C PROGRAMMING ASSIGNMENT – 5

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Dump Truck Problem

Six dump trucks are used to haul coal from the entrance of a small mine to the railroad:

– Each truck is loaded by one of two loaders.

– After loading, the truck immediately moves to the scale to be weighed.

– The loaders and the scale have a FCFS waiting line (or queue) for trucks.

– After being weighed, a truck begins a travel time (during which the truck unloads) and returns to the loader queue.

Purpose: to estimate the loader and scale utilizations (% of time busy).

• The model has the following components:

– System state [LQ(t), L(t), W Q(t), Q(t)], where:

*LQ(t) is the number of trucks in loader queue.

*L(t) is the number of trucks (0,1, or 2) being loaded.

*W Q(t) is the number of trucks in the weigh queue.

*W (t) is the number of trucks being weighed.

– Event notices:

∗ (ALQ, t, DT i), dump truck i arrives at loader queue (ALQ) at time t.

∗ (EL, t, DT i), dump truck i ends loading (EL) at time t.

∗ (EW, r, DT i), dump truck i ends weighing (EQ) at time t.

– Entities: The six dump trucks (DT 1, . . . , DT 6)

SOURCE CODE:

```
#include<stdio.h>
#include<stdlib.h>
#include<string.h>
#define weighmax 1
#define loadmax 2

int LT[] = {10,5,5,10,15,10,10};
int WT[] = {12,12,12,16,12,16};
int TT[] = {60,100,40,40,80};

int wtp, ttp, ltp;
int sysclock = 0;
struct future_event_list
{
     char event[4];
     int truck_no, n_clock;
     struct future_event_list * next;
};

typedef struct future_event_list FEL;
FEL* head = NULL;

struct truckqueue
{
     int truck_no;
     struct truckqueue *next;
};
typedef struct truckqueue TQ;

TQ *loader = NULL;
TQ *weigher = NULL;
int LQ, L, WQ, W, Bl, Bs;

void enqueue(TQ **head, int tno)
{
     TQ* temp = *head;
     TQ* node = calloc(1,sizeof(struct truckqueue));
     node->truck_no = tno;
     node->next = NULL;
     if(*head==NULL)
     {
          *head = node;
          return;
     }
     while(temp->next!=NULL)
          temp = temp->next;

     temp->next = node;
}

int dequeue(TQ **head)
{
     int x = (*head)->truck_no;
     *head = (*head)->next;
```

```
     return x;
}

FEL* genevent(char event[], int tno, int nclock)
{
     FEL* temp = calloc(1,sizeof(FEL));
     temp->next = NULL;
     strcpy(temp->event,event);
     temp->truck_no = tno;
     temp->n_clock = nclock;
     return temp;
}

void insert(FEL* node)
{
     FEL* temp = head;
     FEL* prev = head;
     if(head==NULL)
     {    head = node;
          return;
     }
     if(head->n_clock > node->n_clock)
     {
          node->next = head;
          head = node;
          return;
     }
     while(temp!=NULL)
     {
          if(temp->n_clock > node->n_clock)
               break;
          else{
               prev = temp;
               temp = temp->next;
          }
     }

     node->next = prev->next;
     prev->next = node;
}

void delete()
{
     FEL* temp = head;
     head = head->next;
     Bl += (temp->n_clock-sysclock)*L;
     Bs += (temp->n_clock-sysclock)*W;
     sysclock = temp->n_clock;
     if(strcmp(temp->event,"EL")==0)
     {    enqueue(&weigher,temp->truck_no);
          WQ++;
          L--;
          if(LQ>0)
          {

     insert(genevent("EL",dequeue(&loader),sysclock+LT[(ltp++)
%7]));
               L++;
               LQ--;
          }
```

```
          if(WQ>0 && W<weighmax)
          {

     insert(genevent("EW",dequeue(&weigher),sysclock+WT[(wtp++)
%6]));
               WQ--;
               W++;
          }

     }
     else if(strcmp(temp->event,"EW")==0)
     {
          insert(genevent("ALQ",temp->truck_no,temp-
>n_clock+TT[(ttp++)%5]));
          W--;
          if(WQ>0)
          {

     insert(genevent("EW",dequeue(&weigher),sysclock+WT[(wtp++)
%6]));
               WQ--;
               W++;
          }
     }
     else if(strcmp(temp->event,"ALQ")==0)
     {
          enqueue(&loader,temp->truck_no);
          LQ++;
          if(L<loadmax)
          {
               LQ--;
               L++;

     insert(genevent("EL",dequeue(&loader),sysclock+LT[(ltp++)
%7]));
          }
     }
}

void init()
{
     LQ = 3;
     L = 2;
     WQ = 0;
     W = 1;
     FEL* temp;
     int i=0;
     enqueue(&loader,4);
     enqueue(&loader,5);
     enqueue(&loader,6);

     insert(genevent("EW",1,WT[(wtp++)%6]));
     insert(genevent("EL",2,LT[(ltp++)%7]));
     insert(genevent("EL",3,LT[(ltp++)%7]));
}

void display()
{
     int i=0;
     FEL *temp = head;
```

```
     TQ *top;
     printf("\n\n\n\t\t Clock = %d\n",sysclock);
     printf("\n LQ:\t%d\t L:\t%d\t WQ:\t%d\t W:\t%d\t BL:\t%d\t
BS:\t%d\n",LQ,L,WQ,W,Bl,Bs);
     printf("\nLoader Queue:\t\t");
     top = loader;
     for(i=0;i<LQ;i++)
     {    printf("DT%d\t",top->truck_no);
          top = top->next;
     }

     printf("\nWeighing Queue:\t\t");
     top = weigher;
     for(i=0;i<WQ;i++)
     {
          printf("DT%d\t",top->truck_no);
          top = top->next;
     }

     printf("\n\n--------Event List--------\n");
     while(temp!=NULL)
     {
          printf("\n Event: %s\t Time: %d\t Truck: DT%d\t",temp-
>event, temp->n_clock, temp->truck_no);
          temp = temp->next;
     }
}
void main()
{
     init();
     while(sysclock<=5000)
     {
          display();
          delete();
     }

     printf("\n\n Average loader utilization: %f",(float)
(Bl/loadmax)/sysclock);
     printf("\n Average scale utilization: %f\n\n",(float)
(Bs/weighmax)/sysclock);
}
```

OUTPUT :

```
                Clock = 0

 LQ:    3       L:     2       WQ:    0       W:     1       BL:    0       BS:    0

Loader Queue:           DT4     DT5     DT6
Weighing Queue:

--------Event List--------

 Event: EL       Time: 5         Truck: DT3
 Event: EL       Time: 10        Truck: DT2
 Event: EW       Time: 12        Truck: DT1


                Clock = 5

 LQ:    2       L:     2       WQ:    1       W:     1       BL:    10      BS:    5

Loader Queue:           DT5     DT6
Weighing Queue:         DT3

--------Event List--------

 Event: EL       Time: 10        Truck: DT2
 Event: EL       Time: 10        Truck: DT4
 Event: EW       Time: 12        Truck: DT1


                Clock = 10

 LQ:    1       L:     2       WQ:    2       W:     1       BL:    20      BS:    10

Loader Queue:           DT6
Weighing Queue:         DT3     DT2

--------Event List--------

 Event: EL       Time: 10        Truck: DT4
 Event: EW       Time: 12        Truck: DT1
 Event: EL       Time: 20        Truck: DT5
```

fig1: Truck simulation from clock 0 through 10

```
Loader Queue:
Weighing Queue:         DT4     DT5

--------Event List--------

 Event: EL       Time: 25        Truck: DT6
 Event: EW       Time: 36        Truck: DT2
 Event: ALQ      Time: 72        Truck: DT1
 Event: ALQ      Time: 124       Truck: DT3


                Clock = 25

 LQ:    0       L:     0       WQ:    3       W:     1       BL:    45      BS:    25

Loader Queue:
Weighing Queue:         DT4     DT5     DT6

--------Event List--------

 Event: EW       Time: 36        Truck: DT2
 Event: ALQ      Time: 72        Truck: DT1
 Event: ALQ      Time: 124       Truck: DT3


                Clock = 36

 LQ:    0       L:     0       WQ:    2       W:     1       BL:    45      BS:    36

Loader Queue:
Weighing Queue:         DT5     DT6

--------Event List--------

 Event: EW       Time: 52        Truck: DT4
 Event: ALQ      Time: 72        Truck: DT1
 Event: ALQ      Time: 76        Truck: DT2
 Event: ALQ      Time: 124       Truck: DT3
 Average loader utilization: 0.423077
 Average scale utilization: 1.000000
```

fig2: Average scale and loader utilization

Analysis:

The average loader and scale utilization can give us an idea on whether the investment on such equipment is justified, or if we need to increase or decrease their quantity. For the above simulation upto 50 clock cycles, and for 6 dump trucks, the scale and loader utilization are as follows:

Avg loader utilization: 0.423
Avg scale utilization: 1.00

This gives us an indication that the number of loaders can be reduced whereas the numbers of scales can be increased or kept constant.

For larger values, the simulation for 6 trucks upto 5000 clocks, we can see that:

Average loader utilization: 0.294165
Average scale utilization: 0.844125

This also reinstates our faith in reducing the loaders, as the loaders are idle for most of the time.

Increasing the number of trucks dumping can also increase the utilization and the throughput.