Esame 22/05/2017

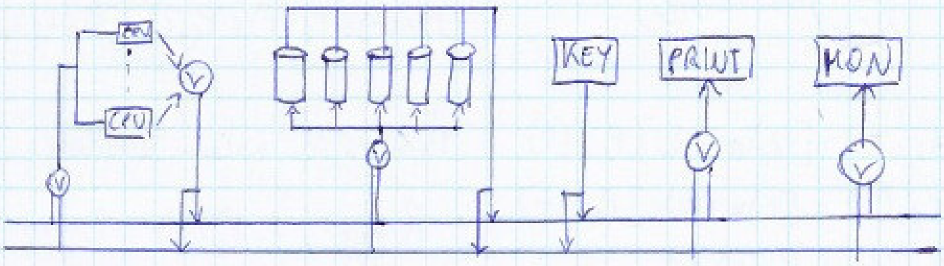
Es. 1

9 CPU + VOTER

RAID 5 - 5 DISK

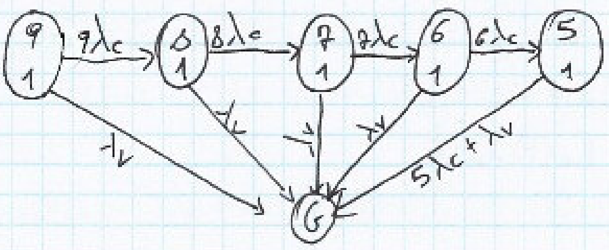
2 BUS + OUTPUT VOTER

KEYBOARD
PRINTER
MONITOR



RELIABILITY:

CPU - SYSTEM



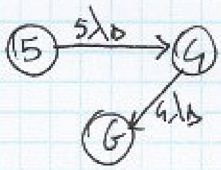
$$P_{9,1}(t+\Delta t) = P_{9,1}(t)[1-(9\lambda_c+\lambda_v)\Delta t]$$
$$P_{8,1}(t+\Delta t) = P_{8,1}(t)[1-(8\lambda_c+\lambda_v)\Delta t] + P_{9,1}(t)\, 9\lambda_c \Delta t$$
$$P_{7,1}(t+\Delta t) = P_{7,1}(t)[1-(7\lambda_c+\lambda_v)\Delta t] + P_{8,1}(t)\, 8\lambda_c \Delta t$$
$$P_{6,1}(t+\Delta t) = P_{6,1}(t)[1-(6\lambda_c+\lambda_v)\Delta t] + P_{7,1}(t)\, 7\lambda_c \Delta t$$
$$P_{5,1}(t+\Delta t) = P_{5,1}(t)[1-(5\lambda_c+\lambda_v)\Delta t] + P_{6,1}(t)\, 6\lambda_c \Delta t$$
$$P_G(t+\Delta t) = P_G(t) + \lambda_v \Delta t[P_{9,1}(t)+P_{8,1}(t)+P_{7,1}(t)+P_{6,1}(t)+P_{5,1}(t)]$$

$$P_{9,1}'(t) = [-9\lambda_c-\lambda_v]P_{9,1}(t)$$
$$P_{8,1}'(t) = [-8\lambda_c-\lambda_v]P_{8,1}(t) + P_{9,1}(t)\, 9\lambda_c$$
$$P_{7,1}'(t) = [-7\lambda_c-\lambda_v]P_{7,1}(t) + P_{8,1}(t)\, 8\lambda_c$$
$$P_{6,1}'(t) = [-6\lambda_c-\lambda_v]P_{6,1}(t) + P_{7,1}(t)\, 7\lambda_c$$
$$P_{5,1}'(t) = [-5\lambda_c-\lambda_v]P_{5,1}(t) + P_{6,1}(t)\, 6\lambda_c$$
$$P_G'(t) = \lambda_v[P_{9,1}(t)+P_{8,1}(t)+P_{7,1}(t)+P_{6,1}(t)+P_{5,1}(t)]$$
$$P_{9,1}(t)+P_{8,1}(t)+P_{7,1}(t)+P_{6,1}(t)+P_{5,1}(t)+P_G(t) = 1$$
$$P_{5,1}(\emptyset) = 1$$

Risolvo il sistema e ottengo le P_i

$$R_{\substack{SUB\\CPU}}(t) = 1 - P_G(t)$$

RAID - SYSTEM



$$P_5(t+\Delta t) = P_5(t)[1-5\lambda_D\Delta t]$$
$$P_4(t+\Delta t) = P_4(t)[1-4\lambda_D\Delta t] + P_5(t)\, 5\lambda_D \Delta t$$
$$P_G(t+\Delta t) = P_G(t) + P_4(t)\, 4\lambda_D \Delta t$$

$$\begin{cases} P_5'(t) = -5\lambda_D P_5(t) \\ P_4'(t) = -4\lambda_D P_4(t) + 5\lambda_D P_5(t) \\ P_G'(t) = 4\lambda_D P_4(t) \\ P_5(t)+P_4(t)+P_G(t) = 1 \\ P_5(\emptyset) = 1 \end{cases}$$

Risolvo il sistema e ottengo le P_i

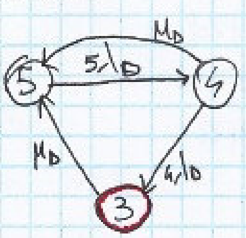
$$R_{RAID}(t) = 1 - P_G(t)$$

$$P_{9,1}(t+\Delta t) = P_{9,1}(t)[1-(9\lambda_c+\lambda_v)\Delta t] + \mu_c \Delta t [P_{8,1}(t)+P_{7,1}(t)] + \mu_v \Delta t P_{9,0}(t)$$
$$P_{8,1}(t+\Delta t) = P_{8,1}(t)[1-(8\lambda_c+\lambda_v+\mu_c)\Delta t] + P_{9,1}(t) 9\lambda_c \Delta t + P_{6,1}(t)\mu_c \Delta t + P_{8,0}(t)\mu_v \Delta t$$
$$P_{7,1}(t+\Delta t) = P_{7,1}(t)[1-(7\lambda_c+\lambda_v+\mu_c)\Delta t] + P_{8,1}(t) 8\lambda_c \Delta t + P_{5,1}(t)\mu_c \Delta t + P_{7,0}(t)\mu_v \Delta t$$
$$P_{6,1}(t+\Delta t) = P_{6,1}(t)[1-(6\lambda_c+\lambda_v+\mu_c)\Delta t] + P_{7,1}(t) 7\lambda_c \Delta t + P_{4,1}(t)\mu_c \Delta t + P_{6,0}(t)\mu_v \Delta t$$
$$P_{5,1}(t+\Delta t) = P_{5,1}(t)[1-(5\lambda_c+\lambda_v+\mu_c)\Delta t] + P_{6,1}(t) 6\lambda_c \Delta t + P_{5,0}(t)\mu_v \Delta t$$
$$P_{4,1}(t+\Delta t) = P_{4,1}(t)[1-\mu_c \Delta t] + P_{5,1}(t) 5\lambda_c \Delta t$$
$$P_{9,0}(t+\Delta t) = P_{9,0}(t)[1-\mu_v \Delta t] + \mu_c \Delta t [P_{8,0}(t)+P_{7,0}(t)] + P_{9,1}(t)\lambda_v \Delta t$$
$$P_{8,0}(t+\Delta t) = P_{8,0}(t)[1-(\mu_c+\mu_v)\Delta t] + P_{6,0}(t)\mu_c \Delta t + P_{8,1}(t)\lambda_v \Delta t$$
$$P_{7,0}(t+\Delta t) = P_{7,0}(t)[1-(\mu_c+\mu_v)\Delta t] + P_{5,0}(t)\mu_c \Delta t + P_{7,1}(t)\lambda_v \Delta t$$
$$P_{6,0}(t+\Delta t) = P_{6,0}(t)[1-(\mu_c+\mu_v)\Delta t] + P_{6,1}(t)\lambda_v \Delta t$$
$$P_{5,0}(t+\Delta t) = P_{5,0}(t)[1-(\mu_c+\mu_v)\Delta t] + P_{5,1}(t)\lambda_v \Delta t$$

$$\begin{cases}
P'_{9,1}(t) = -[9\lambda_c+\lambda_v]P_{9,1}(t) + \mu_c[P_{8,1}(t)+P_{7,1}(t)] + \mu_v P_{9,0}(t) \\
P'_{8,1}(t) = -[8\lambda_c+\lambda_v+\mu_c]P_{8,1}(t) + 9\lambda_c P_{9,1}(t) + P_{6,1}(t)\mu_c + \mu_v P_{8,0}(t) \\
P'_{7,1}(t) = -[7\lambda_c+\lambda_v+\mu_c]P_{7,1}(t) + 8\lambda_c P_{8,1}(t) + \mu_c P_{5,1}(t) + \mu_v P_{7,0}(t) \\
P'_{6,1}(t) = -[6\lambda_c+\lambda_v+\mu_c]P_{6,1}(t) + 7\lambda_c P_{7,1}(t) + \mu_c P_{4,1}(t) + \mu_v P_{6,0}(t) \\
P'_{5,1}(t) = -[5\lambda_c+\lambda_v+\mu_c]P_{5,1}(t) + 6\lambda_c P_{6,1}(t) + \mu_v P_{5,0}(t) \\
P'_{4,1}(t) = -[\mu_c]P_{4,1}(t) + 5\lambda_c P_{5,1}(t) \\
P'_{9,0}(t) = -\mu_v P_{9,0}(t) + \mu_c[P_{8,0}(t)+P_{7,0}(t)] + \lambda_v P_{9,1}(t) \\
P'_{8,0}(t) = -[\mu_v+\mu_c]P_{8,0}(t) + \mu_c P_{6,0}(t) + \lambda_v P_{8,1}(t) \\
P'_{7,0}(t) = -[\mu_c+\mu_v]P_{7,0}(t) + \mu_c P_{5,0}(t) + \lambda_v P_{7,1}(t) \\
P'_{6,0}(t) = -[\mu_c+\mu_v]P_{6,0}(t) + \lambda_v P_{6,1}(t) \\
P'_{5,0}(t) = -[\mu_c+\mu_v]P_{5,0}(t) + \lambda_v P_{5,1}(t) \\
P_{9,1}(t)+P_{8,1}(t)+P_{7,1}(t)+P_{6,1}(t)+P_{5,1}(t)+P_{4,1}(t)+P_{9,0}(t)+P_{8,0}(t)+P_{7,0}(t)+P_{6,0}(t)+P_{5,0}(t) = 1 \\
P_{9,1}(\emptyset) = 1
\end{cases}$$

$$A_{\substack{SUB \\ CPU}}(t) = P_{9,1}(t) + P_{8,1}(t) + P_{7,1}(t) + P_{6,1}(t) + P_{5,1}(t).$$

RAID SYS



$$P_5(t+\Delta t) = P_5(t)[1-5\lambda_D \Delta t] + P_3(t)\mu_D \Delta t + P_4(t)\mu_D \Delta t$$
$$P_4(t+\Delta t) = P_4(t)[1-4\lambda_D \Delta t] + P_5(t) 5\lambda_D \Delta t$$
$$P_3(t+\Delta t) = P_3(t)[1-\mu_D \Delta t] + P_4(t) 4\lambda_D \Delta t$$

$$\begin{cases}
P'_5(t) = -5\lambda_D P_5(t) + \mu_D P_3(t) \\
P'_4(t) = -4\lambda_D P_4(t) + 5\lambda_D P_5(t) \\
P'_3(t) = -\mu_D P_3(t) + 4\lambda_D P_4(t) \\
P_5(t) + P_4(t) + P_3(t) = 1 \\
P_5(\emptyset) = 1
\end{cases}$$

$$A_{RAID} = 1 - P_3(t)$$

BUS-SYSTEM

$$\begin{pmatrix}2B\\4r\end{pmatrix} \xrightarrow{2\lambda_B+4\lambda_r} (G)$$

$$P_{2,4}(t+\Delta t) = P_{2,4}(t)\,[1-(2\lambda_B+4\lambda_r)\Delta t]$$
$$P_G(t+\Delta t) = P_G(t) + P_{2,4}(t)\,[2\lambda_B+4\lambda_r]\,\Delta t$$

$$\begin{cases} P_{2,4}'(t) = [-2\lambda_B - 4\lambda_r]\,P_{2,4}(t) \\ P_G'(t) = [2\lambda_B+4\lambda_r]\,P_{2,4}(t) \\ P_{2,4}(t) + P_G(t) = 1 \\ P_{2,4}(\emptyset) = 1 \end{cases}$$

Risolvo il sistema e ottengo $P_{2,4}(t)$ e $P_G(t)$

$$R_{\substack{SUB\\BUS}} = 1 - P_G(t)$$

MONITOR

$$(\text{MON OK}) \xrightarrow{\lambda_M} (\text{MON KO})$$

$$P_{OK}(t+\Delta t) = P_{OK}(t)\,[1-\lambda_M\Delta t]$$
$$P_{KO}(t+\Delta t) = P_{KO}(t) + P_{OK}(t)\,\lambda_M\Delta t$$

$$\begin{cases} P_{OK}'(t) = -\lambda_M P_{OK}(t) \\ P_{KO}'(t) = \lambda_M P_{OK}(t) \\ P_{OK}(t) + P_{KO}(t) = 1 \\ P_{OK}(\emptyset) = 1 \end{cases}$$

$$R_{MON}(t) = 1 - P_{KO}(t)$$

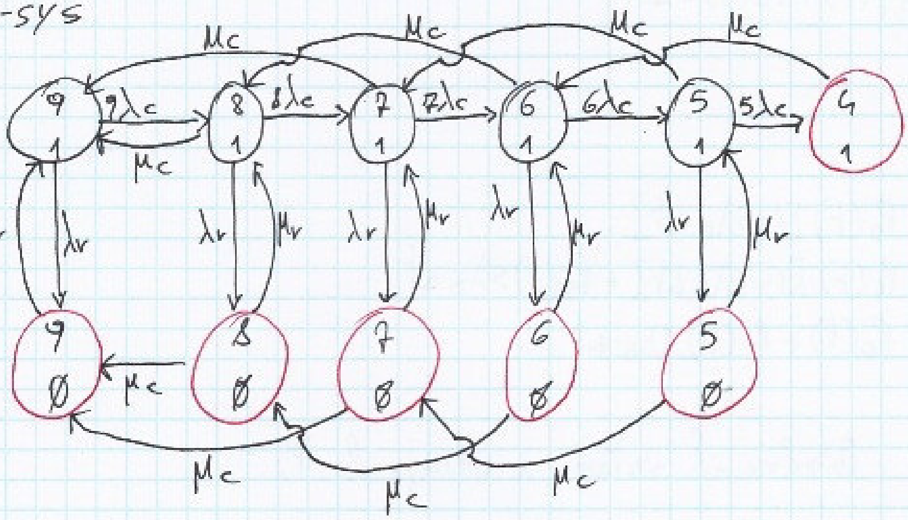
Stesso per PRINTER e KEYBOARD.

$$R_{SYS} = R_{\substack{SUB\\CPU}} \cdot R_{RAID} \cdot R_{\substack{SUB\\BUS}} \cdot R_{MON} \cdot R_{KEY} \cdot R_{PRINT}$$

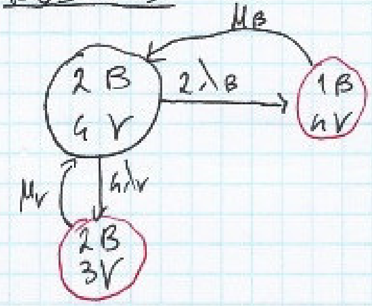
STEADY-STATE AVAILABILITY

Hp: FAIR-STOP

CPU-SYS



BUS-SYS

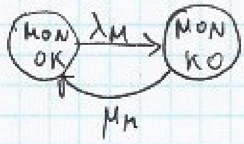


$$P_{2,4}(t+\Delta t) = P_{2,4}(t)\left[1-(2\lambda_B+4\lambda_V)\Delta t\right] + P_{1,4}(t)\mu_B \Delta t + P_{2,3}(t)\mu_V \Delta t$$
$$P_{1,4}(t+\Delta t) = P_{1,4}(t)\left[1-\mu_B \Delta t\right] + P_{2,4}(t)\, 2\lambda_B \Delta t$$
$$P_{2,3}(t+\Delta t) = P_{2,3}(t)\left[1-\mu_V \Delta t\right] + P_{2,4}(t)\, 4\lambda_V \Delta t$$

$$\begin{cases} P'_{2,4}(t) = -[2\lambda_B+4\lambda_V]P_{2,4}(t) + P_{1,4}(t)\mu_B + P_{2,3}(t)\mu_V \\ P'_{1,4}(t) = -\mu_B P_{1,4}(t) + 2\lambda_B P_{2,4}(t) \\ P'_{2,3}(t) = -\mu_V P_{2,3}(t) + P_{2,4}(t) 4\lambda_V \\ P_{2,4}(t) + P_{1,4}(t) + P_{2,3}(t) = 1 \\ P_{2,4}(\emptyset) = 1 \end{cases}$$

$$A_{\substack{SUB\\BUS}} = P_{2,4}(t)$$

MON



$$\begin{cases} P'_{OK}(t) = -\lambda_M P_{OK}(t) + \mu_M P_{KO}(t) \\ P_{OK}(t) + P_{KO}(t) = 1 \\ P_{OK}(\emptyset) = 1 \end{cases}$$

$$A_{MON} = P_{OK}(t)$$

Stesso per KEYBOARD e PRINTER

$$A_{SYS} = A_{\substack{SUB\\CPU}} \cdot A_{RAID} \cdot A_{\substack{SUB\\BUS}} \cdot A_{MON} \cdot A_{KEY} \cdot A_{PRINT}$$

Es. 2

TCP Seg: 130'000 Byte

ETH Ovhd = 18 Byte

MTU = 1500 Byte

Bandwidth = 100 Mbyte/sec

- If TCP does not know MTU:

TCP → |20|65515| → IP { |20|20|1460| ; |20|1480| ×43 ; |20|415| } → ETH → 18|20|20|1460 ; 18|20|1480 ×43 ; 18|20|415

|20|64485| → IP { |20|20|1460| ; |20|1480| ×42 ; |20|865| } → ETH → 18|20|20|1460 ; 18|20|1480 ×42 ; 18|20|865

$$Ovhd = 45\times(18+20)+20 + 44\times(18+20)+20 = 3802 \text{ Byte}$$

$$\text{Service Time} = \frac{\text{TCP Seg} + \text{Ovhd}}{\text{Bandwidth}} = \frac{(130'000+3802)\text{ Byte}}{100 \text{ Mbyte/s}} = 1{,}338 \text{ ms}$$

• If TCP knows MTU

TCP: 20|1460 x89
20|60

IP: 20|20|1460 x89
20|20|60

ETH: 18|20|20|1460 x89
18|20|20|60

$$\text{Ovhd} = 90 \times (18+20+20) = 5220$$

$$\text{Service Time} = \frac{(130\cdot000 + 5220)\,\text{Byte}}{100\ \text{Mbyte}/s} = 1{,}352\ ms$$

Es. 3

3 Server

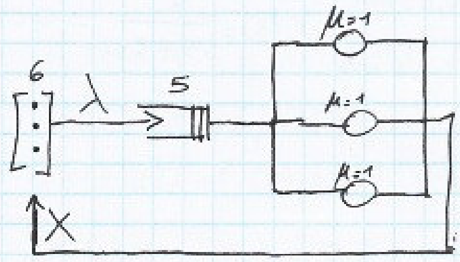
queue len = 5

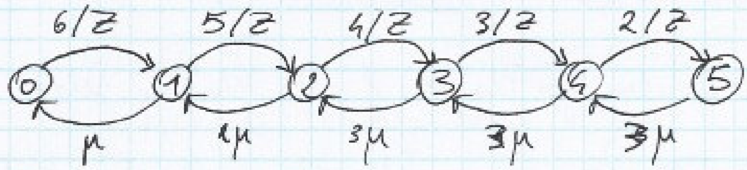
\# users = 6

$Z = 8s$

$S = 1\ sec$

$\bar{R} = ?\ \ \bar{X} = ?$





FLOW-IN = FLOW-OUT

$$\begin{cases} \mu P_1 = 6/Z\, P_0 \\ 6/Z \cancel{P_0} + 2\mu P_2 = 5/Z\, P_1 + \cancel{\mu P_1} \\ 5/Z \cancel{P_1} + 3\mu P_3 = 4/Z\, P_2 + \cancel{2\mu P_2} \\ 4/Z \cancel{P_2} + 3\mu P_4 = 3/Z\, P_3 + \cancel{3\mu P_3} \\ 3/Z \cancel{P_3} + 3\mu P_5 = 2/Z\, P_4 + \cancel{3\mu P_4} \\ \sum_i P_i = 1 \end{cases}$$

$$\begin{cases} P_1 = \frac{6}{Z\mu} P_0 \\ P_2 = \frac{5}{2\mu Z} P_1 = \frac{6\cdot5}{2\cdot1}\left(\frac{1}{Z\mu}\right)^2 P_0 \\ P_3 = \frac{4}{3Z\mu} P_2 = \frac{6\cdot5\cdot4}{3\cdot2\cdot1}\left(\frac{1}{Z\mu}\right)^3 P_0 \\ P_4 = \frac{3}{3Z\mu} P_3 = \frac{6\cdot5\cdot4\cdot3}{3\cdot3\cdot2\cdot1}\left(\frac{1}{Z\mu}\right)^4 P_0 \\ P_5 = \frac{2}{3Z\mu} P_4 = \frac{6\cdot5\cdot4\cdot3\cdot2}{3\cdot3\cdot3\cdot2\cdot1}\left(\frac{1}{Z\mu}\right)^5 P_0 \\ \sum_i P_i = 1\ * \end{cases}$$

$$\boxed{P_0 = \frac{1}{1 + 6\frac{1}{Z\mu} + \frac{6\cdot5}{2}\frac{1}{(Z\mu)^2} + \frac{6\cdot5\cdot4}{3\cdot2\cdot1}\frac{1}{(Z\mu)^3} + \frac{6\cdot5\cdot4\cdot3}{3\cdot3\cdot2\cdot1}\frac{1}{(Z\mu)^4} + \frac{6\cdot5\cdot4\cdot3\cdot2}{3\cdot3\cdot3\cdot2\cdot1}\frac{1}{(Z\mu)^5}}}$$
*

After solving the system I will get $P_0 \dots P_5$ so:

$$\bar{X} = \sum_{i=0}^{5} P_i \cdot \begin{cases} i\cdot\mu & i \le 3 \\ 3\mu & i > 3 \end{cases} \qquad \bar{N} = \sum_{i=0}^{5} i \cdot P_i \qquad \bar{R} = \frac{\bar{N}}{\bar{X}}$$

Follows from Little's Law

Es. 4

$\lambda = 10\ req/s$

2 Servers (workload Balancer)

$D_{CPU} = 20ms$

$D_{DISK} = 5 \times 5ms = 25ms$

queue len = 3

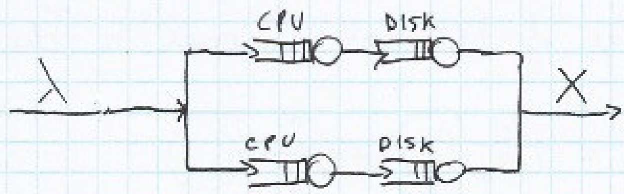
MTTF = 4000h

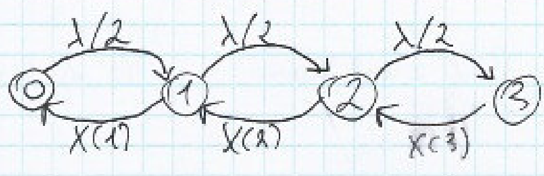
MTTR = 40h

$\bar{X} = ?$

$\bar{R} = ?$

% = ?





Markov Chain of Single Server when two Servers are Working

MVA:

• $M = 1$

$R'_{CPU}(1) = D_{CPU}(1) = 20ms$

$R'_{DISK}(1) = D_{DISK}(1) = 25ms$

$X_0(1) = \frac{1}{20ms + 25ms} = \frac{1}{45ms} = 0,0\bar{2}$ req/s

$M_{CPU}(1) = 0,\bar{4}$

$M_{DISK}(1) = 0,\bar{5}$

• $M = 2$

$R'_{CPU}(2) = 20ms\,[1,\bar{4}] = 28,\bar{8}\,ms$

$R'_{DISK}(2) = 25ms\,[1,\bar{5}] = 38,\bar{8}\,ms$

$X_0(2) = \frac{2}{67,\bar{7}\,ms} = 0,03$ req/s

$M_{CPU}(2) = 0,8525$

$M_{DISK}(2) = 1,1472$

• $M = 3$

$R'_{CPU}(3) = 20ms\,[1,8525] = 37,05\,ms$

$R'_{DISK}(3) = 25ms\,[1,1472] = 28,68\,ms$

$X_0(3) = \frac{3}{65,73ms} = 0,046$ req/s

$M_{CPU}(3) = 1,691$

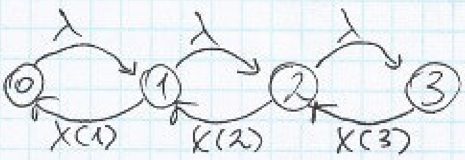
$M_{DISK}(3) = 1,309$

Once I got $X(1)$ $X(2)$ and $X(3)$:

There are 2 Servers, the throughput calculated with MVA is of a single server

$$X_2 = \sum_{i=0}^{3} \underbrace{P_i}_{\text{from FLOW IN = FLOW OUT}} X(i) \qquad N_2 = \sum_{i=0}^{3} i \cdot P_i \qquad R_2 = \frac{N_2}{X_2} \qquad X_2^{TOT} = 2X_2$$

I should repeat the procedure for the case of one Working Server



The throughputs do not change.
What changes is the probabilities $P_0\ P_1\ P_2\ P_3$ due to a different Markov Chain

$$X_1 = \sum_{i=0}^{3} P_i X(i) \qquad N_1 = \sum_{i=0}^{3} i \cdot P_i \qquad R_1 = \frac{N_1}{X_1} \qquad X_1^{TOT} = X_1$$

Now, given q_i the probability that i server work:

$q_2 = A_S^2$

$q_1 = 2A_S(1 - A_S)$

$q_0 = (1 - A_S)^2$

Where $A_S = \frac{MTTF_S}{MTTF + MTTR} = \frac{6000\,h}{6060\,h} = 0,99$

$$\overline{X} = \sum_{i=1}^{2} \frac{q_i}{1-q_0} X_i^{TOT} \qquad \overline{R} = \sum_{i=1}^{2} \frac{q_i}{1-q_0} R_i$$

The percentage of lost users is equal to the average P_3 value:

$$\% = \overline{P_3} = \frac{q_2}{1-q_0} P_{3,2} + \frac{q_1}{1-q_0} P_{3,1}$$

$P_{3,2}$: P_3 of 2 work Servers

$P_{3,1}$: P_3 of 1 work Server

Esame 22/03/2016

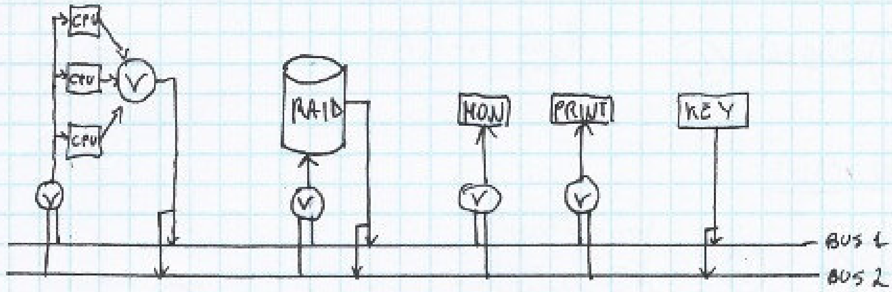
Es. 1

3 CPU + VOTER

RAID 1 (4+4)

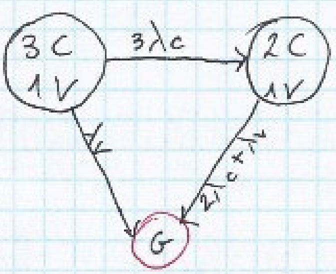
2 BUS + OUTPUT VOTER

KEYBOARD
PRINTER
MONITOR



RELIABILITY

CPU-SYS

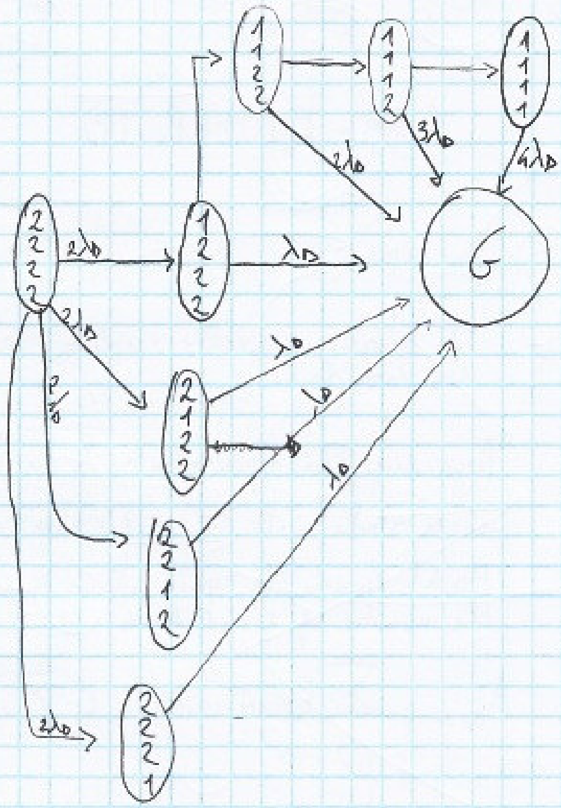


$$P_{3,1}(t+\Delta t) = P_{3,1}(t)\left[1-(3\lambda_c+\lambda_v)\Delta t\right]$$
$$P_{2,1}(t+\Delta t) = P_{2,1}(t)\left[1-(2\lambda_c+\lambda_v)\Delta t\right] + P_{3,1}(t)\,3\lambda_c\Delta t$$
$$P_G(t+\Delta t) = P_G(t) + P_{3,1}(t)\lambda_v\Delta t + P_{2,1}(t)\left[2\lambda_c+\lambda_v\right]\Delta t$$

$$\begin{cases} P'_{3,1}(t) = -\left[3\lambda_c+\lambda_v\right]P_{3,1}(t) \\ P'_{2,1}(t) = -\left[2\lambda_c+\lambda_v\right]P_{2,1}(t) + P_{3,1}(t)\,3\lambda_c \\ P'_G(t) = P_{3,1}(t)\lambda_v + P_{2,1}(t)\left[2\lambda_c+\lambda_v\right] \\ P_{3,1}(t)+P_{2,1}(t)+P_G(t) = 1 \\ P_{3,1}(\emptyset) = 1 \end{cases}$$

$R_{SUB_{CPU}}(t) = 1 - P_G(t)$

RAID-SYS



I cannot represent all the states.
Basically every state contains 4 rows each of which is a pair of disks. (info + replica)
Basically:

- I go to the state $\begin{smallmatrix}X\\X\\2\\X\end{smallmatrix}$ to $\begin{smallmatrix}X\\X\\1\\X\end{smallmatrix}$ with $2\lambda_D$
- I go to the state $\begin{smallmatrix}X\\X\\1\\X\end{smallmatrix}$ to G with λ_D
- I go to the state $\begin{smallmatrix}X\\1\\1\\X\end{smallmatrix}$ to G with $2\lambda_D$
- I go to the state $\begin{smallmatrix}1\\1\\1\\X\end{smallmatrix}$ to G with $3\lambda_D$
- I go to the state $\begin{smallmatrix}1\\1\\1\\1\end{smallmatrix}$ to G with $4\lambda_D$

$R_{RAID}(t) = 1 - P_G(t)$

BUS-SYS

$(2B, 4V) \xrightarrow{2\lambda_B + 4\lambda_V} (G)$ $\qquad R_{SUB_{BUS}} = 1 - P_G(t)$

KEY-MON-PRINT

$(W) \xrightarrow{\lambda_i} (G)$

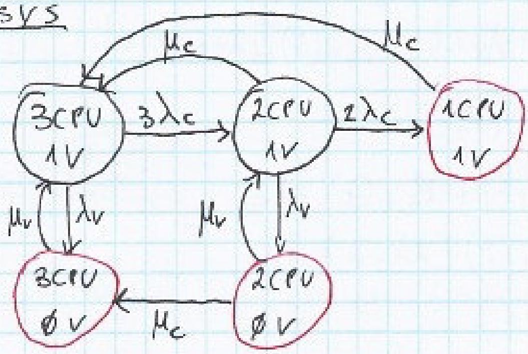
W = Working

$R_i = 1 - P_G(t)$

$$R_{SYS} = R_{SUB_{BUS}} \cdot R_{SUB_{CCPU}} \cdot R_{RAID} \cdot R_{MON} \cdot R_{KEY} \cdot R_{PRINT}$$

AVAILABILITY

CPU-SYS



$$P_{3,1}(t+\Delta t) = P_{3,1}(t)[1-(3\lambda_c+\lambda_v)\Delta t] + \mu_c \Delta t [P_{2,1}(t) + P_{1,1}(t)] + \mu_v \Delta t\, P_{3,0}(t)$$

$$P_{2,1}(t+\Delta t) = P_{2,1}(t)[1-[2\lambda_c+\lambda_v+\mu_c]\Delta t] + P_{3,1}(t)\, 3\lambda_c \Delta t + P_{2,0}(t)\mu_v \Delta t$$

$$P_{1,1}(t+\Delta t) = P_{1,1}(t)[1-\mu_c \Delta t] + P_{2,1}(t)\, 2\lambda_c \Delta t$$

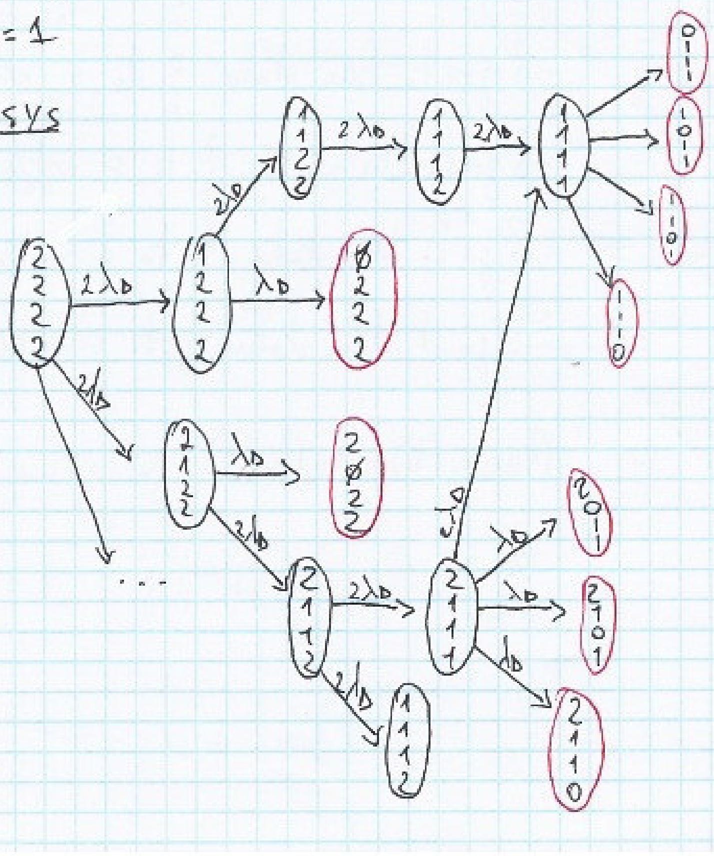
$$P_{3,0}(t+\Delta t) = P_{3,0}(t)[1-\mu_v \Delta t] + P_{3,1}(t)\lambda_v \Delta t + P_{2,0}(t)\mu_c \Delta t$$

$$P_{2,0}(t+\Delta t) = P_{2,0}(t)[1-(\mu_v+\mu_c)\Delta t] + P_{2,1}(t)\lambda_v \Delta t$$

$$\begin{cases} P'_{3,1}(t) = -[3\lambda_c+\lambda_v]P_{3,1}(t) + \mu_c[P_{2,1}(t) + P_{1,1}(t)] + P_{3,0}(t)\mu_v \\ P'_{2,1}(t) = -[2\lambda_c+\lambda_v+\mu_c]P_{2,1}(t) + P_{3,1}(t)\, 3\lambda_c + P_{2,0}(t)\mu_v \\ P'_{1,1}(t) = -\mu_c P_{1,1}(t) + P_{2,1}(t)\, 2\lambda_c \\ P'_{3,0}(t) = -\mu_v P_{3,0}(t) + P_{3,1}(t)\lambda_v + P_{2,0}(t)\mu_c \\ P'_{2,0}(t) = -(\mu_c+\mu_v) P_{2,0}(t) + P_{2,1}(t)\lambda_v \\ P_{3,1}(t) + P_{2,1}(t) + P_{1,1}(t) + P_{3,0}(t) + P_{2,0}(t) = 1 \\ P_{3,1}(\emptyset) = 1 \end{cases}$$

$$A_{SUB_{CPU}} = P_{3,1}(t) + P_{2,1}(t)$$

RAID-SYS

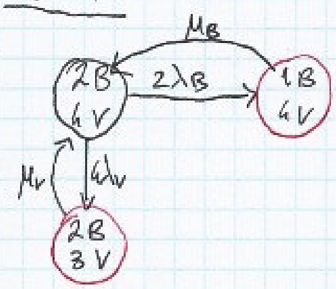


The G state of reliability "explodes" into the RED states here.

Regarding the repairments, I can go from each state into (2, 2, 2, 2) simply with $\mu_D \Delta t$ because the repair rate is μ regardless the number of failed disks

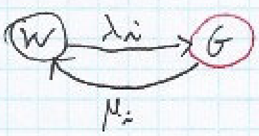
$$A_{RAID} = \sum P_{(BLACK\text{-}STATE)} = 1 - \sum P_{(RED\text{-}STATE)}$$

BUS-SYS



$A_{\substack{SUB\\BUS}}(t) = P_{2,4}(t)$

MON-PRINT-KEY

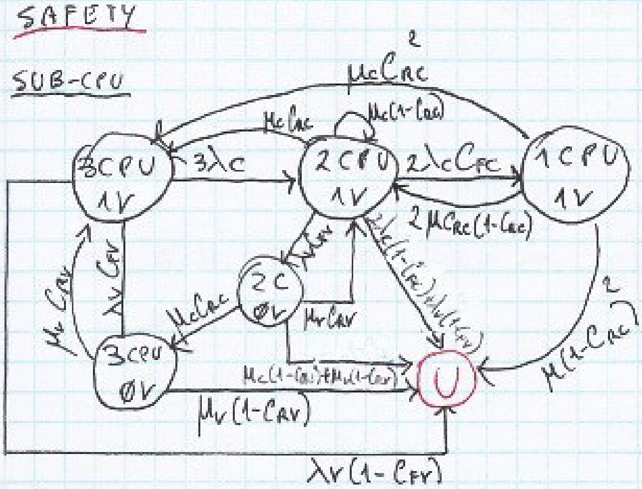


$A_i(t) = P_W(t)$

$A_{SYS} = A_{\substack{SUB\\CPU}} \cdot A_{RAID} \cdot A_{\substack{SUB\\BUS}} \cdot A_{KEY} \cdot A_{MON} \cdot A_{PRINT}$

SAFETY

SUB-CPU



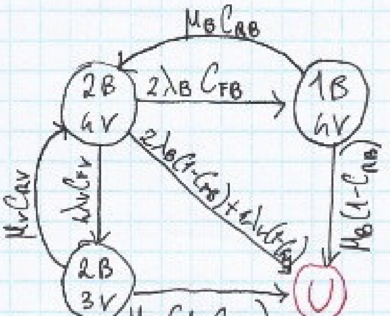
$S_{\substack{SUB\\CPU}} = 1 - P_U(t)$

From (1,1) I can go to (2,1) because It may be that the attempt of repairing both disk fails and I manged to repair only one disk.

From 2,0 I can go into U if I fail into repairing either the CPU or the VOTER

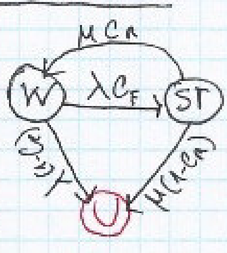
From 2,1 I can go into U if the VOTER fails and I do not detect it

SUB-BUS



$S_{\substack{SUB\\BUS}} = 1 - P_U(t)$

PRINT-MON-KEY



W: Working

ST: Safe Stop

$S = 1 - P_U(t)$

TCP Seg : 10000 byte

ETH Ovhd = 18 byte

MTU = 1500 byte

Bandwidth: 20 Mbyte/s

- If TCP does not knows MTU:

TCP → 20|10000 → IP → 20|20|1460 → ETH : 18|20|20|1460

20|1480 ×5 — 18|20|1480 ×5

20|1140 — 18|20|1140

$Ovhd = (18+20) \times 7 + 20 = 286$ Byte

$$\text{Service Time} = \frac{\text{TCP Seg} + \text{Ovhd}}{\text{Bandwidth}} = \frac{10'286 \text{ Byte}}{20 \cdot 10^6 \text{ Byte/s}} = 0{,}5143 \text{ ms}$$

- If TCP knows the MTU:

TCP → 20|1460 ×6 → IP → 20|20|1460 ×6 → ETH 18|20|20|1460 ×6

20|1240 — 20|20|1240 — 18|20|20|1240

$Ovhd = (18+20+20) \times 7 = 406$

$$\text{Service Time} = \frac{\text{TCP Seg} + \text{Ovhd}}{\text{Bandwidth}} = \frac{10'406 \text{ Byte}}{20 \cdot 10^6 \text{ Byte/s}} = 0{,}5203 \text{ ms}$$

Es. 3

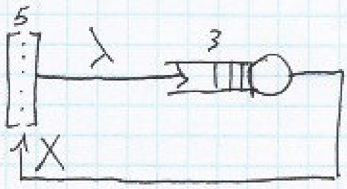
1 Server

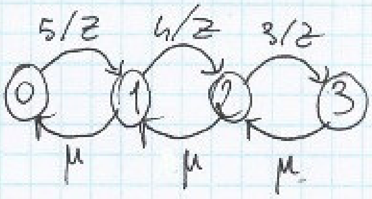
queue len = 3

users = 5

Z = 100 s

S = 10 s





FLOW-IN = FLOW-OUT

$$\begin{cases} \mu P_1 = 5/Z\, P_0 \\ \cancel{5/Z P_0} + \mu P_2 = 4/Z\, P_1 + \cancel{\mu P_1} \\ \cancel{4/Z P_1} + \mu P_3 = 3/Z\, P_2 + \cancel{\mu P_2} \\ P_0 + P_1 + P_2 + P_3 = 1 \end{cases}$$

$$\begin{cases} P_1 = \frac{5}{1} \frac{1}{Z\mu} P_0 \\ P_2 = \frac{4}{1} \frac{1}{Z\mu} P_1 = \frac{5 \cdot 4}{1 \cdot 1} \left(\frac{1}{Z\mu}\right)^2 P_0 \\ P_3 = \frac{3}{1} \frac{1}{Z\mu} P_2 = \frac{5 \cdot 4 \cdot 3}{1 \cdot 1 \cdot 1} \left(\frac{1}{Z\mu}\right)^3 P_0 \\ P_0 + P_1 + P_2 + P_3 = 1 \end{cases}$$

$P_0 \quad P_1 - P_2 - P_3 =$

$$P_0 + \frac{5}{Z\mu} P_0 + \frac{5 \cdot 4}{(Z\mu)^2} P_0 + \frac{5 \cdot 4 \cdot 3}{(Z\mu)^3} P_0 = 1$$

$$P_0 \left(1 + \frac{5}{Z\mu} + \frac{5 \cdot 4}{(Z\mu)^2} + \frac{5 \cdot 4 \cdot 3}{(Z\mu)^3}\right) = 1$$

$$P_0 = \frac{1}{1 + \frac{5}{Z\mu} + \frac{5 \cdot 4}{(Z\mu)^2} + \frac{5 \cdot 4 \cdot 3}{(Z\mu)^3}}$$

Solving the System I obtain $P_0\ P_1\ P_2\ P_3$ then:

$$\overline{X} = \sum_{i=0}^{3} \mu \cdot P_i \qquad \overline{N} = \sum_{i=0}^{3} i \cdot P_i \qquad \overline{R} = \frac{\overline{N}}{\overline{X}}$$

Es. 4

$\lambda = 25$ req/s — $\overline{R} = ?$

5 Server (WORKLOAD BALANCER) — $\overline{X} = ?$

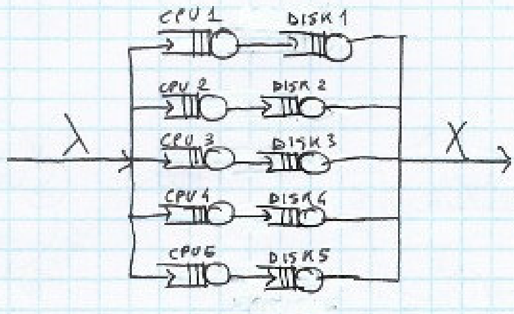
$D_{CPU} = 20$ ms — $\% = ?$

$D_{DISK} = 10 \times 5$ ms $= 50$ ms

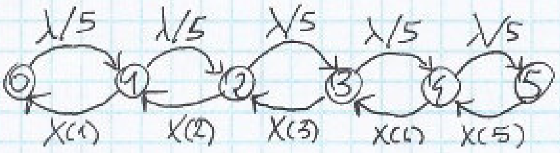
queue len $= 5$

MTTF $= 1000$ h

MTTR $= 10$ h



- Case of 5 Working Servers



MVA

- $m = 1$: $R'_{CPU}(1) = D_{CPU} = 20$ ms; $R'_{DISK}(1) = D_{DISK} = 50$ ms; $X_0(1) = \frac{1}{70 \text{ ms}} = 14{,}29$ req/s; $M_{CPU}(1) = X_0(1)\, R'_{CPU}(1) = 0.2857$; $M_{DISK}(1) = 0.7143$

- $m = 2$: $R'_{CPU}(2) = D_{CPU}(1{,}2857) = 25{,}714$ ms; $R'_{DISK}(2) = D_{DISK}(1{,}7143) = 85{,}715$ ms; $X_0(2) = \frac{2}{111{,}429 \text{ ms}} = 17{,}95$ rq/s; $M_{CPU}(2) = 0{,}4615$; $M_{DISK}(2) = 1{,}5385$

- $m = 3$: $R'_{CPU}(3) = D_{CPU}(1{,}4615) = 29{,}23$ ms; $R'_{DISK}(3) = D_{DISK}(1{,}5385) = 76{,}925$ ms; $X_0(3) = \frac{3}{106{,}155 \text{ ms}} = 28{,}26$ r/s; $M_{CPU}(3) = 0{,}826$; $M_{DISK}(3) = 2{,}1737$

- $m = 4$: $R'_{CPU}(4) = D_{CPU}(1{,}826) = 36{,}52$ ms; $R'_{DISK}(4) = D_{DISK}(3{,}1737) = 158{,}695$ ms; $X_0(4) = \frac{4}{195{,}215 \text{ ms}} = 20{,}49$ r/s; $M_{CPU}(4) = 0{,}748$; $M_{DISK}(4) = 3{,}2517$

- $m = 5$: $R'_{CPU}(5) = D_{CPU}(1{,}748) = 34{,}96$ ms; $R'_{DISK}(5) = D_{DISK}(4{,}2517) = 212{,}585$ ms; $X_0(5) = \frac{5}{247{,}545} = 20{,}198$ r/s; $M_{CPU}(5) = 0{,}706$; $M_{DISK}(5) = 4{,}294$

$$X_5 = \sum_{i=0}^{5} P_i \cdot X_i \qquad N_5 = \sum_{i=0}^{5} P_i \cdot i \qquad R_5 = \frac{N_5}{X_5} \qquad X_5^{TOT} = 5 \cdot X_5$$

I iterate the procedure for 4, 3, 2, 1 working Servers in order to get $X_4\ X_3 \ldots\ R_4\ R_3 \ldots$

Finally:

$$\overline{X} = \sum_{i=1}^{5} \frac{q_i}{1-q_0} X_i^{TOT} \qquad \overline{R} = \sum_{i=1}^{5} \frac{q_i}{1-q_0} R_i \qquad \% = \sum_{i=1}^{5} \frac{q_i}{1-q_0} P_{5,i}$$

$q_5 = A_S^5 \quad q_4 = 5 A_S^4 (1-A_S)$

$q_3 = \binom{5}{2} A_S^3 (1-A_S)^2 \quad q_2 = \binom{5}{2} A_S^2 \ldots$

$q_1 = 5 A_S (1-A_S)^4 \quad q_0 = (1-A_S)^5$

Esame 11/02/2016

Es. 1

3CPU + VOTER

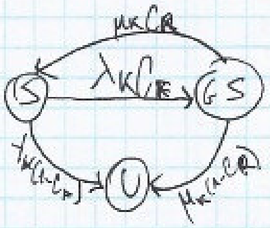
RAID 5 (8 DISK)

3 BUS + OUTPUT VOTER

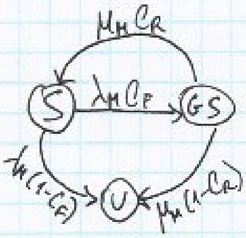
KEY PRINTER MONITOR

SAFETY

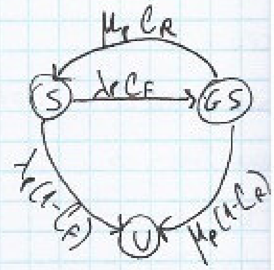
KEY:



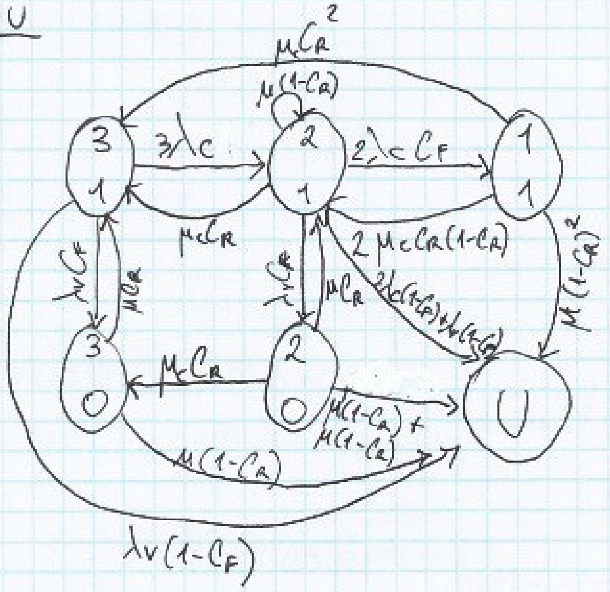
MON:



PRINTER:



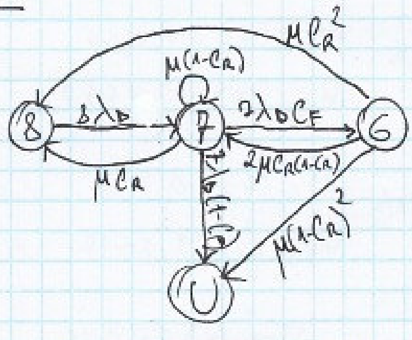
CPU



Hp: I use the voter so when one cpu fails I always detect it

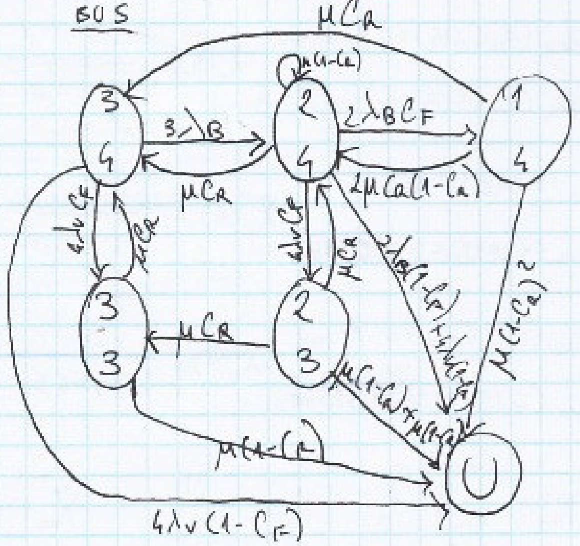
$$S_{SUB_{CPU}} = 1 - P_U(t)$$

RAID 5



I assume that the Microcontroller is able to detect the fault of one disk by means of the parity, so I do not put C_F from state 8 to state 7

BUS



Hp: As for the CPUs I use the voter so I have a majority, I can always detect faults of buses.

8.2

2 SERVER

queue len=5

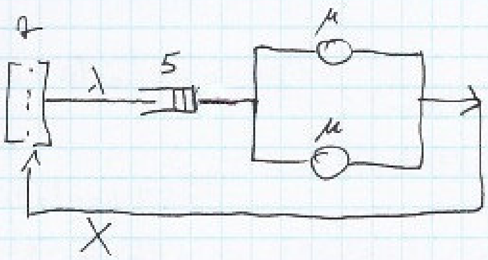
utenti = 7

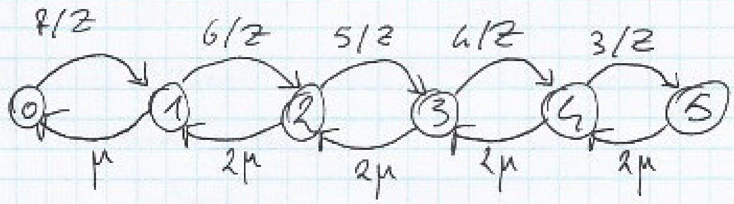
Z = 10 s

S = 4 s

MTTF = 24 mesi

MTTR = 4 h





2 server funzionanti

FLOW-IN = FLOW-OUT

$$
\begin{cases}
\sum_i P_i = 1 \\
\mu P_1 = 7/Z\, P_0 \\
\cancel{7/Z\, P_0} + 2\mu P_2 = \cancel{\mu P_1} + 6/Z\, P_1 \\
\frac{5}{Z} P_2 = 2\mu P_3 \\
\frac{4}{Z} P_3 = 2\mu P_4 \\
\frac{3}{Z} P_4 = 2\mu P_5
\end{cases}
$$

$$
\begin{cases}
\sum_i P_i = 1 \\
P_1 = 7 \frac{1}{\mu Z} P_0 \\
P_2 = \frac{7 \cdot 6}{2} \frac{1}{(\mu Z)^2} P_0 \\
P_3 = \frac{7 \cdot 6 \cdot 5}{2 \cdot 2 \cdot 1} \frac{1}{(\mu Z)^3} P_0 \\
P_4 = \frac{7 \cdot 6 \cdot 5 \cdot 4}{2 \cdot 2 \cdot 2 \cdot 1} \frac{1}{(\mu Z)^4} P_0
\end{cases}
$$

$$
P_0 = \frac{1}{1 + 7\frac{1}{\mu Z} + \frac{7 \cdot 6}{2}\frac{1}{(\mu Z)^2} + \frac{7 \cdot 6 \cdot 5}{2 \cdot 2 (\mu Z)^3} + \frac{7 \cdot 6 \cdot 5 \cdot 4}{2 \cdot 2 \cdot 2} \frac{1}{(\mu Z)^4}}
$$

Risolvo il sistema e trovo $P_0\ P_1\ P_2\ P_3\ P_4$

$$
X(2) = \sum_{i=1}^{5} P_i \begin{cases} \mu \cdot i & i = 1 \\ \mu \cdot 2 & i > 1 \end{cases}
\qquad
N(2) = \sum_{i=1}^{5} i \cdot P_i
\qquad
R(2) = \frac{N(2)}{X(2)}
$$

$$
q_2 = A_S^2 \quad q_1 = 2A_S(1-A_S) \quad q_0 = (1-A_S)^2 \quad \text{where } A_S = \frac{MTTF}{MTTF+MTTR}
$$

$$
\overline{X} = \sum_{i=1}^{2} \frac{q_i}{1-q_0} X(i) = \frac{q_1}{1-q_0} X(1) + \frac{q_2}{1-q_0} X(2)
$$

$$
\frac{q_0}{1-q_2} X(2) + \frac{q_1}{1-q_2} X(1)
$$

$\lambda = 500$ req/s

$|REQ| = 400$ Byte

10 Server (CPU + RAM) (Workload Balancer) $\nearrow$ Ogni server ha la sua coda

FileSystem $\Rightarrow$ 4 CPU_FS + RAID 1 (10 disk)

Router Latency: 10 μsec / packet

$FDDI_1$: 256 Mbit/s full duplex

ETH: 1 Gbps

$FDDI_2$: 2 Gbps

$D_{CPU}^{HIT} = 10$ ms

$D_{CPU}^{MISS} = 20$ ms

$D_{CPU_{FS}} = 10$ ms

$|File| = 100$ Kbyte

$S_{DISK} = 10$ ms for 10 Kbyte

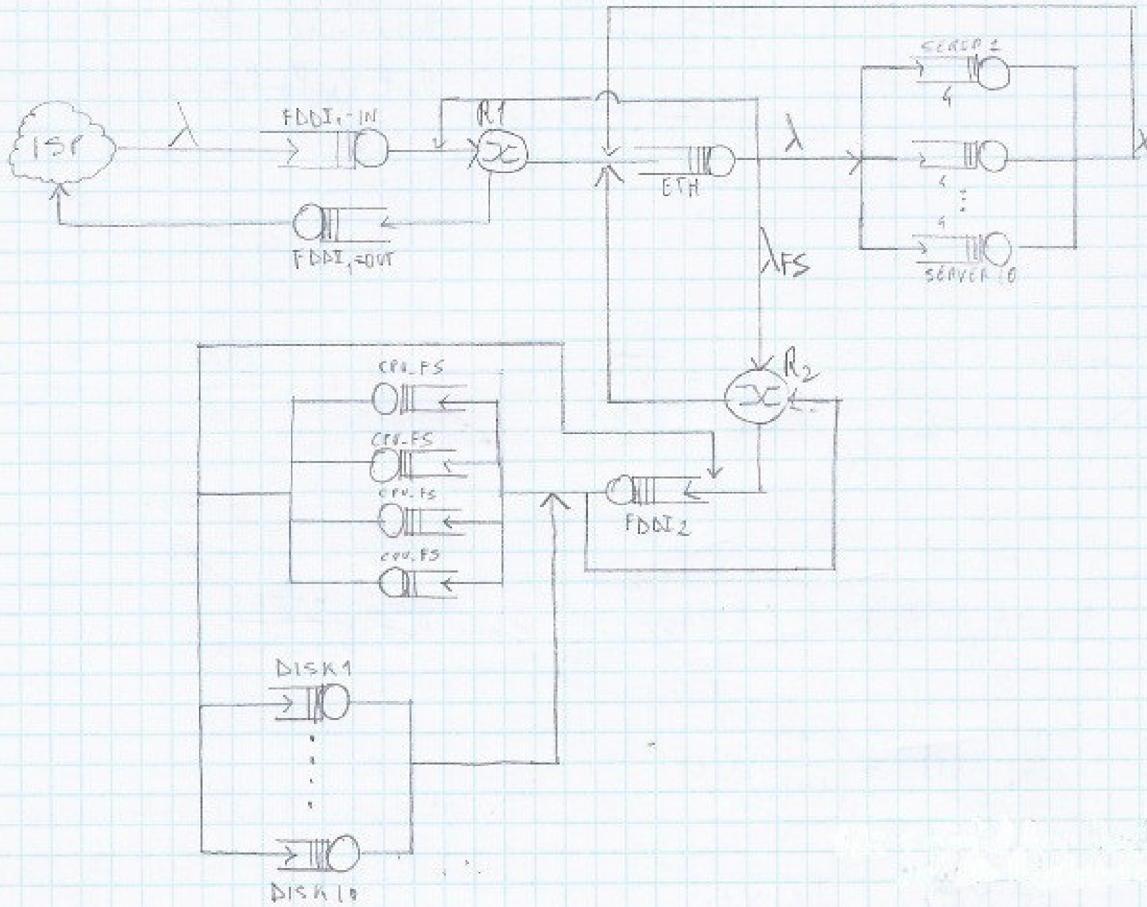
Queue len = 4 users

$P_{HIT} = 50\%$

RQ: 3 pacchetti per l'Handshake, 1 pacchetto per la richiesta. L'Handshake non ha payload. La richiesta ha un payload pari a |REQ|

RES: N pacchetti per il file + 3 pacchetti per la chiusura della connessione. 3 pacchetti per la chiusura non no payload.

Note: Di tutto l'ammontare λ di richieste che arrivano entrano nei Server ma visto che le code sono limitate ne perdo qualcuna dunque $X_0 \neq \lambda$. Inoltre, di questo X_0 una parte ($X_0 \times P_{HIT}$) va in uscita e un'altra ($X_0 \times P_{MISS}$) va nel FileSystem



$X_0 \neq \lambda$

$F_{DDI1,IN}$ Ovh RQ = [1+3]x28 byte = 112 byte

TCP Ovh RQ = [1+3]20 byte = 80 byte

IP Ovh RQ = [1+3]20 byte = 80 byte

$$D_{FDDI1,IN} = \frac{(F_{DDI1,IN}\ Ovh\ RQ + TCP\ Ovh\ RQ + IP\ Ovh\ RQ + |REQ|) \times 8}{Bandwidth\ FDDI\ 1} = \frac{(112+80+80+400)\times 8}{256 \cdot 10^6\ bps} = 0{,}021\ ms$$

$N_{PACK} = \left\lceil \frac{100'000 \text{ Byte}}{1460 \text{ Byte}} \right\rceil = 69$ ↗ Supponendo che TCP conosca MTU

$FDDI_{,1}\ Ovhd_{RES} = [3+69] \times 28 \text{ byte}$

$TCP\ Ovhd_{RES} = [3+69] \times 20 \text{ byte} \qquad IP\ Ovhd_{RES} = [3+69] \times 20 \text{ byte}$

$$D_{FDDI,1\,OUT} = \frac{[100'000 + (3+69)\times 28 + (3+69)\times 20 + (3+69)\times 20] \times 8}{256 \text{ Mbit/s}} = 3,276 \text{ ms}$$

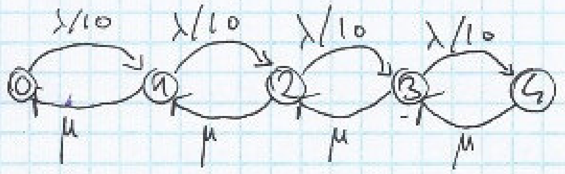
L'approccio che segue è una soluzione che non modella il sistema con il MULTICLASS. Dunque calcolo il Service Demand MEDIO della CPU dei server:

$D_{CPU} = D_{CPU}^{HIT} \times P_{HIT} + D_{CPU}^{MISS} \times P_{MISS} = 15 \text{ ms}$

Un disco del FileSystem ha un S pari a 10 ms per recuperare 10 Kbyte. Un file è di 100 Kbyte. Dunque:

$D_{DISK} = 10 \text{ ms} \times \frac{100 \text{ Kbyte}}{10 \text{ Kbyte}} = 100 \text{ ms}.$

Markov Singolo Server



Nota: non faccio MVA nel singolo Server perché non è costituito da più code ma ha solo la CPU e quindi coda singola: se ho 4 utenti so che uno è nel server e 3 sono in coda. L'output è sempre μ.

$\mu = \frac{1}{D_{CPU}} = \frac{1}{15 \text{ ms}} = 66,6 \text{ req/s}$

Faccio FLOW IN = FLOW OUT e trovo $P_0\ P_1\ \ldots\ P_4$

$X_i = \sum_i P_i \times \mu \qquad X_0 = 10X$

Di tutto X_0 ho una frazione di output pari a P_{HIT} che va in ETH ed esce, mentre un'altra frazione pari a P_{MISS} va nel FileSystem

La ETH vede la prima REQ arrivata dal client, il file preso dal Server in caso di HIT, le REQ inoltrate dal Server al FileSystem in caso di MISS e il file dal FileSystem in caso di MISS. Quindi:

Nota: $X_0 P_{MISS} = \lambda_{FS} \qquad X_0 = \lambda(1-P_4)$

$D_{ETH} = S_{ETH,RQ} + (1-P_4) S_{ETH,RES} + (1-P_4) P_{MISS} S_{ETH,RQ} + (1-P_4) P_{MISS} S_{ETH,RES}$

dove:

$$S_{ETH,RQ} = \frac{(ETH\ Ovhd_{RQ} + TCP\ Ovhd_{RQ} + IP\ Ovhd_{RQ} + |REQ|) \times 8}{ETH \text{ Bandwidth}} = \frac{([1+3]\times 18 + [1+3]\times 20 + [1+3]\times 20 + 400) \times 8}{1 \text{ Gbps}} = 5,056\ \mu s$$

$$S_{ETH,RES} = \frac{(ETH\ Ovhd_{RES} + TCP\ Ovhd_{RES} + IP\ Ovhd_{RES} + |RES|) \times 8}{ETH \text{ Bandwidth}} = \frac{([69+3]\times 18 + [69+3]\times 20 + [69+3]\times 20 + 100'000) \times 8}{1 \text{ Gbps}} = 0,104 \text{ ms}$$

$D_{CPU\_FS} = 10 \text{ ms} \qquad D_{DISK} = 10 \text{ ms}$

Una volta modellato λ_{FS} come $X_0 \cdot P_{MISS}$, quando analizziamo il FileSystem non dobbiamo più preoccuparci di probabilità di HIT o MISS. Dunque:

$$D_{FDDI\,2} = S_{FDDI\,2,RQ} + S_{FDDI\,2,RES}$$

$$S_{FDDI\,2,RQ} = \frac{([1+3]\times 28 + [1+3]\times 20 + [1+3]\times 20 + 400)\times 8}{2\ \text{Gbps}}$$

$$S_{FDDI\,2,RES} = \frac{([69+3]\times 28 + [69+3]\times 20 + [69+3]\times 20 + 100'000)\times 8}{2\ \text{Gbps}}$$

Una volta ovuti tutti i Service Demand, calcolo gli Utilization Factor:

$$U_{FDDI\,1,IN} = \lambda D_{FDDI\,1,IN} \qquad U_{ETH} = \lambda D_{ETH} \qquad U_{DISK} = \frac{P_{MISS} X_0}{10} D_{DISK} = \frac{\lambda_{FS}}{10} D_{DISK}$$

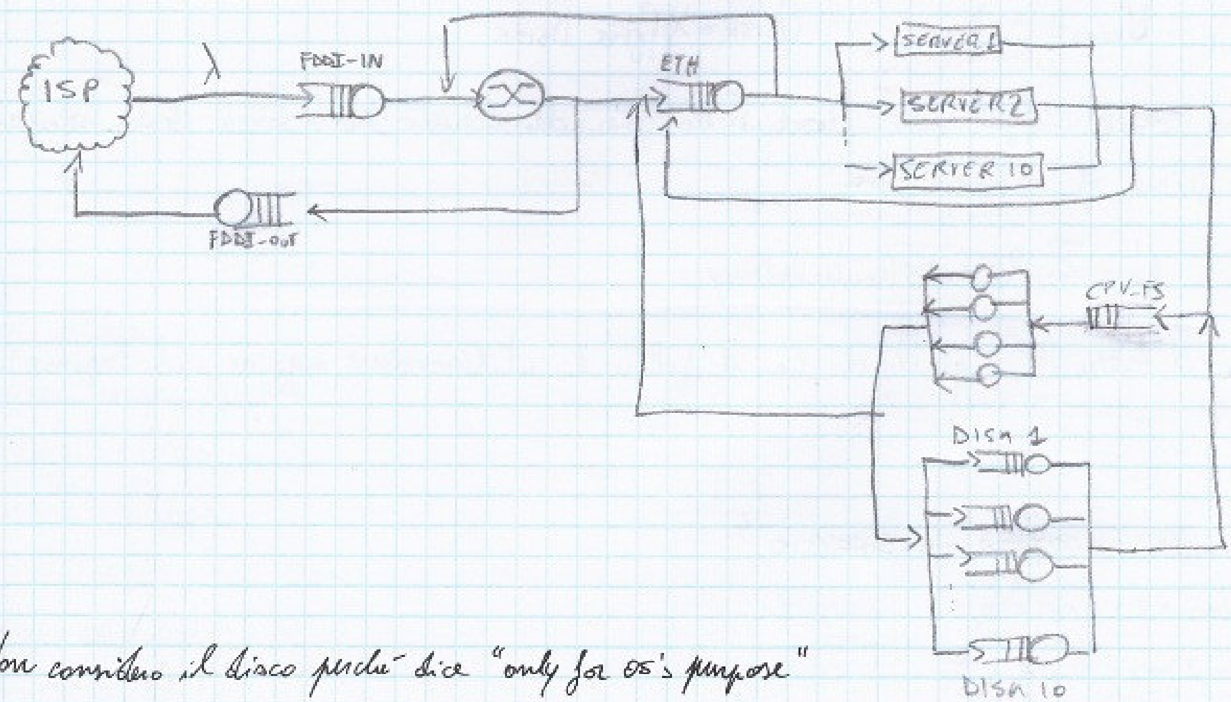
$$U_{FDDI\,1,OUT} = X_0 D_{FDDI\,1,OUT} \qquad U_{FDDI\,2} = X_0 P_{MISS} D_{FDDI\,2} \qquad U_{CPU\_FS} = P_{MISS} X_0 \frac{1}{4} D_{CPU\_FS} = \frac{\lambda_{FS}}{4} D_{CPU\_FS}$$

Infine:

$$R'_i = \frac{D_i}{1-U_i} \qquad R_{TOT} = \sum_i R'_i + \underbrace{2\times \text{RouterDelay}}$$

uno per la REQ e uno per il primo pacchetto della RES (PIPELINING)

Esame 09/09/2015



Non considero il disco perché dice "only for OS's purpose"

ETH : 2 Gbps Server : 4 Core, RAM as cache and LocalDisk $\lambda = 40$ req/s $|FILE| = 120$ Kbytes

Router : 100 μsec/packet FileSystem : RAID5 (10 dischi) $|REQ| = 300$ bytes FDDI : 0,5 Gbps

$D_{CPU}^{HIT} = 20$ msec $D_{CPU}^{MISS} = 40$ msec $D_{CPU\text{-}FS} = 25$ msec $S_{DISK} = 10$ msec for 10 Kbytes

$P_{HIT} = 50\%$

$$D_{DISK} = S_{DISK} \times \left\lceil \frac{120'000}{10'000} \right\rceil = 10\text{ ms} \times 12 = 120\text{ ms}$$

$FDDI\,Ovhd_{REQ} = [1+3] \times 28$ bytes $IP\,Ovhd_{REQ} = [1+3] \times 20$ bytes

$TCP\,Ovhd_{REQ} = [1+3] \times 20$ bytes $ETH\,Ovhd_{REQ} = [1+3] \times 18$ bytes

$$D_{FDDI\text{-}IN} = \frac{(|REQ| + FDDI\,Ovhd_{REQ} + TCP\,Ovhd_{REQ} + IP\,Ovhd_{REQ}) \times 8}{0{,}5 \text{ Gbps}} = 9{,}152\ \mu s = 0{,}009152 \text{ ms}$$

$$N_{PACK} = \left\lceil \frac{120'000 \text{ bytes}}{1460} \right\rceil = 83$$ → Assumo che TCP conosce MTU

$FDDI\,Ovhd_{RES} = [83+3] \times 28$ byte $IP\,Ovhd_{RES} = [83+3] \times 20$ byte

$TCP\,Ovhd_{RES} = [83+3] \times 20$ byte $ETH\,Ovhd_{RES} = [83+3] \times 18$ byte

$$D_{FDDI\text{-}OUT} = \frac{(|RES| + FDDI\,Ovhd_{RES} + TCP\,Ovhd_{RES} + IP\,Ovhd_{RES}) \times 8}{0{,}5 \text{ Gbps}} = 2{,}016 \text{ ms}$$

$$D_{CPU} = D_{CPU}^{HIT} \times P_{HIT} + D_{CPU}^{MISS} \times P_{MISS} = 30 \text{ ms}$$

Siccome il sistema è tutto aperto, il throughput totale dei Server è $X = \lambda$

Di questi λ, λP_{HIT} torna indietro alla ETH e λP_{MISS} va nel FileServer

$$D_{ETH} = D_{ETH}^{RQ} + D_{ETH}^{RES} + P_{MISS} D_{ETH}^{RQ} + P_{MISS} D_{ETH}^{RES}$$

$U_{FDDI,IN} = \lambda D_{FDDI,IN}$ $\quad U_{ETH} = \lambda D_{ETH}$ $\quad U_{CPU\_FS} = \lambda P_{MISS} D_{CPU\_FS}$

$U_{FDDI,OUT} = \lambda D_{FDDI,OUT}$ $\quad U_{CPU} = \frac{\lambda}{10 \cdot 4} D_{CPU}$ $\quad U_{DISK} = \frac{\lambda P_{MISS}}{10} D_{DISK}$

In U_{CPU} divido per 10·4 perché D_{CPU} si riferisce al singolo core e ogni server ha 4 core. Dunque quell' U_{CPU} si riferisce al singolo core

$R_i = \frac{D_i}{1-U_i}$ $\qquad R' = \sum_i R_i + 2 \times RouterLatency$

Per quanto riguarda il bottleneck, è quello che ha il fattore di utilizzazione maggiore o il response time maggiore.

$U_{FDDI,IN} = 0{,}04 \text{ req/ms} \times 0{,}009152 \text{ ms} = 3{,}66 \times 10^{-4}$

$U_{FDDI,OUT} = 0{,}04 \text{ req/ms} \times 2{,}014 \text{ ms} = 0{,}08$

$U_{ETH} = 0{,}04 \text{ req/ms} \times 2 \text{ ms} = 0{,}08$

$U_{CPU} = 0{,}12$

$U_{CPU\_FS} = 0{,}5$

$U_{DISK} = 0{,}24$

$MTTF_{CPU} = 8 \text{ anni} = 70080 \text{ h}$ $\quad MTTF_{ETH} = 6 \text{ anni} = 52560 \text{ h}$ $\quad MTTF_{DISK} = 2 \text{ anni} = 17520 \text{ h}$

$MTTR_{CPU} = 1 \text{ settimana} = 168 \text{ h}$ $\quad MTTR_{ETH} = 2 \text{ settimane} = 336 \text{ h}$ $\quad MTTR_{DISK} = 3 \text{ settimane} = 504 \text{ h}$

$MTTF_{ROUTER} = 10 \text{ anni} = 87600 \text{ h}$

$MTTR_{ROUTER} = 1 \text{ settimana} = 168 \text{ h}$ $\qquad A_i = \frac{MTTF_i}{MTTF_i + MTTR_i}$

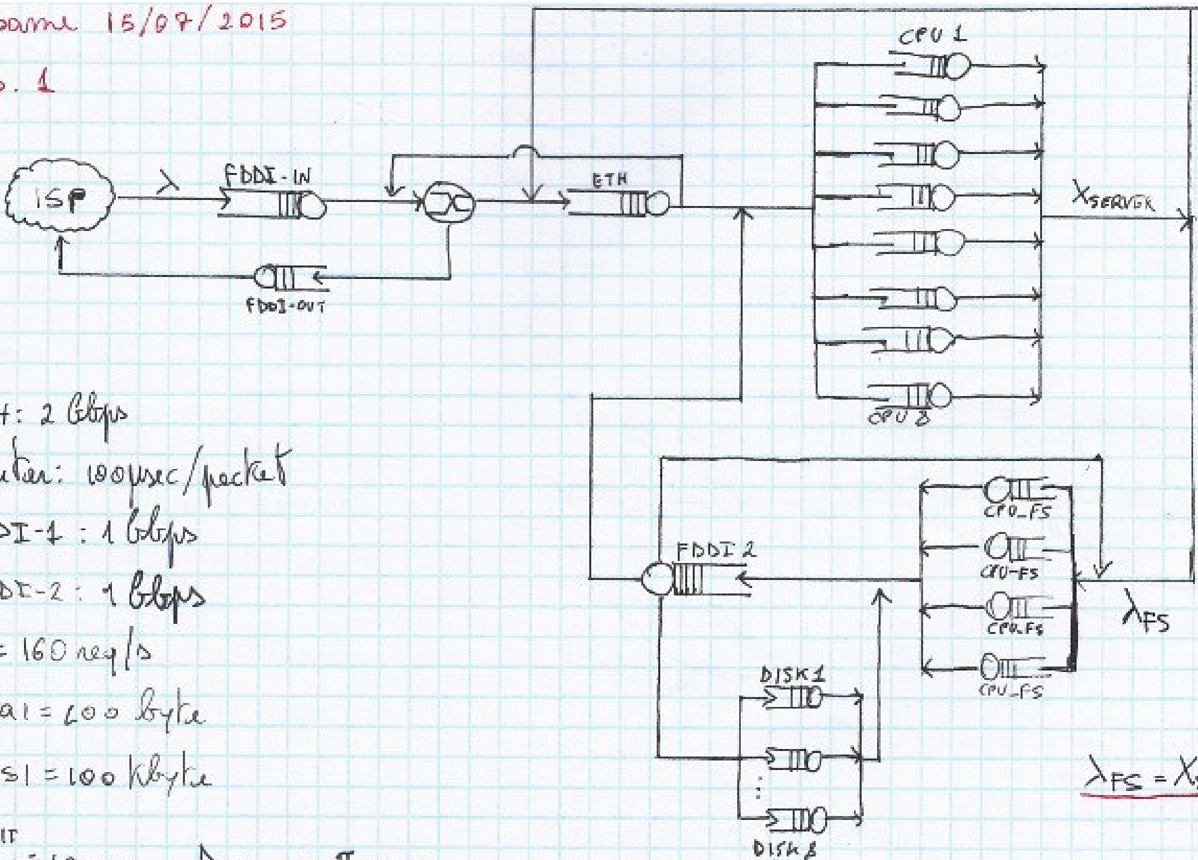
$A_{SYS} = A_{FDDI} \cdot A_{ROUTER} \cdot A_{ETH} \cdot A_{SUB\,SERVER} \cdot A_{CPU\,FS} \cdot A_{RAID}$

$A_{SUB\,SERVER} = 1 - (1 - A_{CPU})^{10}$ $\qquad A_{RAID} = A_{DISK}^{10} + 10 A_{DISK}^{9} (1 - A_{DISK}) + \binom{10}{2} A_{DISK}^{8} (1 - A_{DISK})^2$

In caso di fault dei server il sistema continua a funzionare ma al posto di 10 server ne avrò 10-X dove x è il numero di server guasti. Di conseguenza ogni server avrà un arrival rate pari a $\frac{\lambda}{10-x}$ e si vanno a modificare gli utilization factor. Se avremo un utilization factor che è maggiore di uno per un caso con X server non funzionanti allora vuol dire che il sistema non regge più e quella configurazione non è accettabile.

Esame 15/07/2015

Es. 1



???

ETH: 2 Gbps

Router: 100 μsec/packet

FDDI-1 : 1 Gbps

FDDI-2 : 1 Gbps

$\lambda = 160$ req/s

$|REQ| = 200$ byte

$|RES| = 100$ kbyte

$\lambda_{FS} = X_{SERVER} P_{MISS}$

$D_{CPU}^{HIT} = 10$ msec $\quad D_{CPU\_FS} = 5$ msec

$D_{CPU}^{MISS} = 20$ msec $\quad S_{DISK} = 10$ ms/10KB $\quad P_{HIT} = 80\%$

$FDDI\,Ovhd_{RQ} = [1+3] \times 28\,B \qquad TCP\,Ovhd_{RQ} = [1+3] \times 20$

$ETH\,Ovhd_{RQ} = [1+3] \times 18\,B \qquad IP\,Ovhd_{RQ} = [1+3] \times 20$

$$D_{FDDI-IN} = \frac{(|REQ| + FDDI\,Ovhd_{RQ} + TCP\,Ovhd_{RQ} + IP\,Ovhd_{RQ}) \times 8}{1\,Gbps}$$

$$N_{PACK} = \left\lceil \frac{100'000}{1460} \right\rceil = 69$$

$FDDI\,Ovhd_{RES} = [3+69] \times 28\,B$

$TCP\,Ovhd_{RES} = [3+69] \times 20\,B$

$IP\,Ovhd_{RES} = [3+69] \times 20\,B$

$ETH\,Ovhd_{RES} = [3+69] \times 18\,B$

$$D_{FDDI-OUT} = \frac{(|RES| + FDDI\,Ovhd_{RES} + TCP\,Ovhd_{RES} + IP\,Ovhd_{RES}) \times 8}{1\,Gbps}$$

$$D_{ETH} = S_{REQ}^{ETH} + P_{HIT} X_{SERVER} S_{RES}^{ETH} + P_{MISS} X_{FS} S_{RES}^{ETH}$$

$$D_{FDDI2} = S_{REQ}^{FDDI} + S_{RES}^{FDDI}$$

$$D_{CPU} = P_{HIT} D_{CPU}^{HIT} + P_{MISS} D_{CPU}^{MISS} = 12\,ms \qquad D_{DISK} = 10\,ms \times \left\lceil \frac{100\,kbyte}{10\,kbyte} \right\rceil = 100\,ms$$

$$U_{FDDI\_IN} = \lambda D_{FDDI\_IN} \qquad U_{CPU\_FS} = \frac{X_{SERVER} P_{MISS}}{4} D_{CPU\_FS}$$

$$U_{FDDI\_OUT} = \lambda D_{FDDI\_OUT} \qquad U_{CPU} = \frac{\lambda}{8} D_{CPU} \qquad U_{DISK} = \frac{X_{SERVER} P_{MISS}}{8} D_{DISK}$$

$$U_{FDDI2} = X_{SERVER} P_{MISS} \times S_{REQ}^{FDDI} + X_{SERVER} P_{MISS} \times S_{RES}^{FDDI}$$

$$U_{ETH} = \lambda S_{REQ}^{ETH} + P_{HIT} X_{SERVER} S_{RES}^{ETH} + P_{MISS} X_{FS} S_{RES}^{ETH}$$

MTTF (MTTR) of CPU : 6 years (1 week)

// of ETH and FDDI : 20 years (2 weeks)

// of DISK : 3 year (3 weeks)

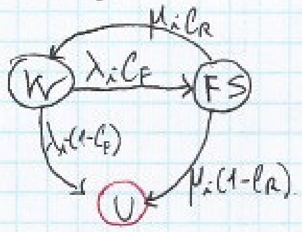
// of ROUTER : 20 year (3 weeks)

$C_F = 99\%$

$C_R = 98\%$

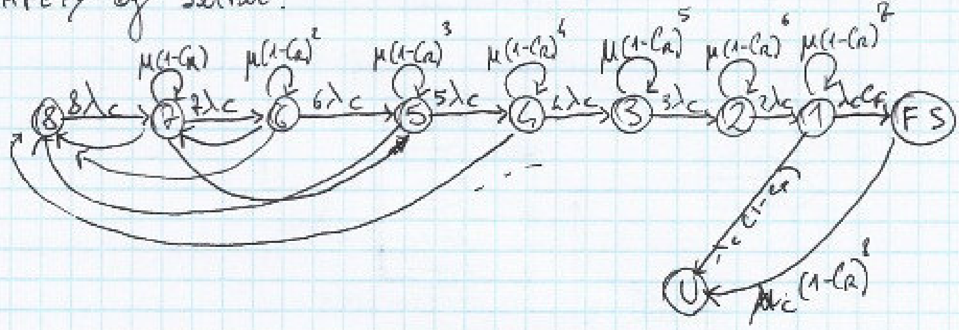
I assume that the repair rate is independent from the number of faults

SAFETY of FDDI, ETH, ROUTER



$S_{FDDI/ETH/ROUT} = 1 - P_U(t)$

SAFETY of Server:

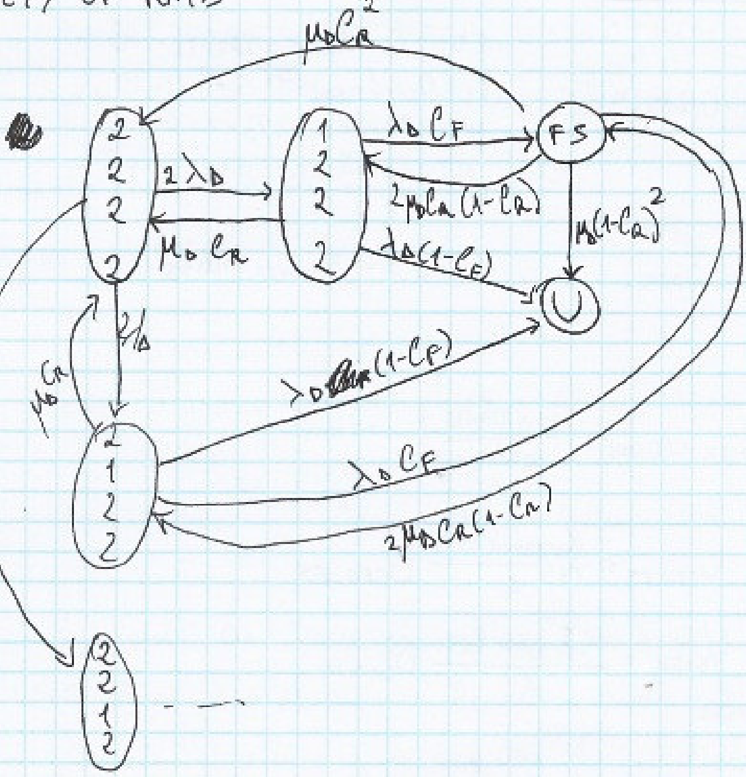


$S_{SERVER} = 1 - P_U(t)$

FS to x $\rightarrow \binom{8}{x} \mu C_R^{x} (1-C_R)^{8-x}$

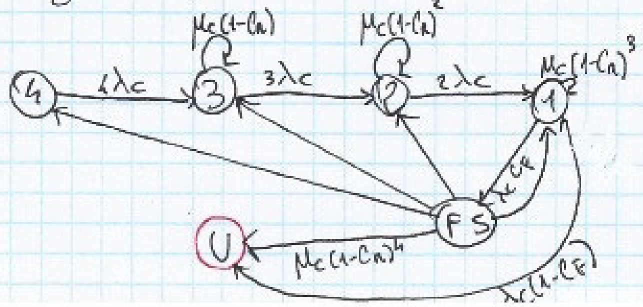
i to j $\rightarrow \binom{8}{i} \mu C_R^{j-i} (1-C_R)^{8-j}$

SAFETY OF RAID



$S_{RAID} = 1 - P_U(t)$

SAFETY of Filesystem CPUs



FS to i $\rightarrow \binom{4}{i} \mu_C C_R^{i} (1-C_R)^{4-i}$

i to j $\rightarrow \binom{4}{i} \mu_C C_R^{j-i} (1-C_R)^{4-j}$

$S_{sys} = S_{FDDI} \times S_{ROUTER} \times S_{ETH} \times S_{SERVER} \times S_{FS\_CPU} \times S_{RAID}$

Es. 2

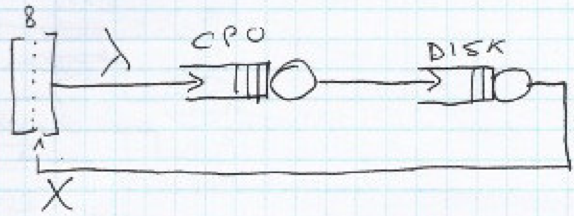
$\#users = 8$

$Z = 10\,s$

$D_{CPU} = 50\,ms$

$D_{DISK} = 10 \times 5\,ms = 50\,ms$

queue len = 4



Siccome ho 2 code uso la MVA:

• $n = 1$

$R'_{CPU}(1) = 50\,ms$ $\quad X_0(1) = \frac{1}{100\,ms} = 10\ req/s$ $\quad n_{CPU}(1) = 0{,}5$

$R'_{DISK}(1) = 50\,ms$ $\quad n_{DISK}(1) = 0{,}5$

• $n = 2$

$R'_{CPU}(2) = 50\,ms\,(1{,}5) = 75\,ms$ $\quad X_0(2) = \frac{2}{150\,ms} = 13{,}\bar{3}\ req/s$ $\quad n_{CPU}(2) = 1$

$R'_{DISK}(2) = 50\,ms\,(1{,}5) = 75\,ms$ $\quad n_{DISK}(2) = 1$

• $n = 3$

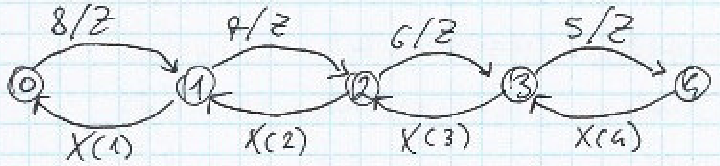
$R'_{CPU}(3) = 50\,(2) = 100\,ms$ $\quad X_0(3) = \frac{3}{200\,ms} = 15\ req/s$ $\quad n_{CPU}(3) = 1{,}5$

$R'_{DISK}(3) = 50\,(2) = 100\,ms$ $\quad n_{DISK}(3) = 1{,}5$

• $n = 4$

$R'_{CPU}(4) = 50\,(2{,}5) = 125\,ms$ $\quad X_0(4) = \frac{4}{250\,ms} = 16\ req/s$ $\quad n_{CPU}(4) = 2$

$R'_{DISK}(4) = 50\,(2{,}5) = 125\,ms$ $\quad n_{DISK}(4) = 2$



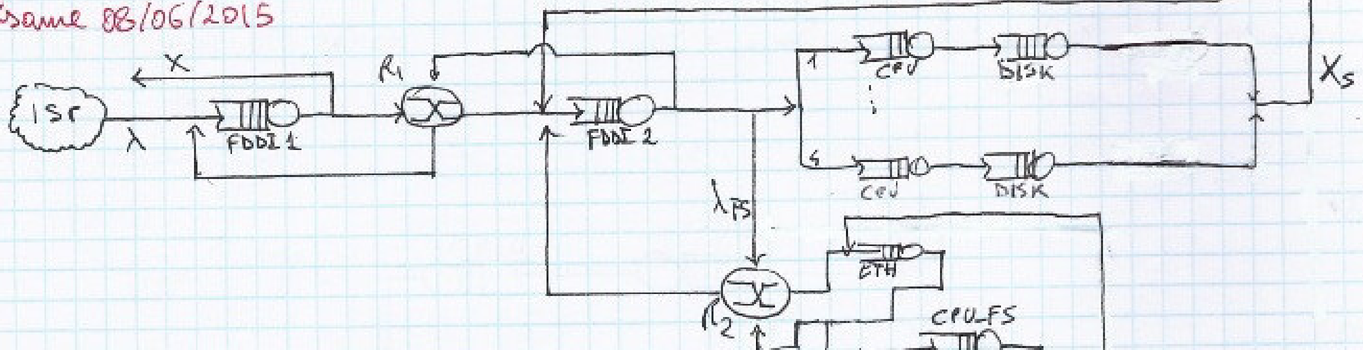
$$\begin{cases} X(1)\,P_1 = 8/Z\,P_0 \\ \cancel{8/Z\,P_0} + X(2)\,P_2 = 7/Z\,P_1 + \cancel{X(1)\,P_1} \\ \cancel{7/Z\,P_1} + X(3)\,P_3 = 6/Z\,P_2 + \cancel{X(2)\,P_2} \\ \cancel{6/Z\,P_2} + X(4)\,P_4 = 5/Z\,P_3 + \cancel{X(3)\,P_3} \\ \sum_i P_i = 1 \end{cases}$$

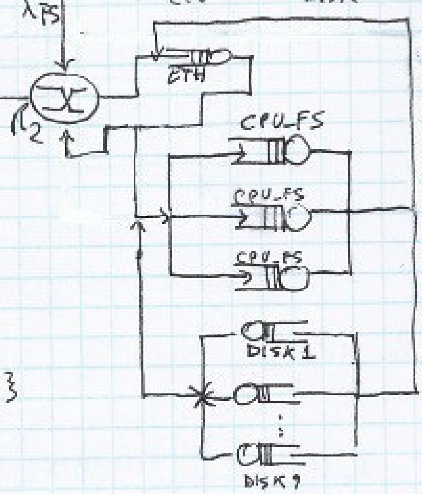
$$\begin{cases} P_1 = \frac{8}{Z\,X(1)}\,P_0 \\ P_2 = \frac{7}{Z\,X(2)}\,P_1 = \frac{8 \cdot 7}{X(1)X(2)}\,\frac{1}{Z^2}\,P_0 \\ P_3 = \frac{8 \cdot 7 \cdot 6}{X(1)X(2)X(3)}\,\frac{1}{Z^3}\,P_0 \\ P_4 = \frac{8 \cdot 7 \cdot 6 \cdot 5}{X(1)X(2)X(3)X(4)}\,\frac{1}{Z^4}\,P_0 \end{cases}$$

$$P_0 = \frac{1}{1 + \frac{8}{Z\,X(1)} + \frac{8 \cdot 7}{X(1)X(2)Z^2} + \frac{8 \cdot 7 \cdot 6}{X(1)X(2)X(3)Z^3}}$$

$$\overline{X} = \sum_{i=0}^{4} P_i\,X(i) \qquad \overline{N} = \sum_{i=0}^{4} i \cdot P_i \qquad \overline{R} = \frac{\overline{N}}{\overline{X}} \qquad \% = P_4 = \frac{8 \cdot 7 \cdot 6 \cdot 5}{X(1)X(2)X(3)X(4)}\,\frac{1}{Z^4}\,P_0$$

Esame 08/06/2015





FDDI 1 : 1,44 Gbps

FDDI 2 : 1 Gbps

R_1 : 50μsec / pacchetto

ETH : 0,5 Gbps

R2 : 100μsec / pacchetto

|REQ| = 400 byte

|RES| = 240 KByte

$\lambda = 100$ req/s

RAM : 5 files $\{F_1\ F_2\ F_3\ F_4\ F_5\}$

DISK : 10 files $\{F_6 \dots F_{15}\}$

$F_i \to P_i = \frac{K}{i}$ $i = 1 \dots 100$

$D_{CPU}^{RAM} = 5ms$ $D_{CPU}^{DISK} = 10ms$ $D_{CPU}^{MISS} = 30ms$ $D_{CPU\_FS} = 10ms$ $S_{DISK} = 10msec$ per 20KB

Per prima cosa la prob. di trovare il file in RAM è : $P_{RAM} = \sum_{i=1}^{5} P_i$

Analogamente: $P_{DISK} = \sum_{i=6}^{15} P_i$

$P_{MISS} = 1 - P_{RAM} - P_{DISK}$

Assumo che TCP conosca MTU

$n°\ pacchetti = \left\lceil \frac{240\cdot000}{1460} \right\rceil = 165$

$FDDI\ Ovhd_{RQ} = [1+3] \times 28$ byte $= 112$ byte

$TCP\ Ovhd_{RQ} = [1+3] \times 20$ byte $= 80$ byte

$IP\ Ovhd_{RQ} = [1+3] \times 20$ byte $= 80$ byte

$ETH\ Ovhd_{RQ} = [1+3] \times 18$ byte $= 72$ byte

$FDDI\ Ovhd_{RES} = [165+3] \times 28$ byte $= 4704$ byte

$TCP\ Ovhd_{RES} = [165+3] \times 20$ byte $= 3360$ byte

$IP\ Ovhd_{RES} = [165+3] \times 20$ byte $= 3360$ byte

$ETH\ Ovhd_{RES} = [165+3] \times 18$ byte $= 3024$ byte

$$D_{FDDI,1} = S_{REQ}^{FDDI} + S_{RES}^{FDDI} = \frac{(|REQ| + FDDI\,Ovhd_{REQ} + TCP\,Ovhd_{REQ} + IP\,Ovhd_{REQ} + |RES| + FDDI\,Ovhd_{RES} + FDDI\,Ovhd_{RES} + IP\,Ovhd_{RES})}{1{,}44\ Gbps} = 1{,}4\ ms$$

Siccome i Server hanno code illimitate lo modello come un sistema aperto dove $X_S = \lambda$

Di tutto X_S ho $(P_{RAM} + P_{DISK})X_S$ che torna al Client e $P_{MISS}\,X_S$ che va nel File System

Dunque $\lambda_{FS} = P_{MISS}\,X_S$

$$D_{CPU} = P_{RAM}\,D_{CPU}^{RAM} + P_{DISK}\,D_{CPU}^{DISK} + P_{MISS}\,D_{CPU}^{MISS}$$

$$D_{ETH} = S_{ETH}^{RQ} + S_{ETH}^{FDDI} = \frac{(|REQ| + ETH\,Ovhd + IP\,Ovhd + TCP\,Ovhd_{RQ} + |RES| + ETH\,Ovhd_{RES} + IP\,Ovhd_{RES} + TCP\,Ovhd_{RES}) \times 8}{0{,}5\ Gbps} = 4\ ms$$

$$D_{DISK} = S_{DISK} \times \left\lceil \frac{240\ KB}{20\ KB} \right\rceil$$

$$D_{FDDI\,2} = S_{REQ}^{FDDI2} + S_{RES}^{FDDI2} + P_{MISS}\, S_{REQ}^{FDDI2} + P_{MISS}\, S_{RES}^{FDDI2}.$$

$$U_{FDDI\,1} = \lambda D_{FDDI\,1}$$

$$U_{FDDI\,2} = \lambda S_{REQ}^{FDDI} + X_S P_{HIT} S_{RES}^{FDDI} + X_S P_{MISS} S_{REQ}^{FDDI} + X_S P_{MISS} S_{RES}^{FDDI}$$

$U_{CPU} = \frac{\lambda}{4} D_{CPU}$ $\quad U_{ETH} = \lambda_{FS} D_{ETH} = P_{MISS} X_S D_{ETH}$ $\quad U_{CPU\_FS} = \frac{\lambda_{FS}}{3} D_{CPU\_FS}$ $\quad U_{DISK\_FS} = \frac{\lambda_{FS}}{9} D_{DISK}$

$R_i' = \frac{D_i}{1-U_i}$ $\quad R_{ROUTER\,1} = [1+6+\cancel{1}65]\cdot 50\mu sec$ $\quad R_{ROUTER\,2} = [1+6+\cancel{1}65]\cdot 10\mu sec$

1 per la req, 3 per l'handshake, 3 per fin e 165 per il file

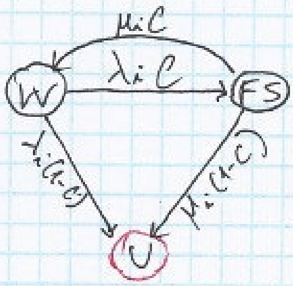
$$R_0 = \sum_i R_i + R_{ROUTER\,1} + R_{ROUTER\,2}$$

Per quanto riguarda il Bottleneck bisogna andare a vedere il componente con il maggior Utilization Factor

$MTTF_{CPU} = 3$ anni $\quad MTTF_{ETH} = 6$ anni $\quad MTTF_{DISK} = 1$ anno $\quad MTTF_{ROUTER} = 6$ anni

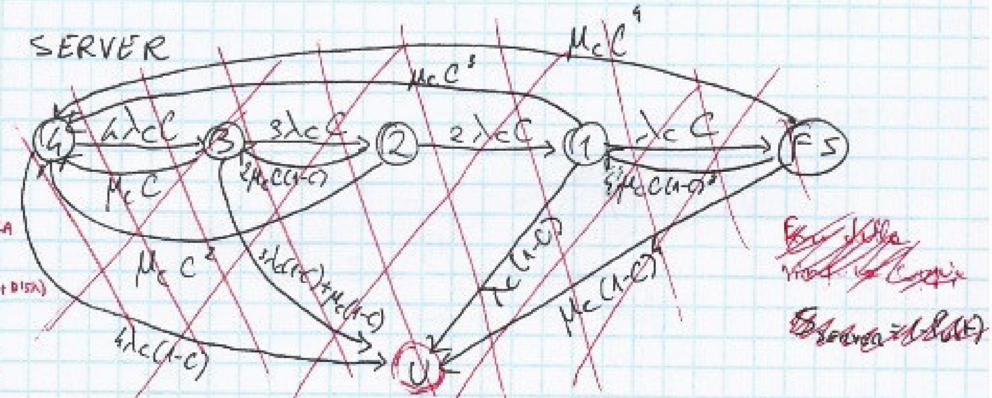
$MTTR_{CPU} = 1$ settimana $\quad MTTR_{ETH} = 2$ settimane $\quad MTTR_{DISK} = 3$ settimane $\quad MTTR_{ROUTER} = 1$ settimana

FDDI/ROUTER/ETH



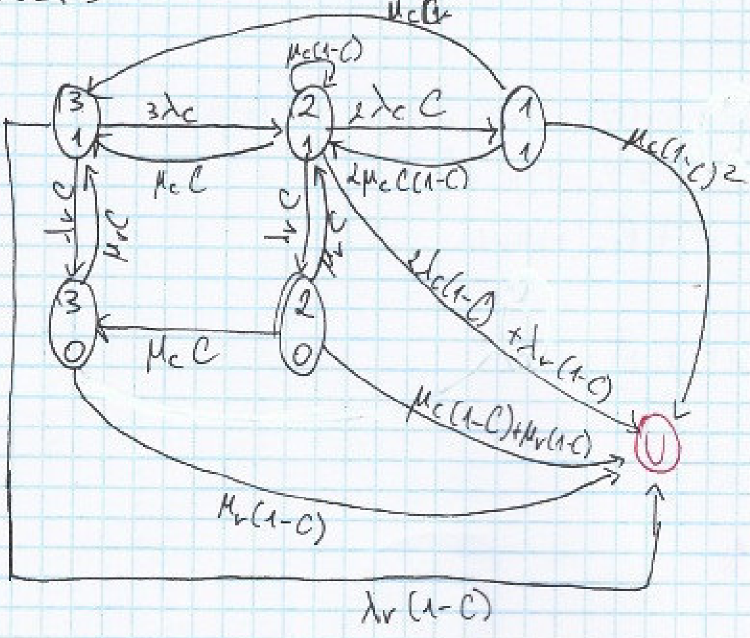
$S_i = 1 - P_U(F)$

SERVER



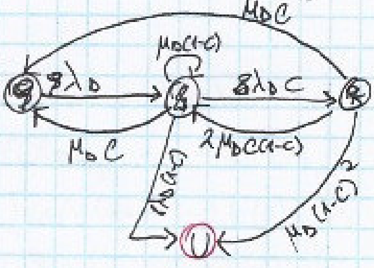
FARE DELLA SINGOLA COPPIA (CPU+DISK) E POI $S = S_{COPPIA}^4$

CPU_FS



$S_{CPU\_FS} = 1 - P_U(F)$

RAID



$S_{RAID} = 1 - P_U(F)$

$$S_{SYS} = \prod_i S_i$$

Esame 19/02/2015

Es. 1

5CPU + voter KEYBOARD

RAID 1 (4+4) PRINTER

2 BUS + voter MONITOR

RELIABILITY

$R_{CPU} = e^{-\lambda_c t}$

$R_{CV} = e^{-\lambda_{cv} t}$

CPU-SYS : $R^{CPU}_{SYS} = \left[R^5_{CPU} + 5R^4_{CPU}(1-R_{CPU}) + \binom{5}{3} R^3_{CPU}(1-R_{CPU})^2 \right] R_{CV}$

RAID : $R_{RAID} = R^4_{COPPIA}$ $\quad R_{COPPIA} = 1-(1-R_{DISK})^2$ $\quad R_{DISK} = e^{-\lambda_D t}$

BUS-SYS : $R_{BUS\,SYS} = R^2_{BUS} \; R^4_{BV}$ $\quad R_{BUS} = e^{-\lambda_B t}$ $\quad R_{BV} = e^{-\lambda_{BV} t}$

KEY : $R_{KEY} = e^{-\lambda_K t}$

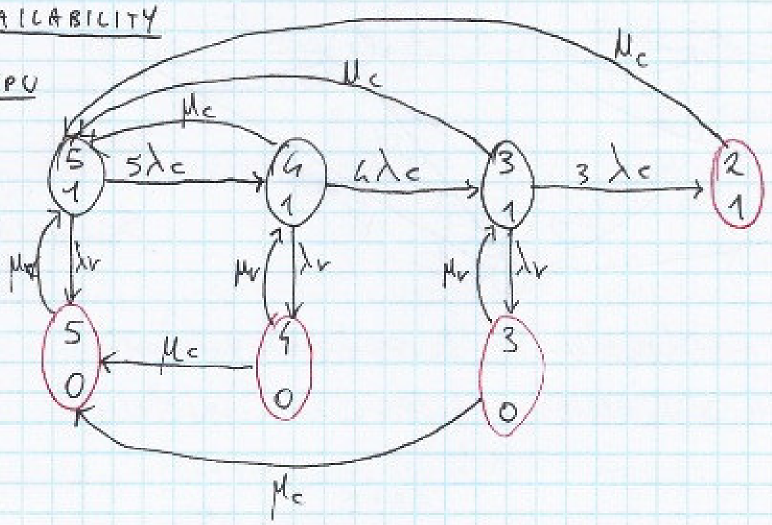
MON : $R_{MON} = e^{-\lambda_M t}$

PRINT : $R_{PRINT} = e^{-\lambda_P t}$

$R_{SYS} = R^{CPU}_{SYS} \cdot R_{RAID} \cdot R^{BUS}_{SYS} \cdot R_{KEY} \cdot R_{MON} \cdot R_{PRINT}$

AVAILABILITY

CPU



$P_{5,1}(t+\Delta t) = P_{5,1}(t)[1-(5\lambda_c+\lambda_v)\Delta t] + P_{4,1}(t)\mu_c\Delta t + P_{3,1}(t)\mu_c\Delta t + P_{2,1}(t)\mu_c\Delta t + P_{5,0}(t)\mu_v\Delta t$

$P_{4,1}(t+\Delta t) = P_{4,1}(t)[1-(4\lambda_c+\mu_c+\lambda_v)\Delta t] + P_{5,1}(t)5\lambda_c\Delta t + P_{4,0}(t)\mu_v\Delta t$

$P_{3,1}(t+\Delta t) = P_{3,1}(t)[1-(3\lambda_c+\lambda_v)\Delta t] + P_{4,1}(t)4\lambda_c\Delta t + P_{3,0}(t)\mu_v\Delta t$

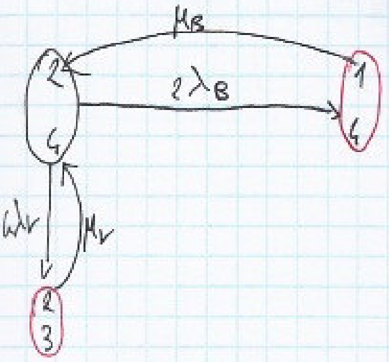
$P_{2,1}(t+\Delta t) = P_{2,1}(t)[1-\mu_c\Delta t] + P_{3,1}(t)3\lambda_c\Delta t$

$P_{5,0}(t+\Delta t) = P_{5,0}(t)[1-\mu_v\Delta t] + P_{5,1}(t)\lambda_v\Delta t + P_{4,0}(t)\mu_c\Delta t$

$P_{4,0}(t+\Delta t) = P_{4,0}(t)[1-\mu_c\Delta t] + P_{4,1}(t)\lambda_v\Delta t$

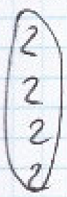
$P_{3,0}(t+\Delta t) = P_{3,0}(t)[1-(\mu_c+\mu_v)\Delta t] + P_{3,1}(t)\lambda_v\Delta t$

BUS-SYS



MON-KEY-PAINT

RAID



Es.2

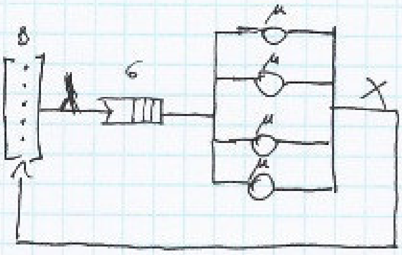
4 Servers   MTTF = 10 weeks

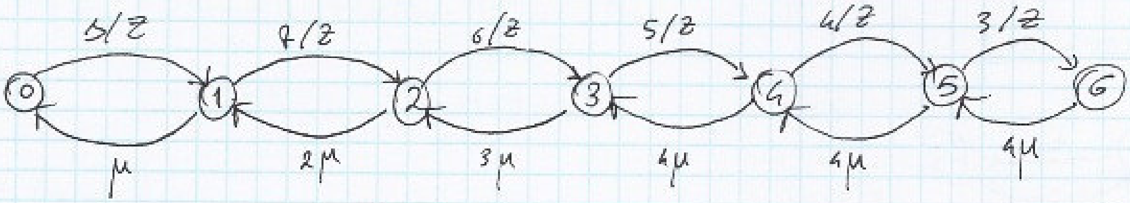
queue len = 6   MTTR = 2 ore

utenti = 8

Z = 10 s

S = 2 s





FLOW-IN = FLOW-OUT

$$\begin{cases} \mu P_1 = 8/Z\, P_0 \\ 8/Z\, P_0 + 2\mu P_2 = 7/Z\, P_1 + \mu P_1 \\ 7/Z\, P_1 + 3\mu P_3 = 6/Z\, P_2 + 2\mu P_2 \\ 6/Z\, P_2 + 4\mu P_4 = 5/Z\, P_3 + 3\mu P_3 \\ 5/Z\, P_3 + 4\mu P_5 = 4/Z\, P_4 + 4\mu P_4 \\ 4/Z\, P_4 + 4\mu P_6 = 3/Z\, P_5 + 4\mu P_5 \\ \sum_i P_i = 1 \end{cases}$$

...

$$X(4) = \sum_{i=0}^{6} P_i \begin{cases} \mu \cdot i & i \le 4 \\ 4 \cdot \mu & i > 4 \end{cases} \qquad N(4) = \sum_{i=0}^{6} i \cdot P_i \qquad R(4) = \frac{N(4)}{X(4)}$$

Nel caso di 3 server funzionanti: ho massimo 3μ $X(3)$ $R(3)$

" 2 " " : ho massimo 2μ $X(2)$ $R(2)$

$$\bar{X} = \sum_{i=1}^{4} \frac{q_i}{1-q_0} X(i) \qquad \bar{R} = \sum_{i=1}^{4} \frac{q_i}{1-q_0} R(i)$$

$q_4 = A_S^4$ $q_3 = 4 A_S^3 (1-A_S)$ $q_2 = \binom{4}{2} A_S^2 (1-A_S)^2$

$q_1 = 4 A_S (1-A_S)^3$ $q_0 = (1-A_S)^4$

Es.3

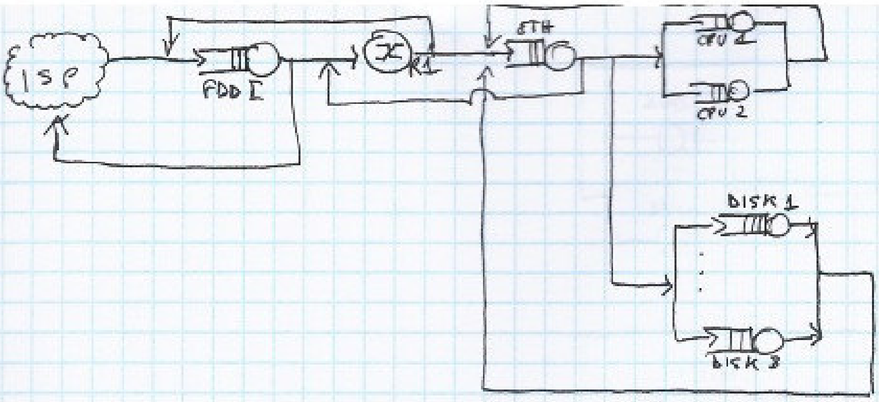
$\lambda = 100$ req/s $|REQ| = 300$ byte

2 CPU + RAID 1 (4+4) $|RES| = 80'000$ byte

ETH: 200 Mbit/s $D_{CPU} = 10$ msec

Router: 100 μs $S_{DISK} = 10$ msec x 10'000 byte

FDDI: 2 Gbps



REQ: 4 pacchetti (3 di handshake e 1 di richiesta)

$FDDI\ Ovhd_{RQ} = [1+3] \times 28\ byte = 112\ byte$

$TCP\ Ovhd_{RQ} = [1+3] \times 20\ byte = 80\ byte$ $\quad n_{pack} = \left\lceil \frac{80'000}{1460} \right\rceil = 55$

$IP\ Ovhd_{RQ} = [1+3] \times 20\ byte = 80\ byte$

$ETH\ Ovhd_{RQ} = [1+3] \times 18\ byte = 72\ byte$

$FDDI\ Ovhd_{RES} = [55+3] \times 28\ byte = 1624\ byte$

$TCP\ Ovhd_{RES} = [55+3] \times 20\ byte = 1160\ byte$

$IP\ Ovhd_{RES} = [55+3] \times 20\ byte = 1160\ byte$

$ETH\ Ovhd_{RES} = [55+3] \times 18\ byte = 1044\ byte$

$$D_{FDDI} = \frac{(300 + 80'000 + 112 + 80 + 80 + 1624 + 1160 + 1160) \times 8}{2\ Gbps} = 0{,}34\ ms$$

$$D_{ETH} = 2 \times S^{ETH}_{RQ} + 2 \times S^{ETH}_{RES} = 2 \times 21{,}28\ \mu s + 2 \times 3{,}34\ ms$$

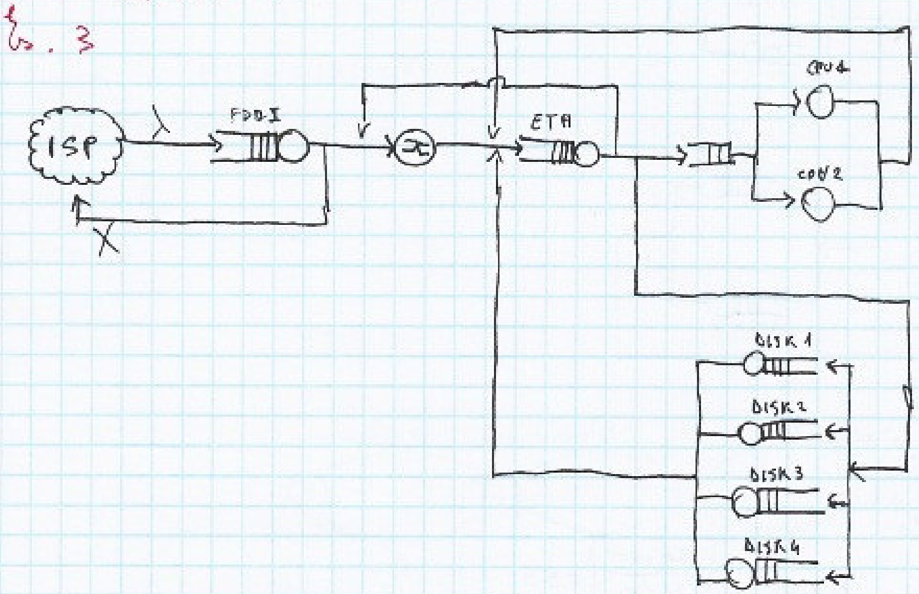
$$S^{ETH}_{RQ} = \frac{(300 + 80 + 80 + 72) \times 8}{200 \times 10^6\ bps} = 21{,}28\ \mu s \qquad S^{ETH}_{RES} = \frac{(80'000 + 1160 + 1160 + 1044) \times 8}{200 \times 10^6\ bps} = 3{,}34\ ms$$

$$D_{DISK} = 10\ ms \times \left\lceil \frac{80'000}{10'000} \right\rceil = 80\ ms$$

$$U_{FDDI} = \lambda D_{FDDI} \qquad U_{ETH} = \lambda D_{ETH} \qquad U_{CPU} = \lambda/2\ D_{CPU} \qquad U_{DISK} = \frac{\lambda}{8} D_{DISK}$$

$$R'_i = \frac{D_i}{1 - U_i} \qquad R_{TOT} = \sum_i R_i + 2RL$$

esame 08/04/2013
Es. 3



$\lambda = 100$ req/s $\qquad$ FDDI: 0,5 Gbit/s $\qquad$ $D_{CPU} = 10$ msec

ETH: 1 Gbps $\qquad$ $|REQ| = 300$ byte $\qquad$ $S_{DISK} = 20'000$ byte $\rightarrow$ 20ms

Router: 50μs/pacchetto $\qquad$ $|RES| = 200'000$ byte

$Ovhd^{FDDI}_{REQ} = [1+3] \times 28 \text{ byte} = 112 \text{ byte}$ $\qquad$ $Ovhd^{IP}_{REQ} = [1+3] \times 20 \text{ byte} = 80 \text{ byte}$

$Ovhd^{TCP}_{REQ} = [1+3] \times 20 \text{ byte} = 80 \text{ byte}$ $\qquad$ $Ovhd^{ETH}_{REQ} = [1+3] \times 18 \text{ byte} = 72 \text{ byte}$

$$n° \text{ pack} = \left\lceil \frac{200'000}{1460} \right\rceil = 137$$

$Ovhd^{FDDI}_{RES} = [137+3] \times 28 \text{ byte}$ $\qquad$ $Ovhd^{IP}_{RES} = [137+3] \times 20 \text{ byte}$

$Ovhd^{TCP}_{RES} = [137+3] \times 20 \text{ byte}$ $\qquad$ $Ovhd^{ETH}_{RES} = [137+3] \times 18 \text{ byte}$

$$D_{FDDI} = \frac{(|REQ| + Ovhd^{FDDI}_{REQ} + Ovhd^{TCP}_{REQ} + Ovhd^{IP}_{REQ} + |RES| + Ovhd^{FDDI}_{RES} + Ovhd^{TCP}_{RES} + Ovhd^{IP}_{RES}) \times 8}{0{,}5 \text{ Gbps}}$$

$$D_{ETH} = 2 S^{ETH}_{REQ} + 2 S^{ETH}_{FILE}$$

$$S^{ETH}_{REQ} = \frac{(Ovhd^{ETH}_{REQ} + Ovhd^{TCP}_{REQ} + Ovhd^{IP}_{REQ} + |REQ|) \times 8}{1 \text{ Gbps}} \qquad S^{ETH}_{RES} = \frac{(Ovhd^{ETH}_{RES} + Ovhd^{TCP}_{RES} + Ovhd^{IP}_{RES} + |RES|) \times 8}{1 \text{ Gbps}}$$

$$D_{DISK} = 20\text{ms} \times \left\lceil \frac{200'000}{20'000} \right\rceil = 200\text{ms}$$

$U_{FDDI} = \lambda D_{FDDI}$ $\qquad$ $U_{CPU} = \frac{\lambda}{2} D_{CPU}$ $\qquad$ $R'_{Ai} = \frac{D_i}{1-U_i}$

$U_{ETH} = \lambda D_{ETH}$ $\qquad$ $U_{DISK} = \frac{\lambda}{4} D_{DISK}$

$R_{ROUTER} = [1+3] \cdot 50\mu s + [137+3] \cdot 50\mu s$ $\qquad$ $R_{TOT} = \sum_i R_i$