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Sistemas de Telecomunicações

Discrete event traffic simulation

Part 3

1. General characterization of the simulation methodology

The types of events considered in this system were as follows: the arrival/departure of an event of **general-purpose** and the arrival/departure of an event of an **area-specific**.

```
#define chegada_operador_geral 1
#define partida_operador_geral 2
#define chegada_operador_especifico 3
#define partida_operador_especifico 4
```

Figure 1: Event types

An event always starts as *chegada_operador_geral*. Then according to probability of occurrence of 30% events for general-purpose and 70% for area-specific there are only 2 ways: event departure on the purpose operator (next event type is *partida_operador_geral*) and free up space in the queue or are forwarded to the area-specific operator (event type is *chegada_operador_especifico*).

A structure has also been created for the list of events to be processed.

```
// definição da lista com os dados
typedef struct{
    int lista_tipo;
    double lista_tempo;
    double lista_tempo_chegada; // tempo de chegada de um evento ao atendimento geral
    double lista_tempo_previsto; // o tempo previsto de quanto tempo um a chamada fica no buffer do atendimento geral
    int lista_buffer_elementos; // número de elementos que estão no buffer do atendimento geral quando esse evento chega (exceto ele próprio)
    struct list * lista_proximo;
} list;
```

Figure 2: list structure

We have implemented a queue for each type of event: a **general queue** for all events, an event queue to be processed by the **general-purpose** operator (fila_operador_geral) and another event queue to be processed by the **specific area** operator (fila_especifica).

```
list *eventos = NULL, *fila_operador_geral = NULL, *fila_especifica = NULL;
```

Figure 3: queues implemented

2. Description of the simulation program

The **simulation program** is a constant check of event that is at the top of the list, using the ordering criteria of the arrival time of the event. Then according to if its an arrival or departure of a **general-purpose or area-specific event** the following schema show us the differents paths and answers.

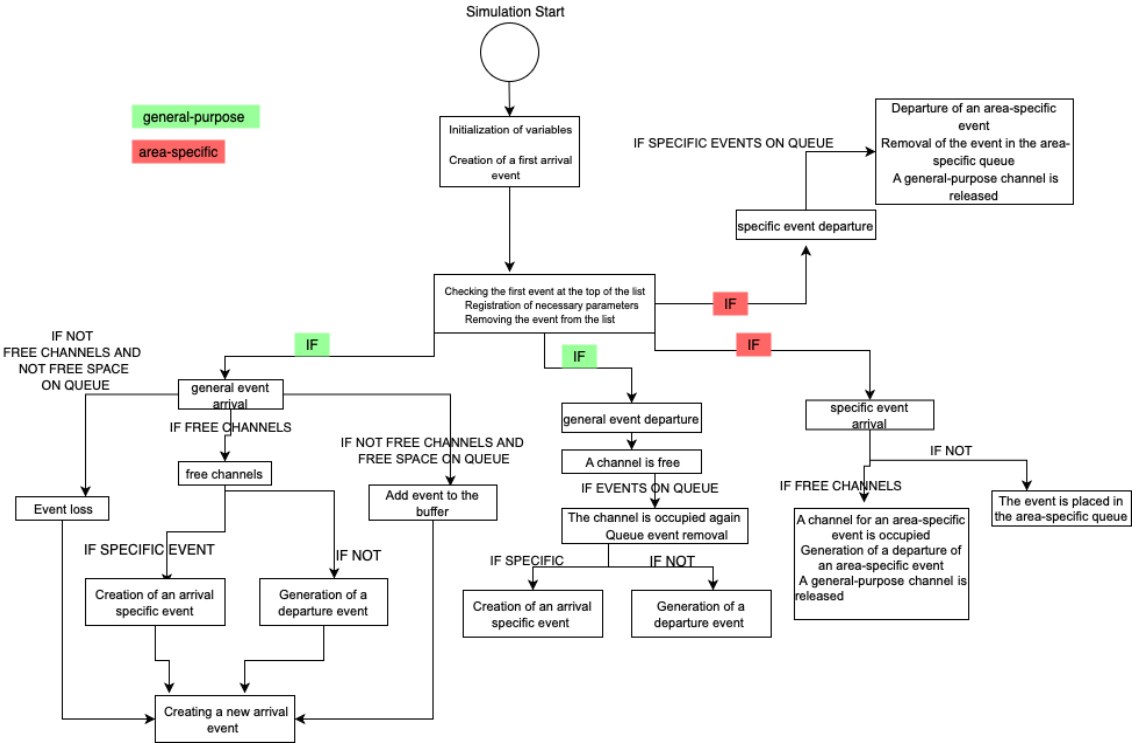

Figure 4: simulation program schema

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

The **waiting delay** is calculated when there is an access to the waiting queue and an event from that list leaves. The running average that was used:

avg[n] = avg[n-1] * (n-1)/n + current_sample* 1/n <=>
avg[n] = avg[n-1] - (avg[n-1]/n) + (current_sample/n) <=>
current_sample = real_time / (#queue_elements + 0.5)

The 0.5 corresponds to an intermediate value in the event, that is placed in the queue and will be the next to be attended.

The value inserted in the **forecast time** of the event structure is defined in two different ways:

1. For the case that there are events in the queue we can consider as the forecast time the multiplication between the running average and the number of events in the queue:

   #queue_elements * average

2. For the case where there are no samples in the queue, the forecast time is defined as multiplying the number of elements in the queue by half the service time, taking into account that the next element to be served has this average waiting time:

#queue_elements * average_time_general_purpose * 0,5

4. Simulation results

```
 * Resources: General_queue = 2, # General_purpose_operators = 3, # Area_specific_operators = 8

Probability of a call being delayed at the input of the general-purpose answering system:: 20.113%

Probability of a call being lost at the input of the general-purpose answering system: 2.196%

Average delay of the calls (for the calls that suffer delay at the input of the general-purpose answering system): = 30.357 sec

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: 73.164 sec
```

Length of general queue=2 | Number of general purpose operators=3 | Number of specific operators=8

The values we obtained in the simulation are quite close to the expectations.
The system we designed, comparing to the minimal goals, has a lower probability of delaying a call at the entrance to the general purpose answering system, which is good but on the other hand it has an higher value in the average total delay of the calls (73.164 - 60 = 13.164 sec) which we couldn't reduce any more.

Expected vs Simulation	Minimal performance goals	Simulation values
probability of a call being delayed at the input of the general-purpose answering system	30%	20,11%
probability of a call being lost at the input of the general-purpose answering	2%	2,20%
average delay of the calls (for the calls that suffer delay at the input of the general-purpose answering system)	30 seconds	30,357 seconds
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 seconds	73,164 seconds

Figure 5: Expected results vs Simulation results

For the values we obtained, the distribution of call delays calculated at the entrance of the system, until the calls are answered by a general operator is shown in figure 6:

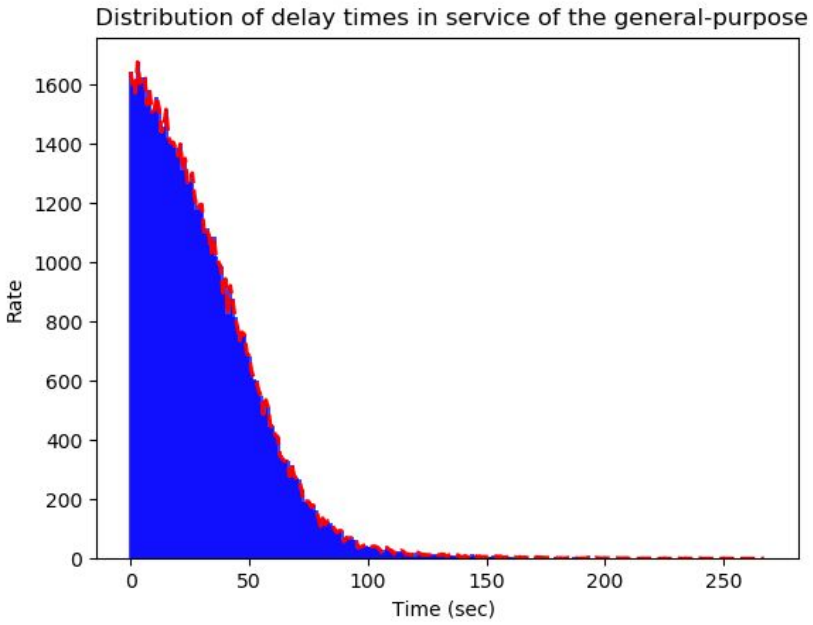

Figure 6: Histogram of the waiting time in the general purpose system input queue

The histogram of the waiting time prediction error in the input queue is shown in figure 7:

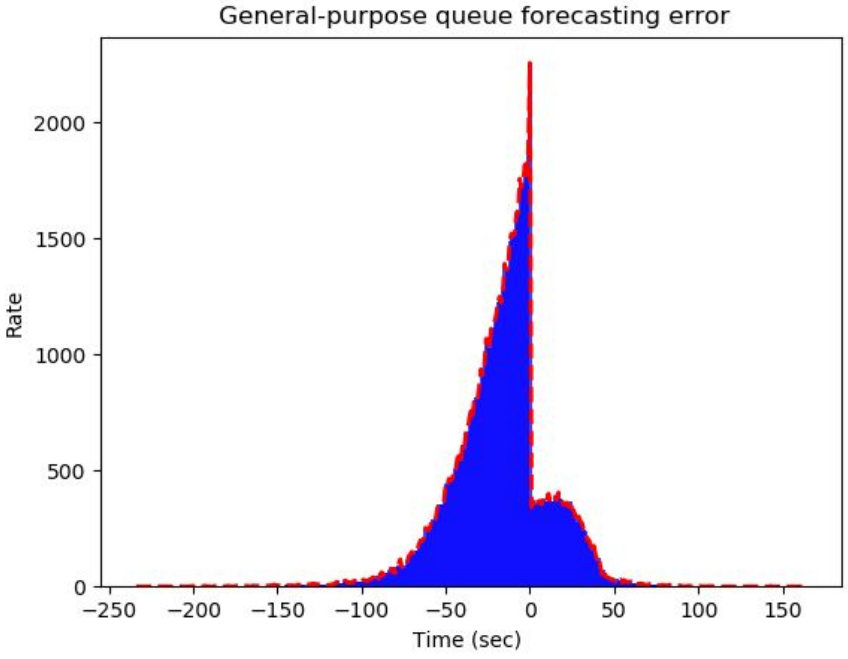

Figure 7: Histogram of the waiting time forecast error in the general system input queue

```
*  Expected waiting time error
Mean of the absolute error of the expected waiting time in the incoming operator_general queue:  24.622 sec
Mean of the relative error of the expected waiting time in the incoming operator_general queue: -17.037 sec
Standard deviation from the expected waiting time in the operator_general queue: 27.633 sec
```

5. Sensitivity analysis

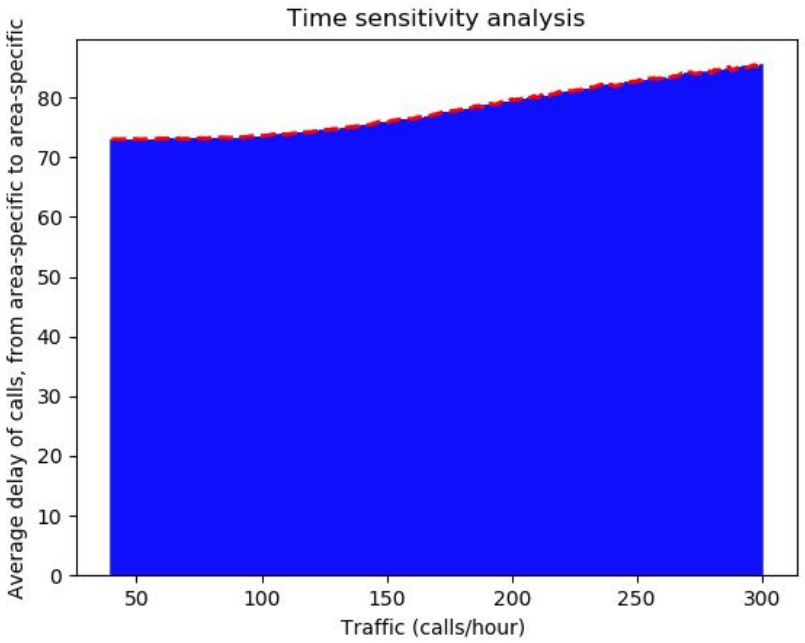

Figure 8: Sensitivity analysis observing the behavior of the average delay of calls through the variation of the traffic offered at the entrance.

The figure above shows us the variation of the average delay with the variation of the number of calls per hour arriving. With this we can observe an increase in the average delay with the increase on traffic. It was expected to have a time below 60 seconds but we obtained 73 seconds with our simulation. Between 40 calls per hour up to 120 calls per hour the system maintained the desired behavior.

Then it was made an analysis of the estimator of the referred test variable when the arrival rate is **80 calls/hour**, considering a confidence interval of **90%**:

```
*  Sensitivity analysis for 80 calls/hour

GENERAL(90%): 73.167 +- 0.166 seg
```