Computer Networks Project

Design the LOYOLA network

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Introduction

This project was assigned by professor Javier Dominguez in the course Computer Networks. The aim of this project is to create our own version of the entire LOYOLA computer network (including the Seville, Cordoba and Granada campus) using the concepts acquired during the duration of this course.

The main parts of this project are the following:

- Requirements of the network
    - Capacity planning
- Architecture design
    - Diagram of the network
    - Topology
    - Connection methods
    - IP addressing
    - Offered services
- Hardware specification
- Cost estimation

Our team had the following team members:

- Ron Ismaili
- Anid Iljazi
- Lum Aliji

Requirements of the network

In this section we will delve deeper into the details of what specific requirements our computer network has (requirements analysis) for performing properly. We also need to perform this step in order to know what we need during the designing part of the project. Depending on the results that we get during this step, our final design may change drastically. That is precisely why this is one of the most important steps during the creation of a computer network.

General information:
Universidad Loyola Andalucía (ULA) has roughly 3’000 students across all of its campuses, according to our research. When it comes to the relative campus sizes (and the campus size : student proportion) we think that Seville > Cordoba > Granada. We have done the following split: 50% (Seville) > 30% (Cordoba) > 20% (Granada) when it comes to size. What we mean by size is the relative size of each of the campuses when compared to each other.

Another estimation of ours (educated guess after online searching) is that ULA has roughly 600 employees, ranging from professors, cleanup workers, administrative staff, researchers, etc. We have performed the same split as above, meaning a 50:30:20 split of the employee numbers.

This means that at a maximum we can estimate roughly 3’600 users across all of the network. For the purposes of this project we bump the number of users that our network can serve up to 5’000 users. We do this to make our network future-proof as well as to support potential events such as conferences and graduation ceremonies for when there may be more users than usual.

This leaves us with the following data:
Our LOYOLA network, more specifically the Universidad Loyola Andalucía (ULA) network will have to support a total of 5’000 users (this includes students, professors, researchers, administrative employees, janitorial

employees, etc.). We have 3 different campuses (Seville, Cordoba, Granada) which have different relative sizes (we don't really care about physical sizes but rather when we refer to size we mean number of users), the split of those relative sizes is a 50:30:20 split.

We also want to host our own services on the ULA network, for different reasons. Some of those reasons are: More cost effective, customizable, reliable and efficient in terms of latency if implemented correctly. Some of those services are our own website, webprint, student record database, staff database, etc.

Capacity planning

Now that we have some concrete numbers to work with, we have to plan the capacity of the entire network, but more importantly than that we have to plan the capacity of each of the individual campuses.

The capacity plan of the entire ULA network is to serve a maximum of up to 5'000 concurrent users. This is a relatively large number when we take a look at the requirements analysis we did, but we want to make sure that our system will work even years into the future, as we expect our numbers to grow (more students & employees) this will make sure to future-proof our system. We also planned for the case of when there might be an unexpectedly large number of concurrent users online.

Seville:

We obviously start from Seville, as this is the biggest campus. Since it is the largest campus of the three, we also think that it would be a good idea to regard the Seville campus as the main campus / main base of operations, but more details on this in the architecture section of the project.

As stated above, the maximum number of users we intend to serve is 5'000 users. When it comes to Seville's size, we said that it had a relative size of

50%. Meaning the Seville campus has to be able to serve 2’500 users concurrently.

Cordoba:
Cordoba is slightly smaller than Seville, meaning a smaller relative size of 30%. Taking into consideration the above numbers, we have to be able to serve 1’500 concurrent users.

Granada:
In the end, we have the smallest campus which we gave a relative size of 20%, meaning that we need to be able to serve 1’000 users concurrently.

Architecture design

When it comes to the architecture of the Universidad Loyola Andalucía (ULA) network, we spent a lot of time experimenting with different models and we came up with the following architectural design.

At first, we examined all of the different campuses and took a look at their physical architecture. After that we divided them into logical parts that we then could use to lay out our own infrastructure (such as cables, routers, firewalls, switches, APs, etc.)

Seville

This is the top down view of the seville campus. As we can see there are currently 3 main buildings: The Main university, the library and the chapel. For the purposes of this project we have removed the chapel because we do not think there is a need for dedicated equipment to be there (saving expenses), we will just use the infrastructure that is already present in the network.

We also think that it would be a good idea to regard the Seville campus as the main campus / main base of operations because it has the largest relative size compared to the 2 other campuses. That means that we will use the Seville campus as our main base of operations, which in turn means that this campus will have all of the important infrastructure and be the most robust part of the ULA network. This campus will host many of the services that the other 2 campuses will utilize. This will save us money because we won't need to have the same infrastructure in 3 different places, and instead we can just rely on the Seville campus. We are aware that if something goes wrong in this part of the network, most of the network will cease to work properly, but that is a risk we are willing to take.

When it comes to the actual division of the spaces, we have gone for the following approach:

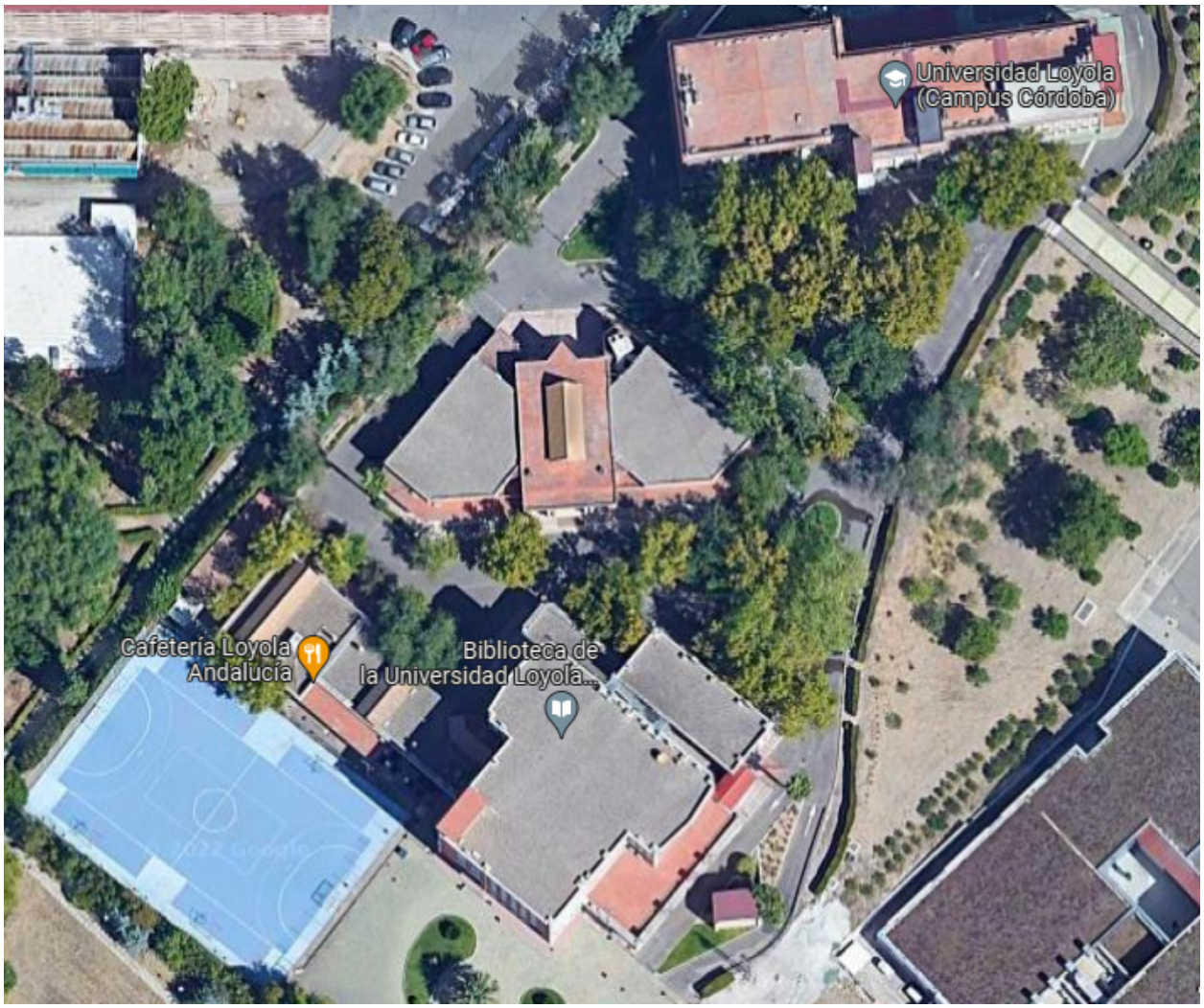
We have 2 main buildings. The university building and the library building.

The main building is then divided into different floors and different sections. We have a total of 4 different floors (-1, 0, 1, 2) and 3 different sections (A, B, C).

For the library we have gone for a slightly simpler approach, we have divided it into 2 different floors: 0 & 1.

For the Cordoba and Granada campuses we have decided to use a slightly simpler architecture. Since most of the important infrastructure will be in the Seville campus, we didn't see a need to make these designs too complicated. Also, we don't have much information about these universities, so it was a bit difficult to do the logical division of floors and sections.

Cordoba



Then we have the Cordoba campus, which is the second campus when we arrange them in order from relative size. In this campus we can see 3 different buildings. We have labeled them A, B and C.
After some research, we have found that building A has 4 floors (0, 1, 2, 3), building B has 5 floors (-1, 0, 1, 2, 3) and building C has 2 floors (0, 1).

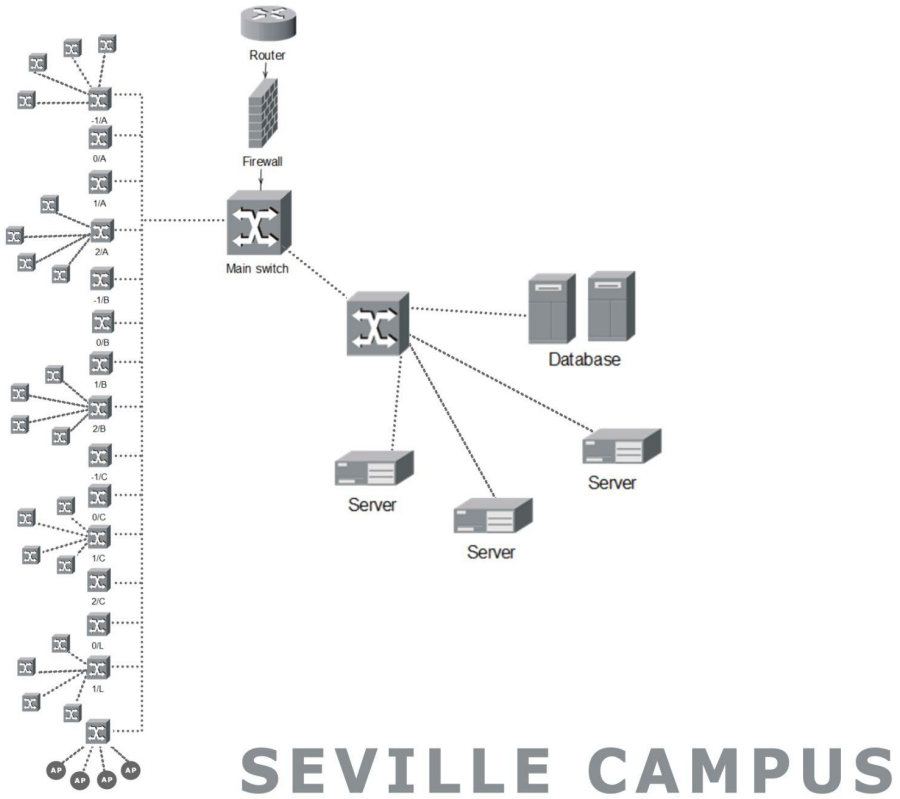
Granada

In this picture we can see the Granada campus. Here we can clearly identify 2 different buildings, which for the purposes of this project we have labeled the main building and the library. The main building is split in 2 parts called North and South side, where they have 3 floors each (-1, 0, 1). Whereas the library is split into just 3 floors (0, 1, 2).

Diagram of the network

Now that we have an idea of how we want to divide the network into logical sections, it's time to draw up some kind of diagram for all of the different campuses and see how the entire network will actually look like. We only have diagrams of how the 3 different campuses are individually connected, but we also have to take into account that the 3 campuses are also connected between themselves, using an ISP, in our case Movistar.

Seville



This is the diagram of the Seville campus. As we can see there are 3 main parts to the diagram. We have split the network into the data and server network, user network and the AP network.

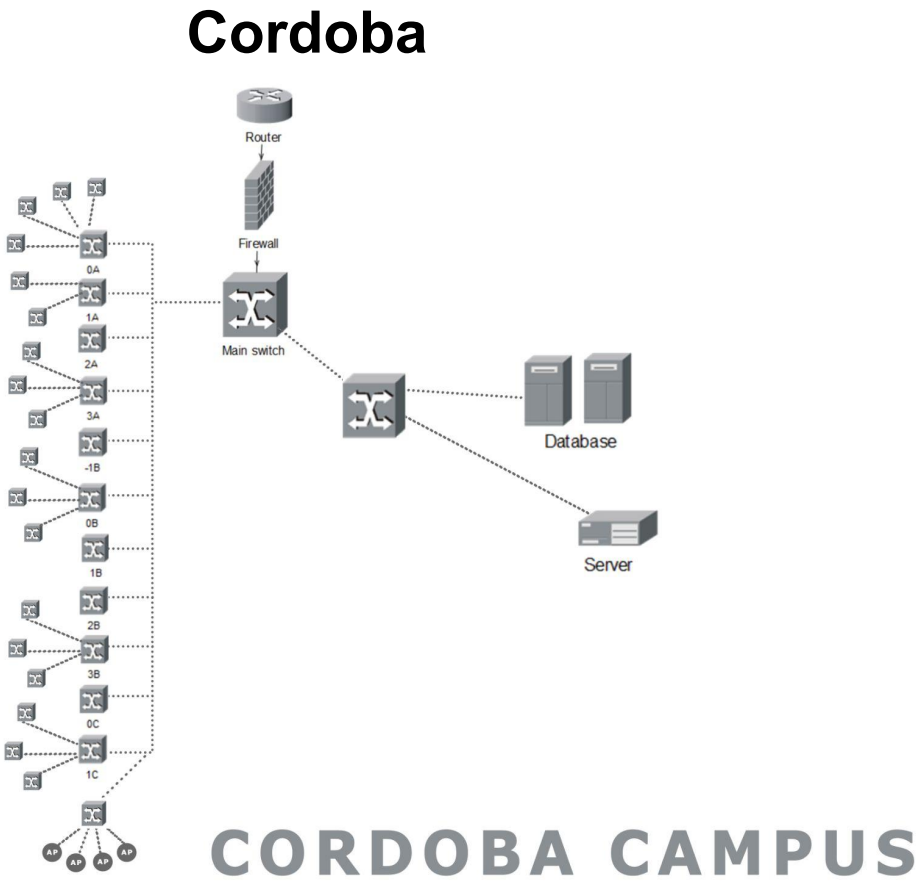
The data and server network is made of databases and servers whereas the user network is made up of many switches that connect to each of the floors and sections.

In the data and server sub-network we have servers and databases. This is where we will host most if not all of the services that are offered from the ULA network, such as web hosting, webprint, etc.

In the user sub-network we went for the approach to have a switch in every floor and every section, so that we can have at least one switch for every part of the main building of the Seville campus. These switches then

connect to all of the classrooms, printing rooms and offices and make it possible to connect equipment/devices to the ULA network.

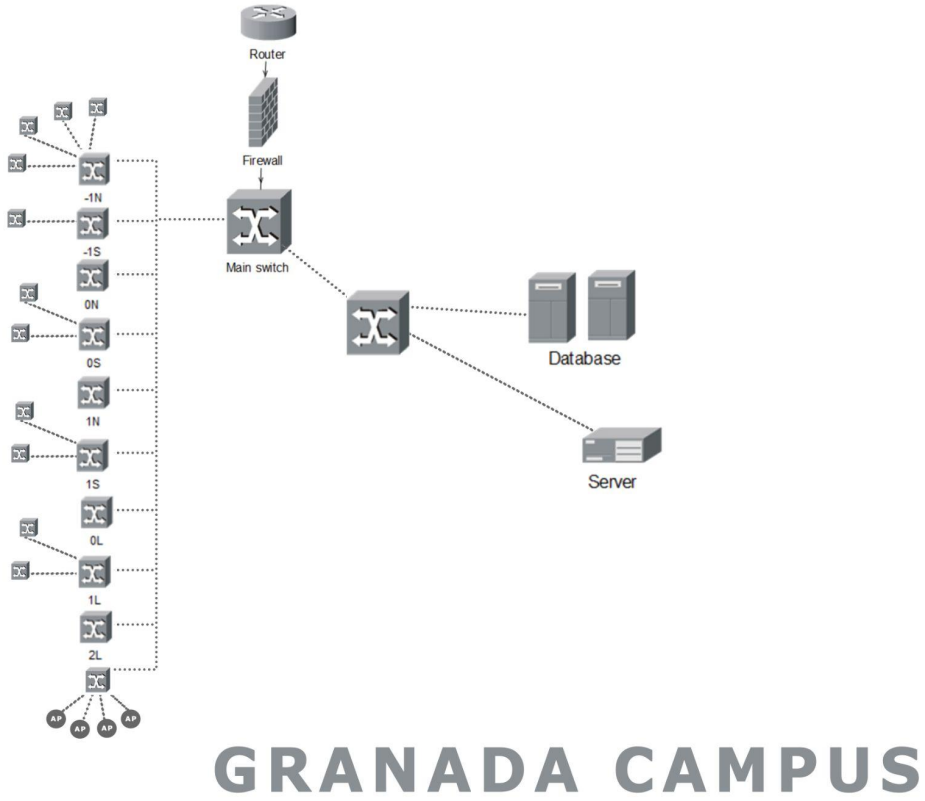
The AP sub-network is made up of multiple different APs that allow for wireless access to the internet. Each section of the main building will have different sub-networks for the wifi, but more details on this down below.



This is the diagram of the Cordoba campus. We have a simpler structure for the Cordoba campus because it has less users, but in principle it is the same as the one in Cordoba, meaning that we have 3 main sub-networks in our cordoba sub-network: The data and server sub-network, the user sub-network and the AP sub-network.

The main difference is that the structure is simpler and we also have a less complicated data and server sub-network, because we will only host the webprint in this campus and some other minor things (more details below).

Granada



This is the diagram of the Granada campus. Again, same as with the Cordoba campus, this campus also has a less complicated structure compared to the Seville campus. There isn't much to talk about here since it is almost identical to the Cordoba campus, just a bit smaller.

Topology

The topologies we have used in our network are akin to the tree network with different nodes and leaves where the root is the main router. But if we take a closer look at the diagrams of our network architecture we see that it is not quite a tree topology. That is the reason why we say that we have

used a mixed topology that was heavily influenced by the tree topology. We used the approach of dividing our network into 3 sections: Core, distribution and access. According to our professor, this is the industry standard and in line with good working practices.

Connection methods

When it comes to the connection methods, there are 2 main ways users can connect to the network. Either via ethernet (cable) or via wifi (using APs to establish wireless connections).

More details on the specifics of the ethernet connections and the APs in the hardware section of the project.

IP addressing

We will use 192.168.0.0/24 for our main network. Since the ULA network has 3 campuses (Seville, Cordoba and Granada) we also need 3 sub-networks for each of the campuses. We will divide the IP block into sections which will be split using the above 50:30:20 split, meaning that Seville will have 50% of the IP addresses, Cordoba will have 30% of the IP addresses and Granada will have 20% of the IP addresses.

With the 192.168.0.0/24 IP address, we have a total of 256 possible different subnets. From these 256 addresses we can realistically use 254 because the first and last IP addresses are reserved for network identification and broadcasting respectively. This leaves us with 254 total usable IP addresses.

50% of 254 means that we have roughly 128 IPs for the Seville sub-network.
30% of 254 means that we have roughly 76 IPs for the Cordoba sub-network.
20% of 254 means that we have roughly 50 IPs for the Granada sub-network.

Now that we have divided the IPs into 3 different sub-networks, let's display them in a better way:

Seville:
IPs: 192.168.1.0/24 -> 192.168.128.0/24 (First and last IP unusable)

Cordoba:
IPs: 192.168.129.0/25 -> 192.168.205.0/24 (First and last IP unusable)

Granada:
IPs: 192.168.206.0/24 -> 192.168.254.0/24 (First and last IP unusable)

Now that we have our IP lists, we can divide them further into subnets:

Seville:
192.168.1.0/24 -> Network IP
192.168.2.0/24 -> Servers & Communications subnet
192.168.3.0/24 -> A - Section subnet
192.168.4.0/24 -> B - Section subnet
192.168.5.0/24 -> C - Section subnet
192.168.6.0/24 -> Library subnet
192.168.7.0/24 -> APs subnet
192.168.8.0/22 -> Wifi A subnet
192.168.12.0/22 -> Wifi B subnet
192.168.16.0/22 -> Wifi C subnet
192.168.20.0/22 -> Wifi Library subnet
… (Unused IP addresses)
192.168.128.0/24 -> Broadcasting IP

Cordoba:
192.168.129.0/24 -> Network IP
192.168.130.0/24 -> Servers & Communications subnet
192.168.131.0/24 -> A - Section subnet
192.168.132.0/24 -> B - Section subnet
192.168.133.0/24 -> C - Section subnet

192.168.134.0/24 -> APs subnet
192.168.135.0/22 -> Wifi A subnet
192.168.139.0/22 -> Wifi B subnet
192.168.143.0/22 -> Wifi C subnet
… (Unused IP addresses)
192.168.205.0/24 -> Broadcasting IP

Granada:
192.168.206.0/24 -> Network IP
192.168.207.0/24 -> -1 Floor subnet
192.168.208.0/24 -> 0 Floor subnet
192.168.209.0/24 -> 1 Floor subnet
192.168.210.0/24 -> Library subnet
192.168.211.0/24 -> APs subnet
192.168.212.0/22 -> Wifi -1 Floor subnet
192.168.216.0/22 -> Wifi 0 Floor subnet
192.168.220.0/22 -> Wifi 1 Floor subnet
192.168.224.0/22 -> Wifi Library subnet
… (Unused IP addresses)
192.168.254.0/24 -> Broadcasting IP

Offered services

Our network will have to offer a long list of services to its users. Most of these services will be hosted on our own ULA network, this is for multiple different reasons, such as being more cost effective, more customizable, more reliable as well as more efficient in terms of latency when trying to reach the ULA servers.

Some of those services that will be offered from our ULA network are the following: Loyola website (hosted only in Seville), our own instance of moodle (hosted only in Seville), webprint (which will be hosted in all of the campuses individually), student record database (hosted only in Seville), staff database (hosted only in Seville), student records (hosted only in Seville).

Hardware specification

Now that we have determined the what, why and how of our network it's time to specify what exact hardware we will use for building our network. This will also aid us in coming up with an approximate cost for the entire project.

Seville:
Core routers: 1 x Cisco ISR4431/K9 Router -> 1 x 10'900 EUR
Core switches: 1 x Cisco WS-C3750-48TS-S -> 1 x 1'000 EUR
Firewalls: 1 x Cisco ASA5510-SEC-BUN-K9 -> 1 x 4'700 EUR
Simple switches: 32 x Cisco S3700-24T4F -> 1 x 210 EUR
APs: 8 x Cisco AIR-CAP3502I-A-K9 -> 1 x 85 EUR
Servers: 4 x HP P11053-421 -> 1 x 9'200 EUR
Ethernet cat6 cables *(meters)*: 7500 x 0.65 EUR
Ethernet cat5 cables *(meters)*: 5000 x 0.95 EUR

Cordoba:
Core routers: 1 x Cisco ISR4431/K9 Router -> 1 x 10'900 EUR
Core switches: 1 x Cisco WS-C3750-48TS-S -> 1 x 1'000 EUR
Firewalls: 1 x Cisco ASA5510-SEC-BUN-K9 -> 1 x 4'700 EUR
Simple switches: 16 x Cisco S3700-24T4F -> 1 x 210 EUR
APs: 8 x Cisco AIR-CAP3502I-A-K9 -> 1 x 85 EUR
Servers: 2 x HP P11053-421 -> 1 x 9'200 EUR
Ethernet cat6 cables *(meters)*: 5000 x 0.65 EUR
Ethernet cat5 cables *(meters)*: 3000 x 0.95 EUR

Granada:
Core routers: 1 x Cisco ISR4431/K9 Router -> 1 x 10'900 EUR
Core switches: 1 x Cisco WS-C3750-48TS-S -> 1 x 1'000 EUR
Firewalls: 1 x Cisco ASA5510-SEC-BUN-K9 -> 1 x 4'700 EUR
Simple switches: 16 x Cisco S3700-24T4F -> 1 x 210 EUR
APs: 8 x Cisco AIR-CAP3502I-A-K9 -> 1 x 85 EUR
Servers: 2 x HP P11053-421 -> 1 x 9'200 EUR
Ethernet cat6 cables *(meters)*: 4500 x 0.65 EUR

Ethernet cat5 cables *(meters)*: 3000 x 0.95 EUR

Cost estimation

Now that we know what hardware we are going to use and how many of each device we can calculate the grand total.

Material cost: *(Cost of the devices)*
Core routers: 3 x Cisco ISR4431/K9 Router = 32’700 EUR
Core switches: 3 x Cisco WS-C3750-48TS-S = 3’000 EUR
Firewalls: 3 x Cisco ASA5510-SEC-BUN-K9 = 14’100 EUR
Simple switches: 64 x Cisco S3700-24T4F = 13’440 EUR
APs: 24 x Cisco AIR-CAP3502I-A-K9 = 2’040 EUR
Servers: 8 x HP P11053-421 = 73’600 EUR
Ethernet cat6 cables *(meters)* = 17’000 x 0.65 EUR = 11’050EUR
Ethernet cat5 cables *(meters)* = 11’000 x 0.95 EUR = 10’450 EUR
Total material cost: 160’380 EUR

Effort cost: *(Workers paid)*
We estimate that this will take 3 months to implement in the real world. Let's say that we work for 3 months non stop. That means we need to pay workers for this project. We estimate this cost to be around 50’000 EUR.

Total cost: ~210’500 EUR

Conclusion

In conclusion, it is very difficult and expensive to design and develop a big scale network. But it also is extremely fun and interesting. We have learned a lot of new things about Computer Networks and we hope that you enjoyed our project.