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A MARKOV CHAIN MODEL FOR ROUND ROBIN SCHEDULING IN OPERATING SYSTEM

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Abstract: In the Round-Robin scheduling scheme, the scheduler processes each job, one after another, after giving a preset quantum of time. In the first-in first out (FIFO) scheduling, next process gets the opportunity only if the earlier arrived job is completely processed. This paper presents a general class of round-robin scheduling scheme in which both the above scheduling procedures are covered like particular cases. This class has many other scheduling schemes also. A Markov chain model is used to compare several scheduling schemes of the class. One scheduling scheme, which is a mixture of FIFO and round robin, is found efficient in terms of model based study approach. The system simulation procedure is used to derive the conclusion of the content.

INTRODUCTION

In an operating system, a large number of processes arrive to the scheduler whose role is to manage the processing of these jobs. There are many scheduling schemes available in literature [see Silberschatz and Galvin (2007), Stalling (2004), Tanenbaum and woodhull (2007)] like FIFO, Round robin, Priority based, Multi-level queue scheduling and so on. All these schemes have some advantages and disadvantages over each other. A unified study of scheduling scheme is required under a common environment of the system. This motivates to design unified a general class of scheduling schemes containing well known schemes so that its members may possess common properties of the class as well as could be mutually compared. With this thought of motivation, a general class of scheduling scheme is designed in this paper containing some well-known schemes like FIFO and Round robin as its member schemes.

Shukla and Jain (2007) have studied the multi-level queue-scheduling scheme in the environment of Markov chain model. Shukla et.al. (2007), studied the setup of space division switches in a Markov chain model scenario. Shukla and Jain (2007) used a Markov chain model for deadlock-based study of multi-level queue scheduling. Some other contributions related to the use of Markov chain model are due to Medhi (1991) and Naldi (2002) and to round robin, queuing system are due to Schassberger (1981), Eiseriberg (1979), Liu and Towsley (1994), Chang (1994), Nelson and Towsley (1994), Shenker and Weinrib (1989), Nelson, Towsley and Tantawi (1988) and Horn (1974) . In present study, the designed general class of scheduling scheme is examined through a Markov chain model in order to perform comparative analysis of performance of member scheduling schemes.

GENERAL CLASS OF ROUND-ROBIN QUEUE SCHEDULING SCHEME

Consider a round-robin scheduling scheme shown in fig 2.1. A general class is laid down below:

A) the S denotes scheduler and there are *m* processes P_1, P_2, P_3,….. P_m in queue;
B) the S provides one quantum of time to each process and next quantum is decided by a random trial;
C) the S starts from any process P_i in queue and then moves to P_j $\left(j \neq i = 1,2,3 \ldots m\right)$;
D) The new process enters from the end i.e. P_{m+1} is placed after P_m and so on;
E) Suppose S is at any process P_i $(i=1,2,3\ldots m)$ at the end of a quantum, then in the next quantum
(a) S will be on P_{i+1} with priority *p,* or
(b) S will be on P_i with priority *s,* or
(c) S will be on P_{i-1} with priority *q.*
F) The S becomes idle when there is no process in the queue. However it is assumed that the scheduler S may be in deadlock state in any quantum;
G) From this deadlock level, the S could be back also to the queue in any other quantum for processing purpose;
H) There is a long waiting queue of processes P_1', P_2'….. outside the processing unit and if one process is over inside, then a new process, waiting outside, enters inside so as to maintain the length of *m* processes there.

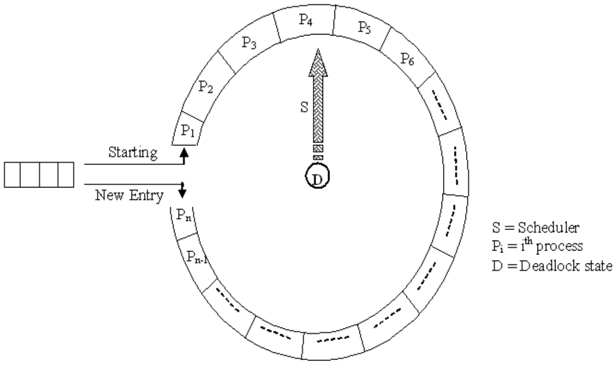

Figure.1 (Round Robin Processing)

P_3' P_2'P_1'

MARKOV CHAIN MODEL

Let $\{X^{(n)}, n \geq 1\}$ denotes a Markov chain with the state space P_1, P_2, P_3… P_m, and D where D is a deadlock state used to denote idle level, blocking or any disturbance caused in the system, during job processing. The $X^{(n)}$ is the state of scheduler of the system at the end of n^{th} quantum (n=1,2,3…). Assume that m processes are in system at a time. Further, let the transition of scheduler S is random over $m+1$ states in n^{th} quantum. The transition diagram for any three processes P_{i-1}, P_i, P_{i+1} and D is given in fig. 3.1

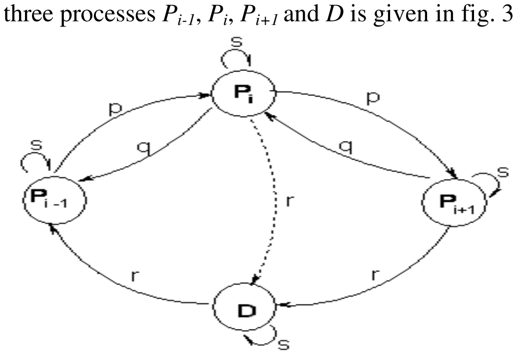

Figure.2 (System Diagram

Define unit-step transition probabilities as

$P[X^{(n+1)}=P_{i+1}/X^{(n)}=P_i] = p$

$P[X^{(n+1)}=P_i/X^{(n)}=P_i] = s$

$P[X^{(n+1)}=P_{i-1}/X^{(n)}=P_i] = q$

$P[X^{(n+1)}=D/X^{(n)}=P_i] = r$

$P[X^{(n+1)}=P_i/X^{(n)}=D] = 0$

The unit step transition probability matrix is:

$$
\xleftarrow{\qquad X^{(n)} \qquad}
$$

$$
X^{(n-1)} \quad
\begin{array}{c|cccccccccc|}
 & P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & & P_{m-1} & P_m & D \\
\hline
P_1 & s & p & 0 & 0 & 0 & 0 & \text{--------} & 0 & q & r \\
P_2 & q & s & p & 0 & 0 & 0 & \text{--------} & 0 & 0 & r \\
P_3 & 0 & q & s & P & 0 & 0 & \text{--------} & 0 & 0 & r \\
P_4 & 0 & 0 & q & s & p & 0 & \text{--------} & 0 & 0 & r \\
P_5 & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \text{--------} & \vdots & \vdots & \vdots \\
P_6 & 0 & 0 & 0 & 0 & q & s & \text{--------} & 0 & 0 & r \\
\end{array}_{(m+1)x(m+1)} \quad \text{......} (3.1)
$$

with p + q + r + s =1 and (m+1)r =1

The initial probabilities, at n=0 for general class are :

$P[X^{(0)}=P_i] = pb_i \qquad (i=1,2,3,4…m)$

$P[X^{(0)}=D] = 0$

The state probabilities after the first quantum are:

$P[X^{(1)}=P_i] = P[X^{(0)}=P_{i-1}]. P[X^{(1)}=P_i / P[X^{(0)}=P_{i-1}] + P[X^{(0)}=P_i]. P[X^{(1)}=P_i / P[X^{(0)}=P_i] + P[X^{(0)}=P_{i+1}]. P[X^{(1)}=P_i / P[X^{(0)}=P_{i+1}]$

$= (pb_{i-1})p + (pb_i)s + (pb_{i+1})q$ (if $i-1=0$ then $i-1=1$ & if $i+1>m$ then $i+1=m$)

$$P[X^{(1)}=D] = r.\sum_{i=1}^{m} pb_i = r$$

Similarly, state probabilities after second quantum can be obtained by simple relationship:

$P[X^{(2)}=P_i] = [(pb_{i-2})p + (pb_{i-1})s + (pb_i)q]p+$
$[(pb_{i-1})p + (pb_i)s + (pb_{i+1})q]s+$
$[(pb_i)p + (pb_{i+1})s + (pb_{i+2})q]q+ r.0$
$= P[X^{(1)}=P_{i-1}].p+ P[X^{(1)}=P_i].s+ P[X^{(1)}=P_{i+1}].q$

$$P[X^{(2)}=D] = \sum_{i=1}^{m} P\left[X^{(1)} = P_i\right]r + P\left[X^{(1)} = D\right]1$$

In the similar way, state probabilities after third quantum are:

$P[X^{(3)}=P_i] = P[X^{(2)}=P_{i-1}].p+ P[X^{(2)}=P_i].s+ P[X^{(2)}=P_{i+1}].q$

$$P[X^{3)}=D] = \sum_{i=1}^{n} P\left[X^{(2)} = P_i\right]r + P\left[X^{(2)} = D\right]1$$

Remark 3.1 The generalized expressions for n quantum could be expressed like:

$P[X^{(n)}=P_i] = P[X^{(n-1)}=P_{i-1}].p+ P[X^{(n-1)}=P_i].s+ P[X^{(n-1)}=P_{i+1}].q$

$$P[X^{(n)}=D] = \sum_{i=1}^{n} P\left[X^{(n-1)} = P_i\right]r + P\left[X^{(n-1)} = D\right]1$$

SOME SPECIAL SCHEDULING SCHEMES

By imposing restrictions and conditions over the ways and procedures, one can generate various scheduling schemes from the generalized class in section 2.0.

SCHEME-III [A]: WHEN Q=0, R=0, P+S=1

Unit step transition probability matrix for $X^{(n)}$ under scheme-III [A] is

$$X^{(n)}$$

$$X^{(n-1)}\quad \begin{array}{c|cccccccc|} & P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & \cdots & P_{m-1} & P_m \\ \hline P_1 & s & p & 0 & 0 & 0 & 0 & \cdots & 0 & 0 \\ P_2 & 0 & s & p & 0 & 0 & 0 & \cdots & 0 & 0 \\ P_3 & 0 & 0 & s & p & 0 & 0 & \cdots & 0 & 0 \\ P_4 & 0 & 0 & 0 & s & p & 0 & \cdots & 0 & 0 \\ P_5 & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ P_6 & 0 & 0 & 0 & 0 & 0 & s & \cdots & 0 & 0 \end{array}_{(m)\times(m)}$$

Remark .1 The initial probabilities at n=0 for scheme-III [A] are:

$P[X^{(0)}=P_i]=pb_i$

and subject to the condition $\sum_{i=1}^{m} pb_i$

Remark.2 The state probabilities after the first quantum are:

$P[X^{(1)}=P_i]=pb_{i-1}.p + pb_i.s$

Remark .3 The state probabilities after the second quantum are:

$P[X^{(2)}=P_i]=P[X^{(1)}=P_{i-1}].p + P[X^{(1)}=P_i].s$

Remark .4 The generalized expressions of scheme-III [A] for n quantum are:

$P[X^{(n)}=P_i]= P[X^{(n-1)}=P_{i-1}].p + P[X^{(n-1)}=P_i].s$

SCHEME-III [B]: WHEN q=0,p+r+s=1

Unit step transition probability matrix for $X^{(n)}$ under scheme-III [B] is

$$X^{(n)}$$

$$X^{(n-1)}\quad \begin{array}{c|ccccccccc|} & P_1 & P_2 & P_3 & P_4 & P_5 & P_6 & \cdots & P_{m-1} & P_m & D \\ \hline P_1 & s & p & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & r \\ P_2 & 0 & s & p & 0 & 0 & 0 & \cdots & 0 & 0 & r \\ P_3 & 0 & 0 & s & p & 0 & 0 & \cdots & 0 & 0 & r \\ P_4 & 0 & 0 & 0 & s & p & 0 & \cdots & 0 & 0 & r \\ P_5 & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ P_6 & 0 & 0 & 0 & 0 & 0 & s & \cdots & 0 & 0 & r \end{array}_{(m+1)\times(m+1)}$$

Remark .1 The initial probabilities at n=0 for scheme-III [B] are

$P[X^{(0)}=P_i]=pb_i \quad (i=1,2,3\ldots m)$

$P[X^{(0)}=R]=0$

and subject to the condition $\sum_{i=1}^{m} pb_i$

Remark.2 The state probabilities after the first quantum are:

$P[X^{(1)}=P_i]= P[X^{(0)}=P_{i-1}].p + P[X^{(0)}=P_i].s$

$P[X^{(1)}=R]= r.\sum_{i=1}^{m} pb_i = r$

Remark.3 The state probabilities after the second quantum are:

$P[X^{(2)}=P_i]=P[X^{(1)}=P_{i-1}].p + P[X^{(1)}=P_i].s$

$P[X^{(2)}=D]= \sum_{i=1}^{m} P\left[X^{(1)} = P_i\right]$

Remark.4 The generalized expressions of scheme-III [B] for n quantum are:

$P[X^{(n)}=P_i]=P[X^{(n-1)}=P_{i-1}].p + P[X^{(n-1)}=P_i].s$

$P[X^{(n)}=D]= \sum_{i=1}^{m} P\left[X^{(n-1)} = P_i\right]$

SIMULATION STUDY

In order to compare all the four scheduling schemes with parts therein, under a common setup of Markov chain model, the following simulation study is performed:

Under Scheme-III [A]:

Consider initial probabilities pb_1 =0.27, pb_2 =0.15, pb_3=0.17, pb_4=0.18, pb_5=0.23 and the transition probability matrix like below:

{Here s=0.5, p=0.5, q=r=0 and p + s = 1}

$$X^{(n)}$$

$$X^{(n-1)}\quad \begin{array}{c|ccccc} & P_1 & P_2 & P_3 & P_4 & P_5 \\ \hline P_1 & 0.5 & 0.5 & 0 & 0 & 0 \\ P_2 & 0 & 0.5 & 0.5 & 0 & 0 \\ P_3 & 0 & 0 & 0.5 & 0.5 & 0 \\ P_4 & 0 & 0 & 0.5 & 0.5 & 0 \\ P_5 & 0.5 & 0 & 0 & 0 & 0.5 \end{array}$$

Table.1 $P\left[X^{(n)} = p_i\right]_{SC-III(A)}$ **for transition probability matrices**

Quantum	Probabilities				
	P_1	P_2	P_3	P_4	P_5
$n=1$	0.25	0.21	0.16	0.175	0.205
$n=2$	0.2275	0.23	0.185	0.1675	0.19
$n=3$	0.20875	0.22875	0.2075	0.17625	0.17885
$n=4$	0.19375	0.21875	0.218125	0.191875	0.1775
$n=5$	0.185625	0.20625	0.218438	0.205	0.184688

$n=6$	0.185156	0.195938	0.212344	0.211719	0.194844
$n=7$	0.19	0.190547	0.204141	0.212031	0.203281

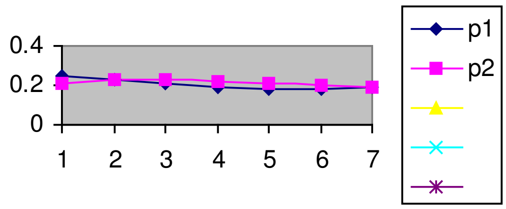

Figure.3

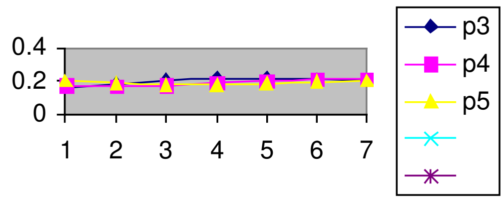

Figure.4

The scheme-III [A] shown in fig 5.5[A] and 5.5[B] is neither FIFO nor a round robin scheme. But it is a mixture of these two. In this, the quantum distribution takes over the same state or to the next state depending upon the outcome of the random experiment. If the number of quantum increases then this scheme shows almost a stable pattern of the state probabilities. This means every process has almost same chance of being processed.

Under Scheme-III [B]:

Initial probabilities are pb_1 =0.27, pb_2 =0.15, pb_3=0.17, pb_4=0.18, pb_5=0.23, pb_r=0 and the transition probability matrix like below:

{Here q = 0, p + r +s = 1 and r = 0.166}

$X^{(n-1)}$ \ $X^{(n)}$	P_1	P_2	P_3	P_4	P_5	D
P_1	0.334	0.5	0	0	0	0.166
P_2	0	0.334	0.5	0	0	0.166
P_3	0	0	0.334	0.5	0	0.166
P_4	0	0	0	0.334	0.5	0.166
P_5	0.5	0	0	0	0.334	0.166
D	0	0	0	0	0	1

Table.2 $P\left[X^{(n)} = p_i\right]_{SC-III(B)}$ **for transition Probability Matrices**

Quantum	Probabilities					
	P_1	P_2	P_3	P_4	P_5	D
$n=1$	0.20518	0.1851	0.13178	0.14512	0.16682	0.166
$n=2$	0.15194	0.164413	0.136565	0.11436	0.128278	0.304444
$n=3$	0.114887	0.130844	0.127819	0.106479	0.100025	0.419906
$n=4$	0.088385	0.101159	0.108834	0.099473	0.086648	0.516202
$n=5$	0.072844	0.077979	0.086696	0.087291	0.078677	0.596512
$n=6$	0.063668	0.062467	0.067946	0.072503	0.069924	0.663491
$n=7$	0.056227	0.052698	0.053928	0.058189	0.059606	0.719352

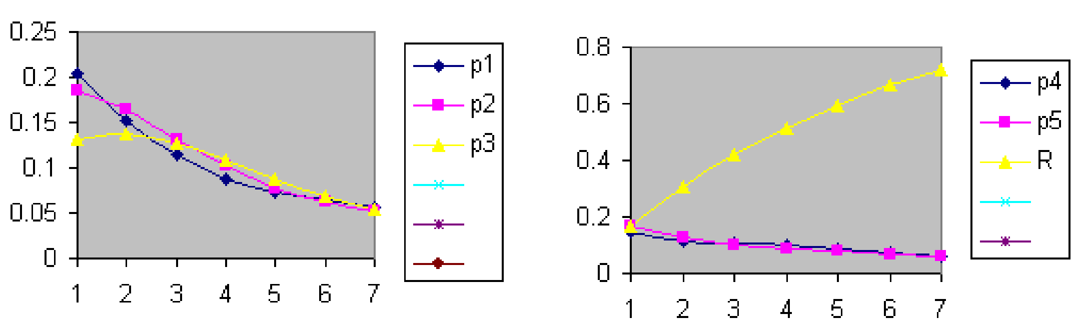

Figure.5 and Figure.6

When III [B] is taken into consideration, which is with deadlock chances also, we found that with the increasing number of attempts, the state probabilities are reducing and there is a high chances of system being transferred to deadlock state. Fig f.6[A] and 5.6[B] are in support of these facts.

CONCLUDING REMARK

The present study incorporates a general class of scheduling schemes with FIFO and round robin as its members. Some other schemes are also member of this class and all these are considered with and without deadlock state. All the schemes are studied under a common Markov chain model. If the number of quantum increases then scheme-III[A] shows almost a stable pattern of state probabilities. The scheme-III seems a good choice because of stability pattern over job processing.

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