DATA / /

(6) $T = 100.000 \text{ bits} = 10^5 = \frac{1}{\mu}$

$\mu C = 500 \text{ mens/seg}$

a) Tráfego médio Total (λ)

$\lambda_1 = \gamma_{13} + \gamma_{14} + \gamma_{23} + \gamma_{24} = 7 + 13 + 12 + 23 = 55 \text{ mens/s}$

$\lambda_2 = \gamma_{13} + \gamma_{23} + \gamma_{34} = 7 + 12 + 16 = 35 \text{ mensg/seg}$

$\lambda_3 = \gamma_{14} + \gamma_{24} + \gamma_{34} = 13 + 23 + 16 = 52 \text{ msg/seg}$

$\lambda_4 = \lambda_3 = 52 \text{ msg/seg}$

$\lambda_5 = \gamma_{12} + \gamma_{13} + \gamma_{14} = 12 + 7 + 13 = 32 \text{msg/seg}$

$\lambda = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 = 55 + 35 + 52 + 52 + 32 = 226 \text{ mens/seg}$

b) $r = \frac{\lambda}{\mu C} = \frac{226}{500} = 0,452$ de utilização

c) g = número de mensagens sendo geradas na rede

$g = \gamma_{12} + \gamma_{13} + \gamma_{14} + \gamma_{23} + \gamma_{24} + \gamma_{34} = 12 + 7 + 13 + 12 + 23 + 16 = 83 \text{ msg/s}$

d) Regra da raiz Quadrada $C_i = \frac{\lambda_i}{\mu_i} + \frac{C(1-\rho)\sqrt{\lambda_i/\mu_i}}{\sum_j \sqrt{\lambda_j/\mu_j}}$

$C(1-\rho) = 500 \cdot 10^5 \cdot (1 - 0,452) = 27,4 \cdot 10^6$

$\sum_{j=1}^{5} \sqrt{\lambda_j/\mu_j} = \frac{1}{\sqrt{\mu}} \sum_{j=1}^{5} \sqrt{\lambda_j} = 316,22 \left(7,41 + 5,91 + 2 \cdot 7,21 + 5,65\right)$

$\sum_{J=1}^{5} \sqrt{\lambda_j/\mu} = 10.561,7$

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$$C_2 = \frac{\lambda_2}{\mu} + \frac{27{,}4 \cdot 10^6 \cdot \sqrt{\lambda_2/\mu}}{10.561{,}7} = \frac{35 \cdot 10^6}{} + \frac{27{,}4 \cdot 10^6 \cdot 1870{,}8}{10.561{,}7}$$

$$C_2 = 3{,}5\,10^6 + 4{,}85 \cdot 10^6 = 8{,}35 \cdot 10^6 \Rightarrow \mu C_2 = 83{,}52 \text{ msg/s}$$

$$C_3 = \frac{\lambda_3}{\mu} + \frac{27{,}4 \cdot 10^6 \cdot \sqrt{\lambda_3/\mu}}{10.561{,}7} = \frac{5{,}2 \cdot 10^6}{} + \frac{27{,}4 \cdot 10^6 \cdot 2280{,}3}{10.561{,}7}$$

$$C_3 = 5{,}2 \cdot 10^6 + 5{,}91 \cdot 10^6 = 11{,}115 \text{ Mbps}$$

$$\mu C_3 = \mu C_4 = 11{,}115 \cdot 10^6 \cdot 10^{-5} = 111{,}15 \text{ msg/seg}$$

a) $T_i = \frac{1}{\mu_i C_i (1-\rho_i)}$ $\rho_i = \frac{\lambda_i}{\mu_i C_i} = \frac{\lambda_i}{C_i} \cdot 10^5$

$$T_2 = \frac{1}{\mu_2 C_2 \left(1 - \frac{\lambda_2 \cdot 10^5}{C_2}\right)} = \frac{1}{10^5 \cdot 8{,}35 \cdot 10^6 \left(1 - \frac{35 \cdot 10^5}{8{,}35 \cdot 10^6}\right)} =$$

$$T_2 = \frac{1}{83{,}5\,(1-0{,}4191)} = 20{,}61 \text{ ms}$$

$$T_3 = \frac{1}{\mu_3 \cdot C_3 \left(1 - \frac{\lambda_3 \cdot 10^5}{C_3}\right)} = \frac{1}{10^{-5} \cdot 11{,}11 \cdot 10^6 \left(1 - \frac{52 \cdot 10^5}{11{,}11 \cdot 10^6}\right)}$$

$$T_3 = \frac{}{111{,}15\,(1-0{,}468)} = \frac{1}{59{,}15} = 16{,}90 \text{ ms}$$

f) As mensagens que vão do Rio de Janeiro à Vitória passam pelos enlaces 2, 3 e 4.

$\therefore T = T_2 + T_3 + T_4 = 20,91 ms + 2 \cdot 16,9 ms = 54,41 ms$

g) $C_2 = 8,35 Mbps \longrightarrow 10,24 Mbps$ ou $\rightarrow$ (8,2 Mbps) → mais próximo

$\therefore \underset{\text{Ajustado}}{MC_2} = 10^{-5} \cdot 8,192 \cdot 10^6 = 81,9$ mensagens/seg

C_3 ou $C_4 = 11,115 Mbps \longrightarrow 12,28 Mbps$ ou $\rightarrow 10,24 Mbps$

$12,28 - 11,11 = 1,17$

$11,11 - 10,24 = 0,87 \rightarrow$ A velocidade mais próxima é de 10,24 Mbps

$MC_3|_{ajust} = MC_4|_{ajust} = 10^{-5} \cdot 10,24 \cdot 10^6 = 102,4$ mens/seg

h) $T_2 = \dfrac{1}{MC_{2ajust}\left(1 - \dfrac{\lambda_2 \cdot 10^5}{C_{2ajust}}\right)} = \dfrac{1}{10^{-5} \cdot 8,192 \cdot 10^6 \cdot \left(1 - \dfrac{3,5 \cdot 10^6}{8,192 \cdot 10^6}\right)}$

$T_2 = \dfrac{1}{81,92 \cdot (1 - 0,427)} = \dfrac{1}{46,92} = 21,31 ms$

$T_3 = \dfrac{1}{MC_{3ajust}\left(1 - \dfrac{\lambda_3 \cdot 10^5}{C_{3ajust}}\right)} = \dfrac{1}{102,4 \cdot \left(1 - \dfrac{5,2 \cdot 10^6}{10,24 \cdot 10^6}\right)} =$

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$$T_4 = T_3 = \frac{1}{102,4(1-0,5078)} = \frac{1}{50,4} = 19,84\,ms$$

$$T_{RJ\,DVT} = 21,31ms + 19,84ms + 19,84_{ms} = 61ms$$

⑦ $L = 80.000\,bits = 1/\mu$

a) $\mu C = 800$ mensagens/seg

Topologia A

$\lambda_1 = \gamma_{21} + \gamma_{23} + \gamma_{24} + \gamma_{25} = 7+10+10+20 = 47\,msg/s$
$\lambda_2 = \gamma_{31} + \gamma_{32} + \gamma_{34} + \gamma_{35} = 1+10+6+8 = 25\,msg/s$
$\lambda_3 = \gamma_{12} + \gamma_{13} + \gamma_{14} + \gamma_{15} = 7+1+3+5 = 16\,msg/s$
$\lambda_4 = \gamma_{12} + \gamma_{13} + \gamma_{52} + \gamma_{53} + \gamma_{14} + \gamma_{54} = 7+1+20+8+3+16 = 55\,msg/s$
$\lambda_5 = \gamma_{15} + \gamma_{25} + \gamma_{35} + \gamma_{45} + \gamma_{55} = 5+20+8+16 = 49\,msg/s$

$\lambda_A = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 = 47+25+16+55+49 = 192\,msg/s$

Topologia B

$\lambda_1 = \gamma_{21} + \gamma_{23} + \gamma_{24} + \gamma_{25} = 7+10+10+20 = 47$
$\lambda_2 = \gamma_{21} + \gamma_{23} + \gamma_{25} + \gamma_{41} + \gamma_{43} + \gamma_{45} = 7+10+20+3+6+16 = 62$
$\lambda_3 = \gamma_{12} + \gamma_{13} + \gamma_{14} + \gamma_{15} = 7+1+3+5 = 16$
$\lambda_4 = \gamma_{12} + \gamma_{13} + \gamma_{14} + \gamma_{52} + \gamma_{53} + \gamma_{54} = 7+1+3+20+8+16 = 55$
$\lambda_5 = \lambda_3 = 16$

$\lambda_B = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 = 47+62+16+55+16 = 196\,msg/s$

b) Nº de mensagens sendo geradas

$g_A = g_B = \gamma_{12} + \gamma_{13} + \gamma_{14} + \gamma_{15} + \gamma_{23} + \gamma_{24} + \gamma_{25} + \gamma_{34} + \gamma_{35} + \gamma_{45} =$

$g_A = g_B = 7 + 1 + 3 + 5 + 10 + 10 + 20 + 6 + 8 + 16 = 86 \text{ msg/s}$

c)

$$C_{i\,opt} = \frac{\lambda_i}{\mu} + \frac{C(1-\rho)\cdot\sqrt{\lambda_i/\mu}}{\sum_{J=1}^{5}\sqrt{\lambda_j/\mu_j}}$$

$$\rho_A = \frac{\lambda_A}{\mu C} = \frac{192}{800} = 0,24$$

$$C = \frac{\mu C}{\mu} = \frac{800}{\frac{1}{8\cdot 10^4}} = 8\cdot 10^2 \cdot 8\cdot 10^4 = 64 \text{ Mbps}$$

$$\sum_{J=1}^{5}\sqrt{\frac{\lambda_j}{\mu_j}} = \frac{1}{\sqrt{\frac{1}{8\cdot 10^4}}}\left(\sqrt{\lambda_1}+\sqrt{\lambda_2}+\sqrt{\lambda_3}+\sqrt{\lambda_4}+\sqrt{\lambda_5}\right)$$

$$\sum_{J=1}^{5}\sqrt{\frac{\lambda_j}{\mu_j}} = 282,84\,(30,28) = 8.564,4$$

$$C(1-\rho_A) = 64\cdot 10^6\,(1-0,24) = 48,64\cdot 10^6$$

$$C_1 = 47\cdot 8\cdot 10^4 + \frac{48,64\cdot 10^6\cdot\sqrt{47\cdot 8\cdot 10^4}}{8.564,4}$$

$$C_1 = 3,76\cdot 10^6 + \frac{48,64\cdot 10^6\cdot 1939,1}{8564,4} = 3,76\cdot 10^6 + 11,01\cdot 10^6$$

$$C_1 = 14,77\cdot 10^6$$

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$$C_2 = 25 \cdot 8 \cdot 10^4 + \frac{48{,}64 \cdot 10^6 \sqrt{25 \cdot 8 \cdot 10^4}}{8.564{,}4} = 10{,}03\ \text{Mbps}$$

$$C_3 = 16 \cdot 8 \cdot 10^4 + \frac{48{,}64 \cdot 10^6 \sqrt{16 \cdot 8 \cdot 10^4}}{8.564{,}4} = 7{,}7 \cdot 10^6$$

$$C_4 = 55 \cdot 8 \cdot 10^4 + \frac{48{,}64 \cdot 10^6 \sqrt{55 \cdot 8 \cdot 10^4}}{8564{,}4} = 16{,}31 \cdot 10^6$$

$$C_5 = 49 \cdot 8 \cdot 10^4 + \frac{48{,}64 \cdot 10^6 \sqrt{49 \cdot 10^4}}{8564{,}4} = 15{,}16 \cdot 10^6$$

Topologia B

$$\rho_B = \frac{196}{800} = 0{,}245 \qquad C = 64 \cdot 10^6$$

$$C(1-\rho) = 48{,}32 \cdot 10^6$$

$$\sum_{j=1}^{5} \sqrt{\frac{\lambda_j}{\mu}} = 282{,}84 \left(\sqrt{\lambda_1} + \sqrt{\lambda_2} + \sqrt{\lambda_3} + \sqrt{\lambda_4} + \sqrt{\lambda_5} \right)$$

$$\sum_{j=1}^{5} \sqrt{\frac{\lambda_j}{\mu}} = 282{,}84 \cdot 30{,}14 = 8527{,}6$$

$$C_1 = 47 \cdot 8 \cdot 10^4 + \frac{48{,}32 \cdot 10^6 \sqrt{47 \cdot 8 \cdot 10^4}}{8527{,}6} = 14{,}74 \cdot 10^6$$

$$C_2 = 62 \cdot 8 \cdot 10^4 + \frac{48{,}32 \cdot 10^6 \cdot \sqrt{62 \cdot 8 \cdot 10^4}}{8527{,}6} = 17{,}58 \cdot 10^6$$

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$$C_3 = 16 \cdot 8 \cdot 10^4 + \frac{48{,}32 \cdot 10^6 \cdot \sqrt{16 \cdot 8 \cdot 10^4}}{8527{,}6} = 7{,}69 \cdot 10^6$$

$$C_4 = 55 \cdot 8 \cdot 10^4 + \frac{48{,}32 \cdot 10^6 \cdot \sqrt{55 \cdot 8 \cdot 10^4}}{8527{,}6} = 16{,}28 \cdot 10^6$$

$$C_5 = C_3 = 7{,}69 \cdot 10^6$$

d) $T_i = \frac{1}{\mu_i \cdot C_i \left(1 - \rho_i\right)} \rightarrow \frac{\lambda_i}{\mu_i C_i}$.

Topologia A

$$T_1 = \frac{1}{\mu \cdot C_1 \left(1 - \frac{\lambda_1}{\mu \cdot C_1}\right)} = \frac{1}{\frac{1}{8 \cdot 10^4} \cdot 14{,}77 \cdot 10^6 \left(1 - \frac{47}{\frac{14{,}77 \cdot 10^6}{8 \cdot 10^4}}\right)}$$

$$T_1 = 7{,}26 \text{ ms}$$

$$T_2 = \frac{1}{\frac{10{,}03 \cdot 10^6}{8 \cdot 10^4}\left(1 - \frac{25}{\frac{10{,}03 \cdot 10^6}{8 \cdot 10^4}}\right)} = 9{,}96 \text{ ms}$$

$$T_3 = \frac{1}{\frac{7{,}7 \cdot 10^6}{8 \cdot 10^4}\left(1 - \frac{16}{\frac{7{,}7 \cdot 10^6}{8 \cdot 10^4}}\right)} = 12{,}44 \text{ ms}$$

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$$T_4 = \frac{1}{\frac{16,31 \cdot 10^6}{8 \cdot 10^4}\left(1 - \frac{55}{\frac{16,31 \cdot 10^6}{8 \cdot 10^4}}\right)} = 6,71\,ms$$

$$T_5 = \frac{1}{\frac{15,16 \cdot 10^6}{8 \cdot 10^4}\left(1 - \frac{49}{\frac{15,16 \cdot 10^6}{8 \cdot 10^4}}\right)} = 7,11\,ms$$

Topologia b

$$T_1 = \frac{1}{\frac{14,74 \cdot 10^6}{8 \cdot 10^4}\left(1 - \frac{47}{\frac{14,74 \cdot 10^6}{8 \cdot 10^4}}\right)} = 7,28\,ms$$

Alterando os valores de C_i e λ_i temos

$T_2 = 6,33\,ms$ $T_3 = 12,47\,ms$

$T_4 = 6,73\,ms$ $T_5 = T_3 = 12,47\,ms$

a) $$\overline{T}min_A = \frac{\left(\sum_i \sqrt{\lambda_i/\mu}\right)}{\gamma C(1-\rho_4)} =$$

$$= \frac{\left(\left(\sqrt{47} + \sqrt{25} + \sqrt{16} + \sqrt{55} + \sqrt{49}\right) \cdot 282,84\right)^2}{86 \cdot 48,64 \cdot 10^6} = 17,52\,ms$$

$$\overline{T}min_B = \frac{\left(\left(\sqrt{47} + \sqrt{62} + \sqrt{16} + \sqrt{55} + \sqrt{16}\right) 282,84\right)^2}{8.6 \cdot 48,32 \cdot 10^6} = 17,49 ms$$

f) Topologia A

$C_1 = 14,77 \cdot 10^6 \rightarrow 14,336$ Mbps

$C_2 = 10,03$ Mbps $\rightarrow 10,24$ Mbps

$C_3 = 7,7$ Mbps $\rightarrow 8,192$ Mbps

$C_4 = 16,31$ Mbps $\rightarrow 16,384$ Mbps

$C_5 = 15,16$ Mbps $\rightarrow 14,336$ Mbps

Pegando os valores mais próximos, multiplos de 2048 Mbps

Topologia B

$C_1 = 14,74 \cdot 10^6 \rightarrow 14,336$ Mbps

$C_2 = 17,58 \cdot 10^6 \rightarrow 18,432$ Mbps

$C_3 = 7,69 \cdot 10^6 \rightarrow 8,192$ Mbps

$C_4 = 16,28 \cdot 10^6 \rightarrow 16,384$ Mbps

$C_5 = C_3 \Rightarrow 8,192$ Mbps

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Topologia A

g) $T_1 = \frac{1}{\mu \cdot C_1 \left(1 - \frac{\lambda_1}{\mu C_{1ajust}}\right)} = \frac{1}{\frac{14,336 \cdot 10^6}{8 \cdot 10^4} \left(1 - \frac{47}{\frac{14,336 \cdot 10^6}{8 \cdot 10^4}}\right)}$

$T_1 = 7,56 \text{ ms}$

Alterando os valor dos C_i ajustados e λ_i

$T_2 = 9,71 \text{ ms}$ $T_3 = 11,57 \text{ ms}$

$T_4 = 6,67 \text{ ms}$ $T_5 = 7,68 \text{ ms}$

Topologia B

$T_1 = \frac{1}{\frac{14,336 \cdot 10^6}{8 \cdot 10^4} \left(1 - \frac{47}{\frac{14,336 \cdot 10^6}{8 \cdot 10^4}}\right)} = 7,56 \text{ ms}$

Alterando os valores de C_i ajustado e λ_i temos:

$T_2 = 5,94 \text{ ms}$ $T_3 = 11,57 \text{ ms}$

$T_4 = 6,67 \text{ ms}$ $T_5 = 11,57 \text{ ms}$

h) $\overline{T} = \frac{1}{f} \cdot \sum_{i=1}^{5} \lambda_i \cdot T_i$

$\overline{T_A} = \frac{1}{86} \cdot (47 \cdot 7{,}56 \cdot 10^{3} + 25 \cdot 9{,}71 \cdot 10^{-3} + 16 \cdot 11{,}57 \cdot 10^{-3} + 55 \cdot 6{,}67 \cdot 10^{-3} + 49 \cdot 7{,}68 \cdot 10^{-3})$

$\overline{T_A} = 17{,}75 \text{ ms}$

$\overline{T_B} = \frac{1}{86} \cdot (47 \cdot 7{,}56 \cdot 10^{3} + 62 \cdot 5{,}94 \cdot 10^{-3} + 2 \cdot 16 \cdot 11{,}57 \cdot 10^{3} + 55 \cdot 6{,}67 \cdot 10^{-3})$

$\overline{T_B} = 16{,}99 \text{ ms}$

i) Podemos concluir que, de acordo com o atraso médio das duas topologias a topologia B obteve menor atraso e portanto é a melhor topologia