P_k = \frac{\rho^k}{m^{k-m} m!} \cdot P_0$

$P_3 = \frac{0,8^3}{2^1 2!} \cdot P_0 \therefore P_3 = 0,054857$

$2 \cdot 2!$

d) Serviço $\Rightarrow S \Rightarrow E[t_s] = ?$

$$E[t_s] = \frac{1}{\mu} \therefore E[t_s] = 13{,}33\ ms/pc$$

e) $E[t_q]$ e $E[q]$

$$E[t_s] = \frac{E[S]}{\lambda} \therefore E[S] = 0{,}8\ pc$$

$$E[t_w] = \frac{E[W]}{\lambda}$$

$$E[W] = \frac{P_0 \cdot \rho^m}{m!} \cdot \frac{\rho/m}{(1-\rho/m)^2} \therefore E[W] = 0{,}15238\ pc$$

$$E[q] = E[W] + E[S] \therefore E[q] = 0{,}95238\ pc$$

$$E[t_q] = \frac{E[q]}{\lambda} \therefore E[t_q] = 15{,}873\ ms$$

2) $m = 3$

$\lambda = 20\ ch/h \rightarrow M$

$E[t_s] = 3\ min \rightarrow M$

buffer infinito $\therefore$ Trata-se de uma fila M/M/3/oo/oo/oo/FIFO

a) $K = 0 \Rightarrow P_0 = ?$

$$P_0 = \frac{1}{\sum_{k=0}^{m-1} \frac{\rho^k}{k!} + \frac{\rho^m}{m!(1-\rho)}}$$

$$\rho = \frac{\lambda}{\mu} \Rightarrow \lambda = 20\ ch/h = \frac{20\ ch}{60\ min} \therefore \lambda = \frac{1}{3}\ ch/min$$

$$\mu = \frac{1}{3}\ ch/min$$

$$\therefore \rho = 1$$

$$\Rightarrow P_0 = \frac{1}{\frac{1^0}{0!} + \frac{1^1}{1!} + \frac{1^2}{2!} + \frac{1^3}{3!\left(1-\frac{1}{3}\right)}} \quad \therefore P_0 = 0{,}3636$$

b) $$E[W] = \frac{P_0 \cdot \rho^m}{m!} \cdot \frac{\rho/m}{(1-\rho/m)^2} = \frac{P_0}{3!} \cdot \frac{1/3}{(1-1/3)^2}$$

$$\therefore E[W] = 0{,}04545\ ch$$

c) Call Center → sistema → $E[t_q] = ?$

$$E[q] = E[s] + E[w]$$

$$E[t_s] = \frac{E[s]}{\lambda} \Rightarrow E[s] = E[t_s] \cdot \lambda = 3 \cdot \frac{1}{3} \therefore E[s] = 1\ ch$$

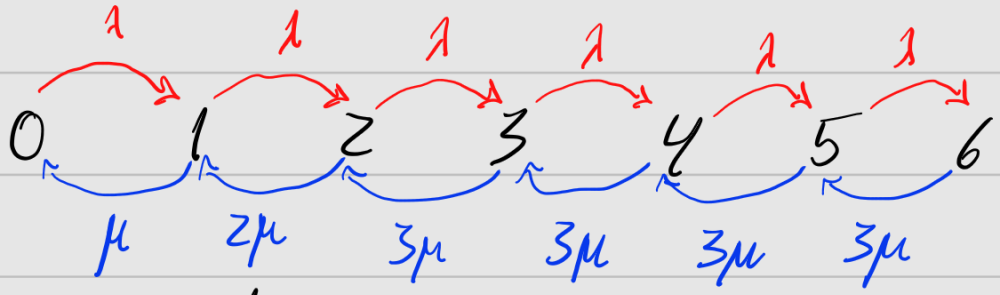
$$\Rightarrow E[q] = 1{,}04545\ ch \Rightarrow E[t_q] = \frac{E[q]}{\lambda} \therefore E[t_q] = 3{,}13636\ min$$

3) $m = 3,\ J = 3 \Rightarrow K = m + J = 6$

$\lambda = 3\ c/h$

$E[t_s] = 45\ min$

a) $M/M/3/3/6/\infty/FIFO$



b) $P_0 = \dfrac{1}{\left(\sum_{K=0}^{m} \frac{\rho^K}{K!}\right)_{*} + \left(\sum_{K=m+1}^{J+m} \frac{\rho^K}{m! \cdot m^{K-m}}\right)_{*}}$

$\rho = \dfrac{\lambda}{\mu} \Rightarrow \lambda = 3\,ch/h = \dfrac{3\,ch}{60\,min} = \dfrac{1\,ch}{20\,min}$

$\mu = \dfrac{1\,ch}{45\,min}$

$\therefore \rho = 2{,}25$

$*: \sum_{K=0}^{3} \frac{2{,}25^K}{K!} = \frac{2{,}25^0}{0!} + \frac{2{,}25^1}{1!} + \frac{2{,}25^2}{2!} + \frac{2{,}25^3}{3!} = 7{,}67969$

$*: \sum_{K=4}^{6} \frac{2{,}25^K}{3! \cdot 3^{K-3}} = \frac{1}{3!}\left(\frac{2{,}25^4}{3^{4-3}} + \frac{2{,}25^5}{3^{5-3}} + \frac{2{,}25^6}{3^{6-3}}\right) = 3{,}296025$

$\Rightarrow P_0 = \dfrac{1}{* + *} \therefore P_0 = 0{,}0911387 = 9{,}11387\%$

c) Prob. de bloqueio: $P_B = P_{m+J} = P_6$

$P_K = \dfrac{\rho^K}{m^{K-m}\, m!} P_0, \quad m \leq K \leq J+m$

$\Rightarrow P_6 = \dfrac{2{,}25^6}{3^{6-3} \cdot 3!} \cdot P_0 \therefore P_6 = P_B = 0{,}072993 = 7{,}2993\%$

d) Empresa → sistema → $E[q] = ?$

$$E[q] = \underbrace{\sum_{k=1}^{m} \frac{k \rho^k}{k!} P_0}_{*} + \underbrace{\sum_{k=m+1}^{J+m} \frac{k \rho^k}{m! m^{k-m}} P_0}_{*}$$

$$= P_0 [* + *]$$

$$*: \sum_{k=1}^{3} \frac{k \cdot 2{,}25^k}{k!} = \frac{2{,}25^1}{1!} + 2\frac{2{,}25^2}{2!} + \frac{3 \cdot 2{,}25^3}{3!} = 15{,}0078$$

$$*: \sum_{k=4}^{6} \frac{k\, 2{,}25^k}{3!\, 3^{k-3}} = \frac{1}{6}\left(\frac{4 \cdot 2{,}25^4}{3^{4-3}} + \frac{5 \cdot 2{,}25^5}{3^{5-3}} + \frac{6 \cdot 2{,}25^6}{3^{6-3}} \right) = 15{,}84$$

$\therefore E[q] = 2{,}62915$ carros

e) 1 carro na fila → 4 no sistema

$$P_4 = \frac{2{,}25^4}{3^{4-3} \cdot 3!} \cdot P_0 \quad \therefore P_4 = 0{,}12977 = 12{,}977\%$$

f) Estacionamento → fila → W

$E[q] = E[w] + E[s] \Rightarrow E[w] = E[q] - E[s]$

$$E[t_s] = \frac{E[s]}{\lambda(1-P_B)} \Rightarrow E[s] = E[t_s]\, \lambda(1-P_B) = 2{,}08577$$

↳ nas mesmas unidades de tempo

$\therefore E[w] = 0{,}543384$ carros

$$E[t_w] = \frac{E[w]}{\lambda(1-P_B)} \quad \therefore E[t_w] = 11{,}7234 \text{ min}$$