ISSN No. 0976-5697

Volume 6, No. 5, May - June 2015

International Journal of Advanced Research in Computer Science

CASE STUDY AND REPORT

Available Online at www.ijarcs.info

A Decentralised Scheduling Tool For An Efficient Information Packet Distribution

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Abstract: Time is an expensive resource and it is an asset to those who respect and use it efficiently. As regards information delivery services, there have been so much delay and loss of information packets in the process of delivery. In this study, we demonstrate the effect of a scheduling algorithm on the speed and reliability of information delivery.Anew decentralized scheduling algorithm and mail delivery and an example of manual mail delivery samples is presented to prove the effect of a proposed scheduling tool on information packets distribution. We useda set of mail information from a private mail bag as locations against some resource agents used in delivering the mail and we applied the algorithm on these locations to see its effects on the time of delivery. The time spam was studied from applying the algorithm and from manually sorting them. The comparism showed differences in the time duration. The research demonstrates the influence of scheduling algorithm on the delivery of mails.We concluded that handling mail procedures using a decentralized scheduling algorithm would have great effects on information management and transfer. These effects should be considered in setting up any information services especially, one with many users.

Key words:information delivery, mail, scheduling packets, algorithm data sorting.

I. INTRODUCTION

Scheduling is an important tool in computing, Artificial Intelligence, management, manufacturing, engineering etc., where it can have a major impact on the productivity of a process. In management, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make an item and on which equipment. Process scheduling aims to maximize the efficiency of the operation and reduce costs [1].

Reference [2] stated that companies and organizations use backwards and forward scheduling to allocate facilities and machinery resources, plan human resources, plan production processes and distribution strategies.

Forward scheduling is planning the tasks from the date resources become available to determine the shipping date or due date, while backward scheduling is planning the tasks from the due date or required-by dates to determine the start date and/or any changes in capacity required.

A. Benefits of Scheduling:

The benefits of process, production and management scheduling include;

a. Process change-over reduction
b. Inventory reduction, leveling
c. Reduced scheduling effort
d. Increased production efficiency
e. Labour load leveling
f. Accurate delivery date quotes
g. Real time information

The concept of scheduling is not new; the pyramids are over 3000 years old, Sun Tzu wrote about scheduling and strategy 2500 years ago from a military perspective, transcontinental railways could not have been accomplished without some form of schedule; i.e. the understanding of activities and sequencing. However, whilst the managers and military larders controlling the organizations responsible for accomplishing the “works” must have an appreciation of “scheduling” (or at least the successful ones would have) there is little evidence of formal processes until the 20th century [3].

Information packets distribution is an example of batch processing. A batch process involves large numbers of very similar records, and a batch process scheduling is the practice of planning and scheduling of batch distribution process. Although, scheduling may apply to traditionally continuous process, such as refining [4]; [5], it is especially important for batch process such as those for pharmaceutical active ingredients, biotechnology process and many specialty information distribution process [6];[7]. Batch production scheduling shares some concepts and techniques with finite capacity scheduling which has been applied to many distribution problems [1]. The specific issues of scheduling batch distribution processes have generated considerable industrial and academic interest.

B. Algorithmic Methods:

According to [1], when scheduling situations becomes more complicated, for example when two or more processes share resources, it may be difficult to find the best schedule. A number of common scheduling problems, including variations on the example described above, fall into a class of problems that become very difficult to solve as their size (number of procedures and operations) grow.

A wide variety of algorithms and approaches have been applied to batch process scheduling. Early methods, which were implemented in some MRP system assumed infinite capacity and depended only on the batch time. Such methods did not account for any resources that would produce infeasible schedules.

Mathematical programming methods involve formulating the scheduling problem as an optimization problem where some objective, e.g. total duration, must be minimized (or maximized) subject to a series of constraints which are generally stated as a set of inequalities and equalities. The objective and constraints may involve zero-or-one (integer) variables as well as non-linear relationships. An appropriate solver is applied for the resulting mixed-integer linear or non-linear programming (MILP/MINLP)problem. The approach is theoretically guaranteed to find an optimal solution if one exists. The disadvantage is that the solver algorithm may take an unreasonable amount of time. Practitioners may use problem-specific simplifications in the formulation to get faster solutions without eliminating critical components of the scheduling model [8].

Constraint programming is a similar approach except that the problem is formulated only as a set of constraints and the goal is to arrive at a feasible solution rapidly. Multiple solutions are possible with this method [9];[10].

Mail distribution entails the reception, accumulation, sorting, forwarding and delivery of mail to destinations within a specified time. The information that is attached to the mail include; name, release time, activation time, termination time and due time. These information are distributed thus to accommodate unforeseen lapses during distribution. The proposed algorithm therefore, sorts the mail according to their names and uses these time information to schedule a preferred route for the carrier within a particular locality.

Postal service is a systematic operation used to dispatch mails and other forms to different destination within a certain locality and within their delivery date.

The two main goals of the postal services include;

a. To maintain an efficient system of collation, sorting and delivery of mail nationwide.
b. Ensure the delivery of mail within the following stipulated time:

a) Intra-city - 24 hours
b) Inter-city - 48 hours
c) Nationwide – 72 hours

Presently according to [11], there are 955 postal offices and over 3000 postal agencies throughout the Nigerian federation, although the Universal Postal Union (UPU) has recommended a post office for an average of 3000 to 6000 people. Going by the recommendation, and given Nigeria's population of over 120 million, there should not be less than 20000 postal establishments in Nigeria. On the average therefore, Nigeria has only 20 percent of what it should provide as postal outlets in the country and needs more efficient system to meet her goals and objectives.

Our objective therefore, is to present a scheduling system for an efficient mail management and distribution. The principal information resources used is the details of the mails. These details especially the mail delivery period is what is mostly affected and distorted during delivery. This distortion is caused by bad sorting techniques which results in missing mails and eventually causes delay in the delivery of the remaining mails packets

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II. MATERIALS AND METHODS

Since scheduling is a key factor for productivity, effective scheduling can help an industry improve on - time delivery, reduce work –in– process inventory, cut 7,m,kj[lead time and improve machine utilization.

A scenario of an application of this tool is given below; On a certain day, fifty (50) mails were collected in a post office; the post-master-in-charge of that office enters their information on the computer system that runs the scheduling tool. The tool then sorts the mails using a simple pattern like:

A. *Activities, Resources, Task:*

An activity is the delivery of a particular mail. A task represents a chain of related activities that is assigned to a carrier every day. A resource will simply be a carrier that executes a task.

By using the above terms, the scheduling tool collects the information of the day's activities, sorts and organizes them into various tasks according to the available resources in that locality. If there are fifty activities today and there are five resources available, then possible routes within that city will include:

Where R = resource

T = task

A = activity

$$R1 \rightarrow T1\ [Ai:\ i \leq 12]$$

$$R2 \rightarrow T2\ [Ai:\ i \leq 14]$$

$$R3 \rightarrow T3\ [Ai:\ i \leq 8]$$

$$R4 \rightarrow T4\ [Ai:\ i \leq 6]$$

$$R5 \rightarrow T5\ [Ai:\ i \leq 10]$$

For all i > 0 and an integer,

$$\Longrightarrow 12A+14A+10A+8A+6A=50A$$

The above illustration describes the routes **R1……R5** as allocated to five resources available for **n** activities**Ai** (for all **i ≥ 0 ≤ n**, where n equals 50 in this case). This gives rise to the tasks **T1….T5.** Therefore**,** assuming ten (10) routes are to be considered for the same five resources and 50 activities, the possible allocation of resources would be in the form:

$\mathbf{R_j = T_j\ [A_k:\ k \leq t]}$

Where

j = 1…5 (number of available resources**)**

k = 1……50 (number of activities**)**

and

t = the specific activity assigned a particular task (by the sorting algorithm based on each activation time)

For the understanding of the consequence of a manual process of information distribution, a sample of a typical mail distribution procedure of a PMB (Private Mail Bag) post office in the University of Abuja is used to determine the reliability of mail delivery in the university. A questionnaire was prepared for each sample procedure. The questionnaire uses the SUS (Service System Usability Scale) questionnaire. According to [12], the SUS is a simple ten-item scale giving a global view of subjective assessment of usability. Usability in this context is not a quality that exists in any real or absolute sense. It can be best summed up as being a general quality of the appropriateness to a purpose of any particular artefact. ISO 9241-11 suggests that measures of usability should cover:

a. Effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks).
b. Efficiency (the level of resource consumed in performing tasks).
c. Satisfaction (users' subjective reactions to using the system).

To calculate the SUS score, first sum the score contributions from each item. Each item's core contribution will range from 0-4. For items 1,3,5,7 and 9 these score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU.SUS scores have a range of 0 to 100.

For the study of the effect of this scheduling algorithm on the of delivering of information packets, a sample of 25 mails is taken from the post office, to be assigned to 5 resources (post office agents) to dispatch them to their various destinations within about 72 hours. The mail details are passed into the scheduling software that implements the algorithm. The software performs two major tasks:

a) ***Sorting****:* the mails are first sorted out according to the time of release and the due time.
b) ***Scheduling***: the mails are then scheduled to suit the assigned localities of each agent in order to economize resources and at the same time meet the due time for each mail.

The scheduling algorithm presented in this paper is the decentralized scheduling algorithm. This kind of algorithm according to the description of projects/production scheduling procedures given in [13], schedules mails for each individual rather than the whole mails as they come into the office. This therefore means that each task to be scheduled is independent of the various tasks available at every given time in a production process.

III. RESULTS AND DISCUSSION

Table 1.0 below shows the results of the SUS analysis for 10 mail recipients. Adding up each of the SUS scores and finding the average will give the real index score for the service industry.

SUS score= (45 + 47.5 + 92.5+ 62.5 + 47.5 + 37.5 + 67.5 + 40 +85 +85) /10 = **61.0.**

This represents 61.0% of the service delivery in the industry. And since accurate and prompt delivery is the part of its quality, the results of the above can also represent 61.0 percent of the actual time of delivery. That means 39.0% short of the actual quality. For example, if the standard time of intra-city mail delivery is 24 hours, then the present mail delivery quality is 39.0% of the standard time plus the standard time.

Table 1: The results of the SUS analysis for 10 mail recipients

People/ question	1	2	3	4	5	6	7	8	9	10
1	4	4	4	4	3	2	3	0	4	3
2	0	3	4	4	2	0	2	0	4	3
3	3	1	1	2	2	0	3	0	4	4
4	0	1	4	0	1	2	3	4	0	4
5	0	2	4	2	2	2	4	0	2	3
6	4	4	4	2	2	0	3	4	4	3
7	0	1	4	4	2	3	3	4	4	4
8	0	1	4	1	1	4	3	4	4	3
9	3	1	4	4	2	1	0	0	4	3
10	4	1	4	2	2	1	3	0	4	4
Total	18	19	37	25	19	15	27	16	34	34
Total*2.5	45	47.5	92.5	62.5	47.5	37.5	67.5	40	85	85

For nationwide, the present mail delivery quality is (39% of 72hrs) + 72 = 28 +72 = 100hrs\

This is a good score but not acceptable in a national setting because it is too low to gain the trust and confidence of the people in the delivery of mail and information packets services.

On the other hand, the decentralized approach under the scheduling system assigns to each resource the responsibility to schedule its activities. The resource applies a three-step procedure that does not require evaluating all the possible permutations of activities.

a. First, the resource orders the activities by their activation time.
b. Second, the resource enforces resource and temporal constraints. This requires shifting the activities' activation time and termination time forward in order to avoid temporal overlapping between consecutive activities.
c. Third, each activity evaluates its performance and proposes a new activation time that rises to minimize earliness and tardiness. The new activation time is evaluated according to the equation below.

a[k +1] = a[k] + g*(d – t)…….1

Where:
g = gain value
k = number of iterations
a = activation time
d - t = difference between the due time and the termination time

Parameter g (gain) represents the strength of the activity's preferences. The greater this value, the stronger is the ability to enforce its preferences. The resource repeats the above procedure for all the tasks until the global performance or the number of iterations (indicated by k) reaches a desired threshold.

The performance value of the algorithm which is the major reason for this tool is regulated by altering the gain (g) value in the interface before scheduling the activities. As a rule, the performance value must remain at minimum to obtain a reasonable system else the system is said to be uncontrollable.

The algorithm resembles a discrete time control feedback loop that minimizes earliness and tardiness. It is shown below:

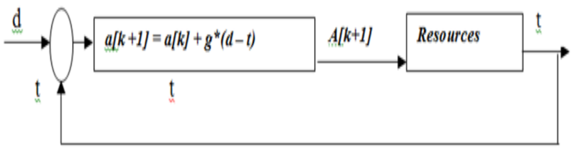

Figure 1:diagram of a discrete time control feedback loop

The performance therefore of an activity is computed as illustrated below in equation **2 through 4** as a function of parameters r, a, t and d(which measure release time, activation time, termination time and due time respectively).

The lower the value of performance, the better is the solution.

Given that:

r *is the release time*
a*is the activation time*
t *is the termination time and*
d *is the due time*
$\boldsymbol{p_e}$*is the earliness performance,*
$\boldsymbol{p_t}$is the tardinessperformance,
$\mathbf{w_e}$ **and** $\mathbf{w_t}$ are the weights on $\mathbf{p_e}$and$\mathbf{p_t}$
and **P** is the activity performance.

$$\mathbf{P_e = \{w_e * (r-a)\} ....2}$$
$$\mathbf{r > a, \quad 0, r \le a}$$

$$\mathbf{P_t = \{w_t * (t-d)\} ......3}$$
$$\mathbf{, t > d, \quad 0, t \le d}$$

The performance of the entire system could be defined as the sum of the performance of all the activities as we can see in equation 4.

$$\mathbf{P} = \mathbf{p_e} + \mathbf{p_t}.........4$$

C. Analysis:

The values of $\mathbf{w_e}$ **and** $\mathbf{w_t}$depend on the problem at hand. For example, we can give more importance to the tardiness constraintif we want the activities to complete as soon as possible. The scheduling algorithm has the goal of minimizing the values of **P** while looking for a solution to the scheduling problem (assignment of new values to the activity parameters) that satisfies the temporal and resources constraints. The algorithm enforces these constraints by sequencing the activities executed by a resource. This implies shifting values of the temporal parameters of each activity forwards or backwards. It is clear that the performance of the results depends on the specific order imposed on the activities by all the resources.

In other to find the optimal solution (the one that corresponds to the minimum value of P) the algorithm would have to permute all the possible sequences of activities for each resource. This is the typical centralized approach, where the algorithm has the visibility of the entire model of the scheduling problem.

D. Interpretation:

The proposed system is basically centered on the implementation of a decentralized scheduling algorithm decentralized scheduling algorithm exploits the natural decomposition of a given scheduling problem into sub problems according to the physical system organization in subsystems and allow the system designer to tackle each sub problem individually. For example, scheduling the time plan for a single mail carrier represents a sub –problem of the entire system. The decentralized approach prevents the algorithmfrom finding the optimal solution of a given scheduling problem (the algorithm does not have global visibility of the state variables) but simplifies the system model identification and solution evaluation. The solution emerges as the result of the interactions with the other subsystems when conflicts arise.

For a wide variety of problems, scheduling algorithms try to minimize earliness and tardiness. This means that an activity should not start before its release time and should not complete after the due time. The earliness and tardiness constraint might be strong or weak. In the former case the constraint cannot be violated, while in the latter case they can be violated to the prejudice of the scheduling performance. For the sake of simplicity we have considered the weak constraints; this guarantees that scheduling problems always has a solution, no matter how bad. The performance of the scheduling algorithm measures the quality of the solution, i.e. how much the solution enforces the temporal constraints.

E. Discussion:

Using a gain value of 0.1 for optimal performance on the scheduling system the file containing the mail detail were uploaded into the application against the 5 resources available to carry those mails. After setting these parameters, the program is made to run and the time plan is generated in the sheet panel of the software. The general performance that the system reads is **176.7**

Therefore, the ***individual performance constraint*** (IPC) against the default gain value is given as:

$$\frac{\text{General performance*gain}}{\text{Number of resources}}$$

Therefore***, IPC =*** $\boldsymbol{\frac{176.7*0.1}{5}}$

=***3.5% of the actual time delivery***

Therefore, compared against the standard time of delivery, we have.

For intra-city, 24 + 3.5% of 24 =24 + 1 = 25 hrs
For inter-city, 48 + 3.5% of 48 = 48 + 2 =50 hrs
For nationwide, 72 + 3.5% of 72 = 72 + 3 = 75 hrs

So, a remarkable difference exists between both approaches on the standard time for mail delivery.

Table 2: time taken (in hours) for a packet or parcel to be delivered to a given location

	Before the algorithm (hrs)	After the algorithm (hrs)
Intra-city	**33**	**25**
Inter-city	**67**	**50**
Nationwide	**100**	**75**

Table 2 above shows the time taken for the information packets to be delivered to various locations including Intra-city, Inter-city or nationwide it was observed that manually sorting, scheduling and distributing the information takes a longer time, and that brings about a longer makespan. But using the algorithm for the same procedure reduces makespan.

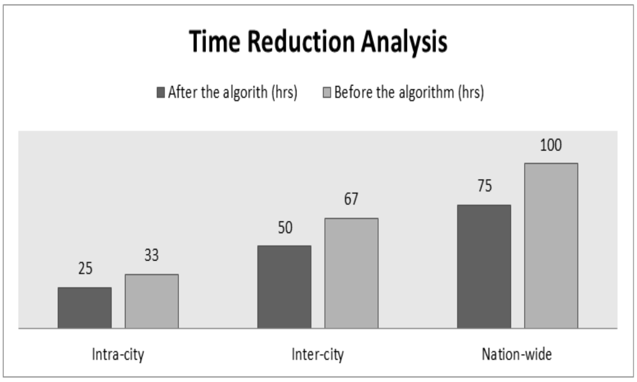

Figure 2: comparison between manual and computerized method of sorting

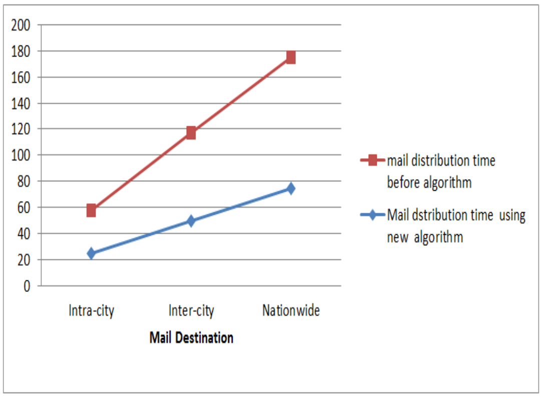

Figure 3: performance evaluation measure

Figure 1 and 2 above have been used to further expatiate and explain the improvement in performance of information packets distribution when the entire process is carried done via automation as against the manual procedure.

IV. CONCLUSION

The study shows the impact of a scheduling system on a mail information packets delivery. Its showsas well that our present information delivery systems is way below the required standard and needs upgrade as soon as possible. Information before being sent must first be sorted out with great accuracy and be scheduled appropriately to arrive at its destination on time without any loss of information. We therefore recommend the implementation of the scheduling system to improve our value of time and business and promote good and fair standard of living.

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