Ready Queue Mean Time Estimation in Lottery Scheduling using Auxiliary Variables in Multiprocessor Environment

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ABSTRACT

The ready queue estimation problem appears when many processes remain in the ready queue after the sudden failure. The system manager has to decide immediately how much further time is required to process all the remaining jobs in the ready queue. In lottery scheduling, this prediction is possible with the help of sampling techniques. To strengthen the prediction methodology, the auxiliary source of data is often utilized. This paper considers the three additional data sources as (i) process size (ii) process priority and (iii) process expected time. The Ratio method, existing in sampling literature, is used to predict the time required for remaining jobs after failure. A comparative study between different auxiliary sources has been made. It is found that highly correlated source of auxiliary information provides better processing time prediction.

Keywords: Scheduling, Ratio Estimator, Bias, Variance, Confidence Interval, Ready Queue, Expected Time (et), Size(s), Priority (p).

1. INTRODUCTION

Suppose there are n processors in multiprocessor and multi-user environment and a large number of processes, say N (N > n), are in the ready queue. Assume the scheduler adopts lottery scheduling to choose randomly any n processes(jobs) from the ready queue and allocates to n processors in the sequential manner. In lottery scheduling, each process is pre-allocated with one (or more) lottery tickets which determine the possibility of that process priority to use the CPU. At each schedule point, a lottery ticket- number is drawn and process in the ready queue with the winning ticket gets the opportunity of CPU utilization. Every job has equal chance of being represented for processing if it has only one pre-allocated ticket. Special feature of Lottery scheduling is that it does not suffer from starvation.

The problem is when N large, the congestion occurs and many processes have to wait until called by lottery manner. During processing through lottery scheduling , if the system fails suddenly due to unavoidable reasons, the system manager has to arrange backup provisions(or recovery) immediately . His problem, at this juncture, is to know how much probable time is required to finish up the remaining processes in queue? This prediction is an uncertain evaluation and needs theoretical probability plus sampling mechanism both to resolve the issue. This paper takes into account same problem and presents a method for predicting the processing time interval.

Shukla and Jain [16] picked up multiprocessor environment with usual lottery scheduling and discussed a procedure to obtain ready queue remaining time estimate. Shukla et al. [14] suggested systematic lottery scheduling scheme to improve upon the prediction of ready queue processing time. Shukla et al. [15] recommended similar when processes are grouped according to specific criteria in different queues and obtained well-predicted confidence intervals. Shukla et al. [17] introduced process-size based priority scheme for the ready queue remaining time length prediction and proved better than usual lottery scheduling prediction.

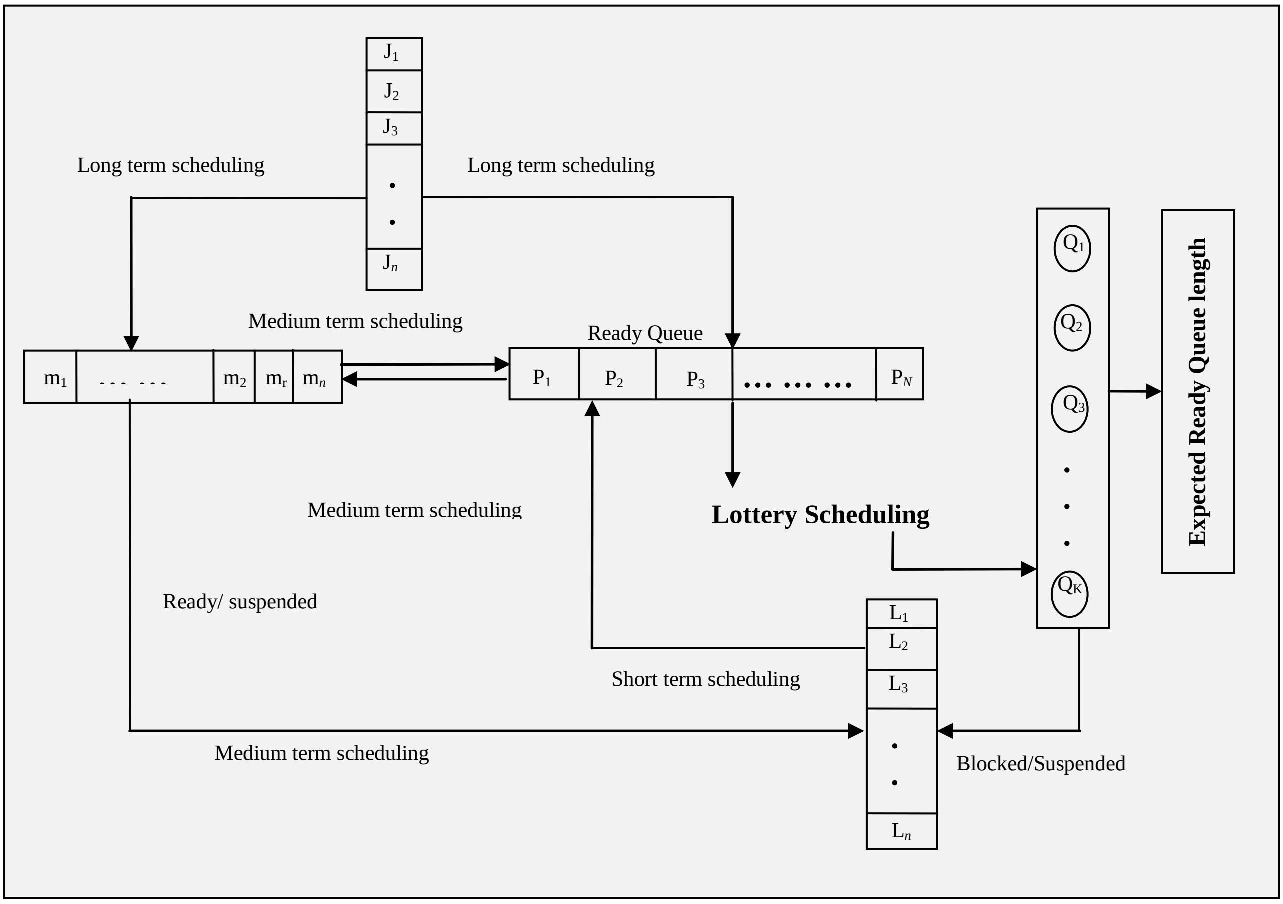
This paper suggests incorporating the auxiliary sources of information related to waiting processes in the ready queue like process size, response time, pre-set priority etc. for the efficient time interval prediction

2. A REVIEW

Cochran [3] contains basics of sampling methods with applications on multiple data. David [7] extended lottery scheduling by a proportional share resource management algorithm to provide the better performance assurance. He introduced dynamic tickets in lottery scheduler to improve the interactive response time and to reduce kernel lock contention. Raz et al. [9] presented a procedure of deciding priorities among jobs maintaining fairness in the selection procedure. Shukla and Jain [4] ,[12] suggested for the Markov chain based study for the behavior of scheduler in the multilevel queue scheduling. Shukla and Jain [5],[6] described procedures of analysis for the Thread scheduling and the Deficit Round Robin Alternated (DRRA) scheduling using the Markov Chain Model. Shukla and Ojha [13] performed an analysis for the multilevel queue scheduling with the special effect of data model. Waldspurger [1],[2] proposed lottery scheduling ticket/currency framework that can be accommodated with scheduling mechanism. He discussed the proportional share resource management technique useful for lottery scheduling. Yiping [22],[23] develop a queuing theory model to predict system behavior and CPU queue length in Microsoft NT , Windows 2000 and devised fair share scheduling which guarantees the application performance by allocating the share of system resources among competing workloads. Some other useful similar contributions are [8], [10], [11], [18], [19], [20], [21].

3. MOTIVATION

It is common believe that more input information provide better prediction subject to condition if information are relevant and related. If a large number of processes are in ready queue then to predict for possible CPU utilization time, additional sources of correlated information may reduce the length of computed time interval. Using motivation with this thought and using estimation technique of sampling theory with auxiliary information, this paper suggests a new useful approach and compares with Shukla, Jain and Chowhary [16].



4. PROCESSOR STRUCTURE AND NOTATIONS

Let $Q_1, Q_2, Q_3 .... Q_k$ be k processors who take intake from the ready queue containing $P_1, P_2, P_3 .... P_N$ processes (n<N). Processes are related to long, medium and short term scheduling queues all transferring to ready queue. When a process remains blocked/suspended, they are back to respective queue. The Figure 1 shows the diagram of scheduling process structure with k processors.

Let Y_i be the CPU burst time of each process and X_{1i}, X_{2i}, X_{3i} are three auxiliary variables like size of process, process priority and processes expected time(time interval between arrival time and processor entering time also called response time) respectively. The mean entire ready queue CPU burst time(Y) of N processes along with auxiliary characters (X_1, X_2, X_3) in the ready queue is:

$$\bar{Y} = \frac{1}{N} \sum_{i=1}^{N} Y_i$$

$$\bar{X}_1 = \frac{1}{N} \sum_{i=1}^{N} X_{1i}$$

$$\bar{X}_2 = \frac{1}{N} \sum_{i=1}^{N} X_{2i}$$

$$\bar{X}_3 = \frac{1}{N} \sum_{i=1}^{N} X_{3i}$$

4.1 MODIFIED MULTIPROCESSOR LOTTERY SCHEDULING [As Shukla, Jain and Choduary [16])

Step i When a process enters into ready queue, it is allotted a random number (in specified range).

Step ii **E**ach processor $Q_1, Q_2, Q_3 .... Q_K$ generates unique and uncommon random number in similar specified range stated in Step I.

Step iii Matching of both random numbers takes place between process and processor. If both random numbers are same for a process in ready queue, it is assigned that processor.

Step iv Processor either blocks or processes the job. It selects another process in random manner.

Step v After when one job processed completely or partially processors generate time consumed by it in processing

as y_i (time by j^{th} processor) where $\left(j = 1,2,3 ...... k\right)$.

Step vi Corresponding to time consumed by n processes as $y_1, y_2, y_3 \ldots\ldots y_n$ there are auxiliary variables X_1, X_2, X_3 in the form $(x_{11}, x_{12}, x_{13} \ldots\ldots x_{1n})$; $(x_{21}, x_{22}, x_{23} \ldots\ldots x_{2n})$; $(x_{31}, x_{32}, x_{33} \ldots\ldots x_{3n})$ respectively.

5. ESTIMATION OF READY QUEUE PROCESSING TIME (as per [16])

Suppose $P_1, P_2, P_3 \ldots\ldots P_N$ processes present in the ready queue of size N and until breakdown occurs, n processes (n<N) have already processed in random manner through lottery scheduling by k processors. Each Processor generates time-consumed by i[th] during processing as y_i. The corresponding auxiliary variable source value is x_i. Now, we have some basic results discussed below used for prediction purpose. The ratios estimates of the population total Y, the population mean, $\bar{Y}$ and the population ratio $\frac{Y}{X}$ are, respectively $\hat{Y}_R = \frac{\bar{y}}{\bar{x}} X$, $\hat{\bar{Y}}_R = \frac{\bar{y}}{\bar{x}} \bar{X}$, $\hat{R} = \frac{\bar{y}}{\bar{x}}$.

In a simple random sample of size n (n large) variances of these estimates are

$$V(\hat{Y}_R) = \frac{N^2(1-f)}{n}\left[\frac{\sum_{i=1}^{N}(y_i - Rx_i)^2}{N-1}\right] \quad (1)$$

$$V(\hat{\bar{Y}}_R) = \frac{1-f}{n}\left[\frac{\sum_{i=1}^{N}(y_i - Rx_i)^2}{N-1}\right] \quad (2)$$

$$V(\hat{R}) = \frac{1-f}{n\bar{X}^2}\left[\frac{\sum_{i=1}^{N}(y_i - Rx_i)^2}{N-1}\right] \quad (3)$$

Where f=n/N is the sampling fraction. So for a sample of processes variance is

$$v(\hat{Y}_R) = \frac{1-n/N}{n\bar{x}^2}\left[\frac{\sum_{i=1}^{n}(y_i - Rx_i)^2}{n-1}\right] \quad (4)$$

$$v(\hat{Y}_R) = \frac{N-n}{nN}\frac{1}{\bar{x}^2}\frac{\sum_{i=1}^{n}(y_i - Rx_i)^2}{n-1} \quad (5)$$

$$\hat{\bar{Y}}_R = \bar{X}\hat{R}, \hat{Y}_R = N\bar{X}\hat{R}$$

We get

$$V(\hat{Y}_R) = \frac{N^2(1-f)}{n(N-1)}\sum_{i=1}^{N}\left[(y_i - \bar{Y}) - R(x_i - \bar{X})\right]^2 \quad (6)$$

$$= \frac{N^2(1-f)}{n(N-1)}\left[\sum(y_i - \bar{Y})^2 + R^2\sum(x_i - \bar{X})^2 - 2R\sum(y_i - \bar{Y})(x_i - \bar{X})\right] \quad (7)$$

This leads to result (using Appendix –A)

$$V(\hat{Y}_R) = \frac{N^2(1-f)}{n}\left(S_y^{\,2} + R^2 S_x^{\,2} - 2R\rho S_y S_x\right) \quad (8)$$

An equivalent form is

$$V(\hat{Y}_R) = (1-f)\frac{Y^2}{n}\left(\frac{S_y^{\,2}}{\bar{Y}^2} + \frac{S_x^{\,2}}{\bar{X}^2} - \frac{2S_yS_x}{\bar{Y}\bar{X}}\right) \quad (9)$$

Where is $S_{yx}=\rho S_y S_x$ the covariance between y_i and x_i. This relation may also be written as

$$V(\hat{Y}_R) = (1-f)\frac{Y^2}{n}\left(C_{yy} + C_{xx} - 2C_{yx}\right) \quad (10)$$

Where C_{yy}, C_{xx} are the square of the coefficients of variation *(cv)* of y_i and x_i respectively and c_{xy} is the relative covariance. Since $\hat{Y}_R$ $\hat{\bar{Y}}_R$ and $\hat{R}$ differ only by known multipliers, the coefficient of variation (i.e., the standard error divided by the quantity being estimated) is the same for all three estimates. From the square of this (cv) is

$$(cv)^2 = \frac{V(\hat{Y}_R)}{Y^2} = \frac{1-f}{n}\left(C_{YY} + C_{xx} - 2C_{yx}\right) \quad (11)$$

The quantity $(cv)^2$ has been has been called the relative variance. Its use avoids repetition of variance formulas for related quantities like the estimated population total and mean.

5.1 ESTIMATION OF THE VARIANCE FROM A SAMPLE

From equation (1) we get estimation of the variance from a sample as a sample estimate of variance.

For the estimated variance, this gives

$$v(\hat{Y}_R)=\frac{N^2(1-f)}{n(n-1)}\sum_{i=1}^{n}(y_i-\hat{R}x_i)^2 \quad (12)$$

$$v(\hat{Y}_R)=\frac{N^2(1-f)}{n(n-1)}\left(\sum y_i^2+\hat{R}^2\sum x_i^2-2\sum y_i x_i\right) \quad (13)$$

$$=\frac{N^2(1-f)}{n}\left(s_y{}^2+\hat{R}^2 s_x{}^2-2\hat{R}s_{yx}\right) \quad (14)$$

$$s_{yx}=\sum(y_i-\bar{y})(x_i-\bar{x})/(n-1) \quad (15)$$

is sample covariance between y_i and x_i.

The Confidence Interval are:

$$Y:\hat{Y}_R\pm z\sqrt{v(\hat{Y}_R)}$$

$$R:\hat{R}\pm z\sqrt{v(\hat{R})}$$

Where

$$z=\frac{\bar{y}-R\bar{x}}{\sqrt{[(N-n)/Nn]}\sqrt{S_y^2+R^2S_x^2-2RS_{yx}}}$$

6. NUMERICAL DATA

Consider 30 processes in ready queue at a time whose size measure X_1 is given in terms of bytes, priority X_2 and arrival time X_3 in second's are given. If we assume that all the processes are processed completely in the ready queue, the CPU burst time Y is mentioned against them.

Table 1: Incoming processes parameters and auxiliary information in ready queue

Process ID	Size Parameter (X_1)	Expected Time(sec) (X_2)	Process Priorities (X_3)	CPU Burst Time (Y_i)
1	210	45	2	30
2	897	07	9	20
3	312	16	7	112
4	171	34	2	40
5	461	56	8	59
6	290	22	2	60
7	379	43	1	30
8	220	33	0	43
9	470	50	1	101
10	636	49	4	69
11	455	55	9	138
12	682	10	6	43
13	952	03	3	109
14	574	29	4	26
15	536	30	3	74
16	416	02	3	89
17	788	5	1	123
18	902	49	7	67
19	623	46	8	58
20	563	26	6	84
21	111	37	9	143
22	341	20	3	29
23	775	51	9	147
24	913	27	4	94
25	745	13	9	131
26	130	19	9	79
27	877	8	9	46
28	927	58	3	59
29	424	31	8	72
30	356	60	4	22

Table 2: Processes parameters in ready queue

Processes Parameters	Sampled Processes I					Sampled Processes II				
Processes	P_9	P_{18}	P_{30}	P_{24}	P_{13}	P_{20}	P_{27}	P_{11}	P_1	P_{22}
CPU Burst Time Y_i	101	67	22	94	109	84	40	138	30	29
Processes Size X_1	470	902	356	913	952	563	171	455	210	341
Expected Time X_2	50	49	60	27	03	26	34	55	45	20
Priorities X_3	01	07	04	04	03	05	02	05	02	02

Table 3: Processes parameters in ready queue

Processes Parameters	Sampled Processes III					Sampled Processes IV				
Processes	P_{15}	P_{23}	P_5	P_{10}	P_{29}	P_{30}	P_6	P_{17}	P_{25}	P_{15}
CPU Burst Time Y_i	74	147	59	69	72	22	60	123	131	74
Processes Size X_1	536	775	461	636	424	356	290	788	745	536
Expected Time X_2	30	51	56	49	31	60	22	05	13	30
Priorities X_3	03	09	05	04	08	04	02	01	09	03

Table 4: Processes parameters in ready queue

Sampled Processes	Sampled Process (k=5)	$\sum X_s$	$\sum X_{et}$	$\sum X_p$	$\sum Y_{pt}$	$\hat{R}_s$	$\hat{R}_{et}$	$\hat{R}_p$
1.	$P_9, P_{18}, P_{30}, P_{24}, P_{13}$	3593	189	19	393	0.1093	2.07	20.68
2.	$P_{20}, P_{27}, P_{11}, P_1, P_{22}$	2446	72	16	321	0.1844	1.78	20.06
3.	$P_{15}, P_{23}, P_5, P_{10}, P_{29}$	2832	217	29	421	0.1486	1.94	14.51
4.	$P_{30}, P_6, P_{17}, P_{25}, P_{15}$	2715	130	19	410	0.1510	3.15	21.57

Table 5: Confidence Intervals with three auxiliary sources of information

Sampled Processes	$\hat{\hat{Y}}_{pt}$	Confidence Intervals In case I X_1:Size	Confidence Intervals In case II X_2:Expected Time	Confidence Intervals In case III X_3:Priority
1.	72.16	(0-226.70)	(0-448.76)	(0-405.29)
2.	75.04	(0-223.80)	(0-275.29)	(0-250.21)
3.	71.04	0-187.91)	(0-267.70)	(0-225.12)
4.	71.48	(0-180.32)	(0-608.34)	(0-411.03)

The Confidence Interval computation is:

$$P\left[\hat{\hat{Y}} \pm 19.6\sqrt{v\left(\hat{\hat{Y}}\right)/n^2}\right].$$

7. CONCLUSION

From above analysis it is clear that auxiliary variables play important role in the prediction of remaining processing time of ready queue. The length of confidence interval gets reduced if the auxiliary variables are selected and used in proper manner. Basically, any selected auxiliary variable may not provide the significant effect in time-length prediction. The variable which has higher correlation with the main variable (time) plays vital role and hence generates the lowest length confidence intervals in the setup of lottery scheduling. The suggested methodology is effective and efficient in predicting the queue processing remaining time if the sudden failure occurs in the job processing system.

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9. Appendix

The correlation coefficient

$$\rho = \frac{E\left(y_i - \overline{Y}\right)\left(x_i - \overline{X}\right)}{\sqrt{E\left(y_i - \overline{Y}\right)^2 E\left(x_i - \overline{X}\right)^2}} = \frac{\sum^{N}\left(y_i - \overline{Y}\right)\left(x_i - \overline{X}\right)}{(N-1)S_y S_x}$$