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Educational case study: evaluation of guaranteed service on low earth orbit satellite networks

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Abstract

There are some important traffic concepts that are more easily understood when dealing with circuit switched networks than with packet switched ones. One of them is the impact on the overall network behavior of flexible routing of communication requests oblivious to the route length as will probably occur in the new low earth orbit satellite networks that are been deployed nowadays. It is expected that these satellites will be able to use lasers to forward traffic among them, so we are going to explore an academic problem where a guaranteed service with previous allocation negotiation takes place in them. In this paper we present an educational case study designed in such a scenario where students should study the service availability for different configurations as offered traffic increases. Moreover, we have enhanced our simulation tool in order to focus on different blocking probabilities, allowing the aggregation of sample values of traffics with the same blocking probability toward a common mean value estimator. We show results and will be commenting upon the experience as it has been deployed on the current academic year.

Keywords: Education, Performance Analysis, Discrete simulation

1. Introduction

Stability of alternate routing in telephone networks is a classic problem amenable to both an approximate analysis and a simulation approach in symmetric configurations (Krupp, 1982). Although pure circuit switching networks are not as ubiquitous as before, services with strict quality requirements may still use resource reservation modeled with blocking queuing networks. Moreover, the impact of diverse route lengths in the performance of any switching network, either packet or circuit switched one, is more easily grasped in the latter case.

On the other hand, low earth orbit satellite networks as shown in Figure 1 are been deployed nowadays. They are scheduled to include laser satellite to satellite packet forwarding in the near future, thus enabling new services to be deployed. We explore a hypothetical guaranteed service with previous allocation negotiation phase in order to study the impact of different routing choices on the performance of the system, measuring the quality of the service through the blocking probability suffered by a new request. We will study a simplified model of the satellite network where satellite movement and roaming of terminals between them is disregarded. With this purpose we use the CSNEE simulation tool—Circuit Switching Network Experimental Environment, Suárez-González et al. (1998), https://icarus.det.uvigo.es/CSNEE/—enhanced in order to lower the number of magnitudes having to be estimated.

In Section 2 we briefly comment on the classical

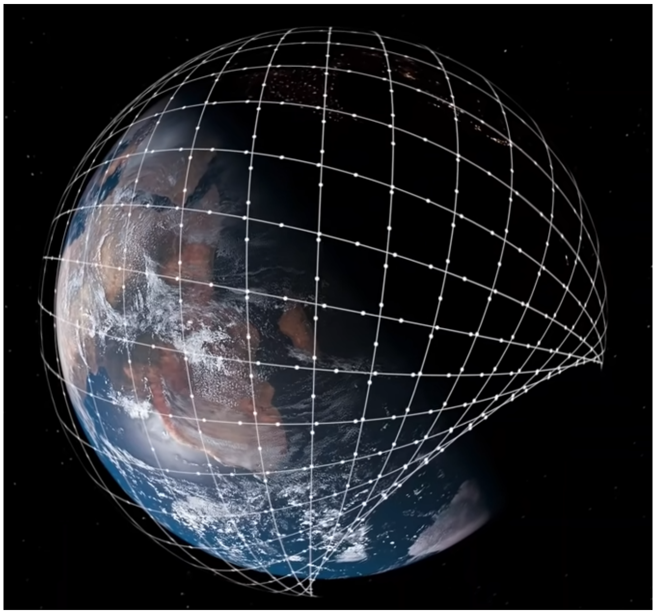

Figure 1. StarLink

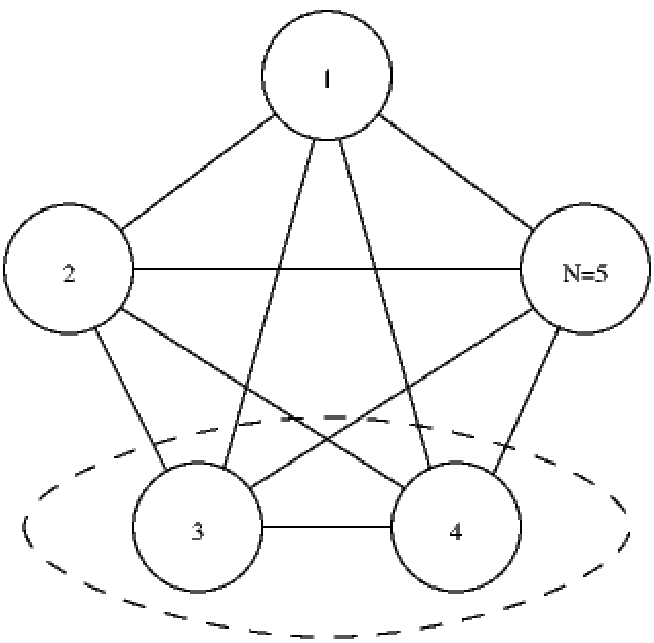

Figure 2. Symmetrical network

problem of alternate routing in circuit switching networks. In Section 3 we briefly present the circuit switching simulation tool and the modifications that we have implemented. In Section 4 we sketch the case study proposed to the students. Finally, in Section 5 we will expose the conclusions from the experience in the actual teaching environment.

2. Alternate routing

In the classical problem all the switching nodes of a given hierarchical level, such as that shown in Figure 2, are interconnected among them. One node will try to route a new request first through the direct link between itself and the destination node. Secondly, it will try one by one all of the routes of two links through a third node. As shown by Krupp (1982), the system misbehaves on overload conditions if no action, such as some reservation for first routed traffic, is taken.

We will propose to the students a similar problem in the context of a guaranteed service on a satellite network under simplifying assumptions.

3. CSNEE simulation tool

CSNEE is a simulation tool aimed to estimate the blocking probability of the traffics offered to a circuit switching network using the batch means algorithm proposed by Law and Carson (1979). The configuration file specifies both how many circuits each link has and the number of offered traffics, each one followed by:

- both the interarrival time and the service time random variables specification, and
- the routes (as sets of links) to be tried.

A new added facility has been incorporated into the simulator, so that traffics can now specify which blocking probability estimator is going to coalesce their sample values using a lower case letter (hence "a" to "z" possible estimators). This way we may take advantage of the symmetry of the specified network and run simulations more efficiently.

4. Case study

Under the simplifying assumption of static satellites, we propose the study of a guaranteed service with the following characteristics:

- connections are deemed homogeneous, that is, each one of them reserve identical capacity,
- up to 40 simultaneous connections for this service can be reserved in every laser link,
- we will consider that the new service will be solicited to access servers in one location, that is, all the connection requests will be forwarded to the area covered by one satellite (satellite A in Figure 3),
- new requests will be offered only from areas near to the servers, that is, we will consider only those from the eight neighbor satellites (B to H in Figure 3).

Several routing approaches will be consider.

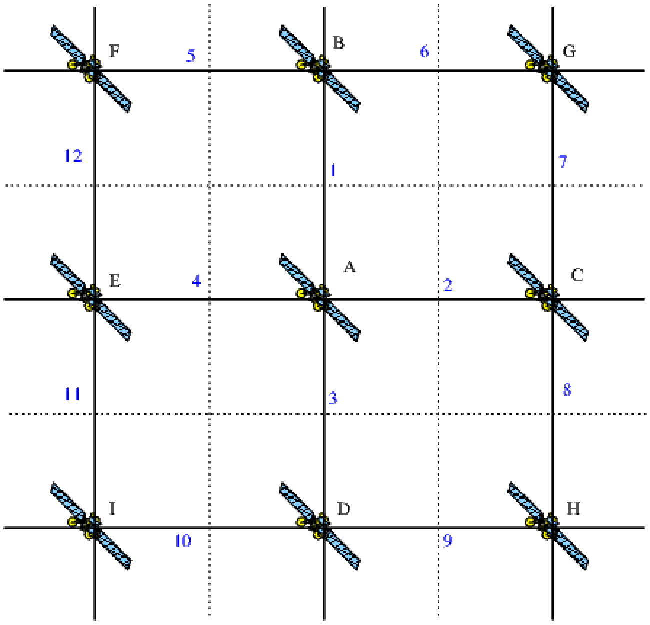

Figure 3. 3 × 3 satellite mesh configuration

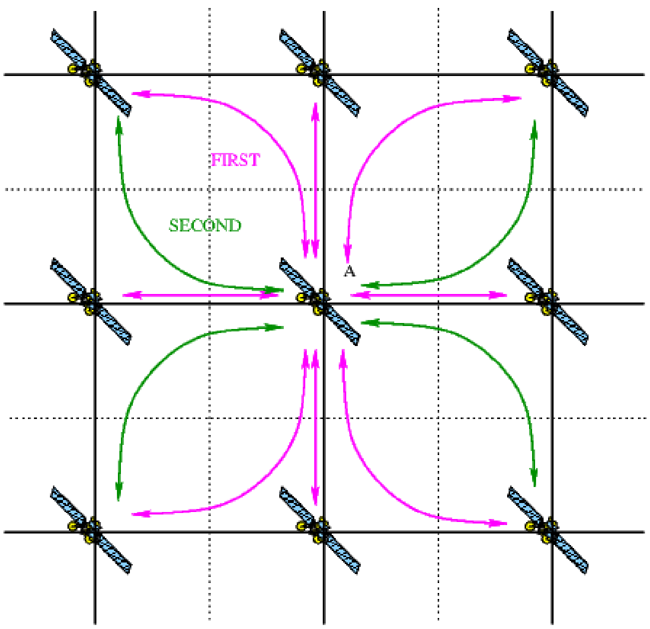

Figure 4. Sequence of routes tried in configuration *N–S*

4.1. Classical routing

Since satellites are deployed in clusters sharing the same orbit, it would be a possible simplifying strategy from the control plane point of view to prioritize routing connections in the last hop to the busier node (A) through satellites both forward (North) and backward (South) in the same orbit, so routes are selected preferentially using links 1 and 3 as numbered in Figure 3. This way the routes from each satellite to the central node will be those shown in Figure 4, where those satellites at two hops from A try first the route with a North–South link entering node A and if it fails then they try the other two hops route.

In this case there will be three sets of traffics sharing the same blocking probability, identified by their source satellite:

1. B and D (using mean value estimator "a")
2. C and E (using mean value estimator "b"),
3. F, G, H and I (using mean value estimator "c").

The configuration file for offered traffics a = 20 between each border satellite and satellite A is:

```
# Number of resources for each link
40 40 40 40 40 40 40 40 40 40 40 40
# Number of offered traffics
8
## Traffic a from B to A
# Interarrival time distribution
 M 1
# Service time distribution
 M 20
# Routes to be tried and mean value aggregator
 1 a
## Ditto from C to A
 M 1
 M 20
 2 b
## Ditto from D to A
 M 1
 M 20
 3 a
## Ditto from E to A
 M 1
 M 20
 4 b
## Ditto from F to A (0 indexes link 12)
 M 1
 M 20
 5,1 0,4 c
## Ditto from G to A
 M 1
 M 20
 6,1 7,2 c
## Ditto H to A
 M 1
 M 20
 9,3 8,2 c
## Ditto I to A
 M 1
 M 20
 10,3 11,4 c
```

In Figure 5 we can see how the dispatched traffic a_c is lower for nodes B and D since each one of them use only one route with one of the two links with the highest load—North (1) and South (3)—towards node A. These two nodes are also the ones whose blocking probability

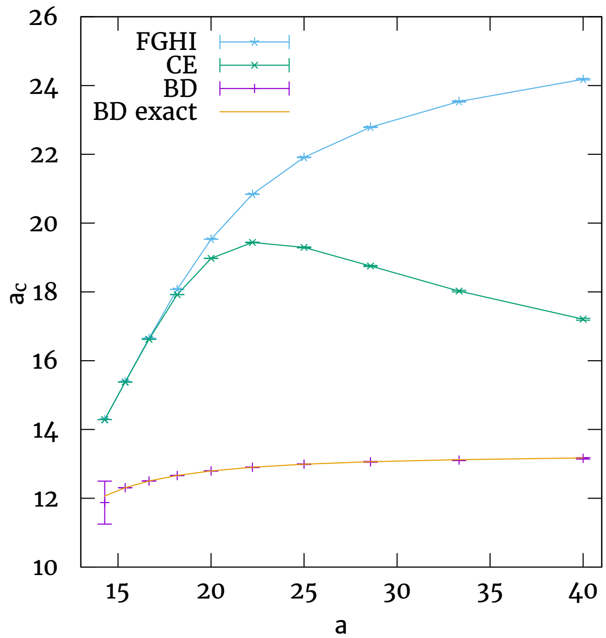

Figure 5. Simulation results—exact for B and D nodes—with North-South routing preference

can be computed through the Erlang-B formula. Nodes C and E receive better service since they use one of the links 2 and 4 with lower load but suffer when higher ratios of traffic from nodes F, G, H and I are routed through their second routes. These latter nodes receive the better quality of service from the network since they have the more flexible routing of all of the nodes.

4.2. Symmetrical routing

This approach to routing requests follows a more homogeneous approach:

- those nodes at 1 hop from A will try the shortest path first,
- those nodes at 2 hops from A will try first the clockwise route, and if it fails the anticlockwise one.

If 3 hops routes are permitted, those nodes at 1 hop will try clockwise and counterclockwise 3 hops routes too.

In this case there will be only two sets of traffics with respect to different blocking probabilities, identified by their source satellite:

1. B, C, D and E;
2. F, G, H and I.

Figure 7 shows the performance when only 1 and 2 hops routes are allowed. We can see how the dispatched traffic a_c for source nodes B, C, D and E gets smaller as the offered traffic a between each other node and A gets to an overload scenario, due to the hoarding of resources by traffic from source nodes F, G, H and I.

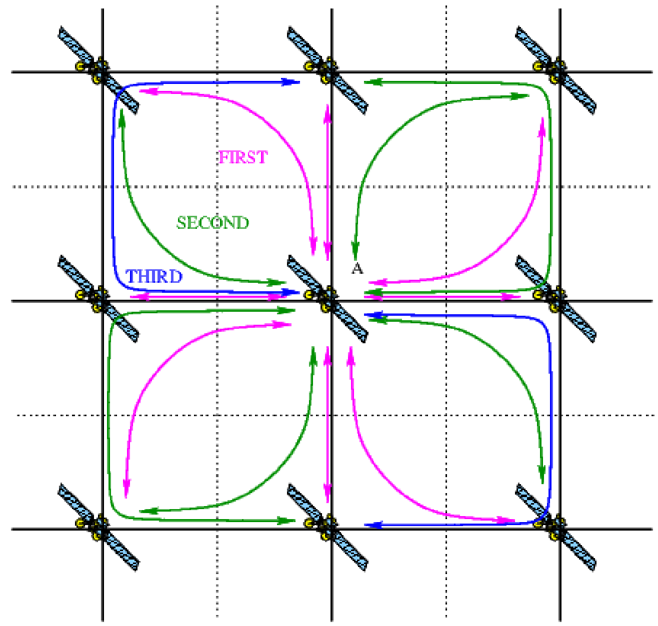

Figure 6. Sequence of routes tried in configuration *clockwise*

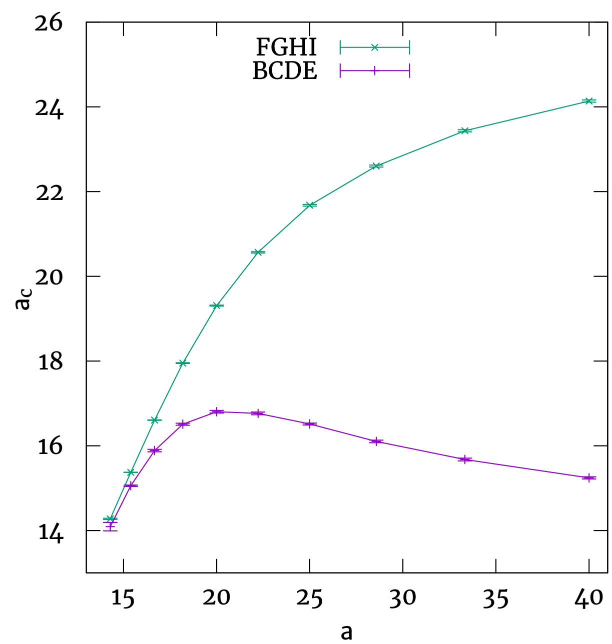

Figure 7. Simulation results with 1 to 2 hops routes

In Figure 8 we see the equalizing effect due to the reservation of the last free resources of the 40 ones in any link for traffic trying its first route. Reserving only the last free one breaks the congestion behavior where the higher the offered traffic the smaller the dispatched traffic is. Reserving the 4 last free resources gives a more even quality of service.

We observe the performance when 1 to 3 hops are

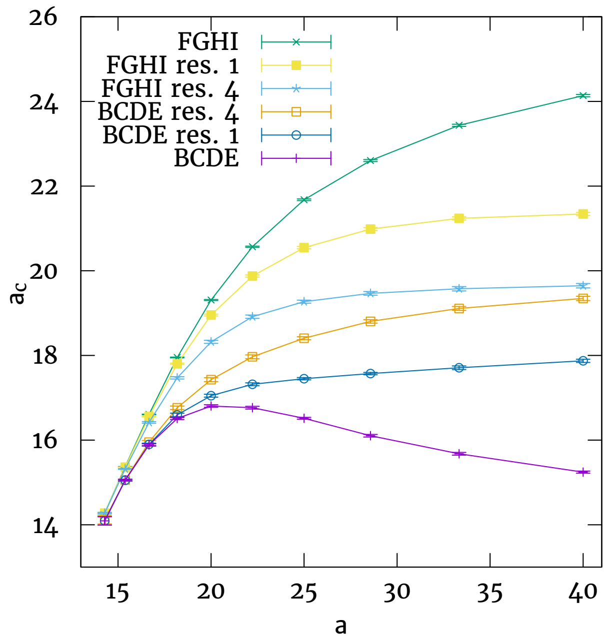

Figure 8. Ditto Figure 7 plus reserving either the 1 or the 4 last free resources for first routes

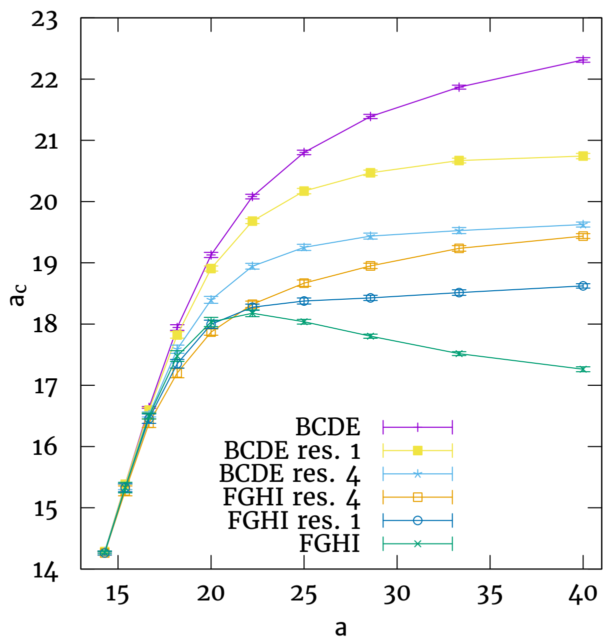

Figure 9. Simulation results with 1 to 3 hops routes with and without reservation of either the 1 or the 4 last free resources for first routes

allowed in Figure 9. The behavior is reversed with respect to Figure 8, with traffics from source nodes F, G, H and I suffering the hoarding of resources by those from B, C, D and E due to their more flexible routing. We see how the classical reservation technique equalizes the quality of service received in this case too.

5. Conclusions

This case study has been proposed to the students of a Third Year Subject—Network and Switching Theory—of the Bachelor Degree in Telecommunication Technologies Engineering at *Universidade de Vigo*. We have proposed an academic study so that students may grasp in a more modern scenario the classical problem inherent to too much flexibility in selecting routes of different sizes.

The students can observe how quality of service not only stagnate when arriving to an overload scenario but how the performance degrades farther with smaller dispatched traffic whenever a higher offered traffic occurs. They observe how the classical reservation technique equalizes the received quality of service breaking this undesirable behavior at the same time.

Overall, we think the students have grasped the concepts appropriately through this case study.

6. Funding

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