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

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Abstract

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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 determeine 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 Ith 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 Ith node the PR arrival time, NODE(I,2), and the PDC system service time, NODE(I,3). For the Ith 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

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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.



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(c) total system idle time

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

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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 <u>entities</u> (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 <u>activities</u> (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:

NODE(I,4)=0

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

NODE(I,6)=NODE(I,2)

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

NODE(I,5)=NODE(I,2)+NODE(I,4) (3)

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

(1)

(2)

(4)

NODE (I,7)=NODE (I,5)+NODE (I,3)

b. For I>1

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

NODE(I,4)=NODE(I-1,7)-NODE(I,2) (5)

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

NODE(1,5) = NODE(1,2) + NODE(1,4) (6)

Table 1 Entities of the Simulation Model

Entities	Designation	
IALL	total simulation time	
NPR	number of PR arriving during the sim- ulation 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(1,5)	PR starting time	
NODE(I,6)	PDC system idle time interval (time in- terval 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 ZR waiting time in the queue	

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*I is the index of paging request.

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

NODE(I,7) = NODE(I,5) + NODE(I,3) (7)

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

NODE(I,6) = NODE(I,5) - NODE(I-1,7) (8)

c. For I>1

Total PDC system service time is the sum of the service time for each PR: NPR ISERVE= Σ NODE(1,3) (9)

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

IDLE=IALL-ISERVE

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

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

(11)

(10)

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

AVG=WAIT/NPR

(12)

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5. <u>Simulation programs</u>

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 and 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 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 NODE(I,3) to the PR starting time 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 NODE(I,6) is computed by subtracting the previous PR finishing time NODE(I-1,7) from the current PR starting time NODE(I,5).
- Box 12 Checks if the computed PDC system idle time NODE(I,6) is negative.
- Box 13 If it is negative, 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 NODE(I,6) is equal to the first PR arrival time 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

Box 17 and the total PR waiting time WAIT are accumulated.

E x 18 Checks if all the PR's have been serviced.

and

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, and PDC system service time ISERVE, and average PR waiting time Box 26 AVG are printed.

5.2 Listings

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





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

6. <u>Simulation examples</u>

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

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Actions

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.

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

Table 2 Input data for example 1

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Total Simulation Time = 1200

Total Number of PR = 10.

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$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	1 60 100 100 20 100 20 200	1 80 100 0 60 100 20 180 0 2 160 100 20 100 20 180 0 3 240 100 40 280 0 0 4 320 100 40 280 0 0 4 320 100 100 60 380 0 0 5 400 100 100 100 560 0 0 6 480 100 120 660 760 0 0 7 560 100 120 560 0 0 0 9 640 100 140 760 0 0 10 100 160 160 160 0 0 0 0 100 160 160 0 0 0 10 100 100 160 160 0<	PR ID AF	RRIVAL TIME SYS	STEM SERVICE TI	ME PP WAITING TIME	PR STRATING TIMF	SYSTEM IDLE TIME	FINISHING TIM	
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			TOTAL S	SYSTEN IDLE TIME	: = 2n0					

17

90.000n SECONDS

AVERAGE WAITING TIME IN THE QUEUE =

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Paging Request Identification	Pajing Request Arrival Time	System Service Time for the Paging Request
1	80	90
2	160	90
3	2.40	50
4	320	50
5	400	60
6	480	60
7	560	70
8	640	70
9	720	90
10	800	90

Table 3 Input data for example 2

Total Simulation Time = 1200

Total Number of $PR = 10_{\pi}$

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

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PR ID ARRIVAL TIME	SYSTEM SERVICE TIME	PR WAITING TIME PR STF	ATING TIME	SYSTEM IDLE TIME	FINING TIME
	06	O	80	80	170
******************************	**************************************	6#####################################	·**********	********	*****
***************	***********	14 ************************************		-	260
J 240	50	20	260	*****	***********
4 320 ***************************	50	******	**********	f * * * * * * * * * * * * * * * * * * *	**********
5 ************************************	60	*************	++++++++++++++++++++++++++++++++++++++	*****	r*********
6 480 480 480 480 484 44 44 44	1. 读读不知 50	*****	**********	,***************	r********
7 560 ********************	70	·*************************************	**********	*****************	*********
640) 8**************************	70	······································	t***≎******		*********** 710
9 720	06	*********	:**********	*************	810 *********
10 800	, 06	*************	********	****	######################################
TOTAL SYSTEM IDLE T	************************************ E = 1200 SECONDS IME = 480	************	*****	*********	********

19

4.0000 SECONDS

AVERAGE WAITING TIME IN THE QUEUE =

TOTAL SYSTEM SERVICE TIME = 720

Paging Request Identification	Paging Request Arrival Time	System Service Time for the Pa gin g Request
1	80	80
<u></u>	00	ou
2	1.60	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

Table 4 Input data for example 3

Total Simulation Time = 1200

Total Number of PR = 10.

Fig.7. Example3%SIMuLATION OF A CHANNEL (arrival time is a multiple of constant system service time)

FINISHING TIME **年我女女年来去去太子女子子子子子子子子,有有不是有有有有有有有有有的,有有有有有有的,有有有有有有的。** PR STRATING TIME CYSTEM IDLE TIME C o င္တ PR WAITING TIME c - 1 ò ο ø C SYSTEM SERVICE TIME 1200 SECONDS AVERAGE WAITING TIME IN THE QUEUE TOTAL SYSTEM SERVICE TIME = TOTAL SYSTEM IDLE TAME = TOTAL SIMULATED TIME = ARRIVAL TIME 00 PR IO ĊV. S đ Ó σ

.000n SECONDS

7. Acknowledgement

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8. References

- 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.
- 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.
- Yeh, J.W., "An TOCS 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

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+RUN AA,001-11-768,KWOK~
 +ALGOCTS
                tors, tors
   STMULA REGIN
 COMMENT SIMULATION OF A MATHEMATICAL MODEL OF A PDC UNDER TOCS****
 COMMENT PAGING REQUESTS ARE STORED IN A HARDWARE QUEUE $
 COMMENT TOTAL PDC SYSTEM SERVICE TIME $
   INTEGER ISERVES
 COMMENT TOTAL SIMULATION TIME $
   INTEGER TALLS
 COMMENT NUMBER OF PAGING REQUESTS IN THE OUFUE $
   INTEGER NPPS
 COMMENT INDEX FOR THE PAGING REQUEST $
   INTEGER I S
 COMMENT TOTAL PDC SYSTEM IDLE TIME $
   INTEGER IDLES
   REAL WATTS
   REAL AVGS
   RFAL XS
   INTEGER ARRAY NODE(1..10, 1..7)$
   FORMAT F1 (A.14.14)$
   FORMAT F2(A, 13,13,13) $
COMMENT PR MEANS PAGING-IN OR PAGING-OUT REQUEST $
COMMENT NODE(I,1) IS PR ID
         NODF(I+2) IS PR ARRIVAL TIME
         NODE(1,3) IS PDC SYSTEM SERVICE TIME FOR THE PR
         NODE (1,4) IS THE PR WAITING TIME IN THE QUEUE
         NODE(1,5) IS THE PR STARTING TIME
         NODE(1,6) IS THE POC SYSTEM IDLE TIME
         NODE(1,7) IS THE PR FINISHING TIME $
COMMENT PRINT TITLES
             SIMULATION OF A PDC SYSTEM PROCESSING PAGING REQUESTS')S
   WRITE(
   ISFRVF = 05
   WATT = 0.09
COMMENT INPUT REQUEST CHARACTERISTICS $
   READ(TALL, NPR, F1) 5
COMMENT GENERATING 10 NODES FOR THE 10 PR'S $
   FOR I = 1 STEP 1 UNTIL NOR DO REGIN
COMMENT INPUT PR-ID, ARRIVAL TIME, SYSTEM SERVICE TIMES
   READ(NODE(1,1),NODE(1,2),NODE(1,3), E2)5.
COMMENT COMPUTE WAITING TIME S.
   IF I NEO 1 THEN GO TO LIA S
  NODE(1,4) = 0.5
   GO TO 1135
L11 .. NODE(1,4) = NODE(1-1,7) - NODE(1,2) $
COMMENT NO WAITING IF THE DIFFERENCE IS NEGATIVE $
   IF NODE(1,4) LSS 0 THEN NODE(1,4) = 0 $
COMMENT PR STARTING TIME &
L13 .. NODE(1,5) = NODE(1,2) + NODE(1,4)5
COMMENT PR FINISHING TIME S
   NODE(T,7) = NODE(T,5) + NODE(I,3) $
   TE I NEO 1 THEN GO TO L14 8
COMMENT COMPUTE INITIAL SYSTEM IDLE TIME 5
   NODF(1,6) = NODF(1,2) 5
```

```
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 NEGATIVES
  IF NODE(1,6) LSS 0 THEN NODE(1,6) = 0 $
COMMENT PRINT INTERMEDIATE RESULT $
L15 ... WRITE( PR-TD = I, NODE(I,1))$
       WRITE( PR ARRIVAL TIME = 1, NODE(1,2))$
       WRITE( + PDC SYSTEM SERVICE TIME = +,NODE(1,3))$
       WRITE( * PR WAITING TIME = *, NODE(1,4))$
       WRITE( PR STARTING TIME = ',NODE(1,5))$
       WRITE( PDC SYSTEM TOLE TIME = +,NODE(1,6))$
       WRITE( * PR FINISHING TIME = (+ NODE(1,7))$
  COMMENT STATISTICS GATHERING 5
COMMENT TOTAL PDC SYSTEM SERVICE TIME $
  ISFRVE = ISERVE + NODF(1,3) $
COMMENT COMPUTE TOTAL PR WAITING TIME $
  WAIT = WAIT + NODF(1,4) \mathfrak{s}
  FND 4
COMMENT COMPUTE AVERAGE PR WAITING TIME $
  X = NPR $
  AVG = WATT /X 5
  WRITE( ' TOTAL SIMULATED TIME IS ', IALL, ' SECONDS')$
COMMENT TOTAL PDC SYSTEM IDLE TIME $
  TOLF = TALL - ISFRVE S
  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!)S
  FNDS
+MAP
1XOT
12000010
  1080100
                                                FIRST JOB
  2160100
  3240100
  4320100
 5400100
 6480100
 7560100
 8640100
 9720100
10800100
                                                LAST JOB
IXOT.
12000010
 1080090
 2160090
 3240050
 4320050
 5400060
 6480060
 7560070
 8640070
 9720090
10800090
IXOT
12000010
 1080080
 2160080
 3240080
 4320080
```

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```
+RUN CS230,001-11-768,KWOK,1,20
IFOR, IS
                CH1,CH2
      DIMENSION NODE(10,7)
      PR IS PAGING REQUEST SERVICED BY THE PDC
C
C
      NODE(1,1) IS PR TO
      NODF(1+2) IS
                     PR-ARRIVAL TIME
Ĉ
      NODE(1,3) IS SYSTEM SERVICE TIME FOR THE PR
C
      NODE(1,4) IS THE PR WAITING TIME IN THE WAITING QUEUF
C
      NODE (1,5) IS THE PR STARTING TIME
Ċ
      NODE(1,6) IS THE SYSTEM IDLE TIME
C
      NODE (1,7) IS THE PR FINISHING TIME
C
      PRINT TITLE
6
      WRITE(6.1)
    1 FORMAT( 1H1, 30X, SIMULATION OF A CHANNEL',//)
      WRITE( 6,2)
                     PR ID ARRIVAL TIME SYSTEM SERVICE TIME
                                                                    PR WAITIN
    2 FORMAT(1H0,
              PR STRATING TIME SYSTEM IDLE TIME FINISHING TIME ! +/)
     1G TIME
      ISFRVF = 0
      WATT = 0.0
      TNPUT
Ċ
      TOTAL NUMBER OF PRIS
C
      TOTAL SIMULATION TIME IN SECONDS
C
      READ( 5,101) TALL, NOR
  101 FORMAT( 14,14)
      GENERATING 10 NODES FOR THE 10 PRIS
1
      ASSIGN CHARACTERISTICS TO EACH PR
C
      DO 10 T = 1 \cdot NPR
      INPUT PR ID, ARRIVAL TIME, SYSTEM SERVICE TIME
С
      READ(5,100)( NODF(1,J),J= 1,3)
  100 FORMAT( 13,13,13)
      WATTING TIME
C
      IF( I .NF. 1) GO TO 11
      NODF(1,4) = 0
      GO TO 13
   11 \text{ NODE}(1,4) = \text{ NODE}(1-1,7) - \text{ NODE}(1,2)
      NO WAITING IS NECESSARY IF THE DIFFERENCE IS NEGATIVE
C
      IF( NODE(1,4).LT. 0) NODE(1,4) = 0
       PR STARTING TIME
   13 \text{ NODE(I,5)} = \text{NODE(I,2)} + \text{NODE(I,4)}
C
       PR FINISHING TIME
      NODF(I_{3}7) = NODF(I_{3}5) + NODF(I_{3}3)
      TE( T .NE. 1) GO TO 14
      COMPUTE INITIAL SYSTEM IDLE TIME
C
      NODE(1,6) = NODE(1,2)
      GO TO 15
      SYSTEM IDLE TIME WHEN THE DR ARRIVES
С
   14 \text{ NODE}(1,6) = \text{NODE}(1,5) - \text{NODE}(1-1,7)
      NO SYSTEM IDLE TIME TE THE DIFFERENCE IS NEGATIVE
C
      IF( NODE(T,6).LT. () NODE(1,6) = 0
      PRINT INTERMEDIATE RESULTS
C
   15 WRITE( 6,3)(NODE(1,J) ,J=1,7)
    3 FORMAT(1H0,2X,12,10X,15,10X,15,10X,15,20X,15,10X,15,10X,15)
      WRTTF(6+9)
```

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```
STATISTIC GATHERING
C
      COMPUTE TOTAL SYSTEM SERVICE TIME
C
      ISERVE = ISERVE + NODE(1,3)
      COMPLITE TOTAL WATTING TIME
C
      WATT = WATT + NODE(T,4)
   10 CONTINUE
      COMPLITE AVERAGE WATTING TIME
0
      X = NPR
      AVG = WATT /X
      WRITE(6,5) TALL
    5 FORMAT( 1H0,5X, TOTAL SIMULATED TIME = 1, 15, SECONDS!)
C
      COMPUTE TOTAL SYSTEM IDLE TIME
      TOLE = TALL- ISERVE
      WRITE(6,6) IDLE
    A FORMAT(1H0,5X, TOTAL SYSTEM THE TIME = 1,15)
      WRITE(6,7) ISERVE
    7 FORMAT(1H0,5X, TOTAL SYSTEM SERVICE TIME = 1,15)
      WRITE(G, R) AVG
    8 FORMAT(1H0,5X, 'AVERAGE WAITING TIME IN THE QUEUE = ',F14.4, ' SECO
     INDSI
    9 FORMAT(1H0, 110(+**))
      FND
+ MAP
1XOT
12000010
  1080100
                                                    FIRST PR
  21 80100
  2240100
  4220100
  5400100
  6480100
  7560100
  8640100
  9720100
 10800100
                                                    LAST PR
IXOT.
12000010
  1080090
  2160090
  3240050
  4220050
  5400050
  6420060
  7560070
  8640070
  9720090
 10800090
1XOT
12000010
 1080080
  2160080
  2240080
  4220080
 5400020
 6480080
 7560080
 8640080
  9720020
10800080
!FTN
```

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