Mestrado Integrado em Engenharia Eletrotécnica e de Computadores

UC Sistemas de Telecomunicações

Discrete event traffic simulation - Part 3

Traffic simulation of packet-oriented loss and waiting systems

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Introduction

In this third and final stage of the assignment about discrete event traffic simulation, the main objective is to finally build a Call Center System that's uses the both finite and infinite queues to deal with constant calls arriving to the imaginary call center.

In the Call Center of a telecom operator calls are received at an arrival rate of 80 calls/hour (Poisson process), during the peak hour. These calls have the following distribution:

- 30% of the calls refer to requests that can be processed by a general-purpose call center operator. These calls have a minimum duration of 1 min plus a duration following an exponential distribution with average equal to 2 min. The maximum duration is 5 min.

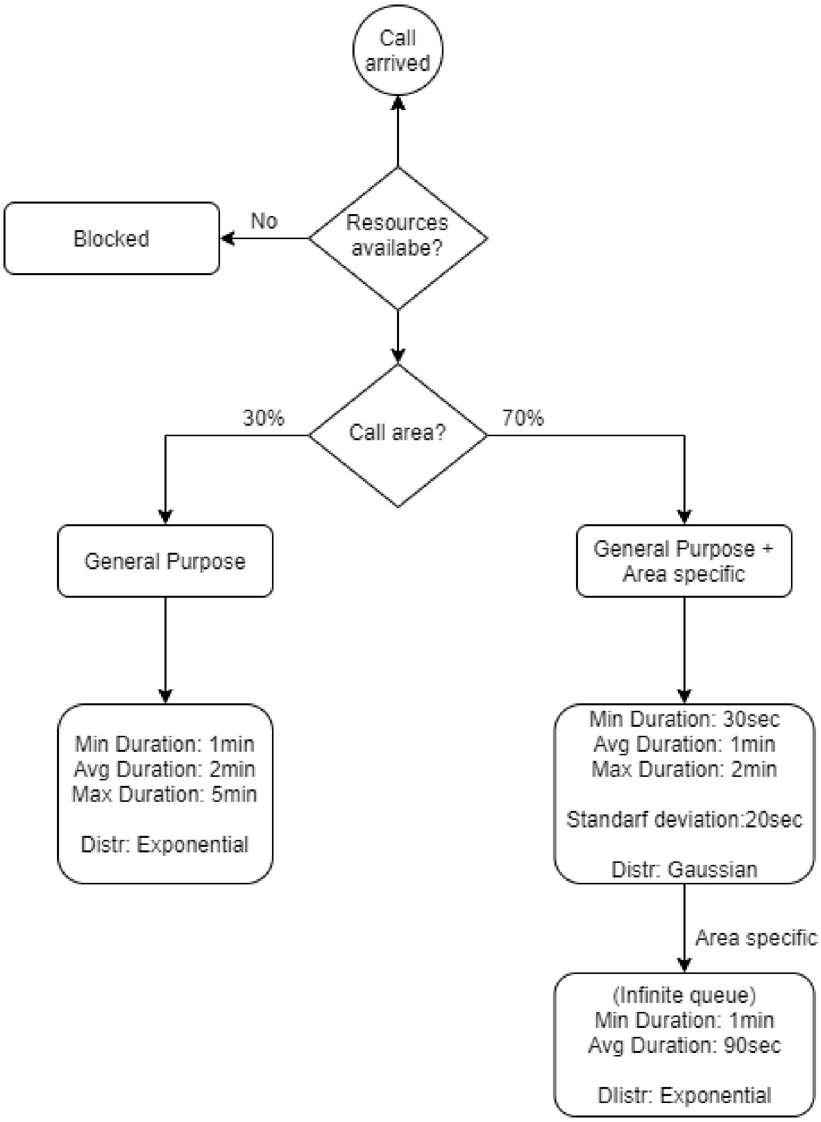
- 70% of the calls require the contact with an area-specific call center operator (e.g., technical issues, billing). These calls are transferred accordingly. Until they are transferred to an area-specific call center operator, the duration of the calls follows a Gaussian distribution with an average of 1 min and standard deviation of 20 seconds. The minimum and maximum duration are respectively 30 and 120 seconds.

The calls that find the system busy are put in a waiting queue with finite length, until its limit is reached. Above that limit the calls are lost.

The calls transferred and answered by an area-specific call center operator have a minimum duration of 1 min plus a duration following an exponential distribution with average equal to 2.5 min. If the area-specific answering system is busy, the calls are put in an infinite waiting queue. The call answered by the general-purpose answering system is only considered processed when it is answered by an area-specific call center operator.

Whenever a call is in the waiting queue to be answered by a general-purpose call center operator, a prediction of the average waiting time is made by the system and communicated in audio format to the user, taking into account the current system load. This prediction must be exclusively based on the duration of previous calls processed by the system (i.e., it must not be estimated based on the duration of calls already declared, considering the corresponding distributions).

1. General characterization of the simulation methodology



2. Description of the simulation program

The program basically runs the same functions form the last versions with the addition of some new ones like:

```
double generalDuration(int area){
double specificDuration(){
int getArea(){
double movingAverage(int n, double sample, double old_average){
double getAvg(double* array, int n){
double STDeviation(double* array, int n, double average){
```

Most are just adaptations to deal with the fact that we now have two different queues, and the rest are functions to aid the statistic calculations like the absolute and relative errors of the predicted waiting time. I also needed a quick solution to compute the error data and parse results to make the final calculations easier, so I made a quick search and got the following code from StackOverflow. These are just the *init*, *insert* and *free* array functions.

In order to predict the waiting time of the incoming calls, some sort of real-time average was needed. That is called running-average and is calculated as follows:

The running average can be calculated using Equation 1:

$$avg[n] = avg[n-1] * (n-1)/n + current\_sample * 1/n \qquad (1)$$

where *avg[n]* is the average of *n* samples, *avg[n-1]* is the average of the previous *n-1* samples, and *current_sample* is the value that will be combined with *avg[n-1]* to obtain the new average.

```
double movingAverage(int n, double sample, double old_average){
    return (old_average*(n-1) + sample)/n;
}
```

Another modification is the fact that the program now prints both histograms (Prediction vs Real) and creates a simple .txt file for both so it is easy to analyse outside the console.

3. Describe the algorithm used to predict the call waiting time

I used the Box-Muller method as the the algorithm used to predict the call waiting time recommended in class.

Method 3 (Box-Muller)

Let U_1 and U_2 be independent and uniformly distributed on (0, 1).
Set $\Theta = 2\pi U_1$ and $R = \sqrt{-2\ln U_2}$.
Then $X = R\cos\Theta$ and $Y = R\sin\Theta$ are independent standard normal variates.

```
else {   //GAUSSIAN  Min: 30 Max: 120 Avg: 60

    double k=newEvent(RANDOM);
    double u=newEvent(RANDOM);   //(Box-Muller)
    double teta = 2*M_PI*u;
    p = (sqrt(-2*log(k))*cos(teta));
    p = 30 + ((p*std_deviation) + mean);

    if(p > (double) 120)
      p = (double) 120;
}
return p;
```

4. Simulation results and Sensitivity analysis

- Probability of a call being delayed at the input of the general-purpose answering system: 30%

```
Lambda :                    0.0222 Calls per second
Delta :                     9.001
Number of samples :         20000
General operators:          6
Specific operators:         6
L :                         8
-------------------------------------------------------------

Avg Packets Delayed:                              30.8900%
Avg Delayed Time:                                 85.1454
Avg Specific purpose Delayed:                     43.1917%
Avg Specific purpose Delayed Time:                1183.8628
Avg Time of specific purpose packets in queues:   541.3095
Avg Blocked packets:                              2.5100%

-------------------------------------------------------------

Avg Absolute prediction Error:   46.961
Avg Relative prediction Error:   87.4396%

Confidence interval of 90% --> 12.7434
```

- Probability of a call being lost at the input of the general-purpose answering system: 2%

```
Lambda :                  0.0222 Calls per second
Delta :                   9.001
Number of samples :       20000
General operators:        4
Specific operators:       4
L :                       3
--------------------------------------------------------------

Avg Packets Delayed:                             26.5400%
Avg Delayed Time:                                37.1040s
Avg Specific purpose packets Delayed:            58.4072%
Avg Specific purpose delayed Time:               194.5523s
Avg Time of specific purpose packets in queues:  123.3164s
Avg Blocked packets:                             1.8500%

--------------------------------------------------------------

Avg Absolute prediction Error:   22.392
Avg Relative prediction Error:   50.6710%

Confidence interval of 90% --> 2.3910
```

- Average delay of the calls (for the calls that suffer delay at the input of the general-purpose answering system): 30 s.

```
Lambda :                  0.0222 Calls per second
Delta :                   9.001
Number of samples :       20000
General operators:        4
Specific operators:       4
L :                       2
--------------------------------------------------------------

Avg Packets Delayed:                             22.6750%
Avg Delayed Time:                                30.7834s
Avg Specific purpose packets Delayed:            54.1596%
Avg Specific purpose delayed Time:               165.8802s
Avg Time of specific purpose packets in queues:  96.6592s
Avg Blocked packets:                             3.6300%

--------------------------------------------------------------

Avg Absolute prediction Error:   19.077
Avg Relative prediction Error:   130.4210%

Confidence interval of 90% --> 1.9948
```

- Average total delay of the calls, since they arrive at the general-purpose answering system until they are answered by the area-specific answering system: 60 s.

```
Lambda :                  0.0222 Calls per second
Delta :                   9.001
Number of samples :       20000
General operators:        6
Specific operators:       6
L :                       9
--------------------------------------------------------------

Avg Packets Delayed:                             4.3400%
Avg Delayed Time:                                21.9872s
Avg Specific purpose packets Delayed:            12.6875%
Avg Specific purpose delayed Time:               62.6149s
Avg Time of specific purpose packets in queues:  8.7994s
Avg Blocked packets:                             0.0000%

--------------------------------------------------------------

Avg Absolute prediction Error:   15.183
Avg Relative prediction Error:   121.4239%

Confidence interval of 90% --> 0.4160
```

Observations:

-The histograms only show if they are shorter than 125 this time, in order to keep the program usable.

-Example results for 6 operators in both parties, 200 calls and a queue length of 10 (lambda =80/3600=0,0222 Calls/sec):

```
Sample ID: 15    ---> Estimated time left: 0.000000
Sample ID: 16    ---> Estimated time left: 30.122127
Sample ID: 17    ---> Estimated time left: 30.122127
Sample ID: 18    ---> Estimated time left: 37.621534
Sample ID: 44    ---> Estimated time left: 41.000249
Sample ID: 45    ---> Estimated time left: 35.010045
Sample ID: 46    ---> Estimated time left: 35.010045
Sample ID: 47    ---> Estimated time left: 35.010045

General Histogram:
08     =  =
07     =  =  =
06     =  =  =
05     =  =  =
04     =  =  =
03     =  =  =  =  =
02     =  =  =  =  =
01     =  =  =  =  =
x: 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24  (s)

Prediction Histogram:
06     =
05     =
04     =
03     =
02     =  =  =
01     =  =  =
x: 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24  (s)
Histogram.txt was created!
Prediction_Histogram was created!

Lambda :                 0.0222
Delta :                  9.001
Number of samples :      200
General operators:       6
Specific operators:      6
L :                      10
--------------------------------------------------------------

Avg Packets Delayed:                             4.5000%
Avg Delayed Time:                                32.8317
Avg specific purpose Delayed:                    7.0922%
Avg specific purpose Delayed Time:               79.1040
Avg time of specific purpose packets in queues:  7.5000
Avg blocked packets:                             0.0000%

--------------------------------------------------------------

Avg Absolute prediction Error:   15.189
Avg Relative prediction Error:   27.0588%

Confidence interval of 90% 3.3216
```