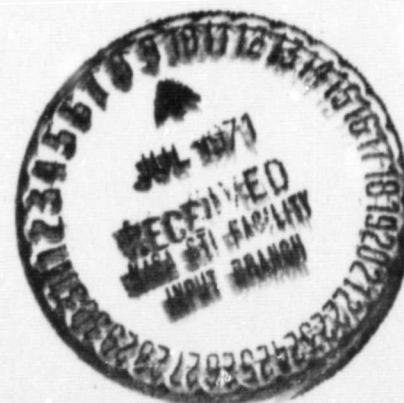


General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.



UNIVERSITY OF MARYLAND
COMPUTER SCIENCE CENTER
COLLEGE PARK, MARYLAND

FACILITY FORM 602

N71-30023

(ACCESSION NUMBER)

31

(PAGES)

CR-115179

(NASA CR OR TMX OR AD NUMBER)

(THRU)

G3

(CODE)

19

(CATEGORY)

Technical Report TR-160
NGR-21-002-197

June, 1971

Simulation of a Single-server Model
for a Paging Drum Channel System

by

Gee-yin Kwok

This research was supported by Grant NGR-21-002-197
from the National Aeronautics and Space Administration to
the Computer Science Center of the University of Maryland.

Table of Contents

Abstract

1. Introduction
2. The waiting queue
3. A single-server model
4. Formulation of the model
5. The simulation programs
 - 5.1 Flow charts
 - 5.2 Listings
6. Simulation examples
 - 6.1 Example 1
 - 6.2 Example 2
 - 6.3 Example 3
7. Acknowledgement
8. References

Appendix A. Listing of the SIMULA simulation program

Appendix B. Listing of the FORTRAN simulation program

Abstract

A Single-server model is an abstract mathematical model which can be applied to many systems. This report presents the formulation of a single-server model which represents a Paging Drum Channel System. Simulation has been carried out by Frotran and Simula assuming uniformly distributed inputs.

Simulation of a Single-server Model for a Paging Drum Channel System

1. Introduction

A single-server model is one where there is only one waiting list (queue). Although the model is simple, it can be abstractedly applied to many applications such as computer systems, service stations, input/output channels, paging drum channels, etc. If it models a computer system, then the waiting queue contains jobs to be processed. If it models a service station, then the waiting queue contains cars to be serviced. If it models a paging drum channel PDC, then the waiting queue contains paging requests PR's.

The objective of this simulation, however, is to determine the following: (a) the average waiting time for each PR arriving at the PDC system and (b) the total PDC system idle time which is essential in deciding whether the number of tasks should be decreased or increased.

2. The waiting queue

The waiting queue is represented by a two-dimensional array with indices K and J. Index K is the pointer to the Kth node in the queue, while index J indicates the field of the node to be taken for computation. Figure 1 shows the format of the $(I-1)^{th}$ node, the I^{th} node, and the $(I+1)^{th}$ node in the waiting queue. Each node represents a paging request entry. However, the user must provide for the I^{th} node the PR arrival time, $NODE(I,2)$, and the PDC system service time, $NODE(I,3)$. For the I^{th} node, $K=I$ and $J=1$, through 7. Similarly, for the $(I+1)^{th}$ node, $K=(I+1)$ and $J=1$ through 7. No link is required since the predecessor of $NODE(I,J)$ is $NODE(I-1,J)$ and the successor of $NODE(I,J)$ is $NODE(I+1,J)$, where $I>1$ and J is the field index. According to this kind of data structure, computation of various statistics is very easily accomplished by using DO loops in Fortran and FOR clauses in Algol and Simula.

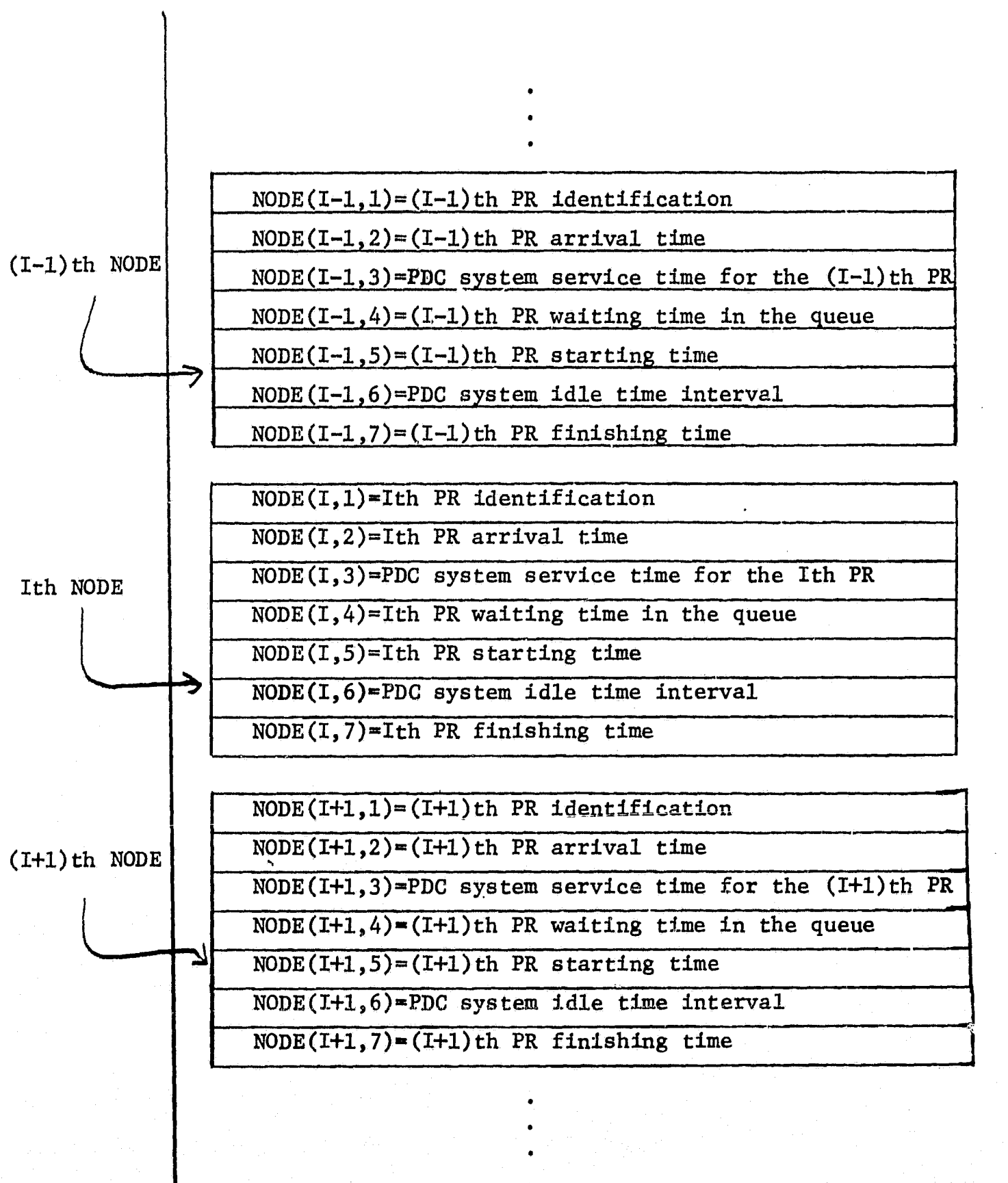


Fig. 1 Format of the (I-1)th node, Ith node, and (I+1)th node in the waiting queue

3. A single-server model

A picture of the single-server model for a paging drum channel is shown in Fig. 2. As a PR arrives at the single-server, it gets the service if there is no other one prior to it, that is, if the single-server is free; otherwise, it enters a paging request queue.

Input parameters are (a) the PR arrival time and (b) the system service time for the PR. Simulation outputs are (a) the average waiting time of the PR in the queue, (b) total system service time, and (c) total system idle time.

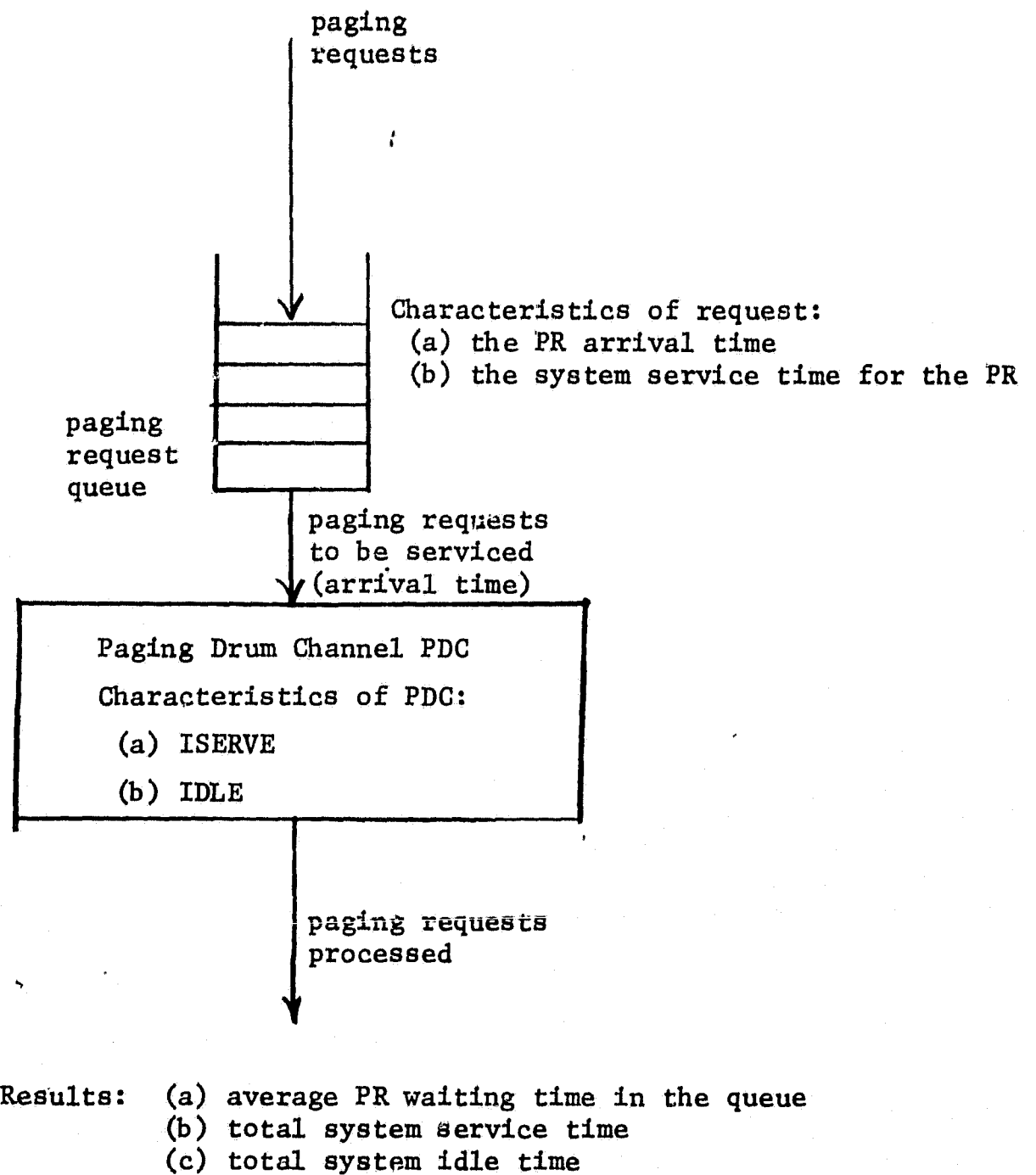


Fig. 2 Block diagram of a single-server model for a paging drum channel

4. Formulation of the model

As shown in Fig. 2, a PR arrives at the PDC system, obtains the service, and leaves the PDC system. Table 1 shows the 13 entities (variables and parameters) in the simulation model, where the entities represent the variable names in the simulation programs. For example, IALL represents the total simulation time while AVG represents the average PR waiting time in the queue.

The activities (functional relationships between variables and parameters) are defined by the following equations where I is the index of page request in the waiting queue:

a. For $I=1$

The PR waiting time in the queue is 0 for the first PR:

$$\text{NODE}(I,4)=0 \quad (1)$$

The PDC system idle time is set to the PR arrival time:

$$\text{NODE}(I,6)=\text{NODE}(I,2) \quad (2)$$

The PR starting time is the sum of the PR arrival time and the PR waiting time:

$$\text{NODE}(I,5)=\text{NODE}(I,2)+\text{NODE}(I,4) \quad (3)$$

The PR finishing time is the sum of the PR starting time and PDC system service time for the PR:

$$\text{NODE}(I,7)=\text{NODE}(I,5)+\text{NODE}(I,3) \quad (4)$$

b. For $I>1$

The PR waiting time is the difference between the PR arrival time and the previous PR finishing time:

$$\text{NODE}(I,4)=\text{NODE}(I-1,7)-\text{NODE}(I,2) \quad (5)$$

The PR starting time is the sum of the PR arrival time and the PR waiting time:

$$\text{NODE}(I,5)=\text{NODE}(I,2)+\text{NODE}(I,4) \quad (6)$$

Table 1 Entities of the Simulation Model

Entities	Designation
IALL	total simulation time
NPR	number of PR arriving during the simulation time interval
NODE(I,1)*	PR identification
NODE(I,2)	PR arrival time (input parameter)
NODE(I,3)	PDC system service time for the Ith PR (input parameter)
NODE(I,4)	PR waiting time in the queue
NODE(I,5)	PR starting time
NODE(I,6)	PDC system idle time interval (time interval between the Ith PR starting time and the (I-1)th PR finishing time)
NODE(I,7)	PR finishing time
ISERVE	total PDC system service time
IDLE	total PDC system idle time
WAIT	total PR waiting time in the queue
AVG	average PR waiting time in the queue

*I is the index of paging request.

The PR finishing time is the sum of the PR starting time and the PDC system service time for the PR:

$$\text{NODE}(I,7)=\text{NODE}(I,5)+\text{NODE}(I,3) \quad (7)$$

The PDC system idle time interval is the difference between the PR starting time and the previous PR finishing time:

$$\text{NODE}(I,6)=\text{NODE}(I,5)-\text{NODE}(I-1,7) \quad (8)$$

c. For $I \geq 1$

Total PDC system service time is the sum of the service time for each PR:

$$\text{ISERVE} = \sum_{I=1}^{\text{NPR}} \text{NODE}(I,3) \quad (9)$$

Total PDC system idle time is the difference between the total simulation time and total service time:

$$\text{IDLE} = \text{IALL} - \text{ISERVE} \quad (10)$$

Total paging request waiting time in the queue is the waiting time for each PR:

$$\text{WAIT} = \sum_{I=1}^{\text{NPR}} \text{NODE}(I,4) \quad (11)$$

Average PR waiting time is the total PR waiting time divided by the number of PR's:

$$\text{AVG} = \text{WAIT} / \text{NPR} \quad (12)$$

5. Simulation programs

The single-server model for the paging drum channel has been simulated by SIMULA and FORTRAN on the UNIVAC 1108.

5.1 Flow charts

The flow charts of the SIMULA and FORTRAN simulation programs for the single-server model are presented in Figs. 3 and 4. The boxes in the flow chart are numbered and explained below:

- Box 1 describes initialization; the number of PR's NPR and the length of the total simulation time interval IALL are read in from card.
- Box 2 is for initializing the index for PR(I), total system service time ISERVE, total PR waiting time WAIT.
- Box 3 assigns PR identification NODE(I,1), PR arrival time NODE(I,2), and the PDC system service time NODE(I,3). These characteristics are read in from card.
- Box 4 checks if the current PR is the first PR or not. If it is the first PR, the PR waiting time is set to 0 since there is no PR prior to it. This is shown in Box 7. If it is not the first PR, go to Box 5 where the PR waiting time NODE(I,4) is computed by subtracting the PR arrival time NODE(I,2) from the previous PR finishing time NODE(I-1,7).
- Box 5
- Box 6 checks if NODE(I,4) is negative. If it is negative, NODE(I,4) is set to 0 since in this case the previous PR has left the PDC system when the current PR arrives.
- Box 7 In Box 7, the PR waiting time NODE(I,4) is set to 0.
- Box 8 In Box 8, the PR starting time NODE(I,5) is computed by adding the PR waiting time NODE(I,4) to the PR arrival time NODE(I,2).

- Box 9 In Box 9, the PR finishing time is computed by adding the PDC system service time $\text{NODE}(I,3)$ to the PR starting time $\text{NODE}(I,5)$ which is the time when the current PR is serviced.
- Box 10 Checks if the current PR is the first PR arriving at the PDC system.
- Box 11 If the current PR is not the first PR, the current system idle time $\text{NODE}(I,6)$ is computed by subtracting the previous PR finishing time $\text{NODE}(I-1,7)$ from the current PR starting time $\text{NODE}(I,5)$.
- Box 12 Checks if the computed PDC system idle time $\text{NODE}(I,6)$ is negative.
- Box 13 If it is negative, $\text{NODE}(I,6)$ is set to 0 and the current PR waits until the previous PR leaves the PDC system.
- Box 14 If it is the first PR, the PDC system idle time interval $\text{NODE}(I,6)$ is equal to the first PR arrival time $\text{NODE}(I,2)$ since so far no PR has been serviced.
- Box 15 In box 15, the attributes or the contents of the entities which are variables in the SIMULA program of the mathematical model are printed out.
- Box 16 In box 16 and box 17, the total PDC system service time ISERVE
and
Box 17 and the total PR waiting time WAIT are accumulated.
- Box 18 Checks if all the PR's have been serviced.
- Box 19 If there are more PR's coming, index I is incremented, and control is then returned to box 3.
- Box 20 In box 20 and 21, the average PR waiting time AVG is computed.
and
Box 21
- Box 22 In box 22, the total simulated time IALL in seconds is printed.
- Box 23 In box 23, the total PDC idle time IDLE is computed by subtracting the total PDC service time ISERVE from IALL .

Box 24, In these three boxes, total PDC system idle time IDLE, total
Box 25, PDC system service time ISERVE, and average PR waiting time
and AVG are printed.
Box 26

5.2 Listings

The SIMULA simulation program is in Appendix A and the FORTRAN simulation program is in Appendix B.

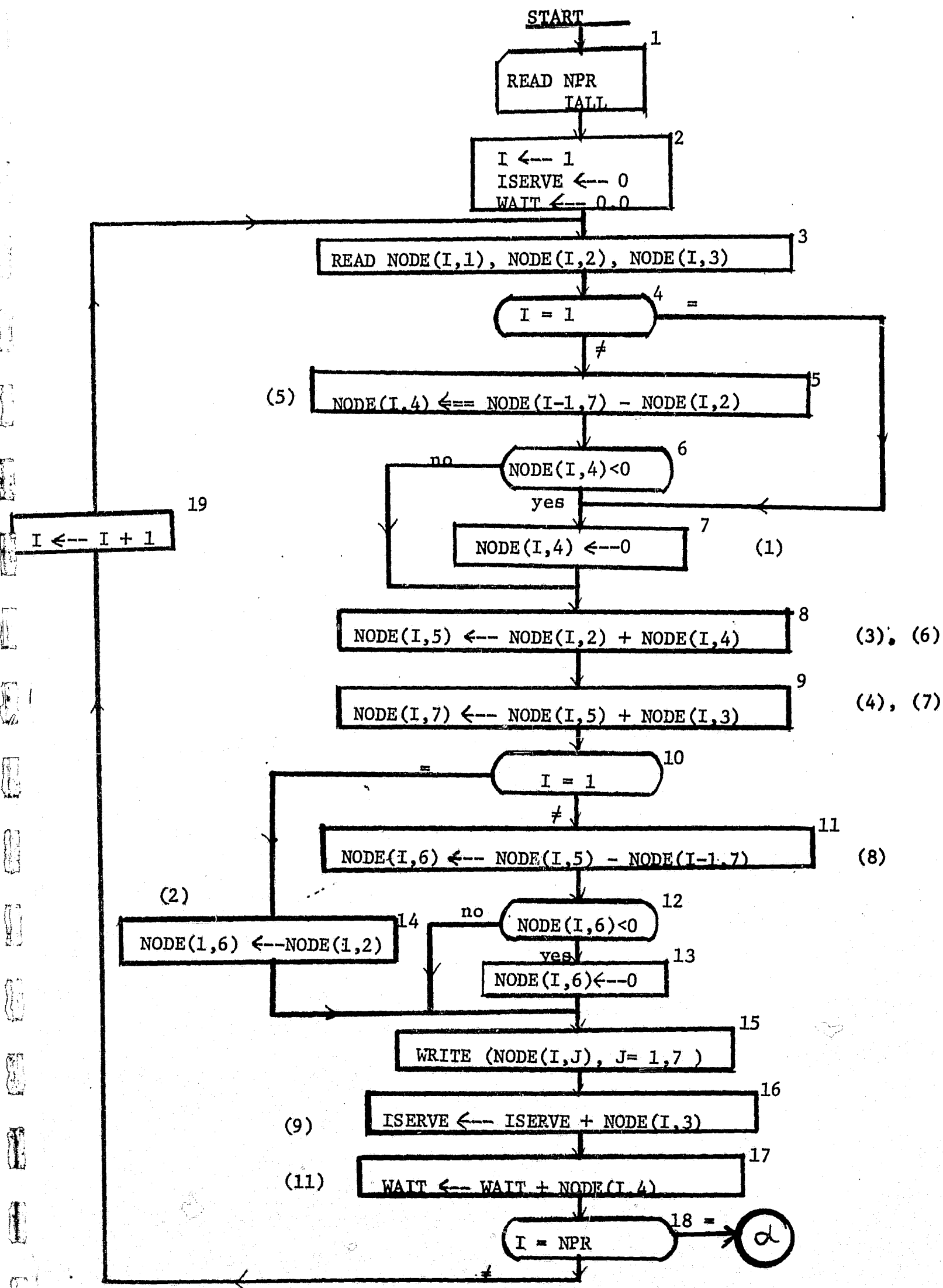


Fig. 3 Flow chart for the simulation programs (Page 1)

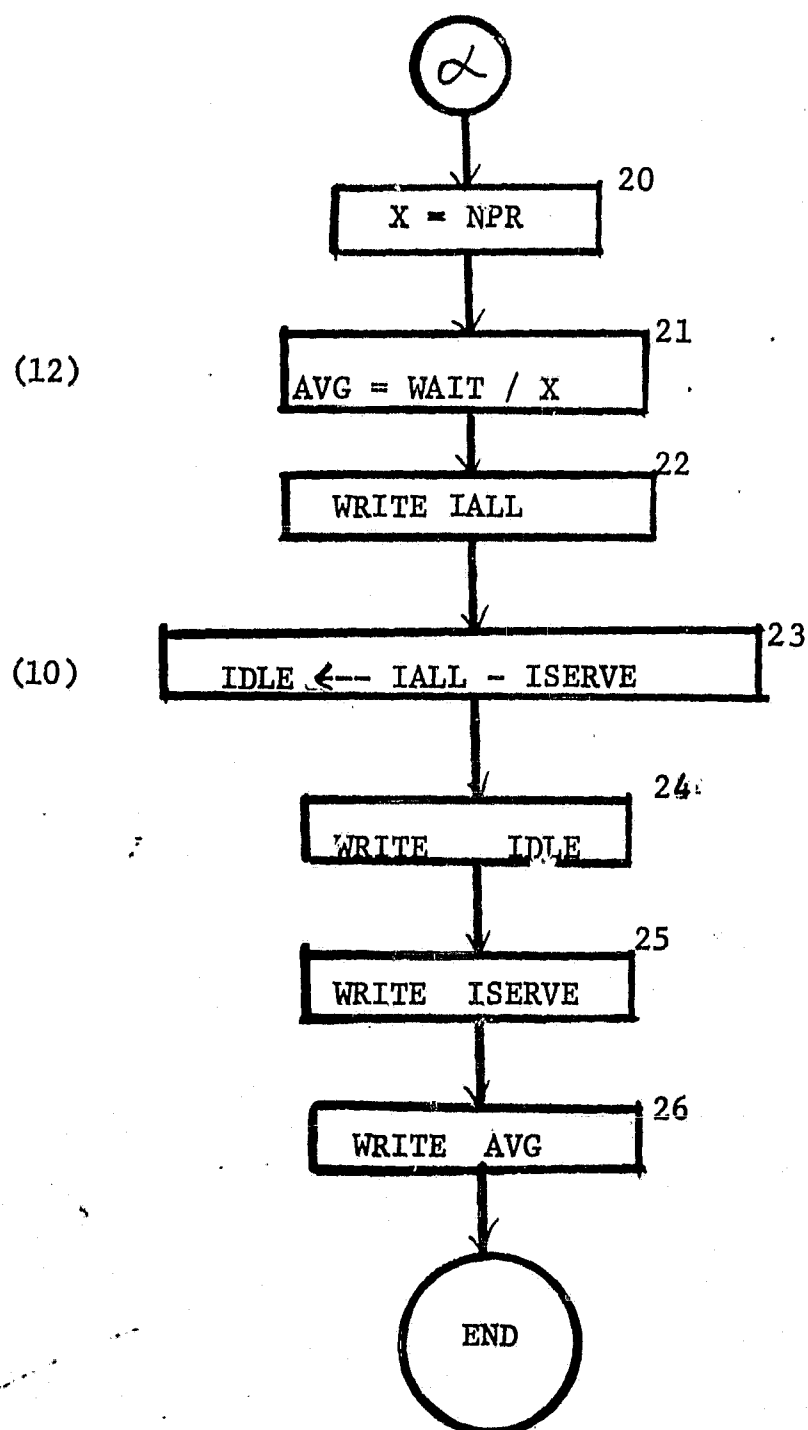


Fig. 4 Flow chart for the simulation programs (Page 2)

6. Simulation examples

Three examples are presented in this section to illustrate the simulation of the given PDC system with different input parameters. The paging requests are assumed to arrive according to Uniform Distribution in the following examples.

6.1 Example 1

The input data for example 1 is shown in Table 2. In this example, the PR arrival rate (80 second interval) is higher than the PDC system service rate (100 seconds/PR). The computer print-out is shown in Fig. 5. The first PR arrives at time 80, waits no time, gets service at time 80, and leaves the system at time 180. The last PR arrives at time 800, waits 180 units of time, gets service at time 980, and leaves the system at time 1080. Thus, the PR's are queued up as they arrive at the system. The average PR waiting time is 90 time units, while the total PDC system idle time is 80 time units. Thus, the number of tasks should be decreased.

6.2 Example 2

The input data for example 2 is shown in Table 3. In this example the PR's require various system service time ranging from 60 to 90 time units. The computer print out is shown in Fig. 6. The first PR arrives at time 80, waits no time, gets service get time 80 and leaves the system at time 170. The last PR arrives at time 800, waits 10 units of time, gets service at time 810, and leaves the system at time 910. Thus, some PR's must wait in the queue and some do not have to wait. The computed average PR waiting time is 4 time units while the total PDC system idle time is 180 time units.

Thus, the number of tasks may be increased.

6.3 Example 3

The input data for example 3 is shown in Table 4. In this example, PR arrival rate (λ) is set equals to PR service rate (μ) at the PDC system. The drum utilization factor of the PDC system is $\rho = \lambda/\mu = 1$. The computer print out is shown in Fig. 7. The first PR arrives at time 80, waits no time, gets service at time 80, and leaves the system at time 160. The last PR arrives at time 800, waits no time, gets service at time 800, and leaves the system at time 880. Thus, no PR has to wait while the total PDC system idle time is minimized. Therefore, the average PR waiting time is 0 time unit and the total PDC system idle time is 80 time units. Consequently, the number of tasks may be increased.

Table 2 Input data for example 1

Paging Request Identification	Paging Request Arrival Time	System Service Time for the Paging Request
1	80	100
2	160	100
3	240	100
4	320	100
5	400	100
6	480	100
7	560	100
8	640	100
9	720	100
10	800	100

Total Simulation Time = 1200

Total Number of PR = 10.

Fig. 5. Example 1. SIMULATION OF A CHANNEL (constant system service time of 100)

PR ID	ARRIVAL TIME	SYSTEM SERVICE TIME	PR WAITING TIME	PR STARTING TIME	SYSTEM IDLE TIME	FINISHING TIME
1	80	100	0	80	80	180
2	160	100	20	180	0	280
3	240	100	40	280	0	380
4	320	100	60	380	0	480
5	400	100	80	480	0	580
6	480	100	100	580	0	680
7	560	100	120	680	0	780
8	640	100	140	780	0	880
9	720	100	160	880	0	980
10	800	100	180	980	0	1080

TOTAL SIMULATED TIME = 1200 SECONDS
TOTAL SYSTEM IDLE TIME = 200
TOTAL SYSTEM SERVICE TIME = 1000
AVERAGE WAITING TIME IN THE QUEUE = 90.0000 SECONDS

Table 3 Input data for example 2

Paging Request Identification	Paging Request Arrival Time	System Service Time for the Paging Request
1	80	90
2	160	90
3	240	50
4	320	50
5	400	60
6	480	60
7	560	70
8	640	70
9	720	90
10	800	90

Total Simulation Time = 1200

Total Number of PR = 10,

Fig. 6. Example 2: SIMULATION OF A CHANNEL (variable system service time from 60 to 90)

PR	ID	ARRIVAL TIME	SYSTEM SERVICE TIME	PR WAITING TIME	PR STRATING TIME	SYSTEM IDLE TIME	FINISHING TIME
1	80	90	0	80	80	170	
2	160	90	10	170	0	260	
3	240	50	20	260	0	310	
4	320	50	0	320	10	370	
5	400	60	0	400	30	460	
6	480	60	0	480	20	540	
7	560	70	0	560	20	630	
8	640	70	0	640	10	710	
9	720	90	0	720	10	810	
10	800	90	10	810	0	900	

TOTAL SIMULATED TIME = 1200 SECONDS
 TOTAL SYSTEM IDLE TIME = 480
 TOTAL SYSTEM SERVICE TIME = 720
 AVERAGE WAITING TIME IN THE QUEUE = 4.0000 SECONDS

Table 4 Input data for example 3

Paging Request Identification	Paging Request Arrival Time	System Service Time for the Paging Request
1	80	80
2	160	80
3	240	80
4	320	80
5	400	80
6	480	80
7	560	80
8	640	80
9	720	80
10	800	80

Total Simulation Time = 1200

Total Number of PR = 10.

7. Acknowledgement

The author wishes to express his thanks to Professor Yaohan Chu for his inspiring advice, helpful suggestions, and guidance; to his wife Marion Kwok for her patience and encouragement; and to Miss N. Nowell for her typing of the entire manuscript.

8. References

1. Coffman, E.G., Jr., "Analysis of a Drum Input/Output Queue under Scheduled Operation in a Paged Computer System", Princeton University, Journal of the ACM, Vol. 16, No. 1, January 1969, pp. 73-90.
2. Kwok, G., "Simulation of a Paging Drum Channel", Technical Report TR-155, NGR-21-002-197, University of Maryland, College Park, Maryland, May 1971.
3. Pardo, O.R., "A Virtual Memory System Design", Technical Report 71-144, Computer Science Center, University of Maryland, January 1971.
4. Yeh, J.W., "An IOCS Algorithm for Microprogramming", Technical Report, 70-124, NGR-21-002-206, University of Maryland, College Park, Maryland, July 1970.

APPENDIX A. LISTING OF THE SIMULA SIMULATION PROGRAM

```

*RUN AA,001-11-768,KWOK
*ALG,CTS      IOCS,IOCS
  SIMULA BEGIN
COMMENT SIMULATION OF A MATHEMATICAL MODEL OF A PDC UNDER IOCS***$
COMMENT PAGING REQUESTS ARE STORED IN A HARDWARE QUEUE $
COMMENT TOTAL PDC SYSTEM SERVICE TIME $
  INTEGER ISERVE$
COMMENT TOTAL SIMULATION TIME $
  INTEGER IALL$
COMMENT NUMBER OF PAGING REQUESTS IN THE QUEUE $
  INTEGER NPR$
COMMENT INDEX FOR THE PAGING REQUEST $
  INTEGER I $
COMMENT TOTAL PDC SYSTEM IDLE TIME $
  INTEGER IDLE$
  REAL WAIT$
  REAL AVG$
  REAL XS
  INTEGER ARRAY NODE(1..10, 1..7)$
  FORMAT F1 (A,I4,I4)$
  FORMAT F2(A, I3,I3,I3) $
COMMENT PR MEANS PAGING-IN OR PAGING-OUT REQUEST $
COMMENT NODE(I,1) IS PR ID
  NODE(I,2) IS PR ARRIVAL TIME
  NODE(I,3) IS PDC SYSTEM SERVICE TIME FOR THE PR
  NODE(I,4) IS THE PR WAITING TIME IN THE QUEUE
  NODE(I,5) IS THE PR STARTING TIME
  NODE(I,6) IS THE PDC SYSTEM IDLE TIME
  NODE(I,7) IS THE PR FINISHING TIME $
COMMENT PRINT TITLES$
  WRITE(' SIMULATION OF A PDC SYSTEM PROCESSING PAGING REQUESTS')$
  ISERVE = 0$
  WAIT = 0.0$
COMMENT INPUT REQUEST CHARACTERISTICS $
  READ(IALL,NPR, F1) $
COMMENT GENERATING 10 NODES FOR THE 10 PR'S $
  FOR I = 1 STEP 1 UNTIL NPR DO BEGIN
COMMENT INPUT PR-ID, ARRIVAL TIME, SYSTEM SERVICE TIMES
  READ(NODE(I,1),NODE(I,2),NODE(I,3), F2)$
COMMENT COMPUTE WAITING TIME $
  IF I NEQ 1 THEN GO TO L11 $
  NODE(I,4) = 0 $
  GO TO L13$
L11 .. NODE(I,4) = NODE(I-1,7) - NODE(I,2) $
COMMENT NO WAITING IF THE DIFFERENCE IS NEGATIVE $
  IF NODE(I,4) LSS 0 THEN NODE(I,4) = 0 $
COMMENT PR STARTING TIME $
L13 .. NODE(I,5) = NODE(I,2) + NODE(I,4)$
COMMENT PR FINISHING TIME $
  NODE(I,7) = NODE(I,5) + NODE(I,3) $
  IF I NEQ 1 THEN GO TO L14 $
COMMENT COMPUTE INITIAL SYSTEM IDLE TIME $
  NODE(1,6) = NODE(1,2) $

```

```

GO TO L15 $
COMMENT SYSTEM IDLE TIME WHEN THE JOB ARRIVES (ACCUMULATED TIME)$
L14 .. NODE(I,6) = NODE(I,5) - NODE(I-1,7) $
COMMENT NO ADDED SYSTEM IDLE TIME IF THE DIFFERENCE IS NEGATIVE$
IF NODE(I,6) LSS 0 THEN NODE(I,6) = 0 $
COMMENT PRINT INTERMEDIATE RESULT $
L15 .. WRITE(' PR-ID = ', NODE(I,1))$
      WRITE(' PR ARRIVAL TIME = ', NODE(I,2))$
      WRITE(' PDC SYSTEM SERVICE TIME = ', NODE(I,3))$
      WRITE(' PR WAITING TIME = ', NODE(I,4))$
      WRITE(' PR STARTING TIME = ', NODE(I,5))$
      WRITE(' PDC SYSTEM IDLE TIME = ', NODE(I,6))$
      WRITE(' PR FINISHING TIME = ', NODE(I,7))$
      WRITE(' *****') $
COMMENT STATISTICS GATHERING $
COMMENT TOTAL PDC SYSTEM SERVICE TIME $
ISERVE = ISERVE + NODE(I,3) $
COMMENT COMPUTE TOTAL PR WAITING TIME $
WAIT = WAIT + NODE(I,4) $
END $
COMMENT COMPUTE AVERAGE PR WAITING TIME $
X = NPR $
AVG = WAIT / X $
WRITE(' TOTAL SIMULATED TIME IS ', IALL, ' SECONDS')$
COMMENT TOTAL PDC SYSTEM IDLE TIME $
IDLE = IALL - ISERVE $
WRITE(' TOTAL PDC SYSTEM IDLE TIME IS ', IDLE) $
WRITE(' TOTAL PDC SYSTEM SERVICE TIME IS ', ISERVE) $
WRITE(' AVERAGE PR WAITING TIME IN THE QUEUE = ', AVG, ' SECONDS')$
END$

```

MAP

XQT

12000010

1080100

2160100

3240100

4320100

5400100

6480100

7560100

8640100

9720100

10800100

FIRST JOB

LAST JOB

XQT

12000010

1080090

2160090

3240050

4320050

5400060

6480060

7560070

8640070

9720090

10800090

XQT

12000010

1080080

2160080

3240080

4320080

5400080
6480080
7560080
8640080
9720080
10800080
IFIN

APPENDIX B. LISTING OF THE FORTRAN SIMULATION PROGRAM

```

RUN CS230,001-11-768,KWOK,1,20
FOR,IS      CH1,CH2
      DIMENSION NODE(10,7)
C      PR IS PAGING REQUEST SERVICED BY THE PDC
C      NODE(I,1) IS PR ID
C      NODE(I,2) IS PR-ARRIVAL TIME
C      NODE(I,3) IS SYSTEM SERVICE TIME FOR THE PR
C      NODE(I,4) IS THE PR WAITING TIME IN THE WAITING QUEUE
C      NODE(I,5) IS THE PR STARTING TIME
C      NODE(I,6) IS THE SYSTEM IDLE TIME
C      NODE(I,7) IS THE PR FINISHING TIME
C      PRINT TITLE
      WRITE(6,1)
1  FORMAT(1H1,30X,'SIMULATION OF A CHANNEL',//)
      WRITE(6,2)
2  FORMAT(1H0,' PR ID ARRIVAL TIME SYSTEM SERVICE TIME PR WAITIN
1G TIME PR STRATING TIME SYSTEM IDLE TIME FINISHING TIME',/)
      ISERVE = 0
      WAIT = 0.0
C      INPUT
C      TOTAL NUMBER OF PR'S
C      TOTAL SIMULATION TIME IN SECONDS
      READ(5,101) IALL, NPR
101  FORMAT(14,14)
C      GENERATING 10 NODES FOR THE 10 PR'S
C      ASSIGN CHARACTERISTICS TO EACH PR
      DO 10 I= 1,NPR
C      INPUT PR ID, ARRIVAL TIME, SYSTEM SERVICE TIME
      READ(5,100)( NODE(I,J),J= 1,3)
100  FORMAT(13,13,13)
C      WAITING TIME
      IF( I.NE. 1) GO TO 11
      NODE(1,4) = 0
      GO TO 13
11  NODE(1,4) = NODE(I-1,7) - NODE(1,2)
C      NO WAITING IS NECESSARY IF THE DIFFERENCE IS NEGATIVE
      IF( NODE(1,4).LT. 0) NODE(1,4) = 0
C      PR STARTING TIME
13  NODE(1,5) = NODE(1,2) + NODE(1,4)
C      PR FINISHING TIME
      NODE(1,7) = NODE(1,5) + NODE(1,3)
      IF( I.NE. 1) GO TO 14
C      COMPUTE INITIAL SYSTEM IDLE TIME
      NODE(1,6) = NODE(1,2)
      GO TO 15
C      SYSTEM IDLE TIME WHEN THE PR ARRIVES
14  NODE(1,6) = NODE(1,5) - NODE( I-1,7)
C      NO SYSTEM IDLE TIME IF THE DIFFERENCE IS NEGATIVE
      IF( NODE(1,6).LT. 0) NODE(1,6) = 0
C      PRINT INTERMEDIATE RESULTS
15  WRITE(6,3)(NODE(I,J),J=1,7)
3  FORMAT(1H0,2X,I2,10X,I5,10X,I5,10X,I5,20X,I5,10X,I5,10X,I5)
      WRITE(6,9)

```

```

C      STATISTIC GATHERING
C      COMPUTE TOTAL SYSTEM SERVICE TIME
      ISERVE = ISERVE + NODE(I,3)
C      COMPUTE TOTAL WAITING TIME
      WAIT = WAIT + NODE(I,4)
10    CONTINUE
C      COMPUTE AVERAGE WAITING TIME
      X = NPR
      AVG = WAIT / X
      WRITE(6,5) IALL
5     FORMAT(1H0,5X,'TOTAL SIMULATED TIME = ',I5,' SECONDS')
C      COMPUTE TOTAL SYSTEM IDLE TIME
      IDLE = IALL - ISERVE
      WRITE(6,6) IDLE
6     FORMAT(1H0,5X,'TOTAL SYSTEM IDLE TIME = ',I5)
      WRITE(6,7) ISERVE
7     FORMAT(1H0,5X,'TOTAL SYSTEM SERVICE TIME = ',I5)
      WRITE(6,8) AVG
8     FORMAT(1H0,5X,'AVERAGE WAITING TIME IN THE QUEUE = ',F14.4,' SECO
      INDS')
9     FORMAT(1H0,110('*'))
      END

```

'MAP

'XQT

12000010

1080100

FIRST PR

2160100

3240100

4320100

5400100

6480100

7560100

8640100

9720100

10800100

LAST PR

'XQT

12000010

1080090

2160090

3240050

4320050

5400060

6480060

7560070

8640070

9720090

10800090

'XQT

12000010

1080080

2160080

3240080

4320080

5400080

6480080

7560080

8640080

9720080

10800080

'FIN