Mode 1 :

Ordonnancement RM -

Exemple 1 { T1(P1 = 8, C1 = 2), T2(P2 = 10, C2 = 2),
T3(P3 = 8, C3 = 1), T4(P4 = 16, C4 = 2) }

2/8 + 2/10 + 1/8 + 1/8 < 4 * (2^¼ - 1)

0.7 <= 0.7568 Exemple 1 ordonnançable

Exemple 2 = { T1(P1 = 8, C1 = 3), T2(P2 = 16, C2 = 3),
T3(P3 = 4, C3 = 1), T4(P4 = 8, C4 = 1)

3/8 + 3/16 + 1/4 + 1/8 < 4 * (2^¼ - 1)

0.93 > 0.7568 Exemple 2 Non ordonnançable condition suffisante –

Exemple 2 Ordo avec Condition necessaire et suffisante - fait sur feuille

Exemple 3 = { T1(P1 = 6, C1 = 2), T2(P2 = 9, C2 = 3),
T3(P3 = 15, C3 = 3), T4(P4 = 8, C4 = 2)

2/6 + 3/9 + 3/15 + 2/8 < 4 * (2^¼ - 1)

1.11 > 0.7568 Exemple 3 Non ordonnançable avec charge > 1 .

Exemple 4 = { T1(P1 = 6, C1 = 2), T2(P2 = 12, C2 = 4),
T3(P3 = 24, C3 = 4), T4(P4 = 6, C4 = 1)

2/6 + 4/12 + 4/24 + 1/6 < 4 * (2^¼ - 1)

1 > 0.7568 Exemple 4 Non ordonnançable avec condition suffisante -

Exemple 4 Ordo avec Condition necessaire et suffisante - fait sur feuille

Ordonnancement EDF -
Exemple 1 { T1(P1 = 8, C1 = 2), T2(P2 = 10, C2 = 2),
T3(P3 = 8, C3 = 1), T4(P4 = 16, C4 = 2) }

2/8 + 2/10 + 1/8 + 1/8 <= 1

0.7 <= 1 Exemple 1 ordonnançable

Exemple 2 = { T1(P1 = 8, C1 = 3), T2(P2 = 16, C2 = 3),
T3(P3 = 4, C3 = 1), T4(P4 = 8, C4 = 1)

3/8 + 3/16 + 1/4 + 1/8 < 1

0.93 <= 1 Exemple 2 ordonnançable

Exemple 3 = { T1(P1 = 6, C1 = 2), T2(P2 = 9, C2 = 3),
T3(P3 = 15, C3 = 3), T4(P4 = 8, C4 = 2)

2/6 + 3/9 + 3/15 + 2/8 < 1

1.11 > 1 Exemple 3 Non ordonnançable avec charge > 1 .

Exemple 4 = { T1(P1 = 6, C1 = 2), T2(P2 = 12, C2 = 4),
T3(P3 = 24, C3 = 4), T4(P4 = 6, C4 = 1)

2/6 + 4/12 + 4/24 + 1/6 <= 1

1 = 1 Exemple 4 ordonnançable

Mode 2 :

Tâches périodiques = { T1(P1 = 8, C1 = 2), T2(P2 = 16, C2 = 2),
T3(P3 = 8, C3 = 1), T4(P4 = 8, C4 = 1)}

Tâches apériodiques Tap1
(instant d'arrivée = 3, CTap1 = 2), Tap2(instant d'arrivée = 4, CTap2 = 5)

1.1 - Calculer RM avec Période du serveur = 16, Capacité du serveur = 4

2/8 + 2 / 16 + 1/8 + 1/8 + 4 / 16 = 0.875
5 * (2^⅕ - 1) = 0.74

0.875 > 0.74 donc non ordo avec Condition suffisante

T2(16,2)
R1 = 2 > 2 + 2* [2/8] + 4*[2/16] + 1*[2/8] + 1 * [2/8] = 10
R2 = 10 > 2 + 2* [10/8] + 4*[10/16] + 1*[10/8] + 1 * [10/8] = 14
R3 = 14 > 2 + 2* [14/8] + 4*[14/16] + 1*[14/8] + 1 * [14/8] = 14

T4(8,1)
R1 = 1 > 1 + 2* [1/8] + 4*[1/16] + 1*[1/8] = 8
R2 = 8 > 1 + 2* [8/8] + 4*[8/16] + 1*[8/8] = 8

T3(8,1)
R1 = 1 > 1 + 2* [1/8] + 4*[1/16] = 7
R2 = 7 > 1 + 2* [7/8] + 4*[7/16] = 7

Serv(16,4)
R1 = 4 > 4 + 2*[4/8] = 6
R2 = 6 > 4 + 2*[6/8] = 6

T1(8,2)
R1 = 2 > 2

1.2 - Calculer RM avec Période du serveur = 6, Capacité du serveur = 2

2/8 + 2 / 16 + 1/8 + 1/8 + 2 / 6 = 0.96
5 * (2^⅕ - 1) = 0.74

0.96 > 0.74 non ordo avec Condition suffisante

T2(16,2)
R1 = 2 > 2 + 2* [2/8] + 2*[2/6] + 1*[2/8] + 1 * [2/8] = 8
R2 = 8 > 2 + 2* [8/8] + 2*[8/6] + 1*[8/8] + 1 * [8/8] = 10
R3 = 10 > 2 + 2* [10/8] + 2*[10/6] + 1*[10/8] + 1 * [10/8] = 14
R3 = 14 > 2 + 2* [14/8] + 2*[14/6] + 1*[14/8] + 1 * [14/8] = 16
R4 = 16 > 2 + 2* [16/8] + 2*[16/6] + 1*[16/8] + 1 * [16/8] = 16

T4(8,1)
R1 = 1 > 1 + 2* [1/8] + 2*[1/6] + 1*[1/8] = 6
R2 = 8 > 1 + 2* [6/8] + 2*[6/6] + 1*[6/8] = 6

T3(8,1)
R1 = 1 > 1 + 2* [1/8] + 2*[1/6] = 5
R2 = 7 > 1 + 2* [5/8] + 2*[5/6] = 5

T1(8,2)
R1 = 2 > 2 + 2*[2/6] = 4

Serv(6,2)
R1 = 2 > 2

2 - Polling serveur

3 - Sporadique serveur

4 - EDF avec Slack-stealing

Slack-stealing => utiliser les capacité en plus après avoir fait les tache périodique pour traiter les tache apériodique

Mode 3 - Transformation RM - resultat des transformations a droite

T1,1(P = 20, r = 1, C = 2), Prio1 = 1 // T1,1(P = 20, r = 1, C = 2), Prio1 = 4

T2,1(P = 20, r = 0, C = 3), Prio2 = 1 // T2,1(P = 20, r = 1, C = 3), Prio2 = 3
T3,1(P = 20, r = 2, C = 4), Prio3 = 1 // T3,1(P = 20, r = 2, C = 4), Prio3 = 2
T4,1(P = 20, r = 0, C = 2) Prio4 = 1 // T4,1(P = 20, r = 2, C = 2) Prio4 = 1

T1 => T2 => T3 => 4

Prio4 = 1
Prio3 = max { prio3 , prio4 + 1 } = 2
Prio2 = max { prio2 , prio3 + 1 } = 3
Prio1 = max { prio1 , prio2 + 1 } = 4

r1 = 1
r2 = max { r1 , r2 } = 1
r3 = max { r2 , r3 } = 2
r4 = max { r3 , r4 } = 2
//
T1,2(P = 30, r = 0, C = 4), Prio1 = 1 // T1,2(P = 30, r = 0, C = 4), Prio1 = 4
T2,2(P = 30, r = 2, C = 3), Prio2 = 1 // T2,2(P = 30, r = 2, C = 3), Prio2 = 3
T3,2(P = 30, r = 0, C = 4), Prio3 = 1 // T3,2(P = 30, r = 2, C = 4), Prio3 = 2
T4,2(P = 30, r = 3, C = 4) Prio4 = 1 // T4,2(P = 30, r = 3, C = 4) Prio4 = 1

T1 => T2 => T3 => 4

Prio4 = 1
Prio3 = max { prio3 , prio4 + 1 } = 2
Prio2 = max { prio2 , prio3 + 1 } = 3
Prio1 = max { prio1 , prio2 + 1 } = 4

r1 = 0
r2 = max { r1 , r2 } = 2
r3 = max { r2 , r3 } = 2
r4 = max { r3 , r4 } = 3

Transformation EDF

T1,1(P = 20, r = 1, C = 2), Prio1 = 1 // T1,1(P = 11, r = 1, C = 2),
T2,1(P = 20, r = 0, C = 3), Prio2 = 1 // T2,1(P = 14, r = 3, C = 3),
T3,1(P = 20, r = 2, C = 4), Prio3 = 1 // T3,1(P = 18, r = 6, C = 4),
T4,1(P = 20, r = 0, C = 2) Prio4 = 1 // T4,1(P = 20, r = 10, C = 2)

P4= 20
P3 = min { P3, P4 - 2 } = 18
P2 = min { P2, P3 - 4 } = 14
P1 = min{ P1, P2 - 3 } = 11

r1 = 1
r2 = max { r1+ 2 , r2 } = 3

r3 = max { r2 + 3 , r3 } = 6
r4 = max { r3 + 4 , r4 } = 10

T1,2(P = 30, r = 0, C = 4), // T1,2(P = 19, r = 0, C = 4),
T2,2(P = 30, r = 2, C = 3), // T2,2(P = 22, r = 4, C = 3),
T3,2(P = 30, r = 0, C = 4), // T3,2(P = 26, r = 7, C = 4),
T4,2(P = 30, r = 3, C = 4) // T4,2(P = 30, r = 11, C = 4)

P4= 30
P3 = min { P3, P4 - 4 } = 26
P2 = min { P2, P3 - 4 } = 22
P1 = min{ P1, P2 - 3 } = 19

r1 = 0
r2 = max { r1+ 4 , r2 } = 4
r3 = max { r2 + 3 , r3 } = 7
r4 = max { r3 + 4 , r4 } = 11

Mode 3 - Calcul ordonnancement après transformation

3.1 Calculer RM pour c'est tache : T1,1(P = 20, r = 1, C = 2), Prio1 = 4
T2,1(P = 20, r = 1, C = 3), Prio2 = 3 T3,1(P = 20, r = 2, C = 4), Prio3 = 2,
T4,1(P = 20, r = 2, C = 2) Prio4 = 1

Fait papier schema, good

3.2 Calculer EDF pour c'est tache : T1,1(P = 11, r = 1, C = 2), T2,1(P = 14, r = 3, C = 3),
T3,1(P = 18, r = 6, C = 4), T4,1(P = 20, r = 10, C = 2)

Fait papier schema , good

3.3 Calculer RM pour c'est tache : T1,2(P = 30, r = 0, C = 4), Prio1 = 4
T2,2(P = 30, r = 2, C = 3), Prio2 = 3 , T3,2(P = 30, r = 2, C = 4), Prio3 = 2
T4,2(P = 30, r = 3, C = 4) Prio4 = 1

Fait papier schema , good

3.2 Calculer EDF pour c'est tache : T1,2(P = 19, r = 0, C = 4),T2,2(P = 22, r = 4, C = 3),
T3,2(P = 26, r = 7, C = 4), T4,2(P = 30, r = 11, C = 4)

Fait papier schema, good

Mode 4 - Ressource partagé avec RM

TP1 : r = 1 ; P = 20 , LR = (r1 [1] ; { r1 [1] || r2 [1]} ; { r3 (1) || r4 [1] })
TP2 : r = 2 ; P = 30 , LR = ({ r4 [2] || r1 [2] } ; r1 [2])
TP3 : r = 1 ; P = 40 , LR = (r3 [3] ; { r4 [2] || r2 [3] } ; { r3 [1] || r4 [2] })
TP4 : r = 0 ; P = 50 , LR = (r2 [1] ; { r1[2] || r2 [2] || r3 [2] } ; { r3 [1] || r4 [2] })

(La notation ci-dessus se lit : pour le type de pièce i, on a la date de réveil (r) de la tâche correspondante, la période (P), la liste (LR) d'utilisation des ressources avec le temps d'occupation (spécifié par [n]) de la ressource. ' ;' signifie que les ressources sont utilisées en séquence et '||' signifie que les ressources sont utilisées en même temps (sections critiques imbriquées).

a) appliquer le protocole PIP (priority inheretance protocol) pour gérer l'accès aux ressources partagées ; Observer les situations d'interblocage avec PIP.

b) appliquer le protocole PCP (priority ceiling protocol) pour gérer l'accès aux ressources partagée .

15 ∞

$R_i = \{(k,m) \mid 1 \le k \le i,\ m = 1, \dots, \lfloor \frac{P_i}{P_k} \rfloor\}$

$\forall i,\ 1 \le i \le n,\ \min \left\{ \frac{1}{mP_k} \sum_{j=1}^{i} C_j \lceil \frac{mP_k}{P_j} \rceil \right\} \le 1$

$T_1 - P_1 = 8\ C_1 = 3\quad T_2 - P_2 = 16,\ C_2 = 3$
$T_3\ P_3 = 4,\ C_3 = 1\quad T_4 - P_4 = 8\ C_4 = 1$

Pour T_1, $\{1,1\}$

$i = 1,\ \frac{1}{P_1} C_1 \lceil \frac{P_1}{P_1} \rceil = \frac{1}{8} \times 3 = \frac{3}{8} \le 1$ T1 ordo ✓

$i = 2,\ \{1,1\}\ \{1,2\}\ \{2,1\}$

$\{1,1\} \rightarrow \frac{1}{P_1} C_1 \lceil \frac{P_1}{P_1} \rceil + \frac{1}{P_1} C_2 \lceil \frac{P_1}{P_2} \rceil$
$= \frac{3}{8} + \frac{3}{8} \times 2 = \frac{3}{8} + \frac{6}{8} = \frac{9}{8} > 1$ ×

$\{1,2\} \rightarrow \frac{1}{2P_1} C_1 \lceil \frac{2P_1}{P_1} \rceil + \frac{1}{2P_1} C_2 \lceil \frac{2P_1}{P_2} \rceil$
$= \frac{3}{16} \times 2 + \frac{3}{16} = \frac{9}{16} \le 1$ T2 ordo ✓

$i = 3,\ \{1,1\}\ \{2,1\}\ \{3,1\}$

$\{1,1\} \rightarrow \frac{1}{P_1} C_1 \lceil \frac{P_1}{P_1} \rceil + \frac{1}{P_1} C_2 \lceil \frac{P_1}{P_2} \rceil + \frac{1}{P_1} C_3 \lceil \frac{P_1}{P_3} \rceil$
$= \frac{3}{8} + \frac{3}{8} \times 2 + \frac{1}{8} \times 2 = \frac{3}{8} + \frac{6}{8} + \frac{2}{8}$
$= \frac{11}{8} > 1$ ×

$\{2,1\} \rightarrow \frac{1}{P_2} C_1 \lceil \frac{P_2}{P_1} \rceil + \frac{1}{P_2} C_2 \lceil \frac{P_2}{P_2} \rceil + \frac{1}{P_2} C_3 \lceil \frac{P_2}{P_3} \rceil$
$= \frac{3}{16} \times 2 + \frac{3}{16} + \frac{1}{16} \times 4 = \frac{6}{16} + \frac{3}{16} + \frac{4}{16} = \frac{13}{16} < 1$
T3 ordo ✓

$\frac{1}{mP_k} \sum_{j=1}^{i} C_j \lceil \frac{mP_k}{P_j} \rceil \quad R_i = \{(k,m) \mid 1 \le k \le i,\ m = 1, \dots, \lfloor \frac{P_i}{P_k} \rfloor\}$

$P_1 = 8$
$C_1 = 3$
$P_2 = 16$
$C_2 = 3$
$P_3 = 4$
$C_3 = 1$
$P_4 = 8$
$C_4 = 1$

$i = 4,\ \{1,1\}\ \{2,1\}\ \{3,1\}\ \{3,2\}\ \{4,1\}$

$\{1,1\} \rightarrow \frac{1}{P_1} C_1 \lceil \frac{P_1}{P_1} \rceil + \frac{C_2}{P_1} \lceil \frac{P_1}{P_2} \rceil + \frac{C_3}{P_1} \lceil \frac{P_1}{P_3} \rceil + \frac{C_4}{P_1} \lceil \frac{P_1}{P_4} \rceil$
$= \frac{3}{8} + \frac{3}{8} \times 2 + \frac{1}{8} \times 2 + \frac{1}{8} = \frac{3}{8} + \frac{6}{8} + \frac{2}{8} + \frac{1}{8} = \frac{12}{8} > 1$ ×

$\{2,1\} \rightarrow \frac{1}{P_2} C_1 \lceil \frac{P_2}{P_1} \rceil + \frac{C_2}{P_2} \lceil \frac{P_2}{P_2} \rceil + \frac{C_3}{P_2} \lceil \frac{P_2}{P_3} \rceil + \frac{C_4}{P_2} \lceil \frac{P_2}{P_4} \rceil$
$= \frac{3}{16} \times 2 + \frac{3}{16} \times 1 + \frac{1}{16} \times 4 + \frac{1}{16} \times 2 = \frac{6}{16} + \frac{3}{16} + \frac{4}{16} + \frac{2}{16}$
$= \frac{15}{16} < 1$

Exemple 3 est ordonnançable. T4 ordo ✓.

Exemple 4 : $T_1 - P_1 = 6\ C_1 = 2,\ T_2 - P_2 = 12\ C_2 = 4$
$T_3 - P_3 = 24\ C_3 = 4,\ T_4 - P_4 = 6\ C_4 = 1$

Pour $i = 1$, $\{1,1\}$ $\frac{1}{P_1} C_1 \lceil \frac{P_1}{P_1} \rceil = \frac{2}{6} < 1$ T1 ordo ✓

Pour $i = 2$, $\{1,1\}\ \{1,2\}\ \{2,1\}$

$\{1,1\} \rightarrow \frac{C_1}{P_1} \lceil \frac{P_1}{P_1} \rceil + \frac{C_2}{P_1} \lceil \frac{P_1}{P_2} \rceil = \frac{2}{6} + \frac{4}{6} = \frac{6}{6} = 1$
T2 ordo ✓

Pour $i = 3$, $\{1,1\}\ \{1,2\}\ \{1,3\}\ \{1,4\}\ \{2,1\}\ \{2,2\}\ \{3,1\}$

$\{1,1\} \rightarrow \frac{C_1}{P_1} \lceil \frac{P_1}{P_1} \rceil + \frac{C_2}{P_1} \lceil \frac{P_1}{P_2} \rceil + \frac{C_3}{P_1} \lceil \frac{P_1}{P_3} \rceil = \frac{2}{6} + \frac{4}{6} + \frac{4}{6} = \frac{10}{6} > 1$

$\{2,1\} \rightarrow \frac{C_1}{P_2} \lceil \frac{P_2}{P_1} \rceil + \frac{C_2}{P_2} \lceil \frac{P_2}{P_2} \rceil + \frac{C_3}{P_2} \lceil \frac{P_2}{P_3} \rceil = \frac{2}{12} \times 2 + \frac{4}{12} + \frac{4}{12}$
$= \frac{12}{12} = 1$
T3 ordo ✓

Pour $i = 4$, $\{1,1\}\ \{2,1\}\ \{3,1\}\ \{4,1\}$

$\{1,1\} \rightarrow \frac{C_1}{P_1} \lceil \frac{P_1}{P_1} \rceil + \frac{C_2}{P_1} \lceil \frac{P_1}{P_2} \rceil + \frac{C_3}{P_1} \lceil \frac{P_1}{P_3} \rceil + \frac{C_4}{P_1} \lceil \frac{P_1}{P_4} \rceil = \frac{2}{6} + \frac{4}{6} + \frac{4}{6} + \frac{1}{6}$
$= \frac{11}{6} < 1$ ×

$\{2,1\} \rightarrow \frac{C_1}{P_2} \lceil \frac{P_2}{P_1} \rceil + \frac{C_2}{P_2} \lceil \frac{P_2}{P_2} \rceil + \frac{C_3}{P_2} \lceil \frac{P_2}{P_3} \rceil + \frac{C_4}{P_2} \lceil \frac{P_2}{P_4} \rceil$
$= \frac{2}{12} \times 2 + \frac{4}{12} + \frac{4}{12} + \frac{1}{12} \times 2 = \frac{14}{12} > 1.$

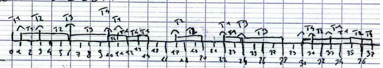
$\{3,1\} \rightarrow \frac{C_1}{P_3} \lceil \frac{P_3}{P_1} \rceil + \frac{C_2}{P_3} \lceil \frac{P_3}{P_2} \rceil + \frac{C_3}{P_3} \lceil \frac{P_3}{P_3} \rceil + \frac{C_4}{P_3} \lceil \frac{P_3}{P_4} \rceil$
$= \frac{2}{24} \times 4 + \frac{4}{24} \times 2 + \frac{4}{24} + \frac{1}{24} \times 4 = \frac{8}{24} + \frac{8}{24} + \frac{4}{24} + \frac{4}{24}$
$= \frac{16}{24} + \frac{8}{24} = \frac{24}{24} = 1$
T4 ordo ✓

- Pour $i = 3$, $\{1,2\} \rightarrow \frac{C_1}{2P_1} \lceil \frac{2P_1}{P_1} \rceil + \frac{C_2}{2P_1} \lceil \frac{2P_1}{P_2} \rceil + \frac{C_3}{2P_1} \lceil \frac{2P_1}{P_3} \rceil$
$= \frac{2}{12} \times 2 + \frac{4}{12} + \frac{4}{12} = \frac{12}{12} = 1$ T3 ordo ✓

Exemple 4 ordonnançable avec CNS.

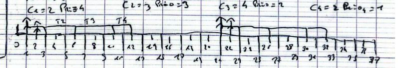
Mode 3 - 3.2 EDF.

$T_1 - P_1 = 11,\ D = 1$
$C_1 = 2$
$T_2 - P_2 = 14,\ D = 3$
$C_2 = 3$
$T_3 - P_3 = 18,\ D = 6$
$C_3 = 4$
$T_4 - P_4 = 20,\ D_4 = 10$
$C_4 = 2$

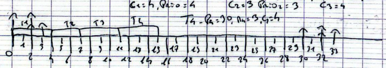


3.1 - RM

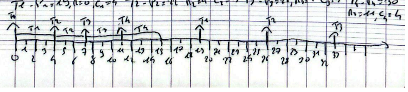
$T_1 - P_1 = 20\ D_1 = 1$, $C_1 = 2$ Prio = 4; $T_2 - P_2 = 20\ D_2 = 1$, $C_2 = 3$ Prio = 3; $T_3 - P_3 = 20\ D_3 = 2$, $C_3 = 4$ Prio = 2; $T_4 - P_4 = 20\ D_4 = 2$, $C_4 = 2$ Prio = 1



3.3 RM - $T_1 - P_1 = 30,\ D_1 = 0$, $C_1 = 4$, Prio = 4, $T_2 - P_2 = 30,\ D_2 = 2$, $C_2 = 3$ Prio = 3, $T_3 - P_3 = 30,\ D_3 = 2$, $C_3 = 4$
$T_4 - P_4 = 30,\ D_4 = 3,\ C_4 = 4$



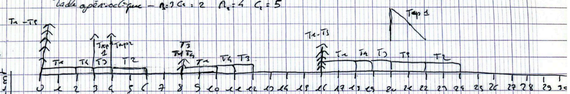
3.4 EDF $T_1 - P_1 = 13,\ D = 0,\ C_1 = 4$ $T_2 - P_2 = 22\ D_2 = 4\ C_2 = 3$ $T_3 - P_3 = 26,\ D_3 = 7\ C_3 = 4$ $T_4 - P_4 = 30$ $D_4 = 11,\ C_4 = 4$



T.P. Ordonnancement

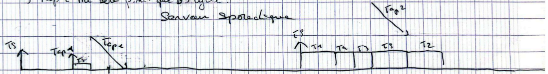
$T_1 - P_1 = 8\ C_1 = 2,\ T_2 - P_2 = 16\ C_2 = 2,\ T_3 - P_3 = 8\ C_3 = 1,\ T_4 - P_4 = 8\ C_4 = 1,\ T_5 - P_5 = 16\ C_5 = 4$
Tâche apériodique - $D_1 = 3\ C_1 = 2\quad D_2 = 4\ C_2 = 5$

Serveur Polling



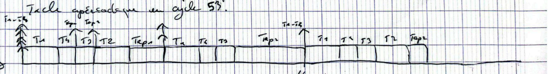
-> Tap 2 ne sera fini que 69 cycle.

Serveur Sporadique

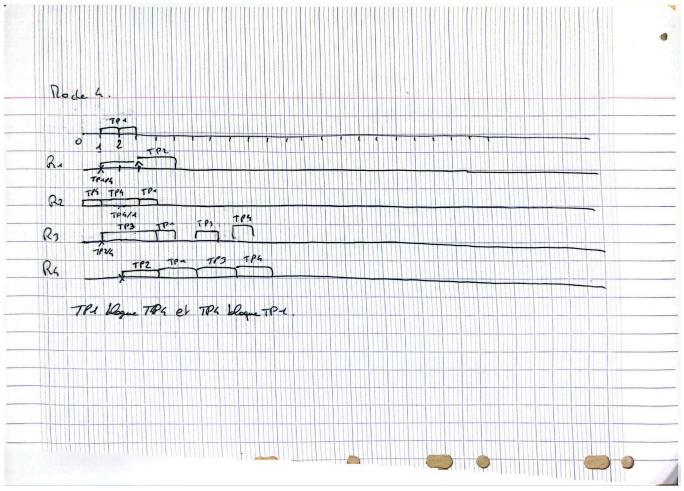


-> Comme le serveur sporadique conserve sa capacité de calcul, il termine la tâche apériodique au cycle 53.

EDF Slack Stealing



-> avec Slack-Stealing, on finit au cycle 23.


Route 4.
TP4
0
1
2
TP1
R1
TP1/4
TP1
TP1
TP4
R2
TP4/1
TP3
TP2
TP3
TP4
R3
TP1/2
TP2
TP2
TP3
TP4
R4
TP1 bloque TP4 et TP4 bloque TP1.