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Response Time Analysis for Computer Database Reorganisation with Concurrent Usage and Changeover State

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ABSTRACT

An online information system may require reorganisation after continuous usage for sometime. In this paper the performance of a database is modelled when reorganisation is performed concurrently with usage in an essentially computer utility environment. A two priority queueing model is considered with activity by users having higher priority and database reorganisation having low priority. In the absence of any user the system goes to changeover state for an arbitrary length of time and if a user arrives, it immediately attends to it otherwise it takes up reorganisation service. Steady-state equations for the model have been solved and the variations in response time are predicted quantitatively through numerical results.

1. INTRODUCTION

A database is a collection of data that can be used for different applications in a computer system. The internal storage structure of database gets disturbed with the passage of time when it is constantly being used. This may either happen due to sudden power failure when database is under use or due to cropping of some bad spot on disk surface because of environmental changes. This affects the performance of a database with respect to user response time. User accesses the database through application programs/query programs and the system takes more time in retrieving the same amount of information from database now. Thus there is a need to reorganise the database after a certain period of time. During reorganisation process each block of data is read and written again. Thus the internal storage structure of database is brought back to initial optimal state (i.e., mismatched file pointers, if any, are removed).

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The reorganisation is normally done offline, i.e., the users of database cannot access it for some time. This strategy is not acceptable where a large database of national importance is involved and the computer facility can not be shut down even for a few hours. In such cases reorganisation has to be planned alongwith the active users.

Models where reorganisation is done offline have been studied[1-3] but very little work is available about the concurrent reorganisation with the usage. Sockut[4] has made some studies in this direction. He has studied this phenomenon in one of his models[5] (this model will be referred hereafter as Model 1) with the help of queueing approach where activity by users has a higher priority. A changeover state has been introduced in this model with a view that after the user service has been completed, the system waits for an arbitrary length of time before starting the reorganisation. If a user's request arrives when the system is in changeover state, pre-emption takes place and the user is serviced first before database reorganisation service is taken up. This model with changeover state will be referred as Model 2.

2. DISK CHARACTERISTICS

Disk is the principal storage medium of a database. The reorganisation of the database is done in terms of steps and at least one step at a time. One step of reorganisation means reading and writing one block of the data on a certain track of the disk. The following steps are performed when it is desired to read or write a block.

(i) Seeking : The arms are moved so that read/write heads are positioned at the cylinder that contains the track from where the block is read or written. This movement is called seeking. The time required for seeking increases with the distance to move.

(ii) Rotational latency : The read/write head mechanism waits until the block begins to pass under the read/write head. This waiting is called rotational latency, and is half of disk's rotation period.

(iii) Data transfer time : As the block passes under the read/write head, the actual reading or writing is performed. This time is called data transfer time which depends upon the amount of data. In general, all blocks are assumed to be of same length.

(iv) Overhead time : Some overhead time is experienced in this process.

The most common disk has 404 tracks on each of the 19 useable surfaces with mean seek time 26.832 ms, with the rotation period 16.7 ms. There are four blocks on each track. These disk characteristics have been used for computation of the model parameters.

3. THE MODEL

The server in this model is the disk whose service behaviour is taken as an exponential distribution. User requests for service by application programs are the high priority customers which are assumed to arrive as a Poisson process with intensity λ. The mean service rate for the user is μ_u and the first come first service discipline is enforced for servicing. After the completion of user service the system moves to changeover state whose behaviour is governed by an exponential distribution with mean service rate μ_ω. If a user request comes at this state, pre-emption takes place and the user service is attended first.

Reorganisers' requests for reorganisation service are low priority customers. When one reorganisation step is complete, there is the request for the next step. If one or more users arrive, the same are attended after completing the reorganisation step which has already started.

It is assumed that the reorganisation is performed within one cylinder at a time. When a consecutive reorganisation step is performed, the service time is short since consecutive reorganisation steps are usually performed within one cylinder (which requires no seek) before moving to the next cylinder. However, when a user is serviced, the next reorganisers must perform a seek in the opposite direction to return the disk arm to the cylinder where reorganisation had been taking place earlier. For this reason, the first reorganisation service immediately after a user has been served has a service rate μ_s (slow), with a subsequent reorganisation service rate μ_f (fast).

The model is used to describe an environment in which consecutive user requests are uncorrelated with respect to cylinder and to which conventional rotating devices (disks) are used. It is assumed that reorganisation is performed within one cylinder at a time. This assumption is valid for reorganisation in several existing commercial database management systems. Users' reorganisation competition for central processor time is ignored.

4. QUEUEING MODEL

Figure 1 shows the state of queueing system and the transitions between them. Each transition is labelled with the intensity of the associate stochastic process. There are three infinitely long columns of the state. The centre column (A) contains states in which a user is being served. The right column (B) contains states in which the customer is reorganiser but the previous customer was a user. The disk performs slow reorganisation service when it is in the B state. The left column (C) contains states in which the current customer is a reorganiser and the previous customer was a reorganiser. The disk performs fast reorganisation when it is in state C.

Each column of states is indexed by the number of users at the disk including the user being served. For example, in state B_2 the previous customer was a user, a reorganiser is being served now (at the slow rate) and there are two users waiting in the queue; there is no A_0 state. A changeover state w has been introduced such that when there is no user the system goes to changeover state w for an arbitrary length of time and then moves towards reorganisation. If a user arrives during the changeover state, the system pre-empts the present state and starts servicing the user. If no user request arrives during the changeover state, slow reorganisation service starts.

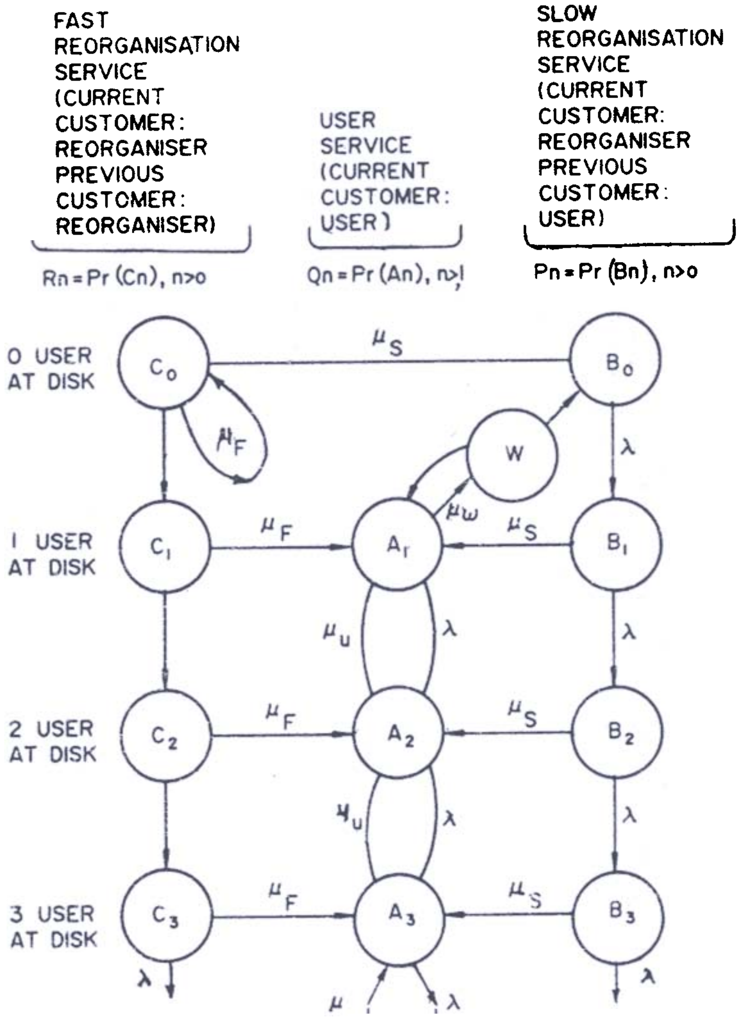

Figure 1 The state transition diagram.

5. SYSTEM OF EQUATIONS

The system of equations governing the conservation of the flow probabilities as shown in Fig. 1 are given below :

$$\frac{d}{dt}P_0(t) = -(\lambda+\mu_s)\,P_0(t)+\mu_u\,W(t) \text{ for } n=0 \tag{1}$$

$$\frac{d}{dt}P_n(t) = -(\lambda+\mu_s)\,P_n(t)+\lambda\,P_{n-1}(t) \text{ for } n>0 \tag{2}$$

$$\frac{d}{dt}Q_1(t) = -(\lambda+\mu_u)\,Q_1(t)+\mu_u\,Q_2(t)+\lambda W(t)+\mu_f R_1(t)+\mu_s P_1(n,t) \text{ for } n=1$$

$$\frac{d}{dt}Q_n(t) = -(\lambda+\mu_u)\,Q_n(t)+\mu_u\,Q_{n-1}(t)+\lambda\,Q_{n-1}(t)+\mu_f R_n(t)+\mu_s\,P_n(t) \text{ for } n>1 \tag{4}$$

$$\frac{d}{dt}R_0(t) = -(\lambda+\mu_f)\,R_0(t)+\mu_f\,R_0(t)+\mu_s P_0(t) \tag{5}$$

$$\frac{d}{dt}R_n(t) = -(\lambda+\mu_f)\,R_n(t)+\lambda R_{n-1}(t) \text{ for } n>0$$

$$\frac{d}{dt}W(t) = (\lambda+\mu_w)\,W(t)+\mu_u\,Q_1(t)$$

Since we are interested in the steady-state distribution, the Eqns. (1)–(7) can be easily solved. The probability that the system is in changeover state is given by

$$W = \frac{\lambda\, \mu_s\mu_f\, (\mu_u - \lambda)\, (\lambda + \mu_s)}{[\lambda\, \mu_f\, (\lambda + \mu_s)\, (\lambda\, \mu_s + \mu_u\mu_w) + \mu_s^2\, \mu_u\mu_w\, (\lambda + \mu_f)} \tag{8}$$

Using Little's formula[6] $L = \lambda W$, the response time of a system is given by the mean queue length of the system/mean arrival rate.

$$R2 \quad \frac{\{\, [\, \mu_s^3\, (\lambda + \mu_f) + \lambda\, \mu_f^2\, (\lambda + \mu_s)\,]\, \mu_u\mu_w + \mu_s^3\, \mu_w\, (\mu_f^2 - \lambda^2) + \lambda\, \mu_f^2\, (\lambda + \mu_s) \qquad (\mu_s^2 - \lambda\, \mu_w + \mu_s\mu_u\mu_w)\, \}}{\mu_s\mu_f\, (\mu_u - \lambda)\, [\lambda\, \mu_f\, (\lambda + \mu_s)\, (\lambda\, \mu_s + \mu_w) + \mu_s^2\, \mu_u\mu_w\, (\lambda + \mu_s)} \tag{9}$$

The response time for Model is given by

$$R1 = \frac{\{\, (\lambda + \mu_f)\, \mu_s^3 + \mu_f^2\, \lambda\, \mu_s + \mu_f^2\, \lambda^2\}\, \mu_u + (\mu_f^2 - \lambda^2)\, \mu_s^3 + \mu_f^2\, \lambda\, \mu_s^2 - \mu_f^2\, \lambda^3}{(\mu_u - \lambda)\, \mu_f\, \mu_s\, \{(\lambda + \mu_f)\, \mu_s^2 + \mu_f\, \lambda\, \mu_s + \mu_f\, \lambda^2\}}$$

The response time in M/M/1 model without concurrent reorganisation is given by

$$RN = 1/(\mu_u - \lambda)$$

6. PARAMETER VALUE

The two parameters that are varied are λ and *NB*. *NB* is the number of blocks that a reorganiser transfers in one reorganisation step. We assume that the user always transfers exactly one block during a disk service. The disk service consists of seek, overhead, rotational latency and data transfer. The mean seek time for user or slow organiser is 26.832 ms. A fast reorganiser's seek time is usually zero. A seek is needed only if the reorganisation has just been completed for one cylinder at which time a seek is required to move to the next cylinder. Since there are four blocks per track and 19 tracks per cylinder and since each block must be read and written once in a complete reorganisation, the total number of blocks that must be transferred to reorganise a complete cylinder is 2×4×19. Since reorganiser performs *NB* of these transfers in each step, the probability that a fast reorganiser must perform a seek is *NB*/(2×4×19). The time to seek one cylinder is 8.0 ms. Thus a fast reorganiser's mean seek time is $(8 \times NB/2 \times 4 \times 19)$ or $NB/19$ ms. The mean overhead time is 0.465 ms. The mean rotational latency is 8.35 ms. The mean data transfer time is 4.175 ms (i.e., for one block) for users and is (4.175) NB for fast or slow reorganisers. Therefore we have :

Mean user service time = 26.832+0.465+8.35+4.175 ms

Mean reorganisation (slow) service time = 26.832+0.465+(4.175)NB ms

Mean reorganisation service time = (NB/19)+0.465+8.35+(4.175) NB ms

We take mean changeover time = mean service time.

6.1 Reorganisation Time

When the reorganisation is performed offline, the expected numbers of steps of reorganisation performed during a period T is $T\mu_f$. Therefore the time for offline reorganisation step is $1/\mu_f$. When reorganisation is performed concurrently with the usage the expected time per concurrent reorganisation step is given by

$$T=1/(\mu_s \sum_{i=0}^{\infty} B_i + \mu_f \sum_{i=0}^{\infty} C_i$$

where B_i and C_i represent the fraction of time spent in B and C states.

7. RESULTS

In order to compare the response time for Model 1 and Model 2 we compute the following parameters by varying λ between 0 and μ_u. NB takes three different values 1, 2 and 4 where 4 is a typical value for offline reorganisation. RN represents normal user response time (with no concurrent reorganisation).

7.1 Model with Concurrent Reorganisation (i.e.. Model 1)

$R1$ – User response time with concurrent reorganisation

$R11$ – Relative degradation of user response time

= (time with concurrent reorganisation – normal response time)/normal response time.

7.2 Model with Concurrent Reorganisation and Changeover State (i.e., Model 2)

$R2$ – User response time with concurrent reorganisation and changeover state

$R22$ – Relative degradation of user response time with concurrent reorganisation and changeover state.

= (time with concurrent reorganisation and changeover state – normal response time)/normal response time.

These parameters have been computed while taking mean changeover time equal to mean service time (slow) in Model 2 and the results are plotted in Figs. 2, 3 and 4.

7.3 Observations from Graphs

Figures 2 and 3 show the variations of user response time with user utilisation for Model 1 and Model 2 for different values of *NB* (= 1, 2 and 4). The bottom curve

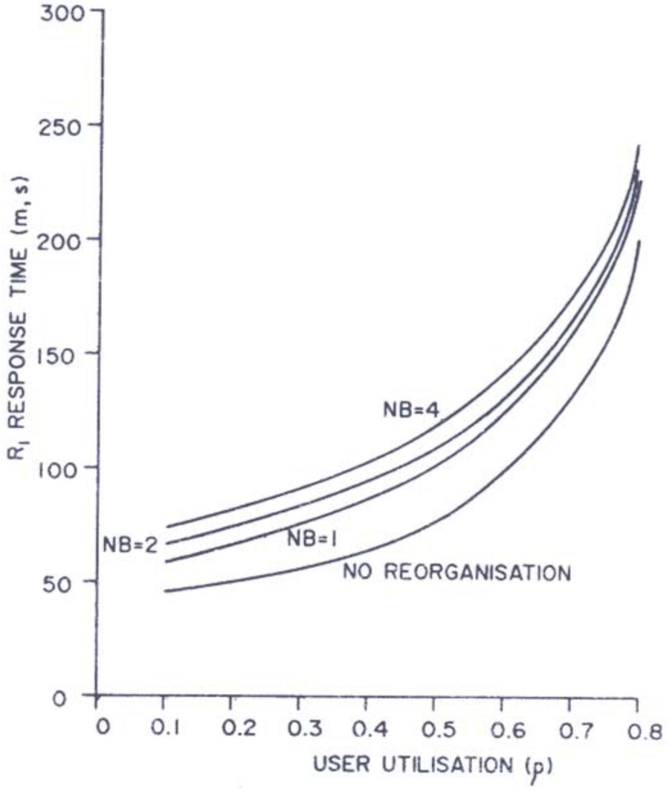

Figure 2. Model 1

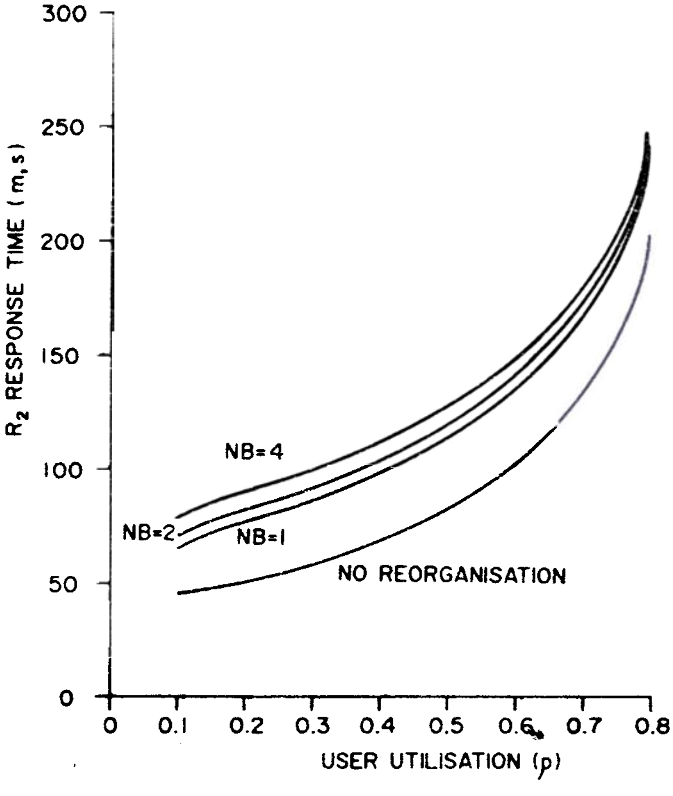

Figure 3. Model 2 (mean changeover time = mean service time (slow))

represents the variation of user response time with user utilisation when there is no concurrent reorganisation. The curves are of the same form and the response time grows as user utilisation approaches 1 because the queue starts growing. Response time increases as *NB* increases since user must wait longer for the last reorganiser to complete its service. Figure 4 shows the relative degradation of user response time versus utilisation. Relative degradation of response time decreases to zero as user utilisation increases to 1 for both the models. When user utilisation is high, *NB* has little effect on user response time degradation but is more in Model 2 as compared to Model 1.

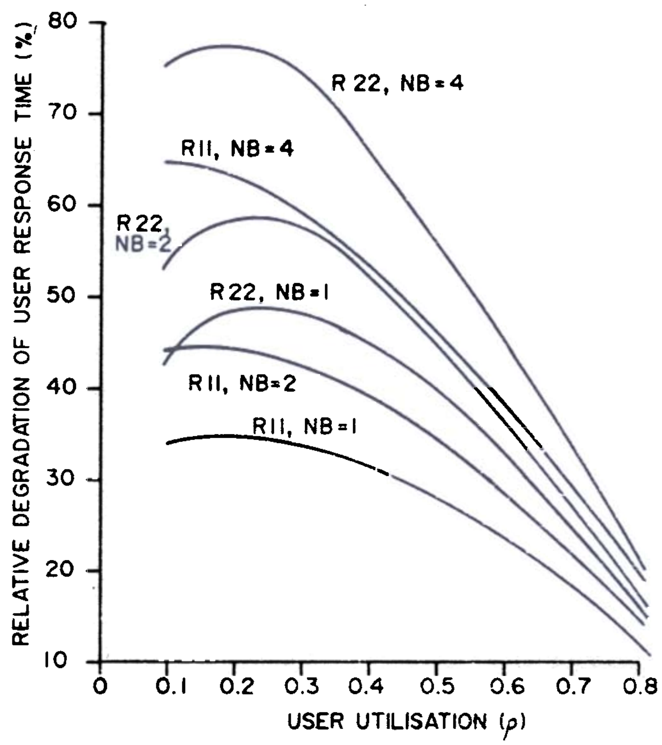

Figure 4. Model 1 and Model 2 (mean changeover time = mean service time (slow) in Model 2).

8. CONCLUSION

i) The user response time is more in Model 2 as compared to Model 1 for same steps of reorganisation, when mean changeover time is equal to mean service time (slow).

ii) The response time in Model 2 approaches to Model if we take the mean changeover time less than the mean service time (slow).

iii) As the user utilisation increases, the user response time increases. Therefore, the reorganisation should be performed in slack periods if the user load varies

iv) As *NB* increases response time increases, and time to reorganise data decreases.

Database manager working in a real Defence environment with voluminuous data can choose the suitable parameters keeping in view the desired optimal user response time and reorganisation time.

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