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Effect of Data Model Approach In State Probability Analysis Of Multi-Level Queue Scheduling

Diwakar Shukla
Department of Mathematics and Statistics, Sagar University, Sagar, M.P. ,470003, India.
Email: diwakarshukla@rediffmail.com
Shweta Ojha
Department of Computer Science & Applications, Sagar University, Sagar, M.P., 470003, India.
Email: meshwetaojha@gmail.com
Saurabh Jain
Department of Computer Science & Applications, Sagar University, Sagar, M.P., 470003, India.
Email: iamsaurabh_4@yahoo.co.in

ABSTRACT

In the uniprocessor environment, the number of jobs arriving at the processor of CPU at a time is very large which causes a long waiting queue. When conflict arises due to shared resources or overlap of instructions or logical error, the deadlock state appears where further processing of jobs is blocked completely. While the scheduler jumps from one job to another in order to perform the processing the transition mechanism appears. This paper presents a general structure of transition scenario for the functioning of CPU scheduler in the presence of deadlock condition in setup of multilevel queue scheduling. A data model based Markov chain model is proposed to study the transition phenomenon and a general class of scheduling scheme is designed. Some specific and well known schemes are treated as its particular cases and are compared under the setup of model through a proposed deadlock-waiting index measure. Simulation study is performed to evaluate the comparative merits of specific schemes belonging to the class designed with the help of varying values of α and d.

Keywords :- Process scheduling, Markov chain model, Data model, State of system, Rest State, Deadlock State, Process queue, Multi-level queue scheduling, Transition probability matrix, Deadlock index.

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1. INTRODUCTION

Operating system plays a major role in managing processes arriving through single or multiple queues. Arrival or occurrence of a process is random along with different categories and types. All these require specific scheduling algorithms to work on over real time environment with special reference to task, control and efficiency. The randomization involved in scheduling procedure motivates to perform a probabilistic study. Cobb et al. [1] picked up fair scheduling of flaros with the consideration of time shifting approach in the area of high-speed networks whereas David [2] has discussed contribution over the study of real time and conventional scheduling with a comparative analysis. Demer et al. [3] presented an analysis of Fair Queuing algorithm. Goyal [4] derived the Hierarchical CPU scheduler in the environment where the multimedia operating system is used. In the similar lines, Hieh [5] discussed smart schedulers for multimedia users. A time driven scheduling model is proposed by Janson [6] attracted attention of researchers for the model formation over functioning and procedure on operating systems.

Medhi [7] has given an elaborate study of a variety of stochastic processes and their applications in various fields. Naldi [8] presented an idea of development of Markov chain model for understanding the internet traffic sharing among various network operators in a competitive market. Shukla and Jain [9] have a discussion on the use of Markov chain model for multilevel queue scheduler in an operating system. Shukla et al. [10] derived an application of Markov chain model for the study of transition probabilities in space division switches in computer networks. Some other useful contributions over detailed methodological description of operating system are due to Silberschatz and Galvin [11], Stalling [12] Tanenbaum [13], Shukla and Thakur ([14], [15], [16], [18]), Jain et al. [17] and Shukla et.al. ([19], [20]). Deriving a motivation from these, a class of scheduling schemes is designed in this paper for performing an integrated approach of efficiency comparison under the assumption of Markov chain model and using a data model approach with deadlock index measure.

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1.1 Deadlock Based General Class of Multi-Level Queue Scheduling

Suppose a multi-level queue scheduling with four queues Q_1, Q_2, Q_3, Q_4 each having large number of processes P_j, P_j', P_j'', P_j''' (j=1,2,3….) respectively waiting for processing. Define four queues Q_1(i=1,2,3,4) like the four states of scheduling system with addition of two other specific states Q_5 and Q_6. First four states are related to arrival and inputation of processes while the last two associate with deadlock and waiting of scheduler. A quantum is a small pre-defined slot of time given for processing, to waiting processes in queues. Symbol n denotes the n^{th} quantum allotted by the scheduler to a process for execution (n=1,2,3,4…). Using above, the structure of given class is:

(1) All the first four queues Q_1, Q_2, Q_3, Q_4 are allowed to accept a new process with initial probabilities pr_1, pr_2, pr_3, pr_4 $\left(\sum_{i=1}^{4} pr_i = 1\right)$

(2) Scheduler has a random movement over all states Q_s(s=1,2,3,4,5,6) on quantum variation.

(3) Scheduler starts processing of any Q_i with probability pr_i (i=1,2,3,4), then picks up the first process of that queue and allot a quantum for processing.

(4) Process remains with processor until the quantum is over. If it completes within that, then gets out of Q_i.

(5) Within quantum, if a process did not complete, scheduler assigns next quantum to the next process of the same queue and so on. The earlier incomplete process moves to next queue Q_{i+1}((i+1)≤4) and waits until next quantum to be allotted for its processing.

(6) States Q_5 and Q_6 are used as resting the transition system like idle state or deadlock state.

(7) Specific conditions over resting (or restricting) transition shall be undertaken within using this class.

(8) Quantum allotment procedure, within Q_i, by scheduler, continues until Q_i is empty. The scheduler jumps from any state to any other state at the end of a quantum. When Q_1, Q_2, Q_3, Q_4 are empty, scheduler moves towards states Q_5 or Q_6. The characters of Q_5 and Q_6 are different and to be defined under the different schemes.

(9) Scheduler attempts processing in queue Q_4 on "first come first serve" basis. Any incomplete process or new process, if appears in Q_4, remains with Q_4 only until processed completely.

2. Markov Chain Model

Let $\{x^{(n)}, n \geq 1\}$ be a Markov chain where $x^{(n)}$ denotes the state of the scheduler at the n^{th} quantum of time. The state space for $x^{(n)}$ is $\{Q_1, Q_2, Q_3, Q_4, Q_5, Q_6\}$ where scheduler X moves stochastically over these in different quantum. Predefined initial selection probabilities of states are:

$P[X^{(0)}=Q_1]=pr_1$

$P[X^{(0)}=Q_2]=pr_2$

$P[X^{(0)}=Q_3]=pr_3$

$P[X^{(0)}=Q_4]=pr_4$

$P[X^{(0)}=Q_5]=pr_5$

$P[X^{(0)}=Q_6]=pr_6$

with $pr_1+pr_2+pr_3+pr_4+pr_5+pr_6=\sum_{i=1}^{6} pr_i = 1$, where pr_5=W.

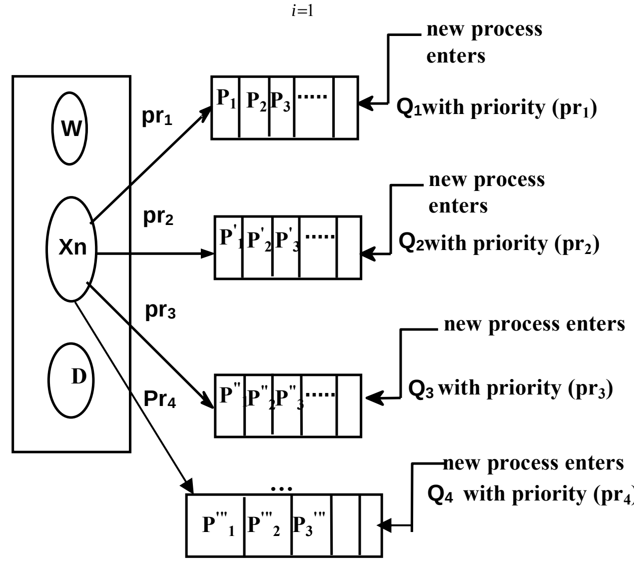

Fig. 2.1 (General Multi-level Queue System Diagram)

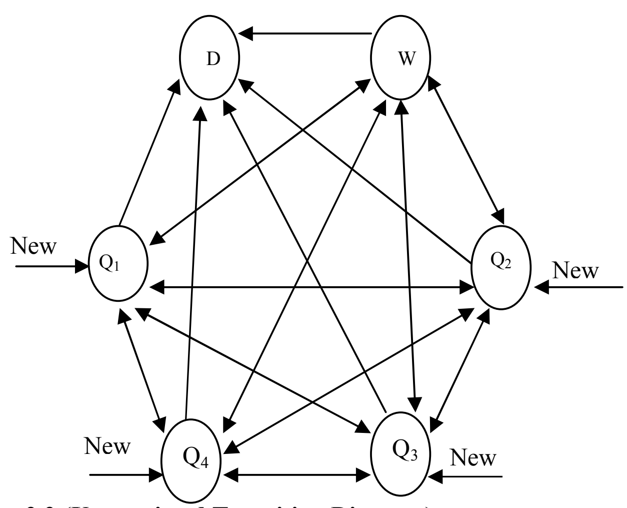

Fig. 2.2 (Unrestricted Transition Diagram)

Let s_{ij}(i,j=1,2,3,4,5,6) be transition probabilities of scheduler over six states then unit-step transition probability matrix for $X^{(n)}$ is

$$s_{ij} = P\left[X^{(n)} = Q_i / X^{(n-1)} = Q_j\right];$$

	$X^{(n)}$					
$X^{(n-1)}$	Q1	Q2	Q3	Q4	Q5	Q6
Q1	s_{11}	s_{12}	s_{13}	s_{14}	s_{15}	s_{16}
Q2	s_{21}	s_{22}	s_{23}	s_{24}	s_{25}	s_{26}
Q3	s_{31}	s_{32}	s_{33}	s_{34}	s_{35}	s_{36}
Q4	s_{41}	s_{42}	s_{43}	s_{44}	s_{45}	s_{46}
Q5	s_{51}	s_{52}	s_{53}	s_{54}	s_{55}	s_{56}
Q6	s_{61}	s_{62}	s_{63}	s_{64}	s_{65}	s_{66}

subject to condition $s_{16} = \left(1-\sum_{i=1}^{6} s_{1i}\right)$,

$$s_{26} = \left(1-\sum_{i=1}^{6} s_{2i}\right), s_{36} = \left(1-\sum_{i=1}^{6} s_{3i}\right),$$

$$s_{46} = \left(1-\sum_{i=1}^{6} s_{4i}\right), s_{56} = \left(1-\sum_{i=1}^{6} s_{5i}\right),$$

$$s_{66} = \left(1-\sum_{i=1}^{6} s_{5i}\right) \text{ and } 0 \le s_{ij} \le 1 .$$

The state probabilities, after first quantum can be obtained by a simple relationship:

$$\begin{aligned} P[X^{(1)}=Q_1] = {} & p[X^{(0)}=Q_1].p[X^{(1)}=Q_1/X^{(0)}=Q_1]+p[X^{(0)}=Q_2].p[X^{(1)}=Q_1/X^{(0)}=Q_2] \\ & +p[X^{(0)}=Q_3].p[X^{(1)}=Q_1/X^{(0)}=Q_3]+p[X^{(0)}=Q_4].p[X^{(1)}=Q_1/X^{(0)}=Q_4] \\ & +p[X^{(0)}=Q_5].p[X^{(1)}=Q_1/X^{(0)}=Q_5]+p[X^{(0)}=Q_6].p[X^{(1)}=Q_1/X^{(0)}=Q_6] \end{aligned}$$

$$= \sum_{i=1}^{6} pr_i s_{i1}$$

$$P[X^{(1)}=Q_2] = \sum_{i=1}^{6} pr_i s_{i2}$$

$$P[X^{(1)}=Q_3] = \sum_{i=1}^{6} pr_i s_{i3}$$

$$P[X^{(1)}=Q_4] = \sum_{i=1}^{6} pr_i s_{i4}$$

$$P[X^{(1)}=Q_4] = \sum_{i=1}^{6} pr_i s_{i4}$$

$$P[X^{(1)}=Q_6] = \sum_{i=1}^{6} pr_i s_{i6}$$

Similarly, the state probabilities after the second quantum could be obtained by simple relationship

$$\left.\begin{aligned} P[X^{(2)}=Q_1] &= \sum_{j=1}^{6}(\sum_{i=1}^{6} pr_i s_{ij})s_{j1} \\ P[X^{(2)}=Q_2] &= \sum_{j=1}^{6}(\sum_{i=1}^{6} pr_i s_{ij})s_{j2} \\ P[X^{(2)}=Q_3] &= \sum_{j=1}^{6}(\sum_{i=1}^{6} pr_i s_{ij})s_{j3} \\ P[X^{(2)}=Q_4] &= \sum_{j=1}^{6}(\sum_{i=1}^{6} pr_i s_{ij})s_{j4} \\ P[X^{(2)}=Q_5] &= \sum_{j=1}^{6}(\sum_{i=1}^{6} pr_i s_{ij})s_{j5} \\ P[X^{(2)}=Q_6] &= \sum_{j=1}^{6}(\sum_{i=1}^{6} pr_i s_{ij})s_{j6} \end{aligned}\right]$$

Remark 2.1 In the similar way, for n quantum, the generalized expressions are: …(2.2.1)

$$\left.\begin{aligned} P[X^{(n)}=Q_1] &= \sum_{m=1}^{6}....\sum_{t=1}^{6}\sum_{k=1}^{6}\left\{\sum_{j=1}^{6}\left(\sum_{i=1}^{6} pr_i s_{ij}\right)s_{jk}\right\}s_{kt}....s_{m1} \\ P[X^{(n)}=Q_2] &= \sum_{m=1}^{6}....\sum_{t=1}^{6}\sum_{k=1}^{6}\left\{\sum_{j=1}^{6}\left(\sum_{i=1}^{6} pr_i s_{ij}\right)s_{jk}\right\}s_{kt}....s_{m2} \\ P[X^{(n)}=Q_3] &= \sum_{m=1}^{6}....\sum_{t=1}^{6}\sum_{k=1}^{6}\left\{\sum_{j=1}^{6}\left(\sum_{i=1}^{6} pr_i s_{ij}\right)s_{jk}\right\}s_{kt}....s_{m3} \\ P[X^{(n)}=Q_4] &= \sum_{m=1}^{6}....\sum_{t=1}^{6}\sum_{k=1}^{6}\left\{\sum_{j=1}^{6}\left(\sum_{i=1}^{6} pr_i s_{ij}\right)s_{jk}\right\}s_{kt}....s_{m4} \\ P[X^{(n)}=Q_5] &= \sum_{m=1}^{6}....\sum_{t=1}^{6}\sum_{k=1}^{6}\left\{\sum_{j=1}^{6}\left(\sum_{i=1}^{6} pr_i s_{ij}\right)s_{jk}\right\}s_{kt}....s_{m5} \\ P[X^{(n)}=Q_6] &= \sum_{m=1}^{6}....\sum_{t=1}^{6}\sum_{k=1}^{6}\left\{\sum_{j=1}^{6}\left(\sum_{i=1}^{6} pr_i s_{ij}\right)s_{jk}\right\}s_{kt}....s_{m6} \end{aligned}\right]$$

3. Mathematical Data Model

The basic and scientific approach for data analysis relates to state transition probabilities managed through a linear data model with two parameters α and d. The i stands for queue numbers and the descriptions are given below:

	$X^{(n)}$					
$X^{(n-1)}$	Q1	Q2	Q3	Q4	Q5	Q6
Q1	α	α +d.i	α +2d.i	α +3d.i	α +4d.i	1-(5 α +10d.i)
Q2	α+d.i	α +2d.i	α +3d.i	α +4d.i	α +5d.i	1-(5 α +15d.i)
Q3	α+2d.i	α +3d.i	α +4d.i	α +5d.i	α +6d.i	1-(5 α +20d.i)
Q4	α+3d.i	α +4d.i	α +5d.i	α +6d.i	α +7d.i	1-(5 α +25d.i)
Q5	α+4d.i	α +5d.i	α +6d.i	α +7d.i	α +8d.i	1-(5 α +30d.i)
Q6	α+5d.i	α +6d.i	α +7d.i	α +8d.i	α +9d.i	1-(5 α +35d.i)

Fig 3.1 (Model matrix)

4. Graphical Analysis on Data Model

Case I with α=0.1

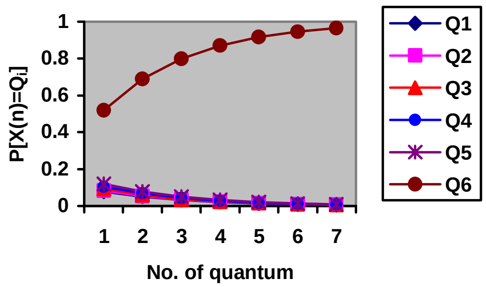

Fig. 4.1.1 (α=0.1, d=0.002)

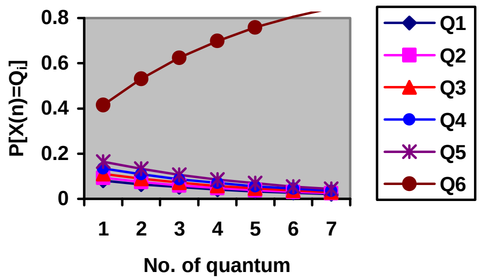

Fig. 4.1.2 (α=0.1, d=0.004)

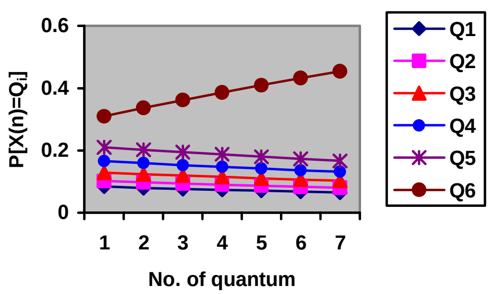

Fig. 4.1.3 (α=0.1, d=0.006)

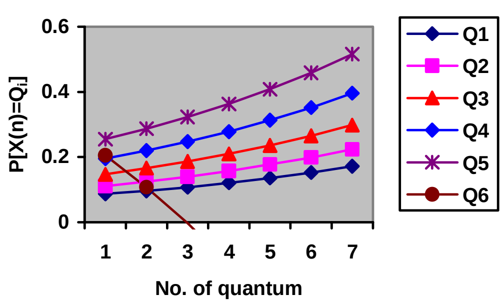

Fig. 4.1.4 (α=0.1, d=0.008)

Case II with α=0.12

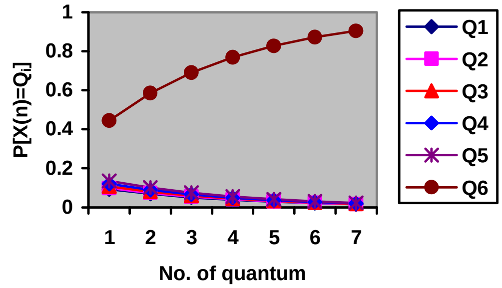

Fig. 4.2.1 (α=0.12, d=0.002)

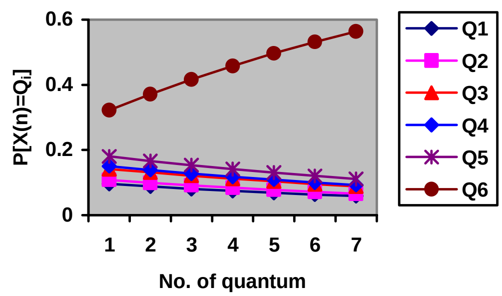

Fig. 4.2.2 (α=0.12, d=0.004)

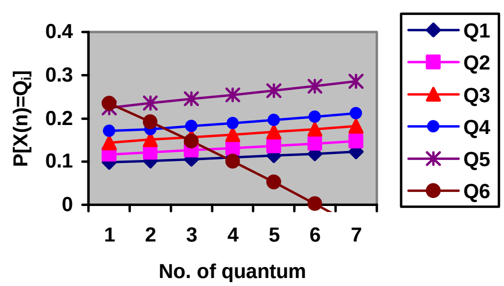

Fig. 4.2.3 (α=0.12, d=0.006)

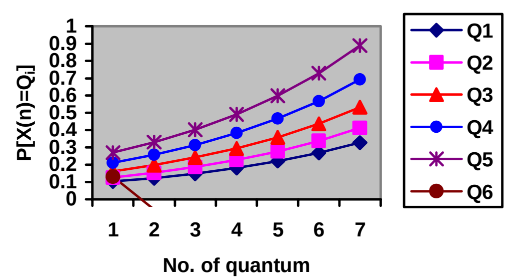

Fig. 4.2.4 (α=0.12, d=0.008)

Case III with α=0.14

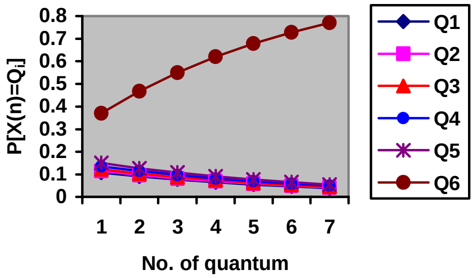

Fig. 4.3.1 (α=0.14, d=0.002)

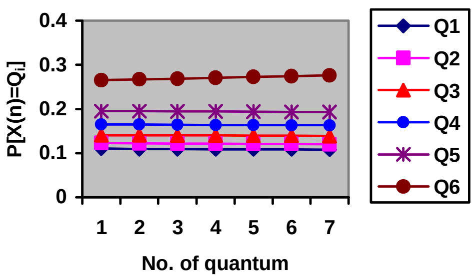

Fig. 4.3.2 (α=0.14 , d=0.004)

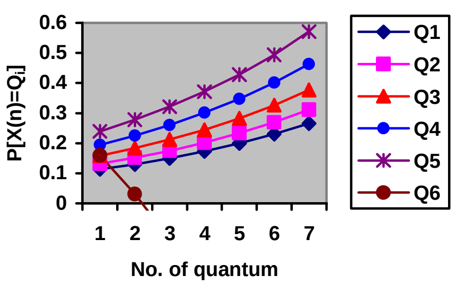

Fig. 4.3.3 (α=0.14 , d=0.006)

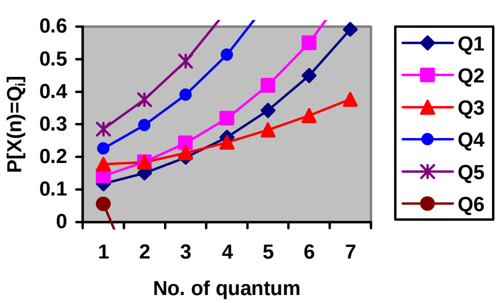

Fig. 4.3.4 (α=0.14 , d=0.008)

Case IV with α=0.16

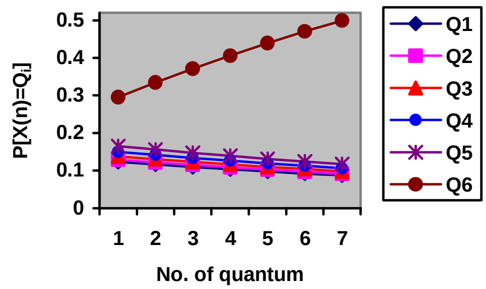

Fig. 4.4.1 (α=0.16,d=0.002)

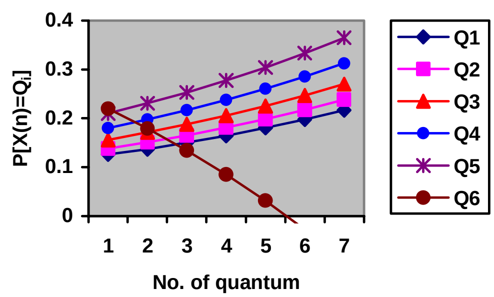

Fig. 4.4.2 (α=0.16,d=0.004)

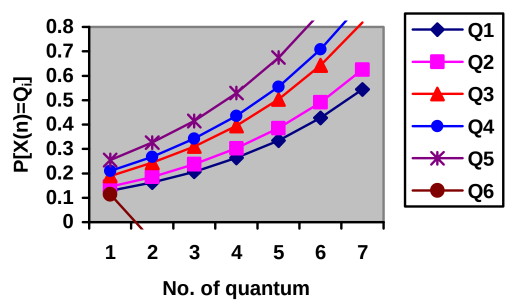

Fig. 4.4.3 (α=0.16,d=0.006)

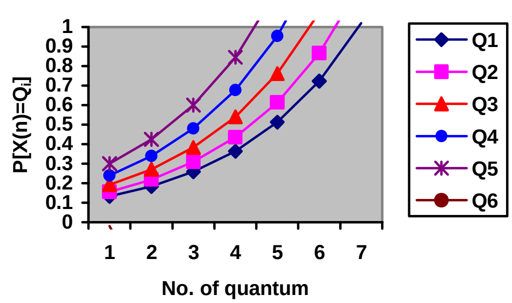

Fig.4.4.4 (α=0.16,d=0.008)

Case V with α=0.18

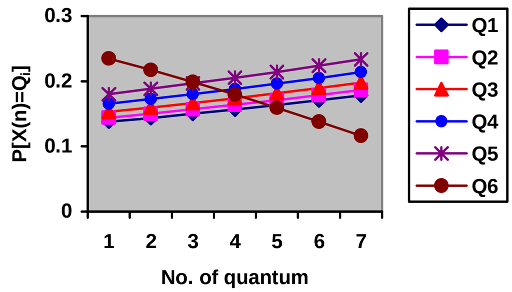

Fig. 4.5.1 (α=0.18, d=0.002)

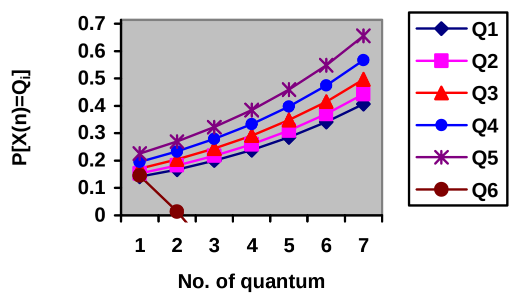

Fig. 4.5.2 (α=0.18, d=0.004)

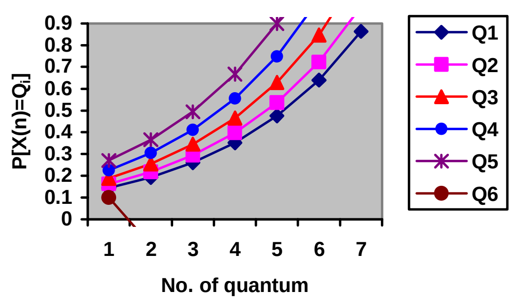

Fig. 4.5.3 (α=0.18, d=0.006)

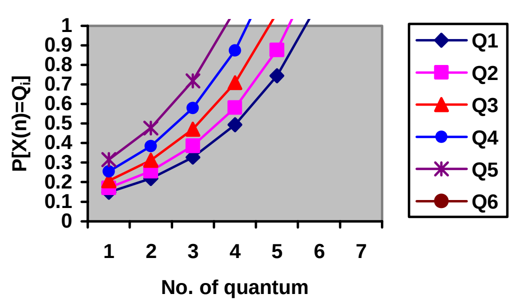

Fig. 4.5.4 (α=0.18, d=0.008)

5. Discussion on Graphs

For case I

With α=0.1 and d varying from 0.002 to 0.008 with an interval of 0.002 at each steps, we find that the initial chance of Q_6 being entertained by the processor is very high, which correspondingly decreases with increasing values of d. A remarkable drop noticed in the processing probability of Q_6 when d reaches to the value of 0.008.

For case II

With α=0.12 and d within the model in the same steps of 0.002 in the range of 0.002 to 0.008, the difference between the processing chances of queues Q_1,Q_2,Q_3 and Q_4 and that of Q_6 is decreasing. Secondly, the drop in processing probability of Q_6 is noticed but at a step earlier to the previous one.

For case III

The noticeable difference in combinations of α and d is seen in the graphs where all the queues are showing a stable pattern of being processed.

For case IV

The drop in the processing probability of Q_6 again moves one step ahead and attained at d=0.004.

For case V

This case all together eliminates the chance of Q_6 being processed at the earliest stage of d=0.002 itself.

6. Waiting Index Analysis

For the state $Q_6=D$, a deadlock index $[I^{(n)}]$ is defined below:

$$[I^{(n)}]_{case} = P[x^{(n)}=Q_5] / [P[x^{(n)}=Q_5] + P[x^{(n)}=Q_6]]$$

where 'case' denotes different conditions of varying values of α and d.[case= I, II, III and IV].

The above equation is a relative measure of scheduler probability towards chances of system being at the deadlock state. The Q_5 $(=W)$ is like an idle state when no process in the queue left or otherwise and Q_6 $(=D)$ is an absorbing state where deadlock of system occurs. Waiting index measures the intensity of chance towards waiting transition faced by the scheduler under specified α and d. As special, if $P[x^{(n)}=Q_5]=0$ then $[I^{(n)}]_{case}=1$ which shows the scheduling scheme highly suffers from waiting possibility. If $P[x^{(n)}=Q_5]=0$ then $[I^{(n)}]_{case}=0$ reveals the high efficiency because the scheme is independent of the waiting fear. Therefore, $0 \le \left[I^{(n)}\right]_{case} \le 1$ and $P[x^{(n)}=Q_5]=1/2$ provides index $[I^{(n)}]_{case}=1/2$. The $0 \le \left[I^{(n)}\right]_{case} \le 1/2$ is the lower zone of index measure while $1/2 < \left[I^{(n)}\right]_{case} \le 1$ is the upper zone as shown in fig 6.1.The lower zone reflects for better possible operation and efficiency of scheduling scheme.

6.1 Calculation of Waiting Index Measure

With reference to data obtained from computation under the effect of the data model with varying values of α and d , the calculation of waiting Index is performed . By a comparative study of these different cases described here, conclusion has been drawn about the efficiency of the system under the described conditions.

This waiting index provides an intuitive view of the fact that how the system behaves in the varying specified conditions.

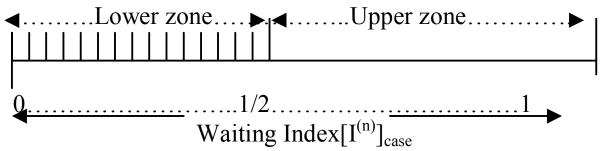

Fig 6.1

Index graph for case I

On the basis of the above obtained values, a waiting index graph is drawn to conclude the result

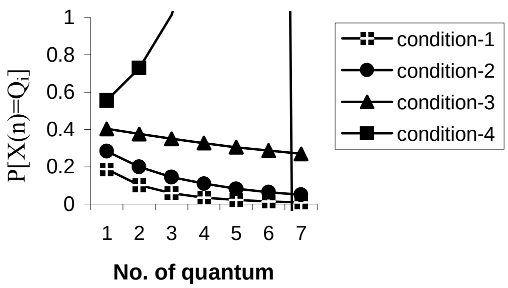

Fig. 6.1.1

Index graph for case II

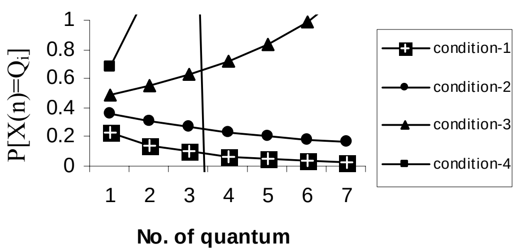

Fig. 6.1.2

Index graph for case III

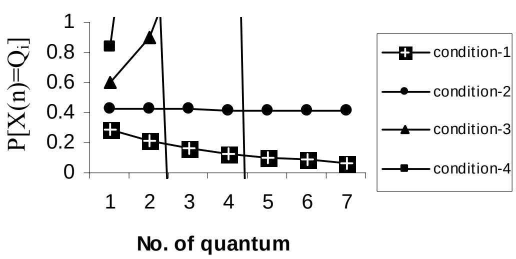

Fig 6.1.3

Index graph for case IV

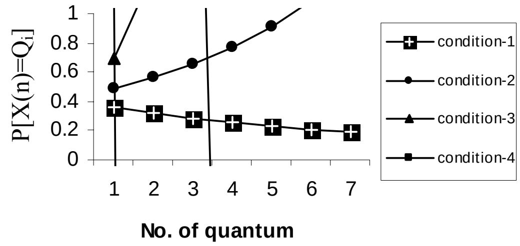

Fig 6.1.4

Index graph for case V

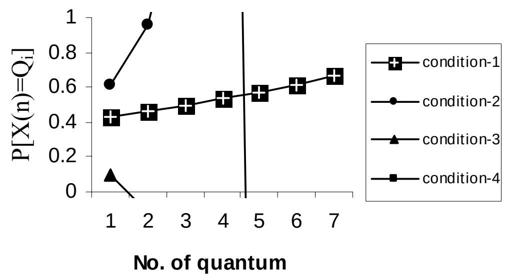

Fig 6.1.5

7. Discussion on Graphs

These index graphs depicts the chances of queues going towards the waiting state. The data model approach clarifies the movement of the queues in specified varying conditions. Here the different cases can be outlined as the different combinations of α and d.

In graph 6.1.1, the condition I is showing a slight decrease with the increasing quantum whereas the condition IV is experiencing initially a steep increase and a sudden drop after some quantum. In graph 6.1.2 the condition I and II are showing similar trend as in graph I whereas the waiting probability in condition III is showing an upward trend. In condition IV the drop can be seen more earlier then the previous conditions. In graph 6.1.3 condition I is showing a similar trend as in graph 6.1.1 and graph 6.1.2 whereas condition II is in steady state . A sudden drop in the waiting probability of condition III and IV can be noticed whereas the waiting probability of condition IV is constantly shifting towards 0. In graph 6.1.4 condition I is similar to the previous graphs but here condition II is also showing an upward trend. The drop in the waiting probability can be seen between the 3^{rd} and 4^{th} quantum. In graph 6.1.5 condition I is finally showing an upward trend. Whereas condition II is showing a drop between 4^{th} and 5^{th} quantum. The condition III is showing a strange negative pattern and 4^{th} condition is out of range for consideration.

8. Conclusion

The multi-level queue scheduling scheme have been reconsidered on the backdrop of the designed data model with five conditions, as members, which are compared using a Markov chain model. In each and every graph, with increasing value of d in the different specified conditions, an increasing trend of waiting probability can be observed. Although this model suggests the fact that the initial combinations of α and d are the better choice as they are showing less chance of system going on waiting state then their higher counterparts. Overall, in the setup of Markov chain model and under waiting index as a performance measure, condition-I is better then condition-II, III and IV under the given assumptions.

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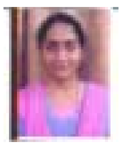
Author's Biography

Dr. Diwakar Shukla is presently working as Associate professor in the Department of Mathematics and Statistics, H.S.Gour University, Sagar, M.P. and having over 21 years experience of teaching to U.G. and P.G. classes. He obtained M.Sc.(stat.), Ph.D.(stat.) degrees from Banaras Hindu University, Varanasi and served the Devi Ahilya University, Indore, M.P. as a permanent Lecturer from 1989 for nine years and obtained the degree of M.Tech.(Computer Science) from there. He joined Dr. H.S.Gour University, Sagar as a Reader in statistics in the year 1998. During Ph.D. from BHU, he was junior and senior research fellow of CSIR, New Delhi through Fellowship Examination (NET) of 1983. Till now, he has published more than 75 research papers in national and international journals and participated in more than 35 seminars/conferences at the national level. He also worked as a Professor in the Lucknow University, Lucknow, U.P., for one (from June, 2007 to 2008) year and visited abroad to Sydney (Australia) and Shanghai (China) for conference participation and paper presentation. He has supervised eight Ph.D. theses in Statistics and Computer Science and six students are presently enrolled for their doctoral degree under his supervision. He is author of two books. He is member of 11 learned bodies of Statistics and Computer

Science at the national level. The area of research he works for are Sampling Theory, Graph Theory, Stochastic Modeling, Data mining, Operation Research, Computer Network and Operating Systems.

Dr. Saurabh Jain has completed M.C.A. degree from Dr. H.S. Gour University, Sagar in 2005. He is presently working as a Lecturer in the Department of Comp. Science & Applications in the same University since 2007. His teaching experience is over 5 years. He did his research in the field of process scheduling modeling in Operating system. In this field, he has authored and co-authored 16 research papers in National/International journals and proceedings. His current research interest is to analyze the scheduler's performance under various algorithms and probability models.



Mrs. Shweta Ojha received her M.C.A. degree from Dr. H.S. Gour University, Sagar in 2005. She is presently working as a Lecturer in the Department of Computer Science & Applications in the same University teaching to U.G. and P.G. classes both. She has a teaching experience of above 5 years. Her research interest is to analyze the scheduler's performance under various algorithms. She has 8 research papers published in National/International journals and Conference proceedings. She is pursuing her Ph.D. work in the same university from two years.