

# Modeling La Salle University's network using OPNET Modeler

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## Abstract

This paper presents the modeling of La Salle University's Campus network in Barcelona (Spain). This model is based on different networking technologies, like switched Ethernet, ATM, LANE, VLAN and Wireless LAN. Using this model we have studied the network behavior and we have detected some performance problems. Then several improvements have been proposed and future changes have been evaluated.

The main goal is to produce a network model as similar as possible to the university network using OPNET modeler to study its efficiency, performance, behavior and to consider future improvements. Several changes in OPNET models have been performed in order to adapt the model to the real equipments and configurations.

## Introduction

One of the main goals of this paper was to research on some important networking technologies like IP, ATM, and Ethernet. We chose modeling La Salle University's Campus network because all of these technologies are used in this network.

Moreover, the resulting model was useful to do some configuration tests using RIP protocol. That routing protocol might be introduced in the future as the interior gateway routing protocol. So some simulation tests have been made and the results have been recorded so that they can be useful when RIP will run in all the routers.

This paper is organized as follows. The first section introduces useful concepts about modeling and simulation methodologies. The second section focuses on the model building, showing the global scheme and topology of our university network. The next sections describe the different parts of the network topology, and focus on all the different technologies. In the next section, the simulation model and results are given. Finally, results, conclusions and further work are presented.

## Modeling methodologies

In this section, we give a brief overview of modeling methodologies, essential concepts to apply in any simulation project. So, first of all we had to look for information about modeling methodologies. There are two main concepts to keep in mind during the model building: equivalence and validation. It is hard to explain the meaning of these concepts in a word. They seem to be not only words but a philosophy and also a way to work.

Equivalence means that your model behaves in some sense like the real system that you want to simulate. It is very difficult to know if your model behaves like the simulated system and it is nearly impossible to work exactly as the real system does. So

one has to state explicitly what an absolute necessity is, and then try to develop these mechanisms in the modeled system.

Validation is the process of checking the modeling decisions that have been taken in order to evaluate if the model can be useful to achieve the proposed goals. The designers can obtain conclusions from the model using this process. During the modeling phase, changes have to be checked at once so their effects in the final results can be easily identified. Validation must be performed continuously as the model is built and it is included in the construction process.

Modeling provides us some validation tools that are extremely useful. Some of them are similar to other tools used in real systems like ICMP protocol or routing tables. Others belong to the simulator and give information about the model itself, like logs, register files or animations.

The next step, based on the use of OPNET Modeler for modeling real systems, consists of choosing a methodology to be followed. Validation is a part of this methodology but other concepts should be considered. This methodology can be explained with the diagram in Figure 1, which shows the different steps to follow:

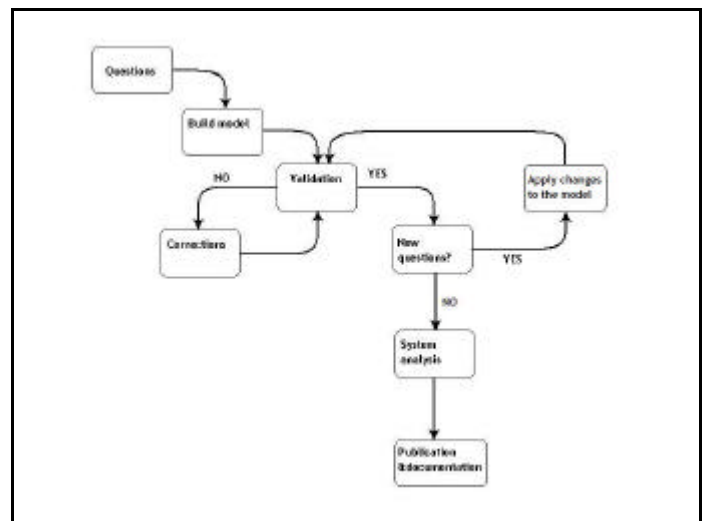


Figure 1: Methodology for modeling

The different steps in the modeling methodology are the following:

1. Make a list of the requirements to be answered by the model.

2. Build a first approach that answers at least some of the questions. For example, the main parts of the model should be implemented first of all.
3. Validate the model built so far in order to assess its equivalence. If differences between real system and model are very important, try to correct the errors. Repeat this process until achieving the desired level of equivalence.
4. Introduce changes in the model in order to solve new requirements. Check that these changes haven't reduced the equivalence achieved so far.
5. If the model is good enough it can be used to analyze the system. Examine the results of the analysis and look for nonsense.
6. When model performance is correct, publish the results and write all the documentation explaining the design decisions. This documentation should help others to use this model in the future.

### Building the Model

This section focuses on the process followed to build the university network model. The first thing to do was to learn how the real system was configured and how it works. The scheme and network topology of La Salle University's Campus network is shown in Figure 2.

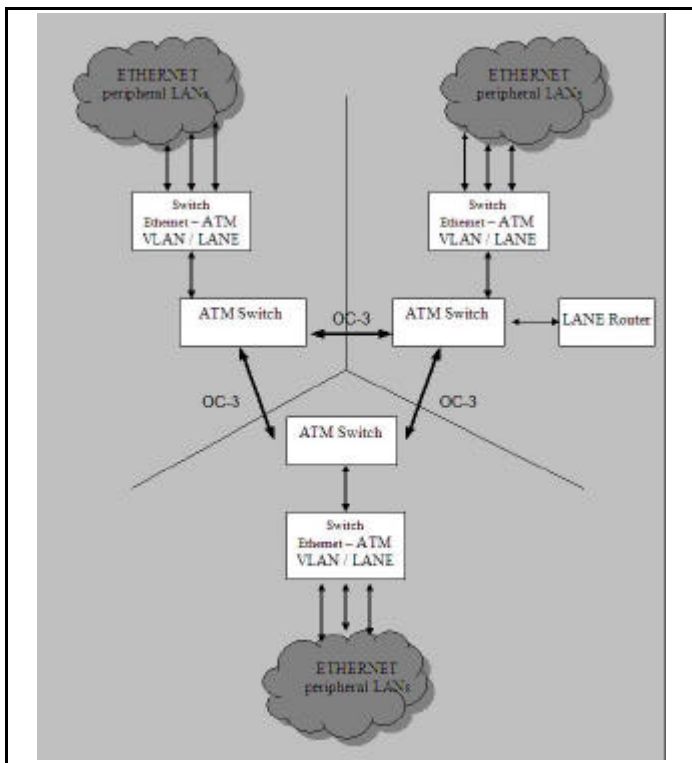


Figure 2: Global scheme of La Salle network

The network to be modeled integrates several technologies. There is an ATM backbone that allows three buildings to communicate between them. Each ATM switch is connected to an ATM – Ethernet translator switch that gives service to LANs in each building.

Several VLANs are configured in these switches in order to segment the ETHERNET layer. VLANs are mapped to ELANs in the ATM backbone. Also, the one-armed LANE router allows VLANs and ELANs communications.

After getting the necessary information about this network, the second step was to learn how these technologies should be applied into OPNET. Some exercises were designed to practice and acquire some experience with them. We built one scenario for each technology and then we developed different scenarios using more than one technology in order to evaluate internetworking problems.

Four scenarios were built in order to practice with VLANs, ATM and LANE, WIRELESS LAN and also the integration of VLANs and LANE. These scenarios will be explained in the next sections.

### The IP addressing scheme

The IP addressing scheme of Enginyeria La Salle cannot be reproduced using OPNET Modeler v8.0 because it is not allowed to join two IP subnets at the same side of a router. This means that, when doing a logical segmentation at the IP level, a physical segmentation must be done too. However, in release 8.1 or later, this problem has been solved with the introduction of IP subinterfaces. But by the time of this project, our available option was Modeler v8.0.

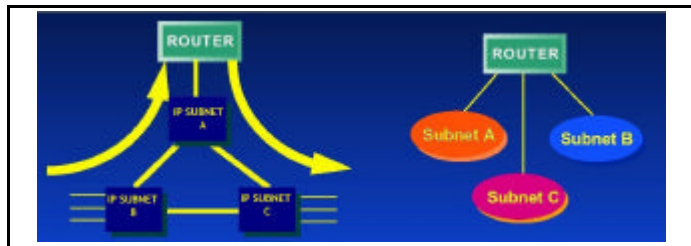


Figure 3: Physical and logical schemes of a one-armed router configuration.

The left side of Figure 3 shows how the one-armed router is connected to the network in the real system. The subnets are physically together, at the same side of the router. The right side of the figure shows the logical scheme, in which subnets are separated by the router.

OPNET Modeler v8.0 does not allow connecting a one-armed router for routing between IP subnets. The one-armed router is only useful for connecting VLANs, but hosts belonging to different VLANs must pertain to the same IP subnet.

Enginyeria La Salle's network has two segmentation systems working together. The first one is the IP subnets segmentation and the second one is the VLAN protocol (IEEE 802.1Q). VLANs are useful in order to map users into ELANs in the ATM backbone.

So a design decision had to be taken for solving this problem. The decision was to maintain the physical topology using one-armed router, so the routing between hosts would be closer to

the real system behavior than if a router with several IP interfaces had been used.

As we wanted to use a one-armed router, the addressing scheme had to be changed. Therefore, only one subnet would exist in the whole network. The VLANs would segment the network logically in order to maintain the same routing mechanisms.

**VLANs scenario**

The goal of the scenario showed in Figure 4 was to learn about configuring VLANs in OPNET, learn about the meaning of “tagged” and “untagged” ports, and learn how to achieve communication among hosts on the same VLAN or between different VLANs.

If VLANs are spread across more than one switch, the link between two switches must be a tagged trunk link. All packets flowing along them will carry information about the VLAN that they belong to. If the destination IP address of a packet does not belong to any host in that VLAN, the packet is discarded unless there is a router.

The router at La Salle University is configured as a one-armed router, so only one port of the router is connected to the network, and it cannot belong to any VLAN in particular. Thus, an untagged trunk link must be used. Untagged trunk ports must be configured in *ethernet promiscuous mode* so that they repeat all the incoming information to other ports. This allows the router to receive all the packets and reroute them if necessary.

A model called “ethernet one-armed router” was used in this exercise and subsequently in the final model. This model was found in the original OPNET libraries.

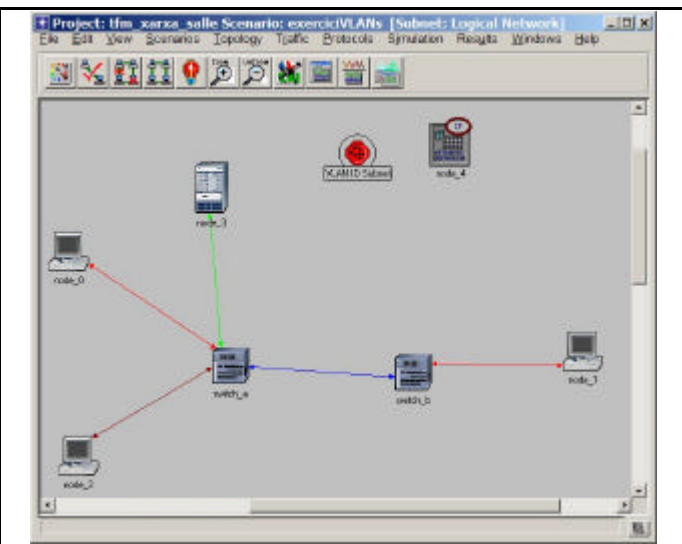


Figure 4: Scenario with VLANs

**ATM and LANE scenario**

Another scenario was built to acquire experience in LANE mechanisms. The main goal of this scenario was to translate the results obtained in the previous section (VLANs) to LANE technology. That is to say, connect hosts in the same ELAN or in different ELANs.

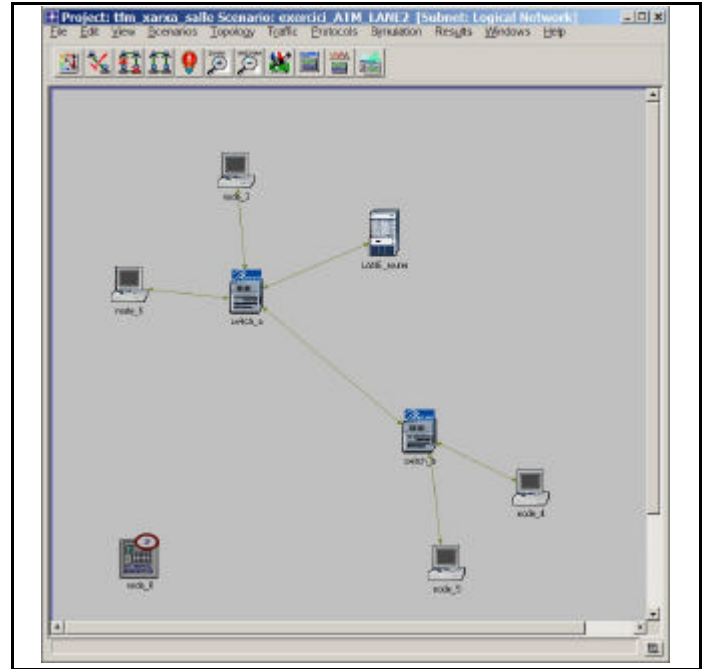


Figure 5: Scenario with LANE

As showed in Figure 5, this scenario has two ATM/LANE switches with two ATM workstations attached to each one and an ATM router with LANE capabilities. All the links are OC-3 fiber links.

The ATM/ETHERNET translator switches do an important function within the real system. They map all the VLANs used into ELANs in the ATM backbone, so that the logical segmentation remains active. This means that there is an ELAN in the backbone for every VLAN in the peripheral networks.

An ELAN consists of a LES (LAN Emulation Service) and several LECs (LAN Emulation Client) attached logically to the LES. So, there should be as many LES as ELANs. There are more than 10 VLANs/ELANs in the real system but only three ATM/LANE switches. OPNET Modeler only allows to configure one LES per switch. Here it is another limitation found to model this system. With only three switches, there is no way to model the real system, as only three ELANs can be configured.

One possible solution to this problem could be to use a model called “ethlane service”. There should be as many “ethlane services” attached to the ATM switches as required ELANs. But this case would create some differences with the real system because there would be some data flowing from the switches to the LES, thus wasting switching resources and causing unreal delays.

Besides, there were other issues to be solved. The only way to achieve communication between different ELANs was to use a router, but the results were not suitable using a one-armed router. The problem is due to OPNET Modeler, which allows only one LEC per physical interface. Using a one-armed router

for routing packets between ELANs is not feasible as one LEC for each ELAN should be needed in the same physical interface.

The best solution would be to enter into the lower layer editors and change the LANE model to allow more than one LEC in the router's interface. This new design should work like the Ethernet one-armed router does. This is one of the future work lines for this project.

**Integrating LANE and VLAN**

The final decision was to use only one ELAN at the backbone. This decision allowed ATM switches achieve connectivity. At least one LANE should be configured because it was considered to be a good enough solution, although a point of discrepancy with real model was issued. The traffic through ATM backbone is not segmented by any protocol and each switch receives all the packets sent by its neighbors although the destinations are not connected to it.

The router was connected to one of the ATM/Ethernet translator switches instead of connecting it to one of the ATM/LANE switches. This decision was taken in order to maintain the configuration using one-armed router for communication between VLANs. Thus, all the traffic that needs to be routed will be sent to the router and passed through the same links. The final scheme for the Ethernet and the ATM segments together looks like Figure 6.

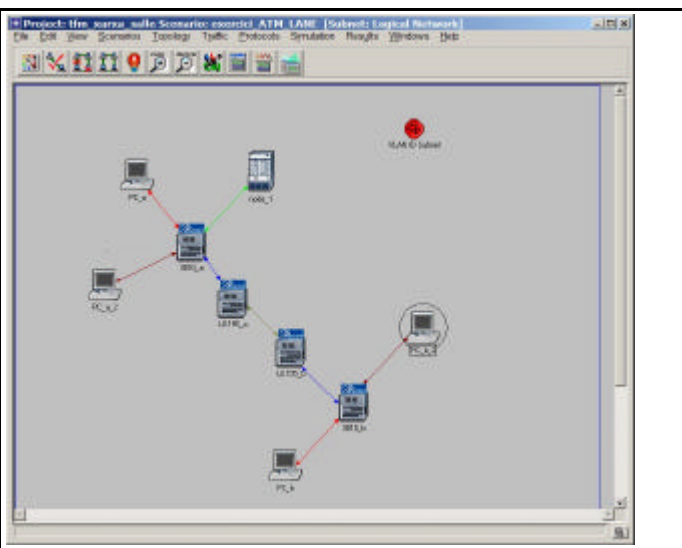


Figure 6: Scenario to simulate ATM / LANE and Ethernet integration

In Figure 6, there are two ATM/LANE switches in the backbone network and there is one Ethernet/ATM translator switch connected to each one. They belong to the same ELAN. Each translator switch has a workstation belonging to VLAN 1 and another to VLAN 2. So there are two workstations of VLAN 1 connected to different switches.

To achieve communication intraVLAN no routing was needed. We only had to activate the "ethernet promiscuous mode" attribute in the switches. On the other hand, for communication

interVLAN, packets need to be forwarded to the router. So "ethernet promiscuous mode" must be enabled to let the router receive data. Ideal configuration was to connect the router to an ATM/LANE switch, but it didn't work as stated before.

**The final model**

The process of building the definitive model turned into a mechanical work as the main problems were already solved. The automatic addressing mode could not be used in some network segments, but in some segments, the hybrid addressing mode was used, and this was really helpful for saving time. Hybrid addressing mode allows configuring only one IP address in a segment. The other hosts are automatically configured by the simulator starting from the one that was configured manually.

Other parameters to be configured manually were the VLAN identifiers for each of the switches link, as the automatic "Configure VLAN for selected links" option seemed not to work properly.

Also some modifications to existing devices had to be made using lower level editors (Node Model Editor) or the Device Creator tool as some devices of the real system were not exactly modeled. These modifications consisted mainly of adding ports to switches or routers in order to support the desired number of links or combining features of two different devices into one.

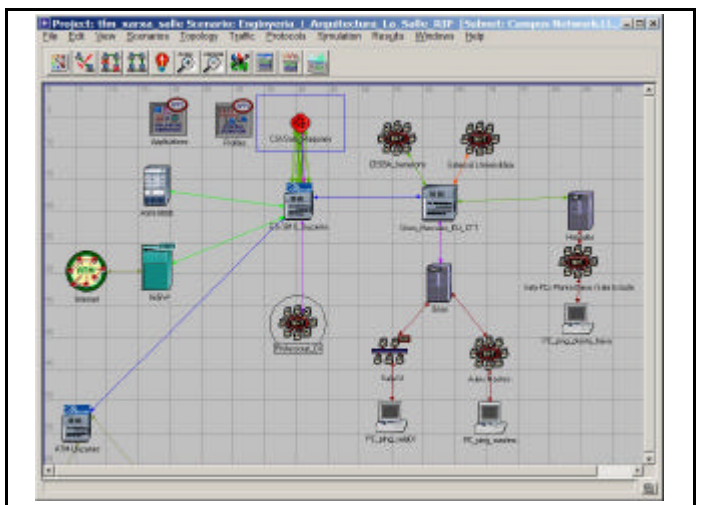


Figure 7: Network of the Lluçanes building

Figure 7 shows the network at the building called Lluçanes. This building contains the main network facilities, as the main router, the internet gateway and the server farm. The main router, which is in charge of interVLAN routing, is a Fore Systems ASN-9000 with an optical-fiber untaged trunk link that connects it to the ATM/Ethernet translator switch.

The ATM switches are also Fore Systems. These are LE-155. There is one of them in each building connected to the backbone. Connected to the LE-155 there is a Fore Systems ES-3810 switch with one ATM/LANE interface and several Ethernet/VLAN interfaces. This switch translates the VLANs

into ELANs in the real system. In the model they are used only for configuring VLANs for each department.

The Internet gateway is a Cisco 7200 router with an ATM interface for the external connection and a FAST ETHERNET interface for the internal connection. The ATM interface operates at 34Mbps.

The servers are connected directly to an ES-3810 switch. One 100BaseT switched LAN hangs from this switch with a VLAN link. Some LANs are beyond a router and have private IP network addresses. So, in addition to the backbone network, there are other peripheral private networks. The links that connect these peripheral routers to the backbone belong to a particular VLAN, but the links on the other side don't, as they use a private IP network address.

In the real system, networks connected directly to the backbone switches use an IP network address which is a subnet of the main private address (172.16.0.0/16), or a public network address within the range of 130.206.42.0/24. This addressing system is not allowed by OPNET, because it joins two different network addresses within the same link-level segment. Therefore, the IP addresses used in the model do not match to the real system ones.

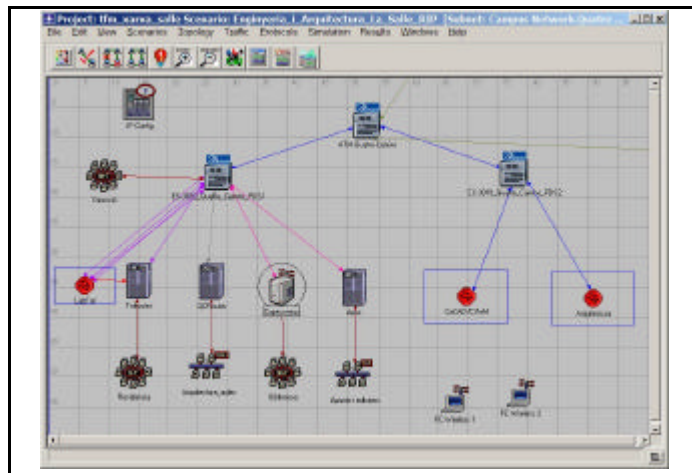


Figure 8: Network of the Quatre Camins building

Figure 8 shows another university building. There is the ATM switch this network to the backbone and two ES-3810 switches that distribute the VLANs. One of the routers has a WIRELESS LAN access point. This router is located at the library and it gives access to the network for students using their own laptops. There are only two wireless workstations, just simulating two different students.

People at each department are responsible for their own subnets. Thus, there are different aggregated LAN objects associated to each department. This means that some aggregation has been needed in order to simplify the work. Otherwise a lot of extra work would have been needed and it would have unnecessary for the objectives of this project.

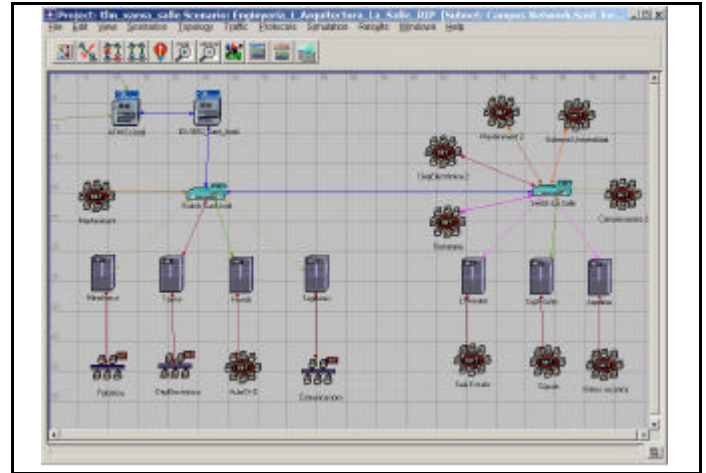


Figure 9: Network of the buildings called La Salle and St. Jordi

Figure 9 shows the last two buildings of La Salle University. These buildings contain more subnets and routers than the others but they are the simplest in terms of topology. There's only one ATM termination for both buildings as they are very close. Here the VLANs are distributed within two Cisco 3550 ETHERNET switches, one for each building.

### Application of RIP to the network

Once the model is built and it is equivalent enough according to the objectives the analysis and study can be started. One of the future studies is the utilization of RIP in order to simplify the configuration tasks. The model built so far allows carrying out a study about how RIP should be configured and the issues that will have to be solved.

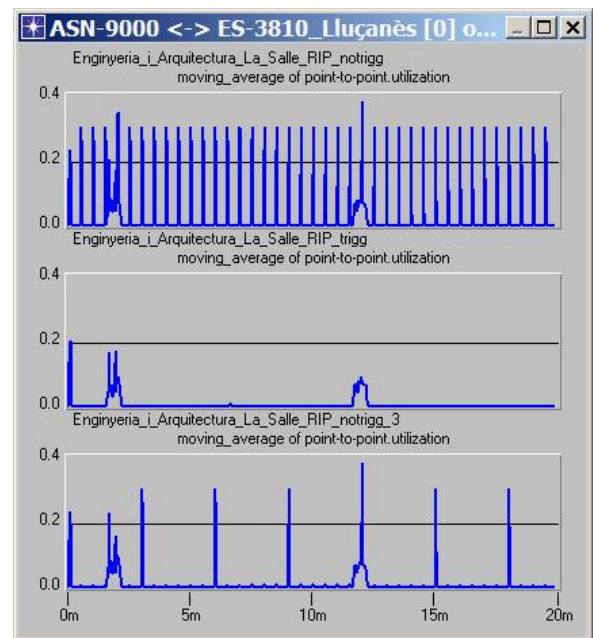


Figure 10: RIP traffic and network utilization

This study was very useful to learn how to configure RIP taking into account the real system particularities. Besides, a study of the traffic generated by RIP has been developed although the addressing system of the model is not the same as in the real network.

Finally we concluded that it is not worthwhile to configure RIP at La Salle because of its star topology. Dynamic routing protocols allow bigger flexibility, shorter time response when changes occur in the network and less maintenance tasks. The disadvantage is that network administrators have less control over it, and some security problems should be considered.

The whole network has an extended-star topology that does not create any redundant paths. Thus, if a link falls, no other paths can be used and the only possible solution is to solve the problem in that link in particular. This means that it is not necessary to change any routing tables dynamically. Anyway, the study has been developed and some conclusions have been extracted from it. First of all, RIP packets shouldn't cause congestion if the parameters are configured correctly. RIPv2 should be used and "Auto Summary" disabled.

In the model, split horizon has been explicitly disabled at the ASN-9000 router because it has only one interface and it needs to send and receive RIP updates through it. It should be studied whether this behavior is the same in the real system because the connection is different (as stated before).

Validation of RIP has been done in two different ways. The first one consisted of configuring some pings with traceroute and see if there was connectivity between the networks and if the routes followed by the packets were correct. The second way was to configure a failure for a link and check if RIP reacted correctly by first erasing the wrong route and then updating it when the link was turned on again.

When configuring RIP one important thing to take into account is the value of the timers that are going to be used. There are three timers: the update interval timer, the timeout timer and the garbage collection timer. The update interval is the time that elapses between the sending of two routing table updates. This allows controlling the amount of traffic that RIP is going to generate and the convergence time.

The timeout timer is the amount of time that a route will be useful without being updated. And, finally, the garbage connection timer indicates the amount of time that a route will be kept in the table after finishing the timeout timer. When the timeout timer expires for a route it won't be erased from the table until the garbage collection timer also expires but it will not be used by the router as it is no longer correct.

Finally, the use of the triggered extensions of RIP can shorten the convergence time when there are changes in the topology, because they stand for sending the new right routes after the changes occur and not waiting for the update interval timer to expire.

### **Conclusion**

In this paper we have presented La Salle University network model. The goal of learning how to use OPNET Modeler for modeling real systems has been achieved. The methodology has been learned and applied successfully and the result has been a model of the network of our University that can be used to make several studies.

It has been surprising to find the explained limitations of OPNET. Although they can be solved by using low level editors, it was not expected to find such problems. Also the configuration using one-armed router in an ATM/LANE environment shouldn't be so strange for not being provided for OPNET libraries, as for example a one-armed router for VLANs.

The IP addressing limitation is even more disappointing because the logical segmentation using IP addressing is commonly used in any network. It allows different IP networks to share some devices as switches when connectivity between them is not needed using VLAN options. A deeper investigation on these issues should be done for answering some open questions.

From now on, there will be a document at our University that teaches how to use OPNET, focused in the IP, ETHERNET, VLAN, ATM and LANE technologies, and from the point of view of a student who is far from the OPNET's resources and who has to learn things somehow by himself. A starting point has been created for whoever wants to use it.

In the future it will be necessary to plan model's network migration from the ATM backbone to a Gigabit Ethernet backbone. Nowadays La Salle University's network has migrated to a Gigabit Ethernet network so the model should be modified. Later we might get all the traffic profiles of the University staff in order to obtain useful results about traffic behavior.

### **References**

- [1] OPNET Modeler v8.0 on-line Documentation
- [2] RFC 1058, Routing Information Protocol. June 1988. C. Hedrick, Rutgers University.
- [3] RFC 1723: RIP Version 2. Carrying Additional Information. November 1994. G. Malkin, Xilogics Inc.