AchoTelecom

"A project for Orange"

M11-G4
Project RECM-SCOM
2021-2022

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Executive Summary

This project proposal aims to empower Orange's competitive position in Región de Murcia. With this project, Orange could reach the second position in market share in the Region and test a deployment that could expand to other territories.

Región de Murcia will serve as the primary pilot for deploying the new set of cutting-edge technologies that Orange has already started to deploy in their central locations of operation. Furthermore, our team formed of 15 top-class engineers has carried out a detailed study of the technological and financial feasibility of a proposal to broaden the range of services offered by Orange. Innovation leads to progress, and Orange can test a set of disruptive B2B services focused on the top industries of the Region.

With this project, Orange will be improving the network's current capabilities by including a virtualized IMS core, which eases maintenance and has better scalability. Its deployment on the cloud, using Clearwater and AWS, will allow Orange to have more control and better specifications regarding multimedia services and telephony, offering VoIP.

Continuing to expand the offer of 5G to more locations will show Orange's compromise with its values and permit the inclusion of new applications of this technology. Complementing this with the IMS core, call will be on VoNR.

This project has considered the upgrade of the fixed access network to FTTH as Murcia is a Region with high uptrend potential as it lags the main regions in Spain. Modernising the current ADSL and HFC infrastructure to FTTH will provide better connectivity to houses and businesses.

Furthermore, with the satellite offer, Orange will be able to test out the long term feasibility of offering connectivity to remote locations where terrestrial access network can not be enough.

And finally, taking advantage of 5G, Orange will be able to enter with a robust set of services to the small and medium enterprises market. These IoT services tackle strategic industries in the Region: eCleanHidroEolic provides air and water quality to reservoirs and ports, showing Orange's compromise with sustainability; eFoodSensing allows meat enterprises to improve their meat quality standards with artificial intelligence; eFreshGreens enable agriculturalists to automate and improve maintenance of their lands through data; eSmartGas allows increasing security and monitorization of gas infrastructures through connectivity.

With an investment of 2.240.740 €the NPV of the project is 1.463.524 €, the IRR over the 5 years is 18.84%, and the payback period is 2.5 years. The project not only performs well on financial ratios but also estimates that it will increase Orange's revenues in Murcia in 26,96% and will bring many new customers and potential leads through the services offering.

1 Analysis, strategy and structure

1.1 Strategy and team organization

1.1.1 Who we are

AchoTelecom is a telecommunications project based in the Region of Murcia presented to the telco operator Orange, and whose goal is to make the region a technological reference in which any European country can look at.

To do this, it sees the need for a large investment in the latest technologies available, as well as 5G or the Internet of Things to monitor the region and offer its industry the best tools and automation so that significant growth can be perceived.

1.1.2 Mission, vision and values

The Mission, Vision and Values of AchoTelecom are aligned with those of Orange: hyper connectivity and global inclusion as starting points.

The main Mission of AchoTelecom is to improve connectivity in the Region of Murcia through the modernization and improvement of the current infrastructure and the introduction of new revolutionary services in its industry. Its Vision is focused on positioning the Region of Murcia as a technological reference, especially in terms of telecommunications, at a European level. We want to be the compass that guides all our future actions.

To achieve this, AchoTelecom will always have strong Values such as flawless connectivity, hyper-connected world, inclusive and committed revolution and responsible digital world. In addition to integrity, honesty, transparency and offering the best service and quality. Without these pillars, none of its objectives can be achieved.

1.1.3 Team

Below, the tasks assigned to each member of the team, see Annex 4.4, can be found differentiating between the three different profiles.

R: Responsible - A: Accountable - C: Consulted - I: Informed.

Responsibility Assignment Matrix Profile 1			
Task	**Yamil M.**	**Mª Pilar R.**	**Pablo J.**
External and Internal Analysis	A	R	C
Socioeconomic Analysis	R	A	R
IoT Services proposal	R	R	R
Strategic Business Plan	R	A	R
Economic Analysis	A	I	R
State of Art	A	R	I
Project Plan – Resources and Times	A	C	R
Team Management and Coordination	R	C	A
Quality Plan	A	R	I
Technical validations	R	R	C
Communication Plan	R	I	A
Risk Management	A	R	I

Table 1.1: Responsibility Assignment Matrix Profile 1.

Responsibility Assignment Matrix Profile 2						
Task	**Rubén M.**	**Javier V.**	**Ángel D.**	**Javier G.**	**Álvaro P.**	**Alejandro S.**
IMS Requirements Specifications	R	C	A	I	I	I
IMS Architecture Design	A	C	R	I	I	I
5G Requirements Specifications	I	I	I	A	R	R
5G Core Network Design	I	I	I	C	R	A
5G Access Network Design	I	I	I	C	A	R
System Validation	A	R	R	R	A	R
Deployment	C	R	A	R	C	A

Table 1.2: Responsibility Assignment Matrix Profile 2.

Responsibility Assignment Matrix Profile 3						
Task	**Rodrigo C.**	**Álvaro P.**	**Kenza E.**	**Pablo I.**	**Javier S.**	**Javier L.**
IoT Services Proposal	R	A	A	I	I	R
e-SmartGas Specifications	A	C	R	I	I	I
e-CleanHidroeolic Specifications	C	R	A	I	I	I
e-FreshGreens Specifications	I	I	I	A	R	C
e-FoodSensing Specifications	I	I	I	C	A	R
System Dimensioning	R	C	A	R	R	A
Technical Support	A	R	I	C	R	C
Deployment	A	R	I	R	C	A

Table 1.3: Responsibility Assignment Matrix Profile 3.

1.1.4 Organization

1.1.4.1 Resource and time management

To coordinate how the different tasks involved in the project will be organized, MS Project has been used. In Figures 4.1 and 1.1, the Gantt chart and a temporal scale of the project are shown.

We can distinguish how the different resources are allocated for each task, the relationships between tasks, the project milestones indicated as M0-M6, and the different costs of resources related to the project. We can appreciate a quasi-waterfall structure for the tasks, as many of them depend on the completion of the ones before, however not always. There are tasks that will be performed in parallel as there are not direct dependencies between some of them. We can distinguish the four different word packages and their corresponding dates in the project. While certain tasks are carried out throughout the whole project, such as the Project Management WP, there are others which are very time-bounded, such as WP2, WP3 and WP4.

In Figure 1.3, the different human and material resources used in the project are shown.

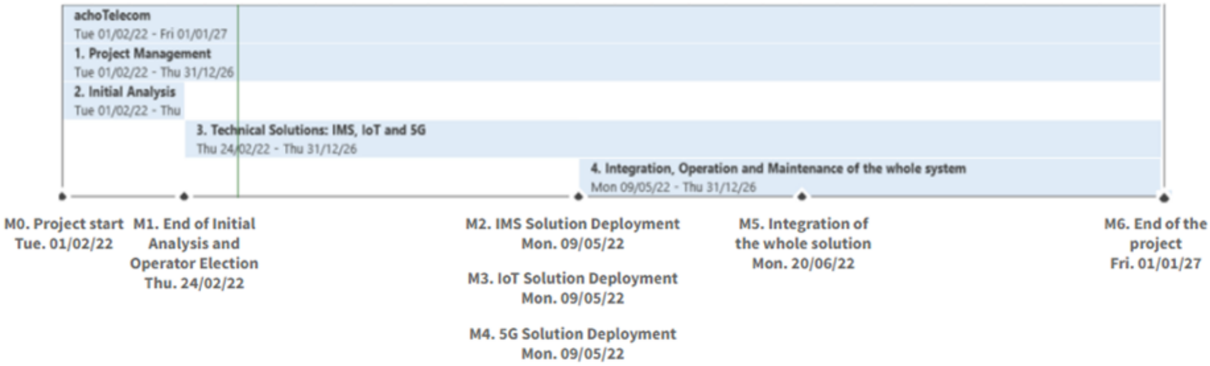


Figure 1.1: Gantt chart time scale.

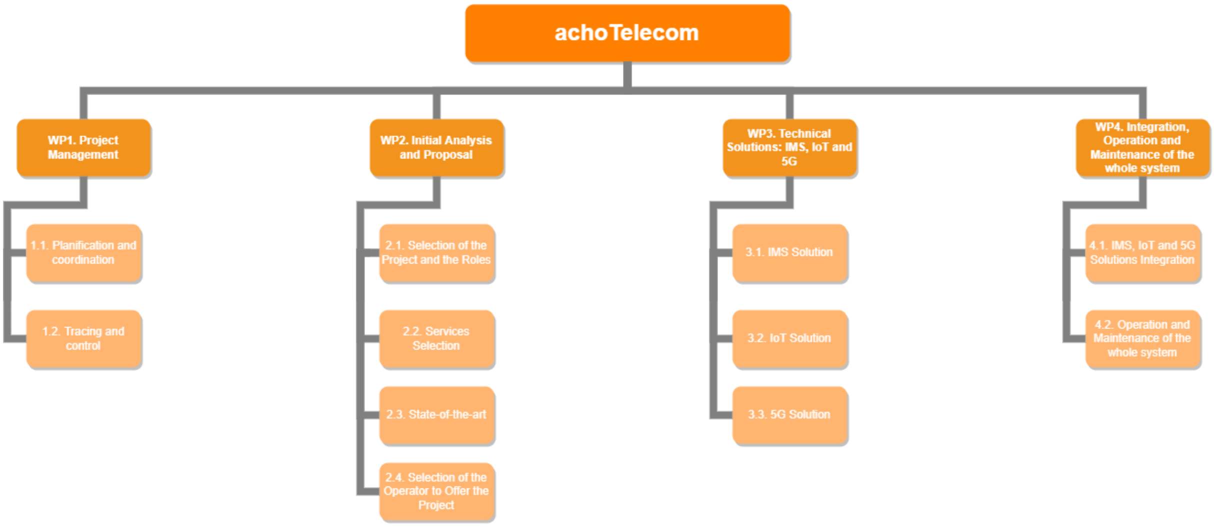


Figure 1.2: Work Package Breakdown Structure.

Resource Name	Type	Ir	Group	Max. Units	Std. Rate	Ovt. Rate	Cost/	Accrue At
CEO	Work	C	Organizational	100%	20,00 €/hr	0,00 €/hr	0,00 €	Prorated
CTO	Work	C	Organizational	100%	20,00 €/hr	0,00 €/hr	0,00 €	Prorated
COO/CFO	Work	C	Organizational	100%	20,00 €/hr	0,00 €/hr	0,00 €	Prorated
Subgroup 2.1	Work	S	IMS Technical Specifications & Architecture Development. Validations	300%	17,00 €/hr	0,00 €/hr	0,00 €	Prorated
Subgroup 2.2	Work	S	5G Technical Specifications & Architecture Development. Validations	300%	17,00 €/hr	0,00 €/hr	0,00 €	Prorated
Subgroup 3.1	Work	S	Services Specificatrions & Deployment Plan	300%	17,00 €/hr	0,00 €/hr	0,00 €	Prorated
Subgroup 3.2	Work	S	Services Dimensioning & Optimization	300%	17,00 €/hr	0,00 €/hr	0,00 €	Prorated
Electrical technician for deployment	Work	E	Subcontracted	1.000%	14,00 €/hr	0,00 €/hr	0,00 €	Prorated
Electrical technician for maintenance	Work	E	Subcontracted	1.000%	12,00 €/hr	0,00 €/hr	0,00 €	Prorated

Figure 1.3: Resources chart.

1.1.4.2 Requirements Compliance Matrix

See compliance matrix in Annex 4.7

1.2 Context Analysis

We have conducted three in-depth analysis to support our strategy, the services in the proposal and our growth estimations.

1.2.1 Demographic

First, the team has carried our a demographic analysis on the whole region but focusing the efforts on the five main cities object of this upgrade. In Table 1.4 there is disclosed information about each of these cities. We may highlight the importance of both Murcia and Cartagena which contribute with 51% and 24% of the population respectively. Regarding the amount of members that form a family core, the average is currently 2.72 members per household.

In terms of extension, Lorca leads the ranking with 1675 square meters of extension compared to 882 square meters of Murcia.

Cities	Inhabitants (2021)	Homes	Area (km^2)
Murcia	460349	156916	882
Cartagena	216365	76599	558
Lorca	96238	29838	1675
Molina de Segura	73498	23146	170
Alcantarilla	42559	14806	16

Table 1.4: Demographic analysis [5].

A more graphic representation can be seen in Figure 1.4, besides the distribution, we have consider to measure the distance between the cities.

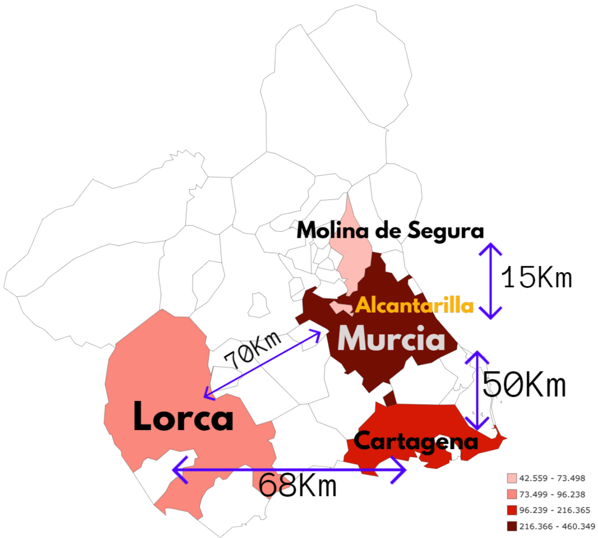


Figure 1.4: Región de Murcia annotated map.

Both the extension and the demographic density are actors in the decisions regarding the dimensioning of the Internet of Things and 5G services that will be detailed.

1.2.2 Socioeconomic

Region de Murcia has a Gross Domestic Product (GDP) per capita of 19.838 € in 2020 [7] and the expending in communications per family core is 865,7 € in this region, whereas in Spain is 939,7 € . Furthermore, the mean national expending during 2021 in 4P packets (Fixed broadband, Fixed Telephony, Mobile Broadband, Mobile Telephony) per household was of 571,2 € , for the 5P offers (4P+paid TV) the national expending was 933,6 € .

Regarding the industrial sectors of this region, analysing the Gross Value Added (GVA) we have identified two sectors that stand out relatively compared to the weight of these sector nationally. Extracting industries, manufacturing industries, energy supply, supply activities and waste and decontamination as a whole contribute with a 18% of the GVA of the region. Agriculture, cattle and fishing industries contribute 5,66% of the GVA regionally, doubling the contribution of these industries nationally.

In terms of companies and their digitization, in [8] there is revealing information about the use of technology in Small and Medium Enterprises (SME). On average, 66% of SMEs have FTTH in Spain, however, in Murcia this is reduced to 54%. In fact, in this region still the 42% of SME have internet speed below 30 Mbps.

Talking about new technologies like cloud computing, big data and the use of software as a service to manage the business processes, SME are trying not to lag behind. Currently, 16% of companies use Internet of Things (IoT) in their activities.

1.2.3 Telco market

Analysing the current situation of the telecommunications market, the whole offer is distributed between the four most important operators. Telefónica leads the market in fixed broadband and fixed telephony, however, in mobile Orange is behind Vodafone. For all the three categories Orange has the third position. However, this could completely change if the merger between MasMovil and Orange takes place. If this happened, the merger would create a new leader in mobile and fixed broadband in this region.

	Fixed Telephony	*Fixed Broadband*	*Mobile*
Telefónica	35.70%	26.80%	23.40%
Vodafone	30.00%	25.50%	28.10%
Orange	18.40%	21.10%	26.00%
MasMovil	10.10%	15.20%	12.50%
Rest	5.80%	11.00%	10.00%

Table 1.5: Comparison of market share in three offers [6].

The trends in the different offers and infrastructures deployed give us a clue about what is going to be the next step.

First, the penetration of FTTH in Región de Murcia is 13,1 lines per 100 inhabitants, comparing this value with the current penetration in the most advanced regions in Spain like Comunidad de Madrid, Cataluña or Comunidad Valenciana the uptrend in penetration starts to slow down a bit when it reaches a value between 28 and 32 lines per 100 inhabitants [9]. It is obvious that the leading access technology is FTTH compared to HFC and xDSL and operators are investing in changing the access of these two technologies to install FTTH and FTTN as well as HEC DOCSIS 3.x in a lower scale. Therefore, 96% of the households have more than 30 Mbps in fixed broadband speed and 86% have more than 100 Mbps.

The situation of the lines of fixed telephony shows that the downtrend in the utilization of this technology is making it dispensable for the customers. Something similar is happening with paid TV, the penetration is not shrinking as hard as in fixed telephony but there is a decadence in its popularity. These two phenomena may be explaining the high and growing penetration of the 5P offer, which is a 38.6% of the total contracted services for retailers followed by the 4P offer with a 33.7% of the total.

The investment in the access network infrastructure of mobile communications keeps growing for 3G, 4G and 5G. In 2020, there were 211 5G nodes installed in the region.

We expect a total growth of 10% for the fixed and mobile offer over the 5 years of the project. This has been assumed following the trend of Orange over the past years and considering that the entrance with new retail services for SMEs and satellite services would create network effects and bring in more clients.

1.3 Service proposal

Our proposal aims at the improvement of the current services offered by Orange to meet the future market needs and get a strategic investment position in the infrastructure deployment and requirements that will bring gain of market share in retail services in this region. Following the trend of wholesale services Orange is providing, we propose a set of services that will present new opportunities to expand the B2B across new sectors.

With the technology upgrade on the fixed access we will add more value to the clients and keep Orange up to date on the latest. However, our main focus will be on 5G and mobile infrastructure, since Orange is the current leader in market share on the mobile lines with 26% in Región de Murcia, our proposal targets a 29,2% market share at the end of 2027. Furthermore, with this uptrend market share and the breakthrough of the services we propose to increase the revenues of Orange in Murcia by a 2,6% from 2022 to 2027, growing from 79 million EUR to 81 million EUR in annual recurring revenue.

1.3.1 5P, connectivity and infrastructure

Regarding the current 5P, Orange has a current ARPU (Average Revenue Per User) of 935 € , including Netflix or Amazon Prime one year. This plan includes two 5G lines with unlimited calls and data and 1000 Mbps in fixed broadband with WiFi 6 and limited calls to mobiles from the fixed telephony. Table 1.6 details similar offers for the main players in Region de Murcia.

	Telefónica	**Orange**	**MasMovil**	**Vodafone**
Lines	2	2	2	2
Mobile BB	5G unlimited	5G unlimited	35GB-4G	5G unlimited
Fixed BB (Mbps)	1000	1000	600	1000
TV	+80 channels, 1y Netflix	+80 channels, 1y Netflix	Agile TV	+80 channels, Amazon Prime
ARPU (€)	908	935	803.1	952

Table 1.6: Telecom operators minorist offer

With the current market trend and the capabilities that 5G and FTTH are bringing, our plan will enable the customers of this region to have fixed speeds up to 1 Gbps with FTTH and up to 400 Mbps with other technologies. Achieving this data rate in mobile will only be possible with the deployment of 5G infrastructure which is detailed in Subsection 2.4.4. For the fixed access network we are betting on new technologies like NG-PON 2.

1.3.2 Services

With the incoming Next Generation EU European Funds, Orange is already promoting the digitalization of SMEs, freelancers and big corporations. Orange already offers IoT services for big companies, in this project we think this should be extended to SMEs too as the competence like Vodafone is doing.

With the industry study carried out in 1.2.2, we have to strategically tackle the main sectors with these services:

- CleanHidroEolic: Among the cities our proposal covers, Cartagena has high influence in maritime ports infrastructures. There are 8 ports being one of them the fourth most important for international trade in Spain. The region has also a total of 10 reservoirs spread over different locations. The value proposal of this service is monitoring both air and water quality through a set of different sensors. The current strict regulations regarding Sustainable Development Goals (SDGs) arises the necessity to have an intensive control in this infrastructure. This service will also enable Orange to demonstrate its intentions towards sustainability. The first consideration of this service considers these infrastructures, however, a possible extension and escalation of the service may be a massive deployment of this sensors into the cities. The target of this service is mainly local institutions in charge of controlling the infrastructure.

- eFoodSensing: The meat industry is big in this region as we introduced. In fact, this industry contributes with 5,2% of all the meat in Spain. Dimensioning the market we have found that there are around 100 meat enterprises including with players like El Pozo. The value proposal of this service is the scanning of the meat through a set of sensors and AI techniques to identify problems in the state of the product. This is really important for meat enterprises since the investment in quality allows them to provide their products to better wholesale clients and met better standards. This service could be a good fit for either SMEs supplying big companies as a new quality standard process requirement or for the last part of the production chain done on these big companies.
- eFreshGreens: the most relevant industry is by far the fresh vegetables and fruit consumption. Murcia exports 20% of the national exportation and the sector grows at a 5.92% CAGR (Compound Anual Growth Rate). In the five cities we address, there is a total of 49 000 hectares of potential cultivated land. The value proposal of this service is a set of sensors that would help landlords and farmers quantize different parameters of their cultivation through a set of sensors. These parameters include carbonization, temperature, electrical conductivity among others and will a set Orange in a leading position in the B2B that could bring positive impact in the retail offer. This is mainly aimed at SMEs that are usually family companies currently maintained by older generations but prone to change and automate.
- eSmartGas: The production and transport of gas is really important here, the region itself has over 335 Km of main gas pipelines and there is one of the most important points for Spanish gas storage and regasification points of Spain in Valle de Escombreras. The value proposition is the digitization of the monitorization of gas pressure to Orange's infrastructure. The amount of earthquakes that this infrastructure suffers and the extreme danger that a failure could cause makes it an appealing use case. Therefore, this service is aimed at the big companies like Enagas, that manage and mantain this infrastructure. In addition, the 2022 context regarding the energy and gas dependence from Russia's supply makes Spain an even more relevant point for the gas inflow from Africa to Europe.

1.4 Project fundamentals

1.4.1 PESTLE analysis

Along this section we will analyse the external environment using a PESTLE analysis. With this tool we can study the different restrictions and opportunities of our environment as well as the impact each variable has on our project.

We can find a detailed analysis in Annex 4.1.

Politic		***Economic***	
Support from institutional bodies	Positive	Wide range of suppliers	Positive
Chip shortages	Negative	Cost of training	Negative
Merges	Neutral	Increasing inflation costs	Negative
		Impact of COVID crisis	Negative
		Impact of Ukraine crisis	Negative

Social		***Technologic***	
More demand by consumers	Positive	Continuous developments in radio standards and electronics	Positive
Improve companies' productivity	Neutral	High broadband connectivity in the area	Positive
Average age below Spanish average	Positive	New algorithms for Machine Learning	Positive
Digital Economy and Society Index	Positive	Already available spectrum in most 5G bands	Positive
Low R&D	Negative	Obsolescence of services	Negative
Impact of adding high broadband connectivity to rural areas	Positive	Improvements in network optimization	Positive
		Increasing cybersecurity risks	Negative

Environmental		***Legal***	
Improvement gas pipelines	Positive	European Policies: GDPR	Neutral
Enviromental Objectives: SDGs	Neutral	European Policies: Open Data	Neutral
European Green Policies	Neutral	European Policies: NGIoT	Neutral
		European Policies: Artificial Intelligence	Neutral
		European Policies: 5G antennas act	Neutral
		European Policies: Harmonising Spectrum	Positive
		CEPT ECC: Use of SRD	Neutral
		Spanish Policies: Telecom Act	Neutral
		Spanish Policies: Network Security Act	Neutral

Table 1.7: PESTLE analysis summary.

1.4.2 SWOT analysis

Figure 1.5: SWOT.

1.4.3 Canvas and Business model upgrade proposal

AchoTelecom's business model is explained with the CANVAS template, as illustrated below.

1.4.4 Key Performance Indicators

KPIs (Key Performance Indicator) are a way of measuring the level of performance in a process. They allow to keep track over time and analyze the degree of compliance with them, so the progress of an activity can be objectively evaluated. Each KPI is associated with a value to be met. A detailed breakdown of the KPIs for each service can be found in Annex 4.3.

1.4.5 Risk management

In order to minimize the probability and consequences of adverse events we have made a risk assessment and management plan.

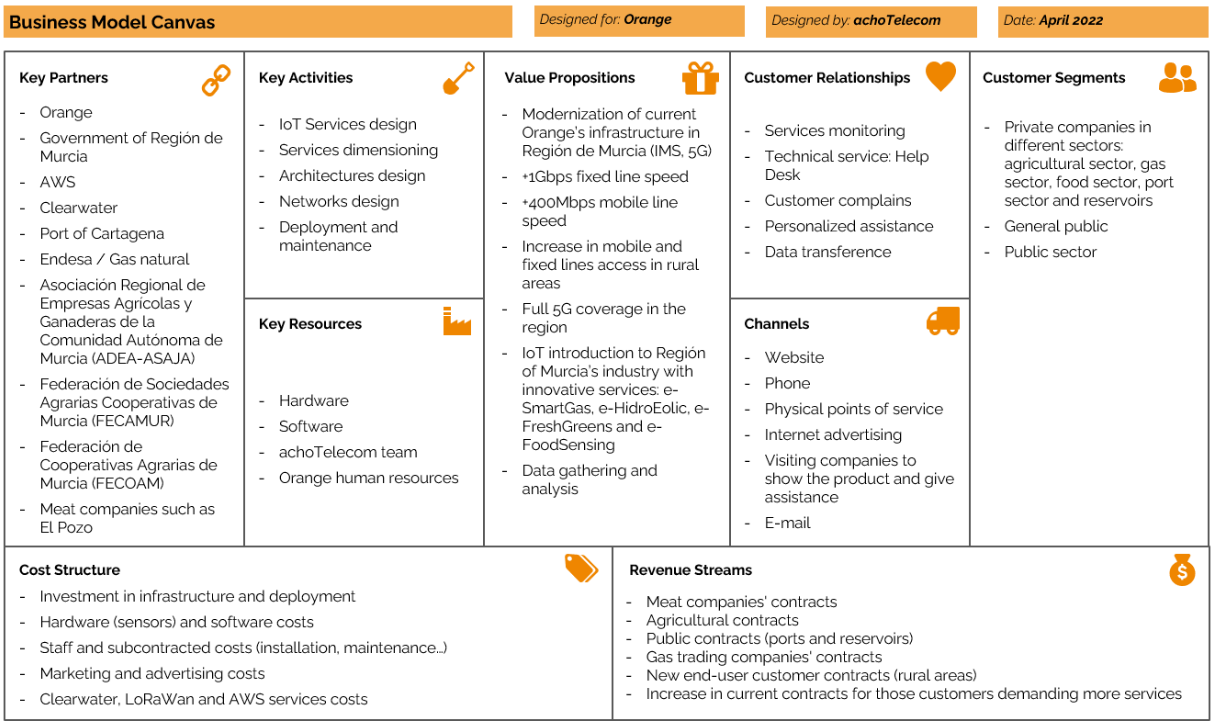


Figure 1.6: AchoTelecom Business Model Canvas.

1.4.5.1 Risk Breakdown structure

Detailed in Annex 4.6 and in Annex 4.5[1].

1.4.5.2 Impact Evaluation Matrix

		PROBABILITY				
		Almost certain (5)	*Probable (4)*	*Occasional (3)*	*Rare (2)*	*Unlikely (1)*
IMPACT	*Catastrophic (5)*		HIGH (> 14)			
	Critical (4)					
	Moderate (3)			MEDIUM (> 5; < 15)		
	Not very relevant (2)					
	Negligible (1)					LOW (< 6)

Table 1.8: Impact Evaluation Matrix[1].

1.4.5.3 Risk Assessment and Contingency Plans

Detailed in Table 1.9 of Annex 4.5.

[1]Tables taken from: GPRO ETSIT UPM and Risk Register

ID	Effect	Prob.	Impact	Risk	Risk Response	Contingency Plan
Gen-01	Reduction of Quality Increase of price	4	4	16	Mitigate	Limiting scope to necessary minimum
Gen-02	Reduction of Quality Need to overwork staff	3	5	15	Accept	Adding new employees to the project outsourcing to a third party
Gen-03	Increase in time to deploy	2	4	8	Exploit	Providing for staff training with experts in the field
Gen-04	Slowing down of processes	1	2	2	Improve	Mediation inside the teams by team leaders
Gen-05	Delays in production / staff moral undermining	2	2	4	Mitigate	Staff working overtime / outsourcing to third party
Gen-06	Slowing down of processes	2	3	6	Avoid	Earlier meeting with local authorities Consulting expert third parties before deployment
Gen-07	Halt of the process	1	5	5	Avoid	Alternative solution proposal before the deployment
Gen-08	Loss of sales / decrease in revenue	2	4	8	Improve	Enhance marketing strategies / organization of workshops
Gen-09	Customers' loss of confidence / may lead to more critical errors	3	3	9	Improve	Act with security measures / hire cybersecurity experts
Gen-10	Decrease in market competitiveness	3	4	12	Exploit	Periodic review of state of the art Consulting expert third parties (consultancy firms) Investment in R+D+I
Gen-11	Restructuring of the network	2	4	8	Accept	Adapt project to new regulations
Gen-12	Restock of equipment	5	2	10	Accept	Efficient monitoring of the network Add redundancy in critical sections
Gen-13	Increase of costs	2	2	4	Accept	Adapt project to new regulations
IoT-01	Reduction in QoS / network congestion	4	3	12	Mitigate	Review design process / add additional bandwidth
IoT-02	Increase in cost / Reinstalling of equipment	3	1	3	Accept	External unpredictable source, cope with it
IoT-03	Loss of trust from customers / loss and halt of service / loss of revenues	1	5	5	Accept	Smaller backup local database to keep running down services
IoT-04	Delays in provision of services	3	3	9	Transfer	Review design process / add additional resources
IoT-05	Loss of data / loss of confidence from customers	2	4	8	Mitigate	Act with security measures / hire cybersecurity experts
IoT-06	Restructuring of network	1	4	4	Accept	Adapt project to new regulations
Mb-01	Restructuring of network	3	4	12	Accept	Adapt project to new regulations
Mb-02	Delays in provision of services	3	3	9	Mitigate	Review design process / add additional resources
Mb-03	Loss of budget	2	2	4	Exploit	Review design process Offer higher bandwidth to users Add additional services on extra resources
Mb-04	Loss of customers / loss of revenues	2	5	10	Improve	Improve marketing strategy / have workshops
Fx-01	Reinstalling of equipment	2	5	10	Accept	Monitoring of the network / redundancy in critical sections
Fx-02	Network congestion / reduced QoS	2	2	4	Mitigate	Review design process / add additional resources
Fx-03	Loss of budget	2	4	8	Exploit	Review design process Offer higher data rates to users Add additional services on extra resources
Fx-04	Delays in deployment	2	2	4	Transfer	Have additional stock / have multiple providers Have margins in schedule

Table 1.9: Risk Assessment and management.

1.4.6 Financial Analysis

This section details the economic offer of the proposed service, which is divided into three main points. Firstly, the main expenditure items will be described. Next, the final price of the service and the revenues associated is stated. Finally, ratios associated to the project viability will be presented.

To study the financial feasibility, the five-year project has been divided into 10 biannual periods as it will be shown in the following tables.

1.4.6.1 Expenditure Analysis

The main expenses of the project amount to a total of 25.511.805,74. These expenses include both direct and indirect ones, related to the basic work packages, that is human resources expenses (see Project Management Section), initial investments and periodic expenses. The indirect expenses comprise both periodic expenses and office rent.

The main costs correspond to periodic expenses. According to these, the largest costs are related to the costs related to the purchase of the sensors as it can be seen in this table.

EXPENDITURE ASSOCIATED WITH THE PROJECT		
EXPENSES	EXPENDITURE NAME	TOTAL (€)
TOTAL HUMAN RESOURCES AND OTHER RESOURCES		
WP1	WP1: Project Management	101,040.00
WP2	WP2: Initial Analysis and Proposal	5,904.00
WP3	WP3: Technical Solutions	545,336.00
WP4	WP4: Integration, Operation and Maintenance	137,913.60
INITIAL INVESTMENT (CAPEX)		
INVESTMENT 1	Core Network	500,000.00
INVESTMENT 2	Edge Network	500,000.00
INVESTMENT 4	CORE (Nx100Gbps)	40,273.48
INVESTMENT 5	Agreggation (Nx10Gbps, Nx40Gbps)	60,762.00
PERIODIC EXPENSES (OPEX)		
EXPENDITURE 1	HidroElectric Sensors (Water)	25,500.00
EXPENDITURE 2	HidroElectric Sensors (Air)	4,183.00
EXPENDITURE 3	eSmartGas Sensors	1,320,000.00
EXPENDITURE 4	eFoodSensing Sensors	8,778.00
EXPENDITURE 5	eFreshGreens Sensors	12,887,850.00
EXPENDITURE 6	Neba Local (Coubication)	84,752.02
EXPENDITURE 7	5G Antenna Infrastructure: Macrocells	450,000.00
EXPENDITURE 8	5G Antenna Infrastructure: Microcells	789,390.00
EXPENDITURE 9	Satellite expense: Transponder use HISPASAT	5,400,000.00
EXPENDITURE 10	Satellite expense: Sat. Operations Centre	1,080,000.00
EXPENDITURE 11	CPD renting	14,976.00
EXPENDITURE 12	Helpdesk	21,600.00
EXPENDITURE 13	AWS - IMS related	371,130.00
Contingency		
EXPENDITURE 1	Contingency	1,162,417.63
TOTAL OF OPERATING EXPENSES ASSOCIATED TO EACH PERIOD		25,511,805.74

Table 1.10: Project expenditure

The costs related to the different Work Packages are explained in more detail in Annex 3.2 (Tasks and Resources).

1.4.6.2 Revenue Analysis

To settle the final price, it is necessary to consider the following points. For the innovative services, a margin of 30% has been established with respect to the main expenses of each kind of sensor for each innovative service. This expenses include management and installation costs (16%), resulting in the following prices.

- CleanHidroEolic: 369.94€/water sensor and 158.64€/air sensor.
- eFoodSensing: 782.64€/sensor.
- eFreshGreens: 67.64€/sensor.
- eSmartGas: 2642.94€/sensor.

For the upgrade in the current network of Orange, we have estimated that there will be an increase in the market share of Orange, transforming that in an increase in the revenues in Murcia of a 2.6% in the end of the five-year project, as it is stated in the following table.

Annual Weighted Revenue Murcia	Current % MS	Ending % MS	Desired Improvement % MS	Revenue increase
102,778,000.00€	16.90%	19.50%	2.60%	26.96%

Table 1.11: Current Orange revenue summary

It has been estimated that the growth in revenue from all the services will be distributed in the following way.

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8	Period 9	Period 10	Total
Weighted Growth	8.00%	8.00%	9.00%	9.00%	10.00%	10.00%	11.00%	11.00%	12.00%	12.00%	100.00%
Period Growth	0.21%	0.21%	0.23%	0.23%	0.26%	0.26%	0.29%	0.29%	0.31%	0.31%	2.60%

Table 1.12: Revenue growth distribution

Consequently, the revenue expected for each service is the one shown in this table

Revenue origin	Periods 1 and 2	Periods 3 and 4	Periods 5 and 6	Periods 7 and 8	Periods 9 and 10	Total
eCleanHidroElectric	32,471.70	36,530.68	40,589.64	44,648.60	48,707.56	202,948.17
eSmartGas	300,857.64	338,464.84	376,072.06	413,679.26	451,286.46	1,880,360.27
eFoodSensing	28,123.46	31,638.90	35,154.34	38,669.76	42,185.20	175,771.67
eFreshGreens	2,706,970.44	3,045,341.74	3,383,713.06	3,722,084.36	4,060,455.66	16,918,565.27
Satellite	1,440,000.00	1,440,000.00	1,440,000.00	1,440,000.00	1,440,000.00	7,200,000.00
Minorists services improvement	213,778.24	240,500.52	267,222.80	293,945.08	320,667.36	1,336,114.00

Table 1.13: Revenue sources

Therefore the revenue for the project in periods is the following

REVENUE FOR THE PROJECT IN PERIODS	
REVENUE PERIOD 1	2,361,100.75
REVENUE PERIOD 2	2,361,100.75
REVENUE PERIOD 3	2,566,238.34
REVENUE PERIOD 4	2,566,238.34
REVENUE PERIOD 5	2,771,375.94
REVENUE PERIOD 6	2,771,375.94
REVENUE PERIOD 7	2,976,513.53
REVENUE PERIOD 8	2,976,513.53
REVENUE PERIOD 9	3,181,651.13
REVENUE PERIOD 10	3,181,651.13
TOTAL REVENUE	27,713,759.38

Table 1.14: Project revenue in each period

1.4.6.3 Cash Flow Analysis

Project Cashflow	Per 0(€)	Per 1(€)	Per 2(€)	Per 3(€)	Per 4(€)	Per 5(€)	Per 6(€)	Per 7(€)	Per 8(€)	Per 9(€)	Per 10(€)	Total
Investment cashflow	-2,240,740.36	-	-	-	-	-	-	-	-	-	-	-2,240,740.36
Operating cashflow	-	1,358,148.83	219,279.84	274,831.17	274,831.17	330,382.50	330,382.50	385,933.83	385,933.83	441,485.16	441,485.16	4,442,694.00
Total cashflow	-2,240,740.36	1,358,148.83	219,279.84	274,831.17	274,831.17	330,382.50	330,382.50	385,933.83	385,933.83	441,485.16	441,485.16	2,201,953.64
Discounted cashflow total	-	1,305,912.34	202,736.54	244,323.91	234,926.84	271,550.33	261,106.09	293,277.99	281,998.07	310,181.62	298,251.55	3,704,265.28

Table 1.15: Project cashflow

The exploitation cash flow is calculated as the difference between the income and the operating expenses, for each period. In this case, for the cash flow analysis, there is no need to calculate taxes since it is the economic analysis of the project and not of the company as such.

It is seen that the initial investment needed to start the project adds up to 2.240.740€, after that investment the project will make enough money to cover periodic expenses. An annual discount rate of 8% has been estimated as the minimum project profitability. This gives us a period discount rate of 4%, that allow us to calculate the Discounted Cash Flow Total.

TYPE OF ANALYSIS ACCOUNTING PERIOD	Biannual
NUMBER OF ACCOUNTING PERIODS	10
DISCOUNT RATE, annual (%)	8.00%
DISCOUNT RATE, for the period considered (%)	4.00%
Reason to use this discount rate:	The project is expected for an 8% of minimum annual profitability for the project

Table 1.16: Parameters for financial evaluation

1.4.6.4 Economic Feasibility Analysis

In the table below we can find the NPV, IRR and PBP of the project. As we can see, the NPV is greater than 0, the IRR is greater than the discount rate and the PBP is 5 periods, that is 2.5 years from the start of the project, therefore the project is viable and apparently there is no reason not to continue with the project. If we analyze the meaning of each value, we see that we would recover the initial investment in the eighteenth month and the NPV and IRR show that the project is profitable.

NPV (€)	1,463,524.92
IRR for the accounting period considered in the analysis (%)	18.84%
INVESTMENT PAYBACK PERIOD	5 periods (2.5 years)

Table 1.17: Feasibility indicators

To calculate the NPV we use the minimum return on equity expected by the company's investors as the discount rate. To select this value (8%) we double the average of the values found on the Internet.

1.4.7 State of the Art

Additionally, we have analysed the different market proposals that we can find for both the 5G network and the IMS.

1.4.7.1 5G State of the Art

5G revolves around three profiles: enhanced mobile broadband (eMBB), ultra reliable and low latency communications (URLLC), and massive machine type communications (eMTC). Throughout our project we will focus on the eMBB to provide better connectivity to the citizens in the region of Murcia and eMTC to provide the IoT services. Regarding the market, we can find over 180 operators that work in 72 countries that have launched 5G, as well as over 1.5 million 5G base stations worldwide, most of which are in China. Regarding users, we can find a doubled rate of adoption compared to the one seen in 4G, reaching 640 million subscribers globally. Finally, we can already find 645 smartphone models that incorporate 5G.

Regarding the improvement in performance, we can achieve a theoretical 20 Gbps peak rate downstream to users ans 10 Gbps upstream, 1 ms latency, 1 meter position accuracy giving way to replacement of GPS technology, 10 years of battery life for devices, 500 Km/h mobility support, 99.999% availability and reliability, and 1million devices per square kilometer.

All these characteristics will give way to a new range of services, some of which we are already making use of in our IoT systems. The most relevant improvement for users will be the higher speeds that will bring with them the new services of Augmented Reality and Virtual Reality, as well as the new fixed wireless access points that will be a cheaper option for the operators to deploy broadband services where fiber is not available. Also, smart home appliances that will benefit from the low latency and high battery duration 5G offers. Finally, users will be able to broadcast and receive 4k video, even in high user density environments, such as the center of the city in Murcia or in a football stadium.

1.4.7.2 IoT State of the Art

The Internet of Things consists of a network of web-connected smart devices and services that are capable of sensing, interconnecting and acting on a certain environment [10]. And while throughout this project we will focus on the more industrial side of IoT, it can also be found in domestic settings. In order to offer quality services to our clients, we have studied the current state of the art regarding IoT technologies and solutions. First we will give a general overview of the system, and later we will go deeper into each of the services [11].

- System Hardware: It is composed of the physical body of the system, a set of sensors to acquire the data and actuators to act depending on the analysis made by the core of the system. These act as doorways between the physical and virtual worlds. Alongside the end devices, we find the IoT gateways, the devices used to communicate between the closed network and the external networks (either other IoT networks or the Internet). All devices that can be converted into "smart" categorise under IoT hardware; however, it is important to take into account the compatibility of devices and the cost that a large deployment of devices has on the final project [12].
- Software device: The software device is the "brain" of the IoT system. It is responsible for device integration and data analysis; as well as being the intermediary between the user and the system. It is composed of several sub-systems, such as the Data acquisition system that converts analog data into digital streams or the edge processing unit that performs a set of operations to validate the data before it enters the data center. This last feature has been enabled by the cloud, that we will analyse in further detail in the Platform section.
- Communication Route: The communication route is responsible for the exchange of data between the hardware system and the software core. At this point, we find several technologies that enable

this communication, both between the devices and the IoT gateways, some of the most used are: Wi-Fi, Lan, 5G/6G, satellite, and Bluetooth. In Annex 4.8 we can find a more detailed explanation of all the technologies analysed beside a a summary table of the ones we have found more relevant for our project [13].

- Platform: The IoT platform is the storage place for all the acquired and processed data. Inside the platform we can divide the data into categories to facilitate the user access and further analysis. There are currently many companies providing platforms for IoT data gathering, some examples are MS Azure, Google Cloud IoT, Amazon Web Services or IBM Watson IoT Platform.
- Network Optimization: Network optimization is defined as the technology used to improve the performance of the network for any environment. Thanks to network optimization we can achieve higher data rates, data recovery, eliminate redundant data, and increase response time. IoT data is much different from typical cellular mobile traffic, due to the heterogeneity of the devices and applications involved. IoT will typically generate less data and therefore will require smaller speeds, however, we will have much more traffic on the control plane. We need a set of algorithms to reduce the burden on the control plane of the network. On "Network optimizations in the Internet of Things: A review" we can find an extensive review of all the state-of-the-art regarding different parameters: Congestion, QoS, Reliability, Security, etc.

1.4.7.3 IMS State of the Art

The IP Multimedia Subsystem is an open architecture standard based on SIP that defines how applications and services are delivered to customers independent of their access network. It was born with the purpose of joining the IP and mobile networks, allowing users to have access on their phones to all services provided by the internet, such as email, video streaming, social media, etc. We can identify the following benefits it offers both the user and the operator.

Benefits for the User	**Benefits for the operator**
Single sign on	Fast and flexible service creation
Application bundling in real time (allows simultaneous usage of voice and data applications)	Innovative real-time multimedia service offers
Real-time messaging without store and foreward	Full control of services by operator
Multiparty communication services	Service differentiation by flexible bandwidth allocation and guaranteed QoS
Enrichment and personalization	Fixed/mobile coverage
Anywhere service access from various access networks	Common service control infrastructure for PS domain for cost optimization and easy service introduction
	Long-term CS migration by shifting voice traffic towards PS domain

Table 1.18: Benefits for the user and the operator.

We have identified a set of IMS providers that offer different services that can add value to our project in Annex 4.9.3.

1.4.7.4 Satellite State of The Art

To choose the best company to use a satellite, we have investigated the different options available in Spain.

- Hispasat [14]: Provides TV and radio distribution services in their connectivity (Europe - Europe, America - America, Europe - America and America - Europe). TvV services include TDT distribution, shared digital platforms, global digital platform, digital cinema distribution and 4K distribution platform. Regarding to the connection, the next points out: cellular and hybrid backhaul, IP trunking, broadband access and triple play services. As a new feature, Hispasat is already considering 5G satellite deployments. It uses C, Ka and Ku bands.

- SpaceX (Starlink) [15] [16]: Two different packets for connection: Starlink and Business. Both offer 24 - 40 ms latency. However, the first offers 50 - 250 Mbps and 12 - 20 Mbps for download and upload bitrates, whereas the second offers 150 - 50 Mbps and 20 - 40 Mbps for the same services. It works using Ku, Ka and E bands and they are situated between 1110 and 1325 km high.
- Oneweb [17]: Carrier, enterprise, government, maritime and aviation solutions in Ka and Ku bands. They offer fixed communications, mobile communications, or both. They can be used as primary, back-up or hybrid bakhaul. Among services, they have IP Access, Business Access and IPVPN.
- Intelsat [18]: Combines the world's largest satellite backbone with terrestrial infrastructure, managed services and an open and interoperable architecture in C and Ku bands. Between the packets, GPSN (Global Private Satcom Network), for government and defense, and NMC (Network Monitoring Centre), for hardware support, network assurance and performance monitoring. Important to point out Scytale Tactical Cloud for data security.
- China satellite communications[19]: Service in long term or occasional use covering C-band, Ku-band and Ka-band. The services offered are Tracking, Telemetry and Control (TTC) Services, Consulting and Training Services and Interference Location Services. Bandwidth rental services for TV channels distribution, contribution and Direct to Home broadcast.

2

Infrastructure upgrade proposal

2.1 Global architecture overview

Below is the global architecture proposed by our company AchoTelecom. Our main objective is to add value to the network by including the innovative services discussed above and incorporating improvements to the current infrastructure by adding 5G network and IMS service through the Cloud among others.

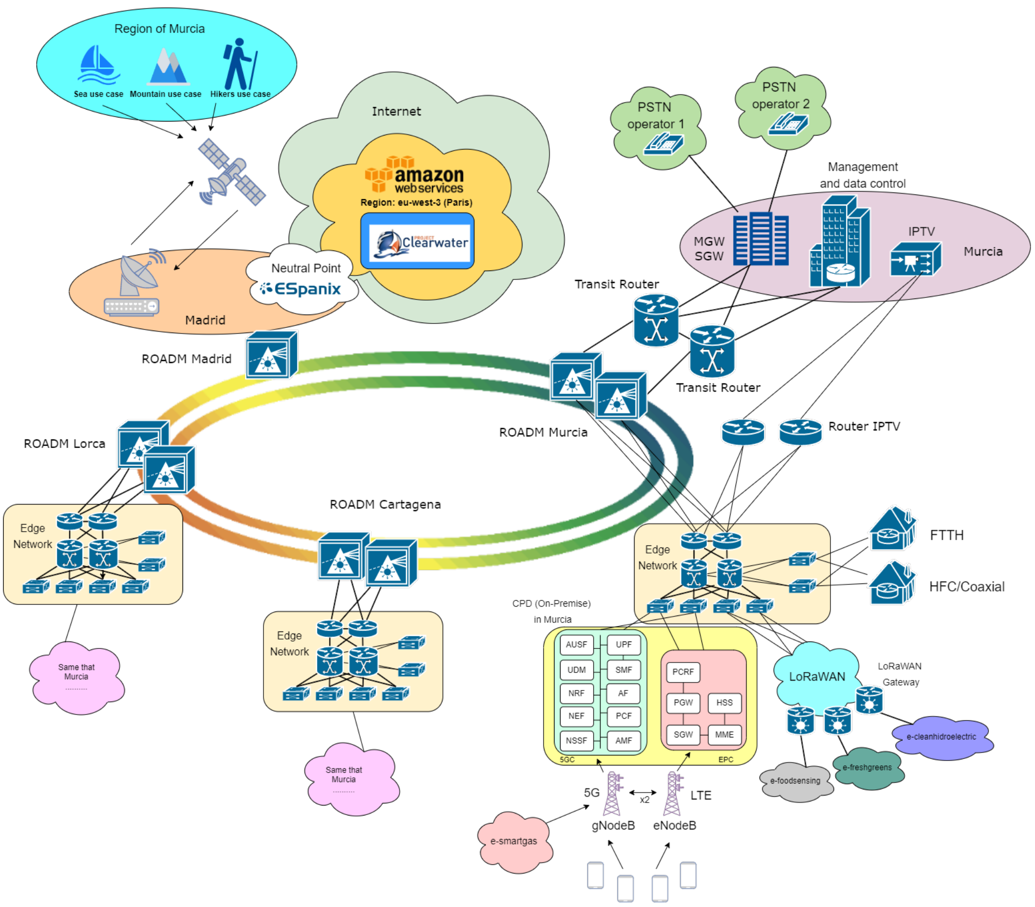


Figure 2.1: Global architecture.

2.2 Network layers

2.2.1 Access

Here we are going to detail the access network for both satellite and fixed. We also have the mobile access network but it is going to be described along the mobile core network architecture in Section 2.4.

2.2.1.1 Fixed

In this section we detail how the modernization of fixed access to homes is carried out within the regions under study. As we have already studied in the analysis of the telco market situation in Murcia, we know that Orange has 21.1% of the fixed broadband accesses in this geography. We also know that FTTH penetration is 13.1 lines, HFC penetration is 4.4 lines and 2.6 for xDSL every 100 inhabitants.

Currently, the region of Murcia has 322.932 FTTH broadband lines and 65.736 HFC lines, being by far the two most used technologies. After analyzing these data, AchoTelecom proposes an evolution towards FTTH with NG-PON2 scheme in 75% of potential homes and towards HFC DOCSIS 3.1 in the remaining 25% of homes. The use of NG-PON2 eliminates the need to install new subscriber lines and a major restructuring of the networks already deployed. The most important changes of this change are in end equipment and intermediaries, such as the WDMr1 element required for the coexistence of the different GPON technologies.

This technology, approved by the ITU-T G.989 standard, allows a 4-fold increase in the theoretical speeds of optical fiber, which can reach up to 40 Gbps. However, a target access speed of 1000 Mbps is proposed for fiber users. It is with this capacity that the necessary elements of the fixed access network have been dimensioned, such as OLTs, ONUs or the different types of splitters [20].

HFC, on the other hand, combines copper and optical fiber cables, with fiber in the core of the network and coaxial cable in the distribution to end users. DOCSIS is the most widely used HFC standard and has a very high performance, sufficient to comply with industry regulations. The upgrade to DOCSIS 3.1 is intended to implement the OFDM multiplexing technique and reduce channel bandwidth, reaching up to 10 Gbps in the DL link and 1 Gbps in UL. In addition, it is clear that xDSL is tending to be eliminated in Spain, while HFC continues to grow slightly, although it is true that it is not as important as fiber [21]. However, we are not planning to deploy HFC lines since we are using the existing ones, we will simply take into account the penetration of the operator when dimensioning.

Currently, ADSL technology is in disuse and, therefore, its use case has been transferred to fiber.

Next, each of these two technologies is explained, including the access architectures and the dimensioning of the different network elements that constitute them.

2.2.1.1.1 FTTH

FTTH access networks are mainly based on the use of fiber optic cables and optical distribution systems adapted to this technology for the distribution of various services. The implementation of this technology is widespread throughout the world, with many operators reducing the promotion of ADSL services in favor of fiber optics in order to offer more attractive broadband services to the user. FTTH technology proposes the use of optical fiber to the end user [22].

GPON technology, standardized in 2004 in the ITU-T G.984 series of recommendations and with commercial systems since 2006, has been the technology chosen by most operators to offer residential broadband services over optical fiber.

The components of the pon technology are as follows: Firstly, the OLT is the device that the operator has outside your home and is responsible for sending the main signal to many customers. On the other hand, the ONT is the device to which the fiber optic cable that enters your home is connected. The ODN is the optical transmission medium for the physical connection of the ONU to the OLT. Its range is 20 km or more. and the ONU, the same as the ONT in essence, with the slight difference that the ONT is generally located at the customer's premises.

For a telecommunications technology to be successful, it must adapt to future requirements and be compatible with its predecessor technologies. Similarly, there are several proposals and evolution paths from GPON to the new generations of PON technologies, known as NG-PON. The main requirements of NG-PONs are to increase the bandwidth and reach of GPON, reusing as much as possible the passive optical network installed from the exchange to the subscribers [23]. Considering that GPON is already implemented in the different areas studied in Murcia, it is proposed to evolve to a NG-PON2 technology, improving the upload and download speeds. WDM-PON is actually quite simpler than the rest of PON technologies, due to the fact that although the same point-to-multipoint architecture of TDM-PON is preserved at the physical level, at the virtual level each ONU has a dedicated λ. Thus, we can logically see each λ as a point-to-point channel, which will be able to carry dedicated and symmetrical speeds to each user up to 10 Gbps. It has several benefits, since there is no sharing in λ time, it is much easier to offer different guaranteed high bandwidths, symmetric or asymmetric, dedicated and without any contention, to each subscriber [23].

As demand for speed continues to increase with each passing year, NG-PON2 networks will provide an upgrade path that should prove positive especially in large enterprise and multi-enterprise customer configurations and as part of 5G wireless networks. A PON network starts at the optical line terminal (OLT) at the service provider's originating location, which is usually referred to as the central or local office and, at other times, as the headend. From here, the fiber optic feeder cable (or feeder fiber) is routed to a passive splitter, along with backup fiber if used. The distribution fibers are connected from the splitter to a drop terminal, which may be located in a street distributor or in a rugged housing installed in a pit, pole or even in a location adjacent to buildings. The drop-in fibers provide a single end connection from the drop-in terminal port to an ONT or an end-user ONU. In some cases, more than one splitter is used in series, known as a cascaded splitter architecture [24].

In order to avoid the need to take off the network from the beginning, there are mechanisms that allow the coexistence of both PON technologies. These can coexist thanks to the evolution of GPON technology to the new standard will be progressive and very simple. Through the element called WDM1r we can allow the coexistence of both systems on the same fiber. The WDM1r will be the element in charge of multiplexing the wavelengths of both standards. Operators need to implement multiplexers that combine GPON ports. Thus, we see how there are different products on the market today. At their output, ports with the signals already multiplexed are available. The WDM1r can be installed in the same rack as the OLT or in a separate rack [25].

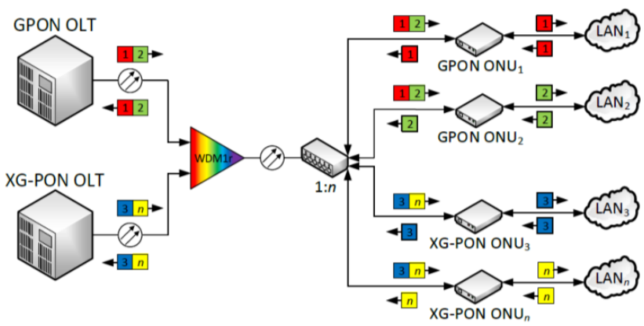


Figure 2.2: Coexistence of PON technologies.

In order to migrate to the new GPON networks, the new elements required for the fixed access network infrastructure must be dimensioned. The most important element is the WDM1r multiplexer, an external wavelength division multiplexing optical filter, which allows the coexistence of GPON and XG-PON systems [23].

All calculations have been made taking into account that the fiber is fully deployed and that AchoTelecom does not need to contribute more subscriber loop to the existing fiber. To calculate the number of total households to be served, information is taken from market research and the penetration of the operator Orange in the fixed broadband market. A 32-port GPON OLT model with a capacity of 80 Gbps on each port has been chosen first. With that we conclude that the throughput of each OLT is 2560 Gbps. The requirement of 1000 Mbps access speed for each user is taken into account in this section. To calculate the number of OLTs required we take into account two criteria: firstly, the traffic to be carried by each OLT and, secondly, the number of users, taking into account the splitters deployed. After carrying out the study, we concluded that the method by number of users is the one that sets the limit of OLTs needed. To reach the homes, 1:4 and 1:16 splitters will be used in cascade, thus guaranteeing a ratio of 1:128. With all this information, the following table is constructed:

	Murcia	**Cartagena**	**Lorca**	**Molina de Segura**	**Alcantarilla**
Fixed lines (FTTH)	27160	12765	5678	4336	4336
OLT per traffic	11	5	3	2	2
OLT per users	14	7	3	3	3
WDMr1	424	199	89	68	68
Transceiver	424	199	89	68	68

Table 2.1: GPON Dimensioning.

Within the study regions, we must differentiate between urban areas and areas of single-family houses. In order to simplify the calculations, we generally assume buildings with 4 floors and 4 homes per floor, as this is approximately the most common distribution in Murcia. In these blocks, a 1:16 splitter and a box per building will be needed to cover the 16 houses and a multiport terminal per floor.We distinguish below the two possible configurations contemplated for the access network between the OLT and the end user. In the case of the regions of Molina de Segura and Alcantarilla, information on the distribution of households has been found ([26, 27]), however, for the rest of the regions, an estimate of these percentages has been made based on the structure of each city using tools such as Google Street View.

	Single-family Houses (%)	**Single-family Houses**	**Housing blocks (%)**	**Housing blocks**
Murcia	25.00 %	39229	75.00 %	7356
Cartagena	35.00 %	26810	65.00 %	3112
Lorca	45.00 %	13428	55.00 %	1026
Molina de Segura	37.09 %	8585	62.91 %	911
Alcantarilla	17.66 %	2615	82.34 %	762

Table 2.2: Housing distribution.

With these estimates and taking into account the previous figures, we can determine the number of splitters we will need for each of the regions and configurations, see Figure 2.3.

	Housing blocks	Single-family Houses		
	Splitters 1:16	**Splitters 1:16**	**Splitters 1:4**	**Splitters 1:2**
Murcia	7356	2452	1022	205
Cartagena	3112	1676	699	140
Lorca	1026	840	350	70
Molina de Segura	911	537	224	45
Alcantarilla	762	164	69	14

Table 2.3: Splitters dimensioning.

To analyze the power budget of GPON links, we follow the rules defined by ITU-T G.652 and ITU-T G.684.2, which define the attenuation of an optical link by the following expression:

$$A = \alpha L + \alpha sx + \alpha cy + Penalty \tag{2.1}$$

Where:

- α : cable attenuation coefficient.
- αs : losses of the splitters.
- x: cable number of splitters.
- αc : insertion losses of the connectors.
- y : number of connectors.
- L : link length.
- Penalty : degradations due to reflections, intersymbol interference, mode partition noise, and laser chirp, which are a maximum of 1 dB.

As mentioned above, the deployment of the NG-PON2 network does not require new fiber deployment, so the attenuation coefficient of the SMF G.652 fiber is considered, which is 0.2 dB/km (3rd window) [28].

Restrictions are also established for the power balances of the ODNs, where the optical losses between the closest ONU to the farthest OLT must be less than 15 dB. They must also have a maximum logical range of 60 km and a maximum differential range of 20 km. In addition, the insertion losses of the connectors are considered to be negligible. To calculate the losses caused by splitters 1: N the following expression is used:

$$\alpha s = 10log(N) \tag{2.2}$$

The following table details these losses due to splitters in the two household configurations considered for this project. On the one hand, the household block scheme has 13 1:16 splitters, if we take 13-block blocks. On the other hand, the infrastructure of single-family houses has 12 splitters 1:16 and 5 splitters 1:4 for 192 houses grouped in blocks of 16 households. In order to know L, we use the document Estudios de forma urbana en la Región de Murcia [29]. From it we obtain that the average compactness of the cities of Murcia is around 21.2%, so we can consider a logical maximum differential range of 40 km for blocks of apartments and 20 km for single-family houses, since in them, the density of lines is much lower.

Single-family Houses		Housing blocks	
Coefficient	**Value**	**Coefficient**	**Value**
αs	12 dB	αs (1:16)	12 dB
x	13	x (1:16)	12
L (km)	20	αs (1:4)	6 dB
		x (1:4)	5
		L (km)	40

Table 2.4: Splitter losses.

Device	Model
ONT	Huawei HG8240H EchoLife
OLT	Huawei SmartAX EA5800
Transceiver	Huawei OEGD01N01
WDMr1	WDM 1r - OE Photonics

Table 2.5: FTTH Devices.

According to the speed and infrastructure specifications we chose the equipment in Table 2.5. We highlight the transceivers, which are of great importance, since they are in charge of converting electrical data signals from data switches into optical signals. These signals can then be transmitted over the optical fiber [30, 31, 32, 33].

2.2.1.1.2 HFC

This technology, Hybrid Fiber-Coaxial, uses hybrid lines, i.e. the part of the optical network that supports higher speeds uses fiber while the last part of the connection uses coaxial cable to establish the connection with the customer. In other words, the speed of the link will be limited by the capacity of the coaxial cable. The protocol used for this type of connection is DOCSIS (Data Over Cable Service Interface Specification), an international telecommunications standard that allows taking advantage of the disused cable TV (CATV) networks for data transport using QAM or QPSK modulation. Currently, most HFC lines in Spain use the DOCSIS 3.0 protocol. However, the operator Orange has promoted the migration to DOCSIS 3.1 to improve connections. DOCSIS 3.1 supports download speeds of up to 10 Gbps and 2.5Gbps upstream, 10 times faster than DOCSIS 3.0, in addition, its performance is much higher and security features are improved. These improvements are due to the expansion of the spectrum from 860 MHz to 1.3 GHz, the use of large modulations (n-QAM) and the use of OFDM multiplexing [34]. The new technology is based on the use of a new technology called OFDM multiplexing, which is a new technology for the DOCSIS 3.0.

Architecture

The HFC architecture is not unique and depends on the surface to be covered. The most commonly used architecture is as follows:

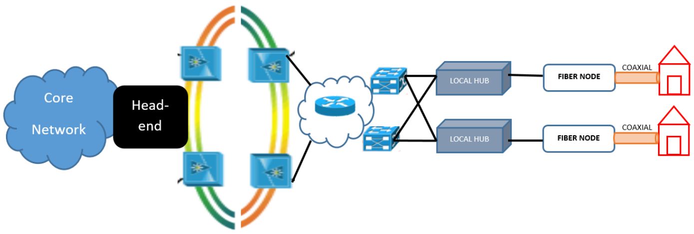


Figure 2.3: HFC Architecture.

As we can see in the image there is a branch, one of fiber and one of coaxial to connect to homes. We highlight the following elements:

- **Headend:** is the element located in the Core network, outside the fixed access network, it is responsible for processing and aggregating all the information transmitted through the network. It coincides with the point of interconnection with the transport, television and telephony networks.
- **Local Hub:** it is the element in charge of aggregating or distributing the information according to the direction of the traffic. In uplink, it collects the signals transmitted by the users whose destination is the Headend. In downlink, it distributes the information through the CMTS (Cable Modem Termination System), which provides high-speed data services, HDT (Host Digital Terminal), which interconnects HFC circuit networks with telephony networks, and VoD (Video on Demand), which manages audiovisual content.
- **Terminal node or fiber node** is the element responsible for making the connection between the fiber cable and the coaxial cable.

To carry out the decentralization of the network, the Modular-CMTS architecture is introduced, which is extremely scalable to a larger number of downstream channels. The physical downstream component is the Edfe WAM (EQAM), which acts as an IP gateway between the operator and the user, in addition, it provides bandwidth reduction facilities [35]. The physical downstream component is the Edfe WAM (EQAM), which acts as an IP gateway between the operator and the user.

Dimensioning

Taking into account the number of total lines in the regions of Murcia, a penetration of the operator Orange in these regions of 21.1% and a percentage of households where fiber has not penetrated of 25%, we calculate the number of actual HFC lines.

It should be noted that the infrastructure is fully deployed so it is not necessary to oversize, the lines that we establish below are those that are considered based on the penetration of our operator.

According to the requirements, the objective is to provide a speed per household of 1Gbps the maximum speed the link speed is going to be limited by the capabilities of the coaxial cable, which in this case thanks to the use of the DOCSIS 3.1 protocol can reach capacities of 10Gbps. It has been assumed that the oversubscription factor is 15, i.e. the throughput is shared by 15 users and together with the number of lines seen above we calculate the number of fiber nodes (EQAM), to calculate the number of amplifiers, we have used a beta factor that represents the ratio of amplifiers by the number of fiber nodes installed, in this case, it is 30%.

	Murcia	Cartagena	Lorca	Molina de Segura	Alcantarilla
Fixed lines (HFC)	8230	3868	1721	1314	761
Number of EQAM	55	26	12	9	6
Number of amplifiers	72	34	16	12	8

Table 2.6: HFC dimensioning.

C100G CCAP [36] fiber nodes have been chosen as it supports the requirements specified above. Full spectrum DOCSIS 3.1, Backward Compatibility, 1.2 Ghz spectrum per service group, 99.999% availability and full redundancy and low power consumption among many others. As for the amplifier, it has been decided to use the Akozon amplifier [37] that meets the requirements specified above.

2.2.1.2 Satellite

Based on the state of the art on satellite in Section 1.4.7.4, we decided to choose Hispasat. The election of the satellite will be explained in the next section.

2.2.1.2.1 Satellite selection

Figure 2.4: Hispasat coverage map.

Regarding the satellite network, we shall make use of this technology in areas that are less accessible, or for those regions where it is not economic to deploy other kind of services, in our case, some of the less populated rural areas and near the Cartagena Port, in the sea. Also, the services that use satellite must not have specific latency requirements, as the latency in this kind of systems tend to be high.

In order to choose the best satellite for our services, we have first researched the satellites of Hispasat that cover our region of interest, in this case we highlight two: Hispasat 30W-5 and Hispasat 30W-6, both working in Ku and Ka bands; the first with 53 transponders and the second with 40 [38].

Satellite	Orbital position	Transponders	Year of launch
Hispasat 30W-5	30º West	53 Ku,Ka	2010
Hispasat 30W-6	30º West	40 Ku, 7 Ka, 10 C	2018

Table 2.7: HFC dimensioning.

In order to choose the best out of these, we must look at the EIRP and footprint, as well as the number of available transponders. In this case, we believe that the best would be the Hispasat 30W-5, as it has the most transponders in the Ku band, and has a good EIRP in the area we want to cover.

As we have mentioned, this satellite has 53 available transponders in the Ku band with 33 MHz of bandwidth, 3 deployed antennas and a payload power of 11 kW. Finally, in our area, it has an EIRP of 54 dBW [39].

2.2.1.2.2 Architecture

The satellite network has been deployed to provide connectivity to the most remote and inaccessible areas. Communication is done in two directions, one from the base station (BS) to the user located in the remote area (forward) and the other communication from the user to the base station (return).

The base station is connected to the core from where the user accesses the operator's services, this core is in turn connected to the ISP network. This base station has an antenna that enables communication with the satellite, and the user must also carry an antenna to communicate with the satellite. Therefore, all communication traffic will be through the satellite.

Satellite communications will be established for those ships whose distance from the antennas located on the coast or in the port of Murcia is greater than the maximum, and for those remote areas such as the town of Aledo, whose population is 1022 inhabitants and is located in the Sierra Espuña from La Santa.

The following shows the forward and return links for a ship located in a remote area:

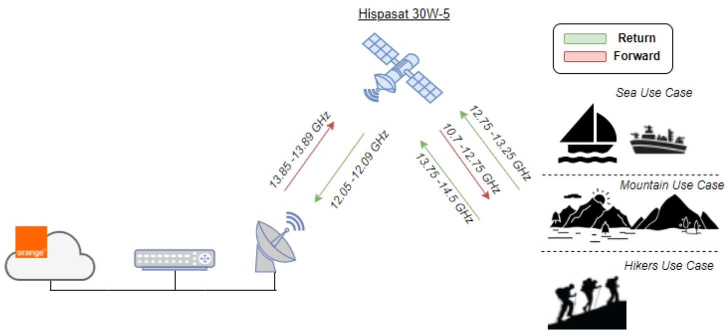


Figure 2.5: Satellite Architecture.

2.2.1.2.3 Dimensioning

Satellite, Frequencies and transponders used

The Hispasat 30W-5 satellite model has been chosen to fit all the requirements of the network communications. The Ku-band transmission frequencies at which the satellite can function are the one listed below, according to its frequency plan [40]. Moreover, the polarization of UL and DL have been evaluated as opposite to minimize counterpolar radiation.

Regarding the frequencies chosen for the system, we have to take into account the forward and return link for the three different use cases involved in the project: hikers, boats and villages located in mountains, both of them provided with a gateway in Madrid. First of all, for the gateway, the frequencies evaluated for UL (forward link) and DL (return link) are respectively 13.85-13.89 GHz and 12.05-12.09 GHz, Then, for the hikers are 12.75-13.25 GHz in UL (return) and 10.7-11.7 GHz in DL (forward). Finally, for boats and mountain villages are 13.75-14.50 GHz in UL (return) and 10.70-12.75 GHz in DL (forward).

The following table shows the main antenna specifications for the three use cases. The larger the diameter of the reflector, the higher the gain and thus, the better the G/T:

User station ID	**Mountain villages**	**Hikers**	**Boats**	**Madrid antenna**	**Units**
Antenna diameter	1.2	0,337 / 0,343 / 0.057	1.03	3.7	m
Antenna model	MA-1200	Ovzon T6	Sailor 900 VSAT Ku	3,7 Meter Manual PMESA	–
URL of datasheet	[41]	[42]	[43]	[44]	–
Antenna gain Reception	41.49	31	40.6	51.5	dBi
User station G/T	20.89	12.23	19.90	30.19	dB/K

Table 2.8: Elements of the architecture for the 3 different link cases.

Power budget calculation

The uplink and downlink power budget is calculated for the forward and return directions using the following equations and data from the table of parameters of the elements of the architecture, considering as well free space losses, rain attenuation (L_{rain}) and gas attenuation (L_{gas}). Rain and gas losses depend on rainfall in the city (mm/h), antenna elevation and frequency band, so it has been estimated that 99.99 % availability is guaranteed in the city of Madrid.

For the free space looses, the equation used is:

$$Lbf = 92,45 + 20log10(frequency(GHz)) + 20log10(distance(km)) \tag{2.3}$$

For C/N in downlink and uplink:

$$C/N = Ptx + Gtx + G/Trx - SM - Lbf - Lrain - Lgas - 10log10(B(Hz)) \tag{2.4}$$

Being SM the security margin.

Signal parameters		
Carrier Symbol Rate	27.5	Msym/s
Roll-off factor	0.2	–
Carrier bandwidth	33.00	MHz
Transponder bandwidth	33.00	MHz
Satellite parameters		
Altitude (Km)	35786	Km
Center angle	6.45^o	

Table 2.9: Forward Link: signal and satellite parameters.

	UPLINK	
Uplink geometry (worst case)		
Range	35833.51	km
Uplink transponder and link budget		
Uplink frequency	13.87	GHz
Transponder polarization	linear	–
Transmitted power	30.00	dBW
EIRP	81.50	dBW
Free space link losses	206.38	dB
Gases absorption	0.50	dB
Rain attenuation	8.00	dB
Satellite G/T	11.00	dB/K
C/N uplink	31.04	dB

Table 2.10: Forward Link: UL and satellite.

		DOWNLINK		
Downlink transponder	**1st case**	**2nd case**	**3rd case**	
Downlink frequency	11.73	11.20	11.73	GHz
EIRPsat-rx	54	54	54	dBW
Downlink geometry				
Range	35833.51	35833.51	35833.51	km
Downlink link budget				
Transponder polarization (downlink)	linear	circular	circular	–
Free space link losses	204.9180438	204.5201472	204.5201472	dB
Gases absorption	0.30	0.30	0.30	dB
Rain attenuation	6.00	6.00	6.00	dB
C/N downlink	17.08	8.42	16.10	dB
Additional Interference				
C/I	25.00	25.00	25.00	dB
Summary				
C/(N+I) total	16.28	8.31	15.45	dB
Additional degradation	0.50	0.50	0.50	dB
Implementation margin	3.00	3.00	3.00	dB
Available Es/No	12.78	4.81	11.95	dB
Required Es/No	12.73	4.68	11.61	dB
Link margin	0.05	0.13	0.34	dB
Carrier bit rate calculation				
MODCOD	32 APSK 3/4	QPSK 4/5	16 APSK 5/6	–
Spectral efficiency	3.703295	1.587196	3.300184	–
Carrier bit rate	101.84	43.65	90.76	Mbps

Table 2.11: Forward Link: DL for the 3 cases and summary.

Table 2.10 and table 2.11 details the complete forward link study. Again, it is necessary to differentiate the between the 3 use cases, notable in the C/(N+I) achieved for each, with the hikers being the more restrictive, mainly due to the lower G/T. Once the C/(N+I) has been calculated and taking into account the available Es/No with the implemented margin, we can decide the modulation performance based on the DVB-S2 tables[45].

RETURN LINK - UPLINK				
Uplink geometry (worst case)	**1st case**	**2nd case**	**3rd case**	
Range	35833.51	35833.51	35833.51	km
Uplink transponder and link budget				
Uplink frequency	14.13	14.13	14.13	GHz
Transponder polarization	linear	circular	circular	–
Transmitted power	16.02	21.46	12.70	dBW
EIRP	59.13	52.46	54.30	dBW
Free space link losses	206.54	206.54	206.54	dB
Gases absorption	0.50	0.50	0.50	dB
Rain attenuation	6.00	6.00	6.00	dB
Satellite G/T	11.00	11.00	11.00	dB/K
C/N uplink	10.51	3.84	5.68	dB

Table 2.12: Return link: UL.

RETURN LINK - DOWNLINK		
Downlink transponder		
Downlink frequency	12.07	GHz
EIRPsat-tx	54	dBW
Downlink geometry		
Range	35833.51	km
Downlink link budget		
Transponder polarization (downlink)	linear	–
Free space link losses	205	dB
Gases absorption	0.30	dB
Rain attenuation	8.00	dB
C/N downlink	24.13	dB
Additional Interference		
C/I	25.00	dB

Table 2.13: Return Link: DL.

RETURN LINK - SUMMARY				
	1st case	**2nd case**	**3rd case**	
C/(N+I) total	10.18	3.77	5.57	dB
Additional degradation	0.50	0.50	0.50	dB
Implementation margin	3.00	2.00	3.00	dB
Available Es/No	6.68	1.27	2.07	dB
Required Es/No	6.62	1.00	1.00	dB
Link margin	0.06	0.27	1.07	dB
Carrier bit rate calculation				
MODCOD	8PSK 2/3	QPSK 1/2	QPSK 1/2	–
Spectral efficiency	1.980636	0.988858	0.988858	–
Carrier bit rate	54.47	27.19	27.19	Mbps

Table 2.14: Return Link: summary.

Analogous to the forward study, table 2.12 and table 2.13 shows the return link study. In addition to this, the MODCOD and spectral efficiency have been calculated according to DVB-RCS [46].

2.2.2 CORE

2.2.2.1 Arquitecture

The main objective of the CORE network is to aggregate and redirect the traffic of the municipalities in the region of Murcia on which this work is focused. The technology used to transport traffic on the CORE network will be DWDM technology with a 100G bidirectional fibre ring (uplink and downlink) interconnecting the cities of Murcia, Lorca and Cartagena. Two ROADM (Reconfigurable Optical Add-Drop Multiplexer) will be installed in each of these cities, connecting the fibre ring with the EDGE network. In this way, in the case of any incident, with two ROADMs, the city can continue having service.

Additionally, another ROADM located in Madrid will be connected to the ROADM in the city of Murcia, to allow connection to the ESpanix neutral point in Madrid. This fibre link will allow the data from the CORE network to be redirected to the global traffic. In addition, due to the long distance between Murcia and Madrid, several optical amplifiers (EDFA) will have to be installed to compensate for the attenuation in the fibre. Between these points, a firewall will be installed to prevent the content being transferred on our network from being filtered. Figure 2.6 shows the architecture for the CORE network.

ESpanix [47] is a neutral point of interconnection to the Internet located in Madrid (Spain), in charge of connecting the networks of operators and Internet content and service providers. Its main objectives include improved latency and bandwidth, cost reduction and fault tolerance [48].

Figure 2.6: CORE network architecture.

2.2.2.2 Dimensioning

The network core must support the traffic of all the services offered by AchoTelecom. In order to dimension the CORE, all the traffic for each ROADM has been taken into account, as not all services have the same influence. Due to the proximity of the cities of Alcantarilla and Molina de Segura, their traffic has been incorporated into Murcia´s ROADM.

Service	**Uplink**	**Downlink**	**Units**
Fixed Broadband	566,01	9215,81870	Gbps
Mobile Broadband	516,48	1032,96	Gbps
IMS	35771,48	35771,48	Kbps
Satellite	65,91	65,98	Mbps
e-CleanHidroeolic	21,19	0,00	Kbps
e-FreshGreens	3,91	0,00	Kbps
e-FoodSensing	0,71	0,00	Kbps
e-SmartGas	0,18	0,00	Kbps
Total	1082,60	2919,79	Gbps

Table 2.15: Traffic from Murcia + Alcantarilla + Molina de Segura.

Service	**Uplink**	**Downlink**	**Units**
Fixed Broadband	204,240	680,800	Gbps
Mobile Broadband	63,358	126,715	Gbps
IMS	13427,508	13427,508	Kbps
e-CleanHidroeolic	16,274	0,00	Kbps
e-FreshGreens	3,91	0,00	Kbps
e-FoodSensing	0,16	0,00	Kbps
e-SmartGas	0,23	0,00	Kbps
Total	267,611	807,529	Gbps

Table 2.16: Traffic from Cartagena.

Service	**Uplink**	**Downlink**	**Units**
Fixed Broadband	90,85	302,84	Gbps
Mobile Broadband	186,51	373,03	Gbps
IMS	5972,48	5972,48	Kbps
e-FreshGreens	6,04	0,00	Kbps
e-FoodSensing	0,10	0,00	Kbps
e-SmartGas	0,42	0,00	Kbps
Total	277,37	675,87	Gbps

Table 2.17: Traffic from Lorca.

Finally, the total traffic supported by the CORE network is described in the following table:

Zone	Traffic Uplink (Gbps)	Traffic Downlink (Gbps)	Total (Gbps)
Murcia	1082,60	2919,79	4002,39
Lorca	277,37	675,87	953,24
Cartagena	267,61	807,53	1075,14
Total	1627,58	4403,19	6030,77

Table 2.18: Total traffic.

For the previous traffic tables, as it was mentioned in the context analysis, fixed and mobile broadband traffic will vary by increasing 10% annually during the 5 years of the project.

In Table 2.19 you can see the different ROADMs defined in the CORE network. And in Table 2.20 the traffic which will flow through our network has been defined. Therefore, now the connections between each one of the ROADMs must be dimensioned, with their corresponding distances between one and another.

ROADMs	Zone
ESpanix (Neutral Point)	Madrid
ROADM 1	Murcia
ROADM 2	Lorca
ROADM 3	Cartagena

Table 2.19: ROADMs.

Number	Connections	Distance
1	Madrid - Murcia	349 km
2	Murcia -Lorca	61 km
3	Lorca - Cartagena	61 km
4	Cartagena - Murcia	42 km

Table 2.20: Connections.

For the downlink channel, 24 connections of 100Gbps will be used, and the uplink channel will require a total of 17 100Gbps connections. The total number of connections used will therefore be 41. The optical amplifier EDFA used has a much higher number of ports to ensure all connections can be established. Analysing the range guaranteed by the ROADM, up to 100km, we can clearly observe how the 3 links Murcia-Lorca, Lorca-Cartagena and Cartagena–Murcia are all within this margin. Even though, the longest connection, which is Lorca–Cartagena with 62km, is under the 100km limit, an EDFA amplifier has been incorporated in the system. This will ensure an output power of around 45dBm, and in case the signal is excessively amplified, an attenuator is incorporated at its reception.

2.2.2.3 Catalogue and selection of products

The resulting traffic has very big size (Tbps). Therefore, to meet these requirements, new generation equipment has been chosen for each connection:

- **PL-1000RO WSS ROADM**: Advanced integrated ROADM platform providing highly flexible wavelength routing, automatic power balancing and amplification for next generation DWDM network infrastructure. It allows a range of up to 100km.
- **Fullwell 64 ports PON and CATV WDM EDFA**: optical amplifier with 64 input and output ports. Provides 45 dBm output on both output and input ports.
- **Corning LEAF Optical Fiber**: optical fibre that meets the requirements of the ITU-T G.655 standard, with a maximum attenuation of 0.19 dB/km for 1550 nm.

2.2.3 EDGE

2.2.3.1 Arquitecture

The main objective of the EDGE network is to interconnect the CORE network and the access network. In this way, the network is in charge of routing and aggregating all the traffic of users and services coming from the 3 main cities of the region (Murcia, Cartagena and Lorca).

The standard used in the EDGE network will be MPLS (Multiprotocol Label Switching) [49]. The main benefits of this standard include optimal traffic flow, better IP over ATM integration or the use of one unified network. In addition, MPLS is composed of different network elements: LSP (Label Switched Path), LER (Label Edge Router) or LSR (Label Switching Router).

Regarding MPLS, the operation is as follows: the LER analyses and classifies the incoming IP packet. The routers add a header MPLS that depends on the QoS required and the IP address, in order to know the next hop where the packet is going to go over the MPLS network. In this way, the LER can send it to the LSR. Once the packet arrives at the destination router, the router removes the MPLS header and forwards the packet on the predefined route with a new MPLS tag.

The EDGE network is mainly made up of 3 components:

- **Router switches**: Its function is the interconnection with the CORE network.
- **Aggregation switches**: Their main function is the aggregation of traffic.
- **Access switches**: They function as access points for the technologies of the access network, such as OLTs, ONTs, fibre access with the NG-PON2 technology, Local Hubs for access via DOCSIS (HFC).

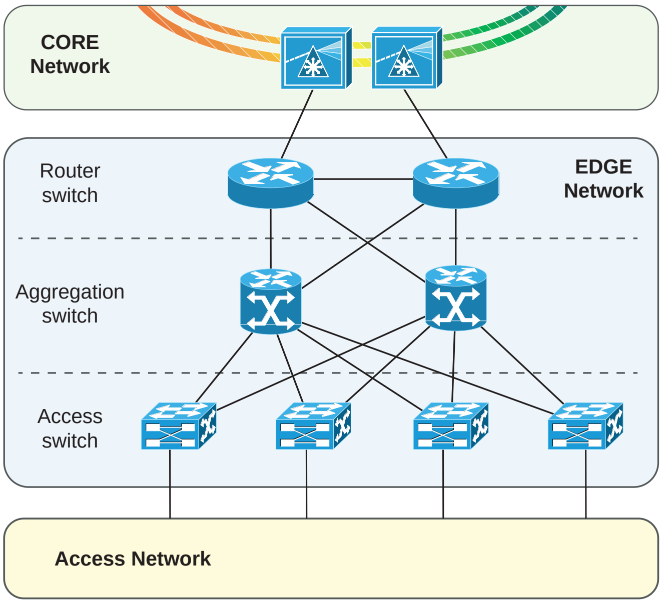


Figure 2.7: EDGE network architecture.

Regarding the EDGE network architecture, a redundant architecture is proposed so that in the event of a network failure (equipment or links), it can continue to provide service. In this way, all the equipment, as shown in the Figure 2.7, is duplicated. Furthermore, through this architecture it is also possible to respond to peaks in demand for services on the network. Finally, it should be noted that if one of these incidents does not occur in the network, the equipment will share the traffic.

2.2.3.2 Dimensioning

In order to calculate the equipment needed, it is necessary to take into account the traffic coming from the fixed and mobile access network and the innovative services offered for Murcia, Lorca and Cartagena. The total traffic to be carried is obtained from the equipment forming the access network.

Since the most abundant traffic is produced in the downlink, the number of equipment is sized according to this, given that each port is capable of handling traffic going through both directions. In the following table it is specified the number of aggregation and access switches needed in each locality. These numbers have been calculated based on the downlink traffic data and applying redundancy to prevent denial of service to happen in the network.

Zone	Aggregation Switch	Access Switch
Murcia	14	38
Lorca	4	12
Cartagena	4	10
Total	22	60

Table 2.21: Switches per location.

Knowing the total Uplink and Downlink traffic and the number of components that the Edge network has, we can calculate the traffic that each one of the components will carry. In the following tables we can appreciate the traffic that will be received by a single access router, a single aggregation switch and a single access switch of our Edge network. It is important to state that these values would change in case of failure on any of the components of the network, however our network is redundant enough to addapt to this scenario.

Zone	Uplink	Downlink	Units
Murcia	77,32	208,55	Gbps
Lorca	69,34	168,96	Gbps
Cartagena	66,90	201,88	Gbps

Table 2.22: Traffic per Aggregation Switch.

Zone	Uplink	Downlink	Units
Murcia	28,48	76,83	Gbps
Lorca	27,72	67,58	Gbps
Cartagena	22,30	67,29	Gbps

Table 2.23: Traffic per Access Switch.

Traffic	Uplink	Downlink	Units
Total	542,52	1467,73	Gbps

Table 2.24: Traffic per Access Router.

2.2.3.3 Catalogue and selection of products

As we have previously stated in the architecture part, we are going to use three components:

- **Access router**: It has been decided to use switches developed by the famous technological company Cisco. The switch chosen is NC57-24DDD that has 24 ports of 400 Gbps each. These ports allow connection to ROADMs. As our total downlink traffic is lower than the 9600 Gbps that this switch offers we are only going to use three of them, the second and the third one in order to have a redundant network, avoid possible failures and to facilitate future expansions of the network [50].
- **Aggregation switches**: we are going to use a switch designed by the company ZTE which is called ZXR 10 8908E. Each switch has 48 ports of 10Gbps. We will have a second component for every one needed for achieving redundancy objectives [51].
- **Access switches**: the switch chosen is from the company Netgear and is called M4300-8X8F. It is capable of supporting 16 ports with 10 Gbps capability. As in the aggregation switches, we will have a second component for every one needed in order to achieve our redundancy objectives [52].

2.2.4 IMS

2.2.4.1 Architecture

The IP Multimedia Subsystem (IMS) is a set of specifications that describe next generation architectures to support multimedia over IP. It must have several hardware components that must work in order to provide the services that clients demand to be available everywhere and at any moment.

Many different organizations have worked in developing a wide variety of architectural models. After analyzing all of them, it was decided that the ClearWater Project was the best solution. It was chosen due to the fact that it is free, open access, widely used in the market and allows virtualization in the cloud. This model is intended to be deployed in the cloud via Amazon Web Services (AWS). The final architecture of the IMS subsystem is as follows:

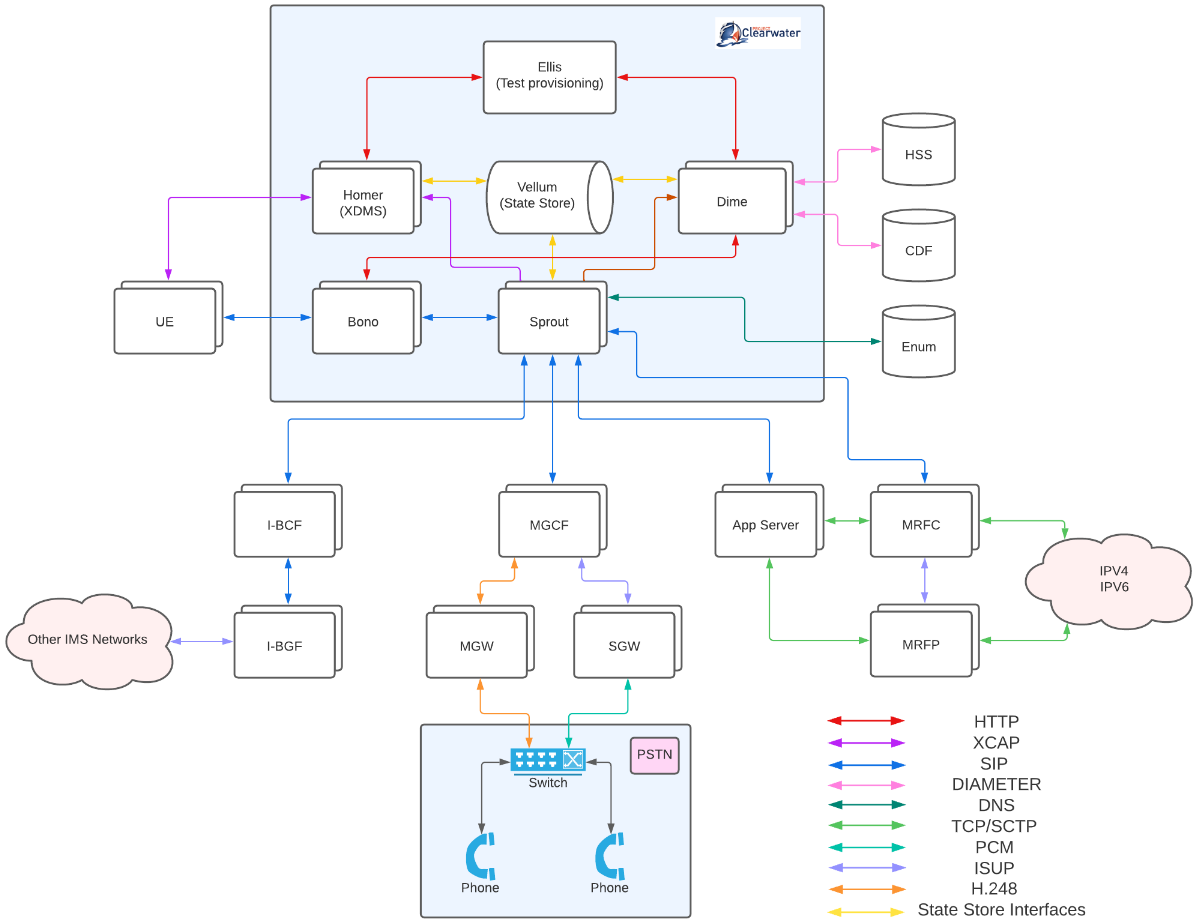


Figure 2.8: IMS architecture.

The ClearWater architecture is mainly divided in five modules:

- Bono (edge proxy): It serves as the entrance for clients to be connected to the clear water subsystem. It contains several nodes which provide a WebRTC interface to clients. Client connections are balanced across the nodes, being assigned to one during its registration but being able to move to another if the connection or client fails. Clients can connect to Bono using SIP/UDP or SIP/TCP. It supports any WebRTC client that performs call setup signaling using SIP over WebSocket. However, the bono subsystem is not mandatory and can be substituted by a Proxy Call/Session Control Function (P-SCF).

- Sprout (SIP Router): it acts as the SIP router providing the functionalities of the Interrogating Call/Session Control Function (I-CSCF) and the Serving Call/Session Control Function (S-CSCF) subsystems. Therefore, this module handles the client authentication and the IMS Service Control (ISC) interface to application servers. Besides, it contains the in-built Multimedia Telephony (MMTEL) application server. Despite this, it does not store any data itself, this functionality is provided by vellum.
- Dime (Diameter gateway): these nodes run Homestead and Ralf components.
  - Homestead (HSS Cache): this component provides a web services interface to sprout for getting user profile information and authentication credentials.
  - Ralf (CTF): this component is responsible for providing an HTTP API to Bono and Sprout to report billable events that should be sent to the Charging Data Function (CDF) over the Rf billing interface. Ralf has no states. It uses Vellum to maintain a long lived session state and run the necessary timers.
- Vellum (State store): as it was described in Ralf section, Vellum is used to maintain all long-lived states in the deployment. In order to achieve this, Vellum uses different cloud optimized, distributed storage clusters.
  - Cassandra is used by Homestead to store authentication credentials and profile information when an HSS is not in use. It is also used by Homer to store MMTEL service settings.
  - Chronos is used by Sprout and Ralf to enable timers to be run.
  - Memcached is used by Sprout for storing registration state, by Ralf for storing session state and by Homestead for storing cached subscriber data.
- Homer (XDMS): it is a standard XDMS that, for each user of the system, stores MMTEL service settings. It uses Vellum to store all long lived data.

Apart from this subsystems, the architecture includes more components:

- Ellis: it is intended to make the system easy out of the box. It provides a portal for self-sign-up, password management, line management and control of MMTEL service settings.
- Enum server: it is a system for mapping PSTN numbers to SIP URIs using DNS NAPTR records, and which sprout supports.
- Interaction with the PSTN network through the Media Gateway Control Function (MGCF). This allows the interconnection between the IMS subsystem and the PSTN network.
- Interaction with other IMS networks: the Interconnect-Border Control Function (I-BCF) and the Interconnect-Border Gateway Function I-BGF serve as the connection to other IMS networks, allowing SIP calls and video calls between users from different operators.
- Interaction with the IP network: the IMS system is connected to the Internet by the Multimedia Resource Function Controller (MRFC) and the Multimedia Resource Function Processor (MRFP). These components handle the SIP requests from the application servers.

2.2.4.2 Interworking scenarios

IMS uses SIP, so all the calling scenarios follow SIP's message squeme and send data through RTP unless it is specified otherwise. This text focuses on SIP messages, as those are the ones treated in the control layer (IMS). Once the SIP session is initiated the data packets travel through the ip network directly between users using RTP or straight through the PSTN as a bit stream. The diagrams of the different scenarios are deeply described in the IMS annex while here a brief explanation is given.

2.2.4.2.1 Audio call between clients of Operator 1 If both users are of the same operator they will both be connected to the same IMS network. Therefore, the caller will connect to its respective Bono (proxy), which will connect with Sprout (S-CSCF). The latter will then redirect the SIP messages towards the receiver's Bono or Sprout (if the Bono is connected to another Sprout), to then reach the called terminal.

2.2.4.2.2 Audio call from Operator 1 to Operator X This scenario has variations depending of the technology used in the receiving end:

- IMS-IMS: the path is similar to the audio call between clients of operator 1, but with the difference of packets traveling between two different IMS networks. In this particular case the IMS network in which the connection starts uses the I-BCF (Interconnection Border Control Function) and I-BGF (Interconnection Border Gateway Function) to allow its own Sprout (the S-CSCF) to ask the receiving network's I-CSCF (which consults the corresponding HSS); and the to connect to the corresponding S-CSCF.
- IMS-PSTN: when the receiving end is in the PSTN the SIP messages need to be converted to ISUP through a MGW (Media Gateway) controlled by a MGCF (Media Gateway Control Function) through the protocol H.248.1. Because of this, the Sprout will send signaling to the MGCF, which will then send the resulting ISUP messages to the SGW (signaling Gateway). Moreover, the data packages (that use RTP) will be sent through the MGW, where they will be converted to a bit stream of voice at 64 kbps.
- IMS-IP: in the case that the receiving end is connected to an IP network, the Sprout will send the SIP messages through the MRF (Media Resource Function), which is composed of the MRFC (Media Resource Function Controller), where the SIP requests are taken and managed; and theMRFP (Media Resource Function Processor), where the actual media streams are processed. The MRF will then connect to the corresponding user's proxy in the IPv4/IPv6 network.

2.2.4.2.3 Audio call from Operator X to Operator 1 In this case the process is almost the same as in "Audio call from Operator 1 to Operator X", but in the opposite order. This time, the Sprout is receiving the SIP INVITE messages and, as it englobes the function of both the I-CSCF and S-CSCF, resending the messages to the corresponding Bono that will contact the User Equipment.

2.2.4.2.4 Videoconference between clients of Operator 1 The videoconference initiation between clients of the same operator occurs in the same IMS network. Therefore, the initiating client will send a SIP INVITE message to the Bono. The message will be transferred to the Sprout, which will resend it to the Application Server and the MRF. After that the original caller sends a REFER message that reaches the AS and MRF, which will respond by sending INVITE messages that will reach all the implicated terminals through their corresponding Sprouts and Bonos. Once the SIP session is established, all the media packages will need to go through the AS and MRF.

2.2.4.3 Dimensioning

2.2.4.3.1 Fixed Telephony IMS telephony dimensioning is based on three operators: Operator 1 (AchoTelecom) and the external Operators 2 and 3. It is known that 30% of the traffic is local (internal to the operator) and the 70% remaining goes or comes from operator 2 and 3. From the local traffic, 50% of it remains in the same city. From the external traffic, 70% is exchanged with operator 2 and 30% with operator 3. The following table summarizes these numbers:

Local	0.3	**Same city**	0.5	Own operator
		Other City	0.5	
External	0.7	**External 1**	0.7	Operator 2
		External 2	0.3	Operator 3

Table 2.25: IMS – Telephony traffic distribution per operator.

Taking into account the number of fixed telephony lines in the region and the market share of Orange in the fixed telephony market of Murcia (18,4%), we are able to dimension the fixed telephony traffic. Therefore, the number of lines estimated is shown below:

Users	**Population**	**Total Lines**	**Hired Lines**
Murcia	460349	193917	35681
Cartagena	216365	91142	16770
Lorca	96238	40539	7459
Molina de Segura	73498	30960	5697
Alcantarilla	42559	17928	3299
Total	889009	374486	68906

Table 2.26: IMS - Fixed Telephony demographic distribution.

The next step is computing the number of calls per hour and the Erlangs, taking into consideration that in the busy hour there is a traffic of 0.9 Erlangs per customer and an average duration of calls of 1000 seconds. The table below shows the rate of calls per hour and the total traffic in Erlangs for each both local (same and different city) and external (to/from operator 2 and 3) calls.

Location	**Call rate (calls/hour)**			**Erlangs**
Murcia	Local	Same city	17340.96	4816.93
		Other city	17340.96	4816.93
	External	Operator 1	56647.15	15735.32
		Operator 2	131941.12	36650.31
	Total		223270.21	62019.50
Cartagena	Local	Same city	8150.22	2263.95
		Other city	8150.22	2263.95
	External	Operator 1	26624.05	7395.57
		Operator 2	62013.01	17225.83
	Total		104937.50	29149.30
Lorca	Local	Same city	3625.074	1006.96
		Other city	3625.07	1006.96
	External	Operator 1	11841.90	3289.41
		Operator 2	5075.10	1409.75
	Total		24167.16	6713.10
Molina de Segura	Local	Same city	2768.74	769.09
		Other city	2768.74	769.09
	External	Operator 1	9044.55	2512.37
		Operator 2	3876.23	1076.733
	Total		18458.28	5127.23
Alcantarilla	Local	Same city	1603.31	445.36
		Other city	1603.31	445.36
	External	Operator 1	5237.49	1454.85
		Operator 2	2244.63	623.51
	Total		10688.76	2969.10
Total			381521.92	105978.31

Table 2.27: IMS - Fixed Telephony Traffic call rates and Erlangs.

2.2.4.3.2 VoNR The amount of clients that need to be given a service is calculated from the data regarding the number of habitants in the five objective cities, a penetration of 74% and assuming a Market Share of 26%.

Users	Population	Total Lines	Hired Lines
Murcia	460349	340658	88571
Cartagena	216365	160110	41629
Lorca	96238	71216	18516
Molina de Segura	73498	54389	14141
Alcantarilla	42559	31494	8188
Total	889009	657867	171045

Table 2.28: IMS - Mobile Telephony demographic distribution.

The dimensioning of VoNR traffic has been carried out assuming conditions similar to those of fixed telephony. As a result, the traffic obtained is distributed according to the Table 2.29.

Location	Call rate (calls/hour)			Erlangs
Murcia	Local	Same city	43045.50	11957.08
		Other city	43045.50	11957.08
	External	Operator 1	140615.31	39059.81
		Operator 2	231783.70	64384.36
	Total		458490.03	127358.34
Cartagena	Local	Same city	20231.69	5619.91
		Other city	20231.694	5619.915
	External	Operator 1	66090.20	18358.38
		Operator 2	108938.84	30260.79
	Total		215492.43	59859.00
Lorca	Local	Same city	8998.77	2499.66
		Other city	8998.77	2499.66
	External	Operator 1	29396.00	8165.55
		Operator 2	12598.28	3499.524
	Total		59991.84	16664.40
Molina de Segura	Local	Same city	6872.52	1909.03
		Other city	6872.52	1909.03
	External	Operator 1	22450.25	6236.18
		Operator 2	9621.53	2672.64
	Total		45816.84	12726.90
Alcantarilla	Local	Same city	3979.36	1105.38
		Other city	3979.36	1105.38
	External	Operator 1	12999.26	3610.90
		Operator 2	5571.11	1547.53
	Total		26529.12	7369.20
Total			806320.26	223977.85

Table 2.29: IMS - Mobile Telephony Traffic call rates and Erlangs.

2.2.4.3.3 Video conference Traffic due to video conferences has been analysed. The parameters used are 20% of the population, 0.1 Erlangs/client (hour loaded), average duration of 2400 seconds and 4 users per videoconference.

Taking into account that the Videoconference penetration in Murcia is 13.6% (we have used the same as FTTH), Orange's market share is 18.4%, and taking into account the above parameters the calculated penetration is 2%. Therefore the number of lines for the sizing can be seen in Table 2.30.

Location	Population	Penetration	Lines
Murcia	460349	2%	9215,818701
Cartagena	216365	2%	4331,454208
Lorca	96238	2%	1926,60777
Molina de Segura	73498	2%	1471,371162
Alcantarilla	42559	2%	851,9971328

Table 2.30: IMS - Videoconference demographic distribution.

Also we have taken into account that companies have 75% of their branches in the same city and thus 25% of the traffic will come from another city.

Location	**Videoconference rate (Videoconference/hour)**			**Erlangs**
		Same city	1036,77	691,18
		Other city	345,59	230,39
Murcia	Total		1382,37	921,58
		Same city	487,28	324,85
		Other city	162,42	108,28
Cartagena	Total		649,71	433,14
		Same city	216,74	144,49
		Other city	72,24	48,16
Lorca	Total		288,99	192,60
		Same city	165,52	110,35
		Other city	55,17	36,78
Molina de Segura	Total		220,70	147,13
		Same city	95,84	63,89
		Other city	31,95	21,30
Alcantarilla	Total		127,80	85,20
Total			2669,58	1779,72

Table 2.31: IMS - Videoconference call rates and Erlangs.

2.2.4.3.4 Clearwater components To calculate the number of requests that each component needs to process we considered three different scenarios.

- **Scenario 1:** calls between the same operator.
- **Scenario 2:** calls between two different operators.
- **Scenario 3:** video conferences.

To compute the results it is necessary to take into account the number of calls per hour in each scenario obtained through the estimations done in sections 2.2.4.3.1 and 2.2.4.3.3. The total number of calls per second for each scenario is displayed in table 2.32.

	Scenario 1	**Scenario 2**	**Scenario 3**
Calls/Hour	107034.04	492340.99	2669.58
Calls/sec	29.73	136.76	0.74

Table 2.32: Number of calls per second in each scenario.

In each scenario, only the requests processed by the proposed Clearwater based IMS network were considered. The results for each scenario in requests per second are displayed in Table 2.33. Finally, the computed total results can be seen in Table 2.34.

	Scenario 1		**Scenario 2**		**Scenario 3**	
Equipment	Req/Call	Req/sec	Req/Call	Req/sec	Req/Call	Req/sec
Bono	10	297.31	16	2188.18	14	10.38
Sprout	18	535.17	19	2598.466353	24	17.79
Dime	4	118.92	2	273.52	4	2.96
AS	8	237.85	4	547.04	8	5.93
SGW	0	0	0	0	5	3.70
MGW	0	0	0	0	3	2.22
MGCF	0	0	4	547.04	10	7.41

Table 2.33: Requests in each scenario.

Equipment	Total Req/sec
Bono	2495.88
Sprout	3151.43
Dime	395.41
AS	790.83
SGW	3.70
MGW	2.22
MGCF	554.46

Table 2.34: Total number of requests per second.

2.2.4.4 Cloud architecture and dimensioning

As we know Clearwater implements IMS to deliver voice, video and messaging to a target of millions of people. It is a service that can scale massively as the number of customers grows so it is ideal to use cloud computing. In addition, Clearwater's microservices-based architecture makes it ideal for using docker containers in conjunction with an orchestration system such as Kubernetes.

Here comes the dilemma of which cloud provider we use, as our aim is to provide a service to Orange we have investigated which provider they use and it is Amazon Web Services (AWS) so choosing AWS will be an added value for them to accept our proposal. We have chosen the Paris servers as they are the closest and we will only have a latency of 19 ms.

Below is the diagram of the proposed infrastructure for the deployment of our Elastic Kubernetes Service (EKS) on AWS along with the internal architecture within EKS considering the main components of Kubernetes.

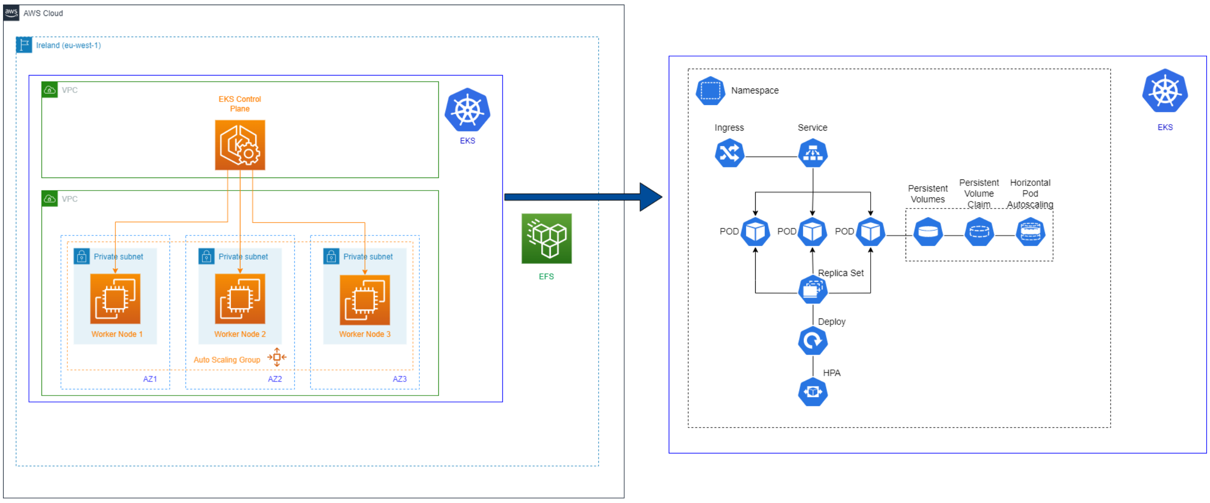


Figure 2.9: Cloud architecture.

The control plane or master node controls the worker nodes, the deployment of the pods and the workloads at runtime (in EKS they are provisioned and managed by AWS). Worker Nodes are the nodes on which PODS are deployed. We can see that the workers are in different VPCs than the Master. To control the storage interface it is necessary to have the EFS service. Within the logical part of Kubernetes the most important are the PODs where the different microservices are run, for more information on the different components you can read the official Kubernetes documentation [53].

One of the main advantages of our architecture is the high availability we have. At Control Plane level it is managed by AWS with the recommendation to deploy workers in MultiAZ (Availability Zones) with a minimum of 1 worker/AZ. For the autoscaling of the workers in the cluster we have decided to enable cluster autoscaler (CA) that automatically adjusts the size of the cluster, adding or removing workers automatically depending on the load. At the POD (service containers) level we have enabled HPA which automatically scales the number of Pods according to the load. In this way we guarantee the scaling at POD level on the existing workers, if any worker runs out of capacity, the CA would jump and would be responsible for deploying a new one.

As mentioned in the worker nodes we will have the PODs deployed with the six different Clearwater roles (Ellis, Bono, Sprout, Homer, Dime, Vellum), the number of PODs will grow depending on how many PODs need to raise each of the roles. The worker node will be an EC2 c5d.2xlarge instance (8vCPU and 16 GB RAM) ensuring more than 1 vCPU and 2 GB RAM for each Clearwater role as specified in the official documentation. With this type of machine we can reach up to 44 PODs per Worker Node, as we have up to 3 Worker Node (one for each availability zone) we could have up to 132 PODs for our service. Each Worker Node (a machine with these characteristics) supports 30.000 users according to the documentation, so the architecture of the figure could support up to 90.000 users with the 3 Worker Nodes, so we need to replicate this three times to support the final user estimate (approximately 250,000 users) with a margin of 20,000 users (90,000*3 - 250,000 = 20,000). The advantage of developing this architecture is that if the number of clients grows, the EKS cluster will automatically create more Worker Nodes in the different availability zones to support more users without any problem. So in our initial architecture we will have a minimum of 9 Workers Nodes but these will auto-scale depending on the load. The estimated price is only for the 9 initial Worker Nodes since we have taken into account that the sum of the services we reach almost 250,000 users, we have a margin in case the number of users grows rapidly without having to build another worker node.

The following is the cost calculated directly from the AWS calculator for the architecture of the figure. [54].

- c5d.2xlarge instance (8 vCPU and 16 GiB) + 120 GB SSD: 0.275/hour$ with instances reserved for 1 year. A total of 641.84$ per month and 7702.2 per$ year (Per instance).
- EKS Cluster: monthly price of 73.00$ and annual price of 876.00$.
- EFS (1000 GB): monthly price of 55,5$ and annual price of 666.00$.

So the total price is 3*(23106.9$ (7702,2*3)$ + 876$ + 666.00$) = 74246,7$/year with 9 Worker Nodes (Up to 270.000 users).

2.3 Network Management

2.3.1 Network Management Architecture

2.3.1.1 Network Management standards : CMIS/CMIP and SNMP

Two main protocols for network management are CMIS/CMIP and SNMP, which will be described below, and which differ in their proposed methodology. On the one hand, SNMP, known as Simple Network Management Protocol, was developed in the 80s and standardized in the 90s. It is known as the default standard for TCP/IP networks. On the other hand, CMIS/CMIP, known as Common Management Information Service / Common Management Information Protocol, is defined by OSI for its network stack.

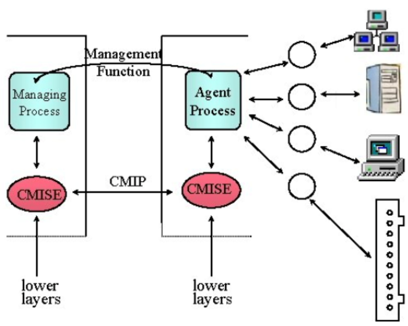


Figure 2.10: OSI System architecture management [1].

In CMIS/CMIP information exchange between network management stations and agents is done. Moreover, it is emphasized that in CMIP, operations are considered complex with sophisticated data structure and numerous attributes, consisting of 11 operations. The advantage of CMIP is the security it brings, because it supports access control, security logs with reporting [55].

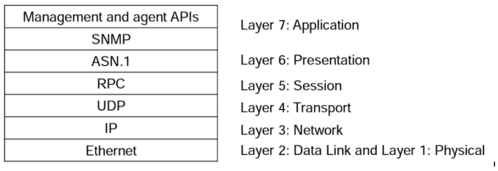


Figure 2.11: SNMP protocol stack.

SNMP has appeared with the objective of providing a simple but useful protocol, with initially only two commands implemented (GET and SET), used to access and modify device parameters [56], in contradiction to the last protocols described, due to its simplicity.

This one is responsible for exchanging data between devices of the network, and in comparison with the CMIS/CMIP protocols, it only employs the operation attributes and the notifications as trap messages, as in CMIP, the operations are seen as very complex, because of its various attributes. SNMP will be chosen because of the reasons explained, to implement a simple and efficient methodology, with the ease that it brings.

2.3.1.2 Telecommunication Management Network (TMN) architecture

TMN architecture is known for using a predefined interface for managing network resources, divided through layers as a global architecture of NM systems.The layers represent each one of the management region [57]. Moreover, the functional areas that are required in this architecture are the FCAPS, present in the network management layer, as can be seen in the figure above. The principal layers are:

- **Network element layer:** It tries to focus on the interaction of the network elements with its topology. For example, it serves to implement signaling and configure the network topology.
- **Element management layer:** It deals with the management of the functions of a network element.
- **Network management layer:** Management of the network systems providing services.
- **Service Management layer:** It is related to all parts of the network that can be experienced by the user, such as quality of service, quality of experiment and so on.
- **Business Management layer:** Focused on the network's overall growth and evolution strategy.

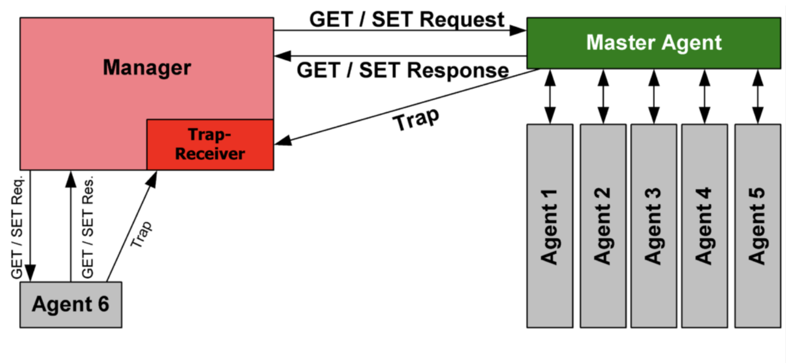


Figure 2.12: TMN layers, NM and FCAPS [2].

2.3.1.3 SNMP architecture

The SNMP architecture is based on a client server kind of model, where servers (managers) collect and process the information about the elements of the network and the clients (agents) are the elements connected to it. Operations are followed for the simple communication done through GET/SET and trap messages.

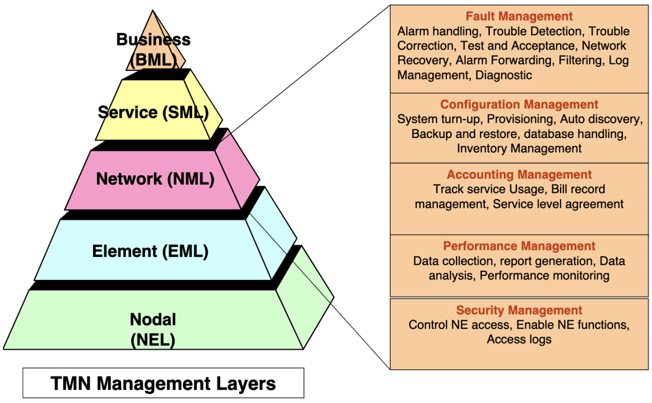


Figure 2.13: SNMP architecture management and communication [3].

The SNMP architecture includes five layers according to IBM [4]:

- **SNMP Network Managers:** It is a program that asks for information from the master agents and represents it.
- **Master agents:** A software program that provides an interface between the SNMP Network Manager and the subagent.
- **Subagents:** A software program that gives information to a master agent.
- **Managed components:** Hardware or software that provides a subagent, like routers, databases, etc.
- **Management Information Base (MIB):** Database used for the management of entities in a communication network, like the resources that will be managed, how to describe them and name them. An OID (Object identifier) is unique and identifies an MIB object, defined following the ASN.1 (Abstract Syntax Notation 1) language, where there is one for each managed feature. A group of tables is used that specify the information that a subagent gives to a master agent.

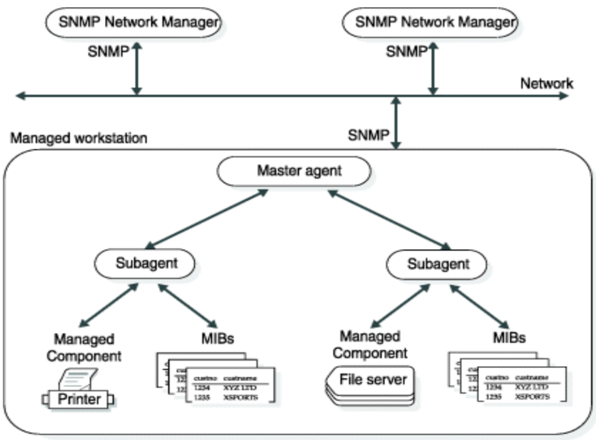


Figure 2.14: SNMP Architecture [4].

2.3.1.4 SNMPv3: dit User- based security model

SNMP has been updated until reaching the SNMPv3 version. The first one, SNMPv1, offered an easy set up, but only accepted 32 bit counters and it stood out because of its lack of security. Following versions, such as SNMPv2c, improved the counters to 64 bits. SNMPv2 started to add security features. However, it is the SNMPv3 the one that has implemented a complete security model, using both encryption and authentication. However, this feature comes with a cons, causing the more complex setup. In the next picture, its architecture is represented:

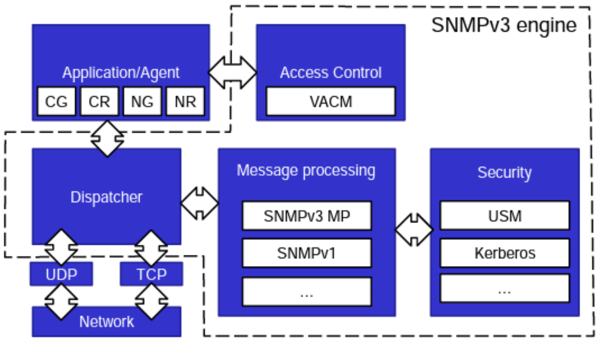


Figure 2.15: SNMPv3 Architecture.

The application types of the image are Command Generator (CG), Command Responder (CR), Notification Generator (NG) and Notification Responder (NR). Typically, the management stations are the four application types and the management agents are the Command Responder and the Notification Generator.

The model that allows to avoid different threats of the SNMP protocol (disclosure, modification of info, masquerade, DoS or message stream modification) is the User-band Security Model (USM). Additionally, the Transport Security Model (TSM) can be implemented in the SNMP architecture, which adds more security protection. It is based on TLS and only recommended to organizations with PKI already implemented.

2.3.2 Network Management SW (NMS) platforms

2.3.2.1 Comparison between different NMS

In the next annex table some of the most popular NMS are analyzed: Table 4.14 [58] .

Some relevant aspects have been searched. All the technologies shown in the previous table could perform the tasks required to manage our network. However, only one must be chosen in order to manage our whole network. In some technologies, the price is the maximum offered. It would be preferable to use the same technology at a lower price, because some new features are not differential enough. However, the great amount of devices that are going to be used in our network, require the most advanced version available for each technology.

2.3.2.2 NMS chosen

After analyzing the technologies, we concluded that the Open-source technologies are the most attractive. The negative point of them is the manual mapping. Some tools offer an automatic creation of maps, which can save a lot of time. For instance, Datadog Network Monitoring, represents the network in an intuitive and appealing graph able to automatically capture the inter-dependencies between services (even when there are thousands). However, to pay for a tool for only implementing this feature, is not considered worth it. In addition, looking for this characteristic, we have found different plugins and parallel services that allow, if not automatically generate maps, to do it in an easy way.

Therefore, we need to choose between Zabbix and Icinga. Let us know about Icinga. As a first indicator, it is more difficult to find information about it and the search for documentation has been a more complex task. One important point is that, when looking for the scalability capabilities of Icinga, the most relevant documents talk about what will be done in further versions. We managed to discover that this tool is prepared for scale, however, the documentation including scalability improvements in future versions, makes us think that it currently may cause problems.

When looking for the presentation of Icinga, we were very disappointed with the maps results. Not only do they have to be created manually, but also the result isn't attractive at all. The good point is that it offers VirtualBox support, but we don't consider it as a key feature. On the other hand, Zabbix' documentation is quite clear. It is quite easy to install it, it can be done using only terminal's commands [59] where the difficult part comes when creating a database (necessary to the use of the tool). However, it is not a requirement to use a Zabbix agent and SQL scripts required are included. Therefore, anyone without specialized Zabbix knowledge can make the installation.

As previously introduced, the negative point of Zabbix is the manual configuration of the network maps. Their own API and templates can be used [60], which is quite an intuitive method and the results are simple but effective. It is easy to understand the network map from the first view. Nevertheless, as we consider this a tedious work, we searched other ways of creating maps, and we found documentation for doing it by using Python scripts [61]. Although the map will still be generated manually, the workload is quite reduced in this way. Therefore, considering the set of features, which are as complete as the others of some expensive tools, its presentation and the facility to find documentation, we have decided to use Zabbix to manage our network. To sum up, this are the features stood out in the Zabbix official site, that perfectly justify how this tool covers all our requirements [62] 2.35:

Data gathering	Flexible threshold definitions	Highly configurable alerting	Real-time graphing
Web monitoring capabilities	Extensive visualization options	Historical data storage	Easy configuration
Use of templates	Network discovery	Fast web interface	Zabbix API
Permissions system	Full featured and easily extensible agent	Binary daemons	Ready for complex environments

Table 2.35: Zabbix features.

2.3.3 Zabbix sizing and features

2.3.3.1 Memory

In the previous section it has been concluded to use Zabbix as our Network Management System. First of all, it is necessary to take into account the memory required in the dimensioning. We have planned to keep a long history of monitored parameters, so it is going to be required a couple of gigabytes in order to store correctly the history in the database. The following table is provided in the documentation of Zabbix to clarify the number of CPUs and the necessary memory depending on the hardware configuration [63] 2.36:

Name	Platform	CPU/Memory	Database	Monitored hosts
Small	CentOS	Virtual Appliance	MySQL InnoDB	100
Medium	CentOS	2 CPU cores/2GB	MySQL InnoDB	500
Large	RedHat Enterprise Linux	4 CPU cores/8GB	RAID10 MySQL InnoDB or PostgreSQL	>1000
Very large	RedHat Enterprise Linux	8 CPU cores/16GB	Fast RAID10 MySQL InnoDB or PostgreSQL	>10000

Table 2.36: Zabbix requirements.

In our case, the chosen election is the very large one.

2.3.3.2 Platforms

The supported platforms by Zabbix technology are Linux, IBM AIX, FreeBSD, NetBSD, OpenBSD, HP-UX, Mac OS X, Solaris and Windows. According to the documentation [63], the most suitable one is Linux, where Server, Agent and Agent2 components are available and tested.

2.3.3.3 Web browser on client side

The latest versions of Google Chrome, Mozilla Firefox, Microsoft Edge, Apple Safari, and Opera are supported.

2.4 Mobile

2.4.1 Requirements

Once previous studies have been carried out to know in depth all the factors that affect these regions, it is necessary to know the requirements of the mobile network that AchoTelecom is going to deploy in Murcia. During the initial phase of the project, a first dimensioned study was carried out to determine the main requirements and obstacles for the deployment phase. For the first sections of this dimensioning, two different scenarios will be distinguished. As can be seen in the attached table, Murcia is the region with the largest number of inhabitants, doubling our target population in Cartagena. Despite this, it is not the region with the highest number of inhabitants per square kilometre, a position occupied by the municipality of Alcantarilla. However, it covers a very small area and the number of inhabitants is not so high as to require an isolated study. The following properties will be required in our 5G infrastructure:

- Traffic volume: For network traffic, we consider a penetration of our service of 26%, which corresponds to the penetration of the mobile broadband service of the operator Orange in Spain. Considering this and a channel capacity of 400 Mbps for the general case and 650 Mbps for the worst one which would be in the city centre of Murcia, we obtain the following table:

General dimensioning		**Worst case dimensioning**	
Potential users	231142	Potential users	119691
Users/km^2	70,03	Users/km^2	135,70
Users/m^2	0,0000700	Users/m^2	0,0001357
Data rates($Mbps/km^2$)	5,71	Data rates($Mbps/km^2$)	4,79

Table 2.37: Traffic volume requirements.

  Taking into account the capabilities of the 5G network and seeking to improve the service, downstream speeds of 400 Mbps and 100Mbps upstream speeds have been proposed. None of the services to be implemented require such speeds, however, the user experience will improve drastically. The maximum transmission speed recorded was 623 Mbps in the previous year [64].

- Latency: Given that we want to improve the 5G infrastructure and network performance that Orange currently offers, we want the latency for standard users to be between 10 and 50 ms. The only one of the services offered by AchoTelecom that will require the use of 5G infrastructure will be eSmartGas, because it needs very low latencies. However, its requirements will be detailed in the corresponding section of this document.

- Reliability, channel environment and mobility: In this scenario, it is projected that the infrastructure will be capable of completing around 98% of the data transfer tasks performed on 5G networks. Since our scenario is of a general nature, there are no restrictions in terms of channel environment or mobility. The network should be able to run on static devices and on other devices at any speed. It must also be available indoor and outdoor. In fact, among the services offered, there are some that are performed indoors (e.g. eSmartGas) and others that are performed outdoors (e.g. e-CleanPorts).

- Availability: In terms of availability, the aim is to have a value of 99,99%, as usual when using this type of technology.
- Energy consumption: In terms of energy consumption, we noted that the solutions that are going to make use of 5G technologies do not require a large expenditure of energy, so in this dimensioning section we consider a low energy consumption.
- Cost: The total cost of 5G deployment will derive from the number of new antennas, cell types and interconnections. The scalable cost per number of sensors for e-SmartGas must also be considered. However, a detailed analysis of all project costs will be performed in the economic-financial analysis.

2.4.2 Architecture

The term 5G refers to the fifth generation of mobile networks and represents improvements in bandwidth and latency, enabling services that could not be provided with previous networks. Although most of the services offered belong to the MTC group and do not require 5G technology, we developed a 5G infrastructure for services that do require critical specifications such as 1ms latency. There are two different ways to deploy 5G infrastructure:

- 5G Non Standalone (5G NSA): It relies on the 4G infrastructure deployed by operators.It uses 5G for the antenna-terminal communication protocols, which allows an increased performance, but the rest of the procedures are performed using elements of the 4G network.
- 5G Standalone (5G SA): Operates entirely with 5G elements, enabling speeds up to 10 times faster than those achieved with 5G NSA.

Our project will rely on the LTE network already deployed by Orange, however, the 5G network will be considered as Standalone as shown in the architecture. Many services and activities require the use of LTE technology, which is why it is necessary to incorporate eNB stations into our 5G standalone architecture shown below.

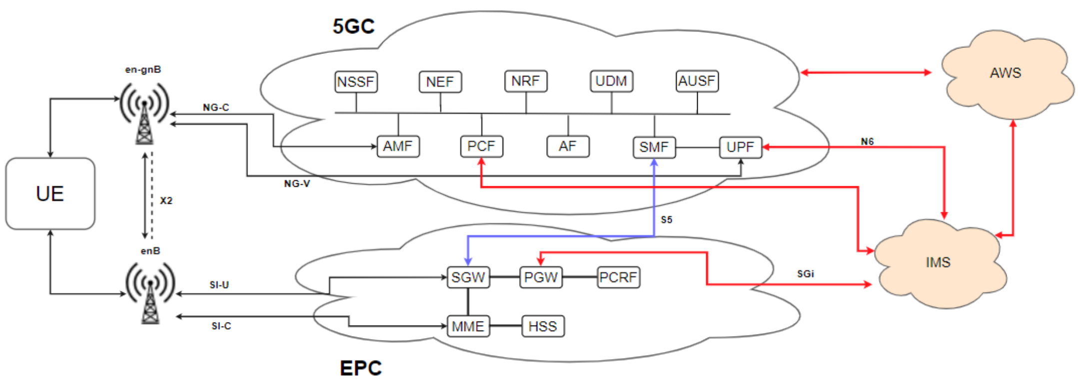


Figure 2.16: Mobile architecture.

At the botton of the image we can see the Evolved Packet Core (EPC), which provides access to the existing 4G eNB antennas in the study regions of the province of Murcia. This EPC represents the core of the LTE network and consists of multiple nodes. Among these nodes we can find:

- MME (Mobility Management Entity) S1 interface connects the eNBs of the E-UTRAN to the MME within the EPC. It is responsible for idle mode User Equipment (UE), paging, tagging and retransmissions. It also takes care of user requests in terms of network access and selects the SGW and PGW that will be used for a given session.

- SGW (Serving Gateway) For user plane information, one or more SGWs will be needed to serve a group of eNBs. It is responsible for routing IP packets from the UE to the LTE core network. SGW receives instructions from MME to set up and tear down sessions for particular UE. In order to connect to the PDN Gateway it uses the S5 interface.
- PGW (PDN Gateway) UE can be connected with multiple PGWs but it will still be served by only one SGW. It is a network node that connects the EPC to other external IP networks, the IMS network in our scenario. It is also in charge of controlling certain policies on user traffic.
- HSS (Home Subscriber Server) This node is in charge of storing and updating when necessary the database containing all the user subscription information, including user identification and addressing and user profile information. It also ensures information security regarding the user's identity keys.

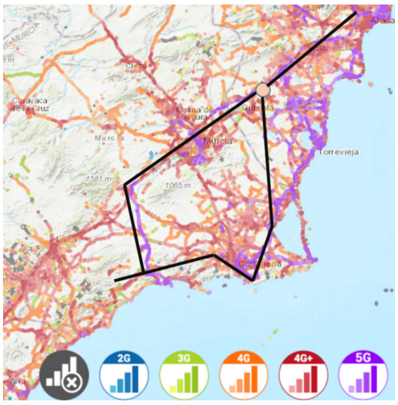
In contrast, at the top of the image we can find the 5G network, in which we can encounter the following network functions:

- AMF (Access and Mobility Management Function) It is equivalent to the main control function within the network. It interacts with user equipment via encrypted signaling, with most of the signaling message flow passing through it. We can see how it is directly connected to the en-gnBs, with the NG-C interface.
- PCF (Policy control function) Whose main mission is to provide the policies for the control of the resources within the 5G network.
- SMF (Session Management Function) It is the function in charge of managing user sessions. This refers to the establishment, modification and release of sessions, as well as the assignment of IP addresses per device. The SMF communicates indirectly with users via the AMF and interacts with other network functions such as the UPF.
- UPF (User Plane Function) Processes and forwards user plane traffic, and is under the control of the SMF. In turn, it is the connecting element to external IP networks via the N6 interface and acts as a point of attachment of the IP of the devices to external networks. On the one hand, it generates traffic usage reports for the SMF, which then includes them in its reports to other network functions. On the other hand, it can analyze the content of the data packets and make it an additional element in policy decisions. From the picture of the architecture we can see that they are connected to the en-gnBs via the NG-V interface.
- UDM (Unified data management) Manages network user data in a single and centralized element. It uses a similar technology to HSS in LTE, with the difference of being cloud-native and designed only for 5G networks and requirements. It is connected to the 5G core network thanks to the SMF and AMF nodes.

It can also be show that de 5G Core Network is directly conected to the AWS provider. In addition, we can see how the N26 interface connects the AMF of the 5G network with the MME of the EPC to enable context transfer and network-controlled mobility as the handover between LTE and 5G. The S5 interface performs the user and control plane connection between the SMF/ UPF session management function representing the 5GC entities and the service gateway (SGW) representing the EPC entity. From the EPC point of view, the S5-U interface replaces the public data network (PGW) gateway for voice services, as they are now logically established through the UPF.

2.4.3 Dimensioning

A study of Orange's coverage area in the cities of Murcia, Alcantarilla, Lorca, Molina de Segura and Cartagena has been carried out using the nperf tool [65]. The first thing that stands out is the superiority in 5G connection of the Orange operator with respect to the competition. In addition, it is observed that the cities of Murcia and Cartagena are the ones with the highest number of areas with 5G coverage while Molina de Segura and Alcantarilla have less than 5 antennas throughout their location so most of the coverage is 4G+. Finally, Lorca does not have any 5G antenna and most of the populated areas have 4G and 4G+ coverage but being the second largest municipality in Spain with 1675.21 km2, the areas outside the population centres only have 3G connection and those more remote have no coverage at all.



Looking for an improvement in 5G coverage, it has been considered advisable to give priority to the installation of 5G antennas in those areas with the highest percentage of population per terrain so that a greater number of inhabitants can benefit from the service. Of all the services offered, e-SmartGas is the only one that requires the characteristics of a 5G connection [66]. As can be seen in the figure, the gas pipeline in the region of Murcia coincides in its route with a large part of the 5G antenna network already deployed by Orange. However, there are areas where this connection does not exist, therefore, it has been considered convenient to install new 5G antennas taking into account that the distance between them should be no more than 1,4 km as it is explained later on.

Taking into account the next three figures. The total number of 5G antennas needed to provide the gas pipeline that crosses the region of Murcia with 5G connection in its entirety is 50. The rest of the services offered do not require the characteristics of the 5G connection, however, those located in the main cities mentioned above will have the possibility of implementing this connection. For example, the eCleanPorts service in Cartagena could use a 5G connection since the entire coastal area has connectivity.

(a) (b) (c)

Figure 2.17: Distance in the pipeline without 5G connections.

Finally, taking into account that in the region of Murcia there are 211 antennas already deployed and considering Orange in possession of 40% of all of them, since it is the leading operator with quite a margin in number of antennas with respect to the rest. There are a total of 85 antennas, added to the 50 antennas needed for the Smart Gas service, a total of 135 5G antennas. Next we will carry out a study of the coverage and traffic dimensioning to decide the final number of antennas to deploy in this region.

2.4.3.1 Coverage

First of all, it is necessary to establish the frequency bands in which to work. According to the national 5G plan covering the years 2018 to 2020, the bands used for 5G services are established [67]. In addition, the Spanish government has completed the reorganization of the concessions held by telecommunications operators in the 3400-3800 MHz frequency band, one of the priority bands for the introduction of mobile services based on 5G technology in Europe[68]. Finally, thanks to the information note on the 3600-3800 MHz band spectrum auction, we can see that the bandwidth awarded to the operator we are interested in, Orange SA, is 60 MHz [69].

When dimensioning the coverage, it is necessary to focus on the base stations. In this way, the area covered by one of these stations can be calculated by means of a power balance. As can be seen in the following expression, the following terms are taken into account:

$$P_{TX} + G_{TX} + G_{RX} – MS – Lb \geq S_{RX} \tag{2.5}$$

As can be seen, both transmit and receive gains are considered, as well as free space and path losses. To the right of the equality, we find the sensitivity at the receiver. The following table shows the values used to calculate the link losses at a later stage:

	Base Station	User equipment
Transmit power [dBm]	35	23
Gain [dBi]	23	0
Sensibility [dBm]	-95	-105
Fading margin [dB]	5	

Table 2.38: Base station and user equipment parameters.

As can be seen, parameters are set at the base station as well as at the user equipment. The sensitivity parameters can be obtained from the 3GPP Release 15 standard for 5G connections. For the gain, as will be explained in more detail below, we have selected antennas from the supplier Cellnex, as we consider them to be the most suitable for our needs, which are massive MIMO Adaptive Antennas, providing a gain around 23 dBi.

In order to establish the transmitted powers, the power that can be transmitted by the macrocells that we are going to dimension has been consulted, which is between 33 and 37 dBm, choosing an average value of 35 dBm. [70] Finally, a fading margin of 5 dB has been taken into account. In this context, the losses in the link have been calculated, obtaining the following values, which, as can be seen, are both upstream and downstream:

$\mathbf{L_{UL}}$ [dB]	$\mathbf{L_{DL}}$ [dB]
158	**136**

Table 2.39: Losses in both uplinks and downlinks.

Once these calculations have been made, it is necessary to obtain the transmission losses. For this purpose, use will be made of the alpha-beta-gamma (ABG) introduced by 3GPP, the formula for which is as follows:

$$PL_{ABG} = 10 \cdot \alpha \cdot logd[m] + \beta + 10 \cdot \gamma \cdot logf[GHz] + X_{\mu} \tag{2.6}$$

In this scenario, alpha describes how the PL increases as the distance between transmitter and receiver increases, beta is a floating offset, gamma is the PL variation across frequency and X_{μ} is the shadow-fading term. The parameters chosen have been using the “Urban Macro Cell with NLOS” (UMa-NLOS) model. For this calculation, an alpha value of 3.4, a beta value of 19.2, a gamma value of 2.3 and an X_{μ} value of 6.5 dB were taken into account. Finally, the distance value 711.06 m is obtained, which implies a cell radius of 1.58 km2.

In this dimensioning phase, we will consider only the urban centres of the regions and their closest peripheries as the surface area to calculate the number of microcells per coverage. This is because regions like Lorca cover more than 1600 square kilometres, with about 90% of the population located in this urban core. In addition, deploying 5G coverage throughout the entire municipality would not be profitable for the operator. To show which parts of the regions are considered, the following images are presented, in which the urban centres of each city are approximated with circles.

(a) Murcia (b) Lorca (c) Cartagena

(d) Alcantarilla (e) Molina de Segura

Figure 2.18: Urban centres in the different cities in the region of Murcia.

Using all this calculated information, we conclude with the number of microcells needed for the five regions through the coverage study.

Cities	Area (km2)	Nº of Microcells (Coverage)
Murcia	85	54
Cartagena	90	57
Lorca	79	50
Molina de segura	8	5
Alcantarilla	5	3

Table 2.40: Microcells by coverage study.

2.4.3.2 Traffic

At this stage we need to know the number of customers we will be offering the service to. Using the information provided by the CNMC we know the number of mobile lines in the Region of Murcia. We consider a distribution of mobile lines proportional to the number of inhabitants in each region. In this way the estimated number of lines for each region is as follows. We will also consider an oversizing factor of 10% in case of a high increase in demand.

	Murcia	**Lorca**	**Alcantarilla**	**Cartagena**	**Molina de Segura**
Mobile lines	165348	77714	34567	26399	15286

Table 2.41: Mobile lines per region.

In order to know the number of cells that limit the study by traffic, we will make a balance between supply and demand of the service. For this purpose, we determine the following variables. The spectral efficiency used is the average indicated in the ITU recommendations for IMT-2020 (Page 5) for eMBB communications in a dense urban scenario [71]. In the 5G spectrum auctions held in 2021, the total bandwidth allocated to Orange is determined to be 110 MHz in the 3.5 GHz band [72]. In the 5G NR basic features in Rel 15, the 8x8 MIMO scheme is specified, which is to be extended with up to 8 layers in downlink and 4 layers in uplink to successfully deploy the SA 5G network [73]. Also, for user traffic, a rate of 60 Mbps in DL and 30Mbps in UL has been considered sufficient for the average user of the network.

Frequency Band (GHz)	3.5
Bandwidth per Cell (MHz)	110
MIMO	8x8
Traffic UL per user (Mbps)	30
Traffic DL per user (Mbps)	60
Espectral Efficiency UL (bps/Hz)	5.4
Espectral Efficiency DL (bps/Hz)	7.8
Tc (Busy hour)	18%
Tc	10%

Table 2.42: Traffic dimensioning variables.

Considering a 18% concurrency rate (tc) in the busy hour and matching supply and demand we are able to calculate the number of uplink and downlink cells needed in each of the regions. We also take into account the inhabitants of each region, based on our demographic study carried out in the initial phases of the project

$$Offer = \frac{BW[MHz] * E[bps/Hz]}{Scell[km^2]} \tag{2.7}$$

$$Demand = Tuser[Mbps] * tc * d[users/km^2] \tag{2.8}$$

Cities	**Nº of Microcells UL (Traffic)**	**Nº of Microcells DL (Traffic)**
Murcia	3	5
Cartagena	3	4
Lorca	1	1
Molina de segura	3	4
Alcantarilla	15	21

Table 2.43: Microcells by traffic study.

2.4.4 Deployment

AchoTelecom will consider 3 cell sizes for dimensioning the mobile network infrastructure: macrocells, microcells and femtocells. Macrocells have a maximum range of 30 km and serve microcells and femtocells. A macrocell is part of the radio access network (RAN) and provides radio coverage for the cellular network. It operates through an antenna mounted on a tower, or 5G transmitter mast, typically 15 to 60 metres tall. Its capabilities enable it to connect billions of devices while reducing latency or response time. In addition, it receives radio signals using MIMO. The height of the macrocell antennas is due to the fact that they must exceed the height of the main buildings, thus avoiding interference and shadow zones in the coverage. Making a geographic study of the areas that will use both the mobile network and the gas pipeline pressure service, we decided that 3 macrocells will be placed in the territory, as shown in the following picture. However, none of the study areas have high buildings, so it will be enough to place it on the roof of a building of about 50 metres.[70] The microcells, on the other hand, cover a range from 10 metres to about 2 km. Small-cell base stations, known as transceivers, use low power and are implemented in densely populated areas and are cheaper and much faster to deploy than the larger macrocells. The number of microcells placed is given by the study of our scenario by traffic and coverage.[70]

Making a geographic study of the areas that will use both the mobile network and the gas pipeline pressure service, we decided that 3 macrocells will be placed in the territory, as shown in the following picture.

Figure 2.19: Map of the 3 macrocells to deploy.

As can be seen in the image, one of the macrocells covers the cities of Murcia, Molina de Segura and Alcantarilla as they are close to each other with a radius of less than 20 km, another macrocell is created with the aim of serving Cartagena, the nearby coastal towns and the port with a radius of 19 km. Finally, the third macrocell, with a radius of 27 km, has been deployed for the city of Lorca and surrounding areas. This is the largest radius because its main objective, in addition to providing 5G service to the city of Lorca, is to offer it to the areas of the pipeline without any coverage. In this way, we ensure the provision of eSmartGas service in the region in addition to improving the 5G coverage in the main cities. For the implementation of the 3 macrocells, we have taken into account an error that has been added to the final distance of the total radius in order to avoid areas that are not connected. Therefore, the final radio of the macrocells are 23 km, 21 km and 29.8 km respectively. As for the microcells, it has been decided to deploy them in those areas where there is a higher traffic flow.

Finally, it has been decided to establish femtocells in those strategic indoor locations where large numbers of people gather, such as shopping malls, hospitals or sports stadiums. Within each of the 5 study regions, the following number of femtocells are proposed to be deployed in the following locations:

- Lorca Complejo deportivo Felipe VI, Hospital Virgen del Alcazar, Lorca-San Diego Train Station, Plaza de Colón, Plaza de España building (4).
- Molina de Segura Vega Plaza shopping center, Ribera Hospital de Molina (2).
- Alcantarilla Alcantarilla Sports Center and Hospital Viamed San José (1).
- Cartagena 3 distributed throughout the ports surrounding the Bay of Cartagena, Arsenal de

Cartagena, Teatro Romano, 2 shopping centres and 2 hospitals (9). The placement of the femtocells in the city of Cartagena is of special importance, since the cells located in the port will serve to provide coverage to recreational boats and the femtocell located in Arsenal de Cartagena will provide access and 5G services to the military base.

- Murcia Nueva Condomina Stadium and bullring, Glorieta de España, casino, Catedral de Murcia, Teatro Romea, Casa Consistorial, 4 shopping centers and 5 hospitals (15).

In summary, the final distribution of the deployed cells is as in Table 2.44

	Murcia	Molina de Segura	Alcantarilla	Cartagena	Lorca
Macrocells	1			1	1
Lines/macrocell	165348	15286	34567	26399	77714
Microcells/macrocell	54	5	21	57	50
Lines/microcell	3062	3058	1647	464	1555
Femtocells	15	2	1	9	4
Busy Hour Data Rate (Microcell)					
Demand (UL) [Mbps/sqkm]	53	465	674	37	7
Demand (DL) [Mbps/sqkm]	106	930	1348	74	26
Offer (UL) [Mbps/sqkm]	944	944	944	944	944
Offer (DL) [Mbps/sqkm]	1363	1363	1363	1363	1363
Average Data Rate (Microcell)					
Demand (UL) [Mbps/sqkm]	30	259	375	21	4
Demand (DL) [Mbps/sqkm]	59	517	749	42	14
Offer (UL) [Mbps/sqkm]	944	944	944	944	944
Offer (DL) [Mbps/sqkm]	1363	1363	1363	1363	1363

Table 2.44: Final deployment chracteristics.

After the studies carried out, we have reached the conclusion that 186 microcells will be needed in urban areas and 50 5G antennas along the pipeline route in order to provide the eSmartGas service. Taking into account that 85 of them have already been deployed by the operator, it will only be necessary to deploy the remaining ones to reach the calculated number of microcells.

2.4.5 Equipment Selection

For the selection of equipment, Cellnex has been the supplier of choice. Cellnex Telecom is the leading wireless telecommunications infrastructure operator in Europe. The company has made a firm commitment to the development of its network, which currently has nearly 128,000 sites, placing it at the top in terms of the development of new generation networks.

Thus, for each of the necessary nodes, a BBU (Base Band Unit) and three RRUs/RRHs (Remote Radio Unit/Head) will be used. Therefore, 220 BBU, 575 RRH and 575 Antennas will be required.

2.5 SDN/NFV

2.5.1 Introduction and the role of SDN/NFV in the progress towards 5G

SDN and NFV refer to Software Defined Networking and Network Function Virtualization respectively. These two technologies aim to transform networks from the traditional hardware paradigm to a software context. Nowadays the requirements of networks have changed, and they need to support the increase of traffic, reduce costs, simplify network management, and allow fast innovation in networks.

On the one hand, SDN consists of a way to design, build and manage networks by separating the control and user planes. This allows networks to be easily adapted to new infrastructure and the new requirements of networks. This separation between control and user planes produces benefits such as centralized management, lightweight network devices, or network virtualization.

On the other hand, NFV has the objective of taking advantage of standard virtualization technology to include network equipment in high-volume servers located in data centers, network nodes, and end-user premises. This has a lot of benefits like reducing CAPEX and OPEX, improving interoperability and scalability, reducing time to market, or allowing to have a single platform for different applications.

The increasing consumption of multimedia services and the demand for high-quality services from customers have triggered a fundamental change in the administration of networks in terms of abstraction, separation, and mapping of forwarding, control, and management aspects of services. The industry is embracing 5G as the future network capable to support next-generation vertical applications with different service requirements. To realize this vision in the 5G network, the physical network must be sliced into multiple isolated logical networks of varying sizes and structures which are dedicated to different types of services based on their requirements with different characteristics and requirements (e.g., a slice for massive IoT devices, smartphones or autonomous cars, etc.). Softwarization using Software-Defined Networking (SDN) and Network Function Virtualization (NFV) in 5G networks are expected to fill the void of programmable control and management of network resources.

SDN and NFV promise to provide and implement new capabilities and solutions for enabling future 5G networks control and management to be adaptable, programmable and cost-effective. The concept of network slicing is the heart of 5G and will play a significant role in addressing more stringent and business-critical requirements of the vertical industries, such as real-time capabilities, latency, reliability, security and guaranteed ELAs/SLAs.

Although SDN/NFV networks are still being developed, they have a big potential in different solutions for flexible and scalable networks. Due to that, we have performed a techno-economic analysis comparing a deployment on traditional paradigms and novel SDN/NFV paradigms, showing the advantages and drawbacks of this implementation, and the changes in cost after implementing it.

2.5.2 Techno-economic analysis of traditional deployment vs SDN/NFV

In Traditional Networking, dedicated devices were needed for the implementation of each of the network elements. These devices were common for both the control and the data planes, and were able to distinguish between the two through the use of differentiated control and line cards. This is really expensive and has little resilience, making monitoring, updating and upgrading the network really costly. Moreover, all of the changes in the network need to be done physically which represents even more expenses.

With SDN, the control and data plane can be easily separated without hardware borders (just by programming them accordingly). This results in a flexible network that can provide different services according to the demand and that can be easily monitored.

On his behalf, NFV allows the centralization of all the different components of the network in centralized, clustered components. The advantages that NFV provides revolve around easy incidence attendance, due to it centralized nature; cheap network modification, as physical intervention is usually no longer required; and finally, agile and efficient network upgrading, as the components are virtually implemented and clustered.

SDN and NFV are often combined to get the most out of both technologies. When used together, not only the control and data planes would be separated, but also the components of the network would be virtually implemented and centralized. As a consequence, the costs of operating the Network would be considerably reduced while providing a better quality of service.

All of the commented above plus the enabling of Network slicing services like 5G, explains why companies are switching from Traditional Networking to SDN.

2.5.3 SDN providers

2.5.3.1 Cisco

Cisco is one of the leading companies in SDN technology, which offers solutions from the data centre to network managers. The first solution is based on Application-Centric Infrastructure (ACI), which improves automation and consistency and achieves great elasticity, and is committed to multicloud acceleration, protecting the network with a zero-trust security policy and centralised management. The network manager solution is based on network design to provide high security for access to any application. We have several possibilities such as Cisco DNA Center, SD-Access, SD-WAN and SD-Branch [74].

2.5.3.2 VMWare

Another provider is VMware, which bases its SDN offering on the NSX service. Its main value proposition is security and a 60% reduction in OPEX thanks to its automations. They also claim that service monitoring can save approximately 65% by using their service. NSX ensures agile application delivery using multi-cloud, containers and load balancers [75].

2.5.3.3 Juniper

The American company Juniper is also well known for its SDN solutions which offers virtualised networking and traffic engineering solutions to its customers. Its value proposition is based on multi-cloud solutions with open SDN for better automation, security and abstraction of control. It has two main services for SDN networks, Contrail Service Orchestration and Contrail Networking. The first is based on the orchestration of services using VPNs, SD-WAN, NGFW, uCPE and virtual cloud endpoints along with automation mechanisms. The second is based on network engineering techniques [76].

2.5.4 NFV providers

2.5.4.1 RedHat

Red Hat offers an open source NFV solution based on OpenStack. It is the only open source approach to NFV that describes all the components needed to develop this technology and has been created to help service providers converge to this technology [77].

2.5.4.2 Ericsson

Ericcson is one of the leaders in NFV technology which offers automated orchestration services. It has a complete solution that they call NFVi. It is also working hand in hand with other leading companies in the sector such as VMWare to accelerate and improve its services [78].

2.5.5 Conclusions

In conclusion, taking all these things into consideration, it has been decided that no SDN/NFV solutions will be implemented apart from IMS, at least in the short term. This decision is based on the fact that Orange does not follow a vendor lock-in policy because of issues that may happen in the future. Therefore, only IMS is going to be implemented as an NFV solution.

2.6 Help desk

A help desk software is a tool that offers a lot of services to support customer activities. It is composed by a technical team easily accessible by the customer and gives help in supporting and solving IT problems. The help desk uses tickets for communication, that is why it is also known as a ticketing system. It acts as the connection point between customers and the IT department by escalating complicated problems to specialized team members, which are also called "agents". The objective of the help desk is facilitating life of the customers of a determined service.

To offer this service, it is possible to acquire a specialized service for this purpose that some companies offer. For example, HelpDesk [79] is a company that offers a web platform where customers can open tickets, organize messages and receive assistance from specialized agents at a single point of contact 24 hours a day. It offers many features such as ticket management, team collaboration, automation, analytics, personalization, communication and multichannel support.

In order to dimension the telephone service of this help desk, an incoming call rate of 0.1% of the total number of customers has been considered, that is, 806 calls per day. In addition, an average duration of 5 minutes has been considered, with an average waiting time of 20 seconds. Entering this data, in the Erlang-C model [80], a maximum of 20 agents are needed to answer 90% of the calls. The price of this service is 18 €/month per agent. This way, the company will contract 20 agents dealing with incidents that have a price of 360 €/month for the whole service.

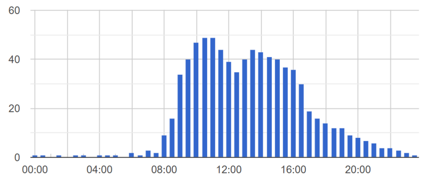


Figure 2.20: Distribution of calls across the day.

2.7 Services

2.7.1 e-CleanHidroeolic

2.7.1.1 State of the art

Nowadays the environmental policies are gaining more importance, and the use of sensors in order to analyze both the state of the water and air polluting emissions are one of the most interesting initiatives. This type of service is nothing new, in Spain there are two main cases of success, as it will be described below. The first one was located in the city of Bilbao [81], where the Port Authority has created a service to study and analyze in real time the diffuse emissions and, more specifically, PM10 particles in the port. The solution was carried out by the company Kunak Air by installing 5 sensor units in the zone. Similar to the previous one, the Port Authority of Baleares has developed an installation of different sensors to measure the air quality of the ports located in the islands [82].

In this service, an improved solution to the previous explanation is going to be designed. For this task, we need to take a look at the different alternatives of sensors offered in the market.

2.7.1.2 Integration

2.7.1.2.1 Architecture

We plan to use LoRa. The architecture of LoRa is similar for all platforms. It is shown in the following figure:

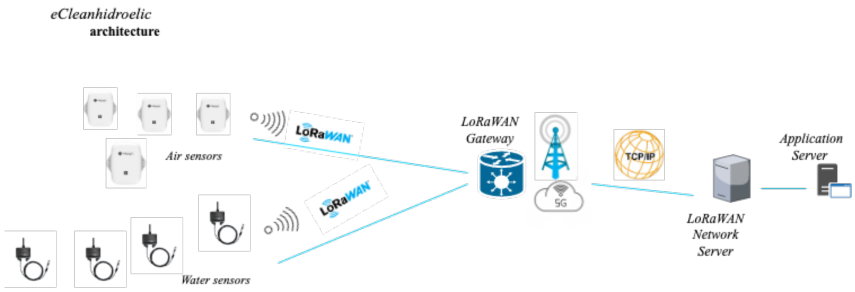


Figure 2.21: e-Cleanhidroelic Architecture.

In this service, we want to connect the chosen sensors to gateways. For this first step, we will use both LoRa physical layer and LoRaWan in the Mac Layer. Once data reaches the gateways, it will be sent to the network server using the 5G network that we will deploy, using, IP connection.

- LoRa sensor: For this service, we want to use a specific sensor able to provide key measurements of the quality of the water. We will explain this election in further sections. However, we can stand-out the LoRa sensor that will perform the connection to the gateway.
- LoRa gateway: The gateways are common devices for all services using LoRa. They receive data from sensors and send it to the network server. Using gateways we are performing a star topology around the network server [83].
- Network server: It will receive data from gateways and perform different operations required by the users. It must be able to support the whole traffic.

According to this, the next stack protocol figure is presented:

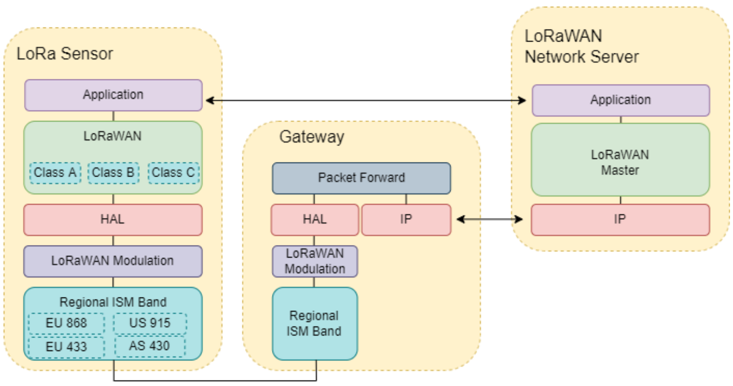


Figure 2.22: LoRaWAN stack protocol

There will be a different protocol stack depending on the edge analyzed. In the connection between sensors and gateways, LoRa stack will be used. However, in the connection between gateways and servers, IP protocol will be used.

Related to the end devices election, LoRAWAN allows the choice between three different types of classes (A, B and C).

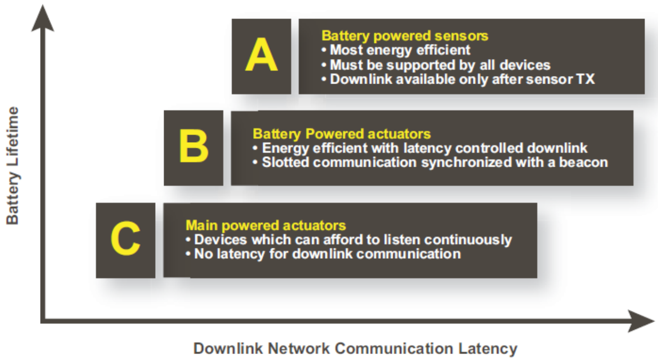


Figure 2.23: LoRaWAN sensor end classes

In our service, low communication latency is not required, whereas low battery consumption is a powerful requirement. Therefore, our service is going to use class A.

2.7.1.2.2 Used sensors and placement

Regarding the location of the sensors, the operation is easy for this service. We plan to take measurements of the water and air quality of both the reservoirs and the ports. Therefore, the sensors will only be located in these areas. Between the regions covered, there are ports only in Cartagena. The great part of them are leisure ports. However, Cartagena Port stands out among them all, being the fourth most important industrial port in Spain. The reservoirs are more distributed between regions. In the next figure both reservoirs and ports covered are pointed out. The sensors that have been used to provide this service have been temperature and humidity sensors to measure air quality, and water quality measuring sensors. The particularity of these sensors is that they are all devices that connect to the LoRa network, making their use and implementation possible.

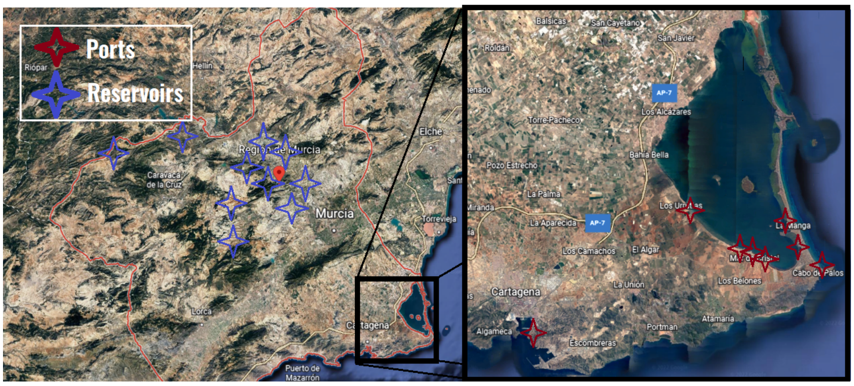


Figure 2.24: Reservoirs and ports covered.

Starting with the temperature and humidity sensor, the chosen model is known as Milesight EM300-TH, defined with the following characteristics [84]:

- It provides a service life of 5 to 10 years (Ultra Low Power Consumption)
- Dual battery holders, one by default, easy to replace
- Solid stability and reliable connectivity can be realized through LoRaWAN protocol
- IP67 Waterproof
- High Sensitive Sensor (-40ºC to 70ºC and 0-100 percent of RH of humidity)
- Range up to 15 km in rural areas and 2 km in urban areas

Figure 2.25: Milesight temperature and humidity sensor.

The price is 89 US dollars per sensor [85].

Following with the water quality sensor, the chosen model is known as LoRa-Sensor for in-line conductivity, water quality transmitter, water treatment Industrial (iOca 13SHWEC1), defined with the following characteristics [86]:

- The transmission distance can reach 3km to 10km
- Can be directly put into water without adding a protective tube
- IP68 Waterproof
- Automatic temperature compensation
- Solid stability and reliable connectivity can be realized through LoRaWAN protocol
- Precision of 1,5 percent F.S
- Operating temperature 0-65ºC
- Battery : 9000 mA

Figure 2.26: iOca water quality sensor.

The price is 250 US dollars per sensor [86].

2.7.1.2.3 Dimensioning

According to the previous section, we are going to dimensionate 8 ports in Cartagena [87] and 10 reservoirs in the region of Murcia [88]. We used Google Earth and different data to calculate the area of each of the areas we want to digitalize. As units of measurement it has been used the length (in meters), and the number of berths in case of the leisure ports. The service offers analysis of both air and water quality levels, so two dimensioning processes can be differentiated in this part: air and water.

- **Air** Based on successful situations, such as the Mallorca's ports [89], we have decided to divide the areas between different levels. First, we want to use 2 air sensors in all ports except Cartagena one and those reservoirs bigger than 1000 meters. The leisure ports are not big enough to consider them as exceptional cases and, using two sensors, we will be able to compare measurements in order to detect exceptional situations. In the second level, we will use 4 air sensors. This level will be applied for those reservoirs whose size is greater than 1000 meters.

  Finally, we pretend to use 5 sensors in the Cartagena Port. The importance of this industrial port must be taken into account. And not only its importance, but also the contamination that can be assumed by the different boats, make us decide to ensure this area with at least 5 air sensors.

- **Water** Again, we decided to divide the dimensioning into different levels. First, we will use one water sensor each 50 moorings. This decision will be applied only for the leisure port. All the rest of the areas (i.e. reservoirs and Cartagena port) will have a number of sensors according to their size. We will implement a sensor each 200 meters.

ID	Name	Length(m)/berths	Water Sensors	Air Sensors
P1	Puerto de Cabo de Palos	180	4	2
P2	P. Deportivo Dos Mares (La Manga Mar Menor)	300	5	2
P3	P. Deportivo de los Nietos (Cartagena)	210	9	2
P4	P. Deportivo LA ISLETA (La Manga Mar Menor)	290	4	2
P5	P. Deportivo de Islas Menores	140	3	2
P6	P. Deportivo Mar de Cristal (Cartagena)	277	5	2
P7	P. Deportivo Los Urrutias - Cartagena	187	6	2
P8	P. de Cartagena	1700	9	5
E1	Embalse del Cárcabo	900	5	2
E2	Embalse de Doña Ana	554.04	3	2
E3	Embalse de José Bautista Martín	2320	12	4
E4	Embalse de la Risca	369.39	2	2
E5	Embalse de los Rodeos	1180	6	4
E6	Embalse de Mayés	587	3	2
E7	Embalse de Moratalla	43.58	1	2
E8	Embalse de Ojós	1400	7	4
E9	Embalse de Pliego	3125	16	4
E10	Embalse de la Rambla del Moro	275	2	2
Total			102	47

Table 2.45: Dimensioning of both air and water sensors.

2.7.1.2.4 Traffic analysis

In this section the study of the Iot traffic analysis is going to be explained. First of all, according to the datasheet of the air sensor (Milesight EM300-TH), we have obtained the 300bps necessary per device. This bitrate is related to the minimum amount of signal needed in the receiver (sensitivity). In this case, there is now low latency needed, so we are going to use this value to estimate the total air quality bitrate.

On the other hand, from the datasheet of the water quality sensor (iOca 13SHWEC1), we know that the sensitivity is 6 dB lower than the one of the air sensor. This means that supports lower SNR limit in the receiver, which means lower bitrate. Hence, we have estimate a signal bandwidth of 125 kHz, an spreading factor SF of 12 which gives us a bitrate estimation of 146 bps [90].

	Total number of sensors	Bitrate per device (bps)	Total bitrate (kbps)
Water sensors	102	300	30.6
Air sensors	47	146	6.862

Table 2.46: Traffic analysis for e-CleanHidroeolic.

2.7.1.3 Requirements and non-functional requirements

Environmental issues in water areas can cause severe damages in public health. Murcia's problems with the contamination of its waters is a known problem, especially clear in the Mar Menor current state. Because of these reasons, it is mandatory to track these areas. To perform this activity, next requirements are distinguished:

FR1	Ability to take measures of the air quality
FR2	Ability to take measures of the water quality
FR3	Connectivity with LoRa
FR4	Send data tracks periodically
FR5	Almost full coverage

(a) Functional requirements e-CleanHidroeolic.

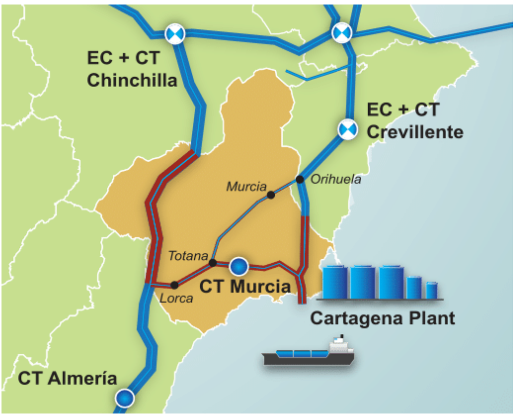
NFR1	Very low battery consumption
NFR2	Accurate measurement of values
NFR3	Outdoor degradation resistance
NFR4	Low traffic rate
NFR5	Almost full time available

(b) Non-functional requirements e-CleanHidroeolic.

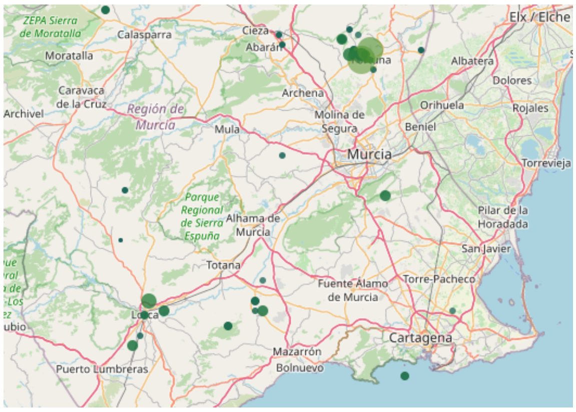
2.7.2 e-SmartGas

Worldwide, the transportation of gas has become a major engineering operation, as it is one of the main sources of energy used today. Gas encounters earthquakes, landslides, ice, floods, etc. that during the transportation process can damage the natural gas pipeline, causing it to rupture or be damaged, resulting in natural gas leaks.

In the region of Murcia, there are numerous gas pipelines. In addition, the city of Cartagena is home to the Escombreras Dock, which receives gas by sea for the whole southwest of Spain. The monitoring of various parameters in the distribution of gas, especially pressure, is something very important to take into account. Since we are dealing with dangerous and flammable goods, we have to be able to quickly detect leaks if they occur, and other types of anomalies in a short period of time. For example, last year in the Gulf of Mexico, a gas leak in an undersea pipeline [91] caused serious environmental problems. A rupture in the gas transport line causes a variety of problems of all kinds, having an incalculable impact. This is why gas pressure monitoring in distribution networks is a major challenge. Figure 2.28a shows the distribution of gas pipeline networks in Murcia region.



(a) Distribution of gas pipeline networks in Murcia region.



(b) Earthquakes in the Region of Murcia in 2021.

Landslides caused by various geological faults or seismic activity can affect gas pipelines and distribution networks. The region of Murcia is one of the most seismically active areas in Spain, as it is located near the friction point between the African and Eurasian tectonic plates. Specifically, Lorca is located on the so-called "Iberian microplate" [92]. Figure 2.28b shows a map of the last earthquakes registered in the National Geological Institute that have occurred in the area [93]. As it can be seen, the area of Lorca and Fortuna, close to the municipalities of Molina de Segura, Alcantarilla and Murcia, concentrate all the seismic activity in the region. In addition, in 2011 an earthquake of magnitude 5.1 on the Richter scale occurred in Lorca, seriously affecting all types of infrastructures, such as gas pipelines.

2.7.2.1 State of the art

Currently, there are a number of technologies designed to monitor and protect natural gas distribution networks and detect potential leaks through different methods and parameters. The main methods include detection methods outside the pipeline, visual detection methods and methods based on taking measurements inside the pipeline.

Measurements [94, 95] taken inside the pipeline can be of flow, pressure, acoustic vibrations or temperature, among others. While the external measurements base their operation on the surveillance of the areas near the pipeline, security cameras, temperature, fire detection, infrared, humidity, soil parameters, etc. One factor to take into account is that one of the main ways to transport large quantities of gas is through underground pipelines.

Currently, there are some companies that offer solutions related to the monitoring of gas distribution networks, such as KROHN [96], which manages pipelines and offers a complete package of services, not only focusing on gas leaks. On the other hand, Wenglor offers a solution based on the inspection of pipe sections using 3D sensors [97]. Finally, among the most relevant companies in the sector, it is worth highlighting the solution offered by Netbiter [98], which allows online monitoring of the different operations by connecting to the cellular network.

The data collected by the sensors must be sent through a network to a data processing centre. The paper [99] highlights the main benefits of using LoRaWAN within the Oil and Gas sector. However, as discussed in [100] 5G networks feature high speed, low latency, large connection and edge computing technology, improving the efficiency of pipeline exploration and anomaly detection. In addition, the article [101] discusses the opportunities for the gas sector using 5G.

2.7.2.2 Integration

2.7.2.2.1 Architecture

As we have previously mentioned, our plan for e-SmartGas service is to use 5G. The architecture of this service can be observed in the following figure. In order to connect the sensor to the network we are going to require the use of 5G modem that will connect with 5G base stations and end in the core network.

As mentioned in previous chapters, one of the main requirements (section 1.4.4) is latency. In order to prevent catastrophes related to gas leaks or other types of anomalies, a fast detection is necessary in case they occur. Finally, we have to take into account that these sensors would be placed inside the pipelines, so a low power consumption is necessary to ensure that the device lasts for a long time. Therefore, the network chosen for this service will be 5G, as it meets all the requirements.

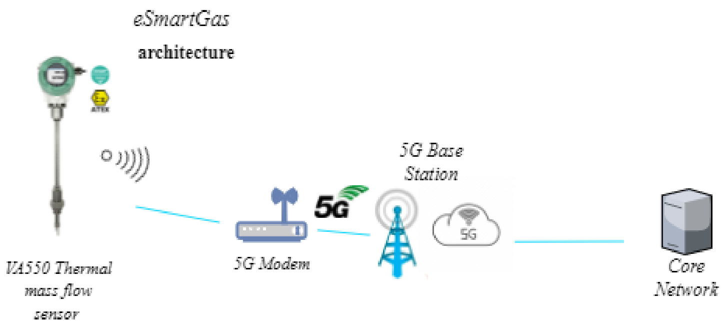


Figure 2.29: eSmartGas Architecture

Regarding the stack of protocols of the system it will have the following form:

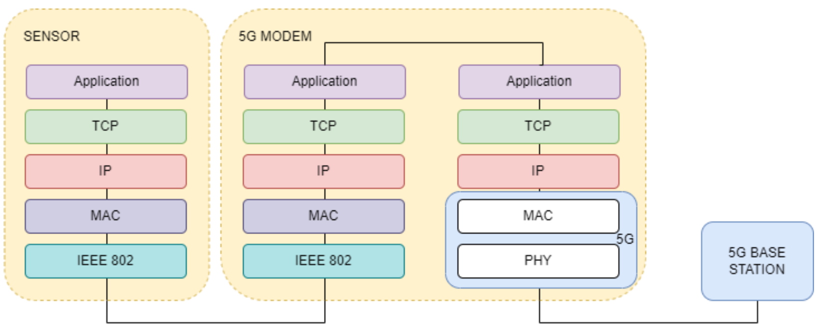


Figure 2.30: eSmartGas Protocol Stack

2.7.2.2.2 Used sensors and placement

In order to decide which sensors were selected to monitor the gas pressure along the pipes of Murcia, we carried out a complete analysis of the different kinds of sensors in the market.

The first step carried out was establishing the requirements these sensors needed to have. This way, as the pipe distribution system along the Eje-Levante and Almeria-Lorca-Chinchilla should have a **pressure of 80 bar**, the sensor must be able to measure precisely this pressure. In addition, these pipes have a wide variety of sizes, having a **diameter from 10 inches (254mm) to 42 inches (1066,8 mm)**, consequently the sensors to be used should be able to be installed in these different amplitudes. The last requirement we set was to ensure the sensors had a very low latency, we therefore decided to use 5G communications to ensure fast connections with the set of sensors.

Figure 2.31: VA 550 flowmeter.

The gas pressure sensor which was finally incorporated into the project was the VA 550 flowmeter, made by the experienced company of this sector CS Instruments GmbH. This high quality stainless steel sensor is recommended for flammable gasses such as natural gas. It allows mass flow measurement, compensating pressure and temperature by thermal mass flow principle. This flowmeter has a very easy installation under pressure and it has no moving parts, therefore requiring low maintenance. Its technical specifications fit this project perfectly as it can measure up to 100 Pa and 180 ºC, it can be installed in pipes with diameters from DN 20 (mm) up to DN 2000 (mm) and it is very accurate with an accuracy of ±1.5% or ±1% of v.m., as well as ±0.3% of f.s.

Other sensors which were analyzed were the diaphragm Gauges, the rotary meters and the Ultrasonic flowmeters. Even though they have not finally been implemented in the project, each one of them had very interesting specifications which we took into account. For example, the rotary meters allowed to regulate the gas flow rate, a very interesting feature but unnecessary for this project. Moreover, the advantage of using an ultrasonic flowmeter was the fact that it had no mechanical parts, increasing its life span enormously as it isn´t prone to wear and tear.

2.7.2.2.3 Dimensioning

The dimension of this service is carried out in gas pipeline networks of Murcia region. In order to make this analysis, it has been necessary to calculate the total number of kilometers of this pipeline network. According to the information supplied by Enagas [102] of the most significant gas pipeline networks and branches in Spain, it can be seen that two gas pipeline axes pass through the region of Murcia (the Levante axis and the Almeria-Lorca-Chinchilla axis).

		Pressure (bar)	**Diameter (inches)**	**Length (km)**
Levante Axis	*Orihuela - Cartagena*	80	30”-10”	72,14
	Orihuela - Murcia	80	20”-10”	25,60
	Totana-Murcia	80	10”	53,33
	Cartagena-Lorca	80	20”-10”	61,55
Almeria-Lorca-Chinchilla	*Almeria - Lorca*	80	42”	127,50
	Conexión Lorca	80	20”	40,21
	Lorca - Chinchilla	80	42”	168,03

Table 2.47: Parameters of gas pipeline networks in the Murcia region.

In addition, we have to keep in mind that in Cartagena, there is the Port of Escombreras, which has 5 large tanks for storing gas. The total capacity of these tanks is 587.000 m^3.

However, these axes do not pass through the whole of the Murcia region, so the effective distance has been calculated by estimation. According to Google Earth's point-to-point measurement tool, the total effective distance is approximately equal to 335 km. No gas pipeline passes through the municipalities of Alcantarilla and Molina de Segura.

For proper gas pressure monitoring, the ideal distance between measurement points is 512 metres [103]. Thus, the total possible number of sensors in the pipelines will be 655. Whereas, to correctly monitor the pressure in the gas tanks in Cartagena, one sensor per tank will be necessary. Therefore, the potential number of sensors in e-SmartGas will be 660.

2.7.2.2.4 Traffic analysis

In this section, the total traffic the e-SmartGas service sends to the 5G network has been calculated, in order to guarantee low latency times. Taking into account that on average data is sent every 60 seconds, with a size of 20 bytes. These are divided into 12 bites for the payload and 8 bytes for the header plus the CRC. Therefore, the traffic per sensor is 32 bps. The Table 2.48 shows this information summarized.

Sensor	Payload (bits)	Header + CRC (bits)	Total (bits)
Sensor VA 550	12	64	76

Number of sensors	660
Delivery period (seconds)	60
Data rate por sensor	1,26 bps
Total eSmartGas traffic	0,836 Kbps

Table 2.48: Traffic Analysis of e-SmartGas.

In Table 2.49, the size of the payload generated by each one of the gas sensors is detailed.

Sensor VA 550	
Measurement	Pressure
Pressure Range	Up to 100 bar
Diameter tube range	DN 20 - 2000
Precision	±1%of v.m.
Payload	12 bits

Table 2.49: Payload generated by each gas sensor.

2.7.2.3 Requirements and non-functional requirements

The functional and non-functional requirements to be met by the system to ensure its correct functionality are described in Tables 2.50 and 2.51.

FR1	Sensors will measure the gas pressure in every pipeline each 60 seconds
FR2	All sensor data is sent via 5G connection
FR3	The stored data must be accessible to remote users through a user interface
FR4	The stored data must be stored for a week after it´s detection, for further analysis of the gas pipeline system
FR5	The system must have a gas pressure threshold value, below which an alert will be sent instantly to the administrators of the pipeline involved
FR6	The interface should automatically report when a device needs a preventive maintenance check
FR7	The monitoring system must receive data from all sensors and evaluate whether the system is functioning properly or malfunctioning

Table 2.50: Functional requirements e-SmartGas.

NF-R01	Performance	It must have a very low latency
NF-R02	Performance	The pressure sensor must have a ±0.3 of precision scale
NF-R03	Performance	Must be able to withstand pressures of up to 100 Pa
NF-R04	Performance	High resistance to degradation due to gas
NF-R05	Performance	Almost full time availability
NF-R06	Security	Confidential and secure user authentication system
NF-R07	Security	Integrity and security of the database
NF-R08	Safeguard	Weekly backup storage to ensure data integrity. Server redundancy to ensure system availability

Table 2.51: Non-functional requirements e-SmartGas.

2.7.3 e-FoodSensing

Finally, the last innovative service is e-FoodSensing. One of the main foodstuffs consumed by today's society is meat. In the region of Murcia there are numerous companies that market sausages, hams and other meat products, like *ElPozo*. When these products are placed on the market, there is a high level of quality control. For this, our company uses different sensors to measure certain gases given off by the meat in poor condition and colour sensing techniques to determine the condition of the meat.

According to [104], there are 172 companies with the CNAE code (Spanish National Classification of Economic Activities) number 4632, which refers to wholesale trade of meat and meat products and the SIC code, 5147 (meat products). From these 172 companies, a total of 107 carry out their activity in one of the 5 municipalities in which AchoTelecom is going to develop its services. Figure 2.32 shows the distribution of these meat companies in the region of Murcia. It can be seen that the majority of meat companies concentrate their activity in the city of Murcia.

Municipality	Number of meat enterprises
Cartagena	18
Murcia	68
Alcantarilla	5
Molina de Segura	5
Lorca	11
Total number of meat enterprises	**107**

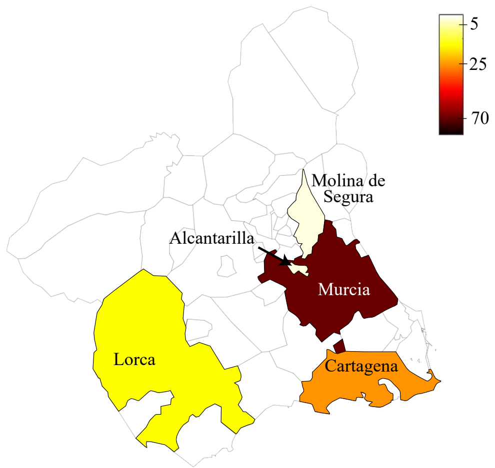


Figure 2.32: Distribution of meat enterprises in each municipality in Murcia region.

2.7.3.1 State of the art

In the past, techniques were based on the evaluation of their structure, such as colour, texture or even odour. However, these techniques are rarely used nowadays due to their inaccuracy of measurement and the high number of failures.

Nowadays, there are other more reliable techniques for detecting the condition of the meat. In a previous study they counted the number of microorganisms and/or bacteria that were present in chilled pork [105]. In this study, different types of red meat were also tested with good results. Other studies focus on determining the total volatil basic nitrogen (TVB-N) content in chicken, quantifying it through colorimetric sensors arrays without damaging the product [106]. Finally, there are other techniques that measure the pH level, optical spectroscopy or FTIR spectroscopy.

The most common gases in meat are metal oxides, can be easily evaluated by means of gas sensors for food quality evaluation [107]. To detect these gases, an e-nose system consisting of 6 sensors is used in the [108] study.

On the other hand, to replace the visual analysis performed by people, there are camera-based recognition techniques, which capture the RGB value of each pixel to determine the state of the meat. These cameras necessarily have to be of high resolution, and then the acquired data are processed and analysed on a computer. However, although camera-based recognition has good results, these are substituted by a colour sensor, due to their much lower price [109].

2.7.3.2 Integration

2.7.3.2.1 Architecture

We plan to use LoRa. The architecture of LoRa is similar for all platforms. It is shown in the following figure:

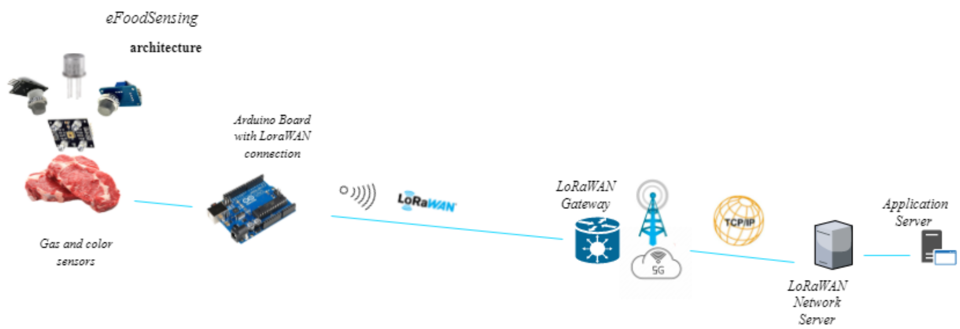


Figure 2.33: eFoodSensing Architecture

2.7.3.2.2 Used sensors and placement

To ensure there is a deep analysis of the freshness of the meat products analysed, a wide range of sensors will be used. This will provide reliable results from a diverse number of sources: 3 gas sensors will monitor the presence of different gases and a colour sensor will also make measurements of the appearance of the meat products.

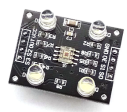
In first place, the sensor MQ-136 oversees measuring the presence of Hydrogen sulphide in the meat. In second place, a MQ-137 sensor will be used, in charge of detecting any ammonia NH3 present in the proximity of the meat. Finally, the TGS 2620 sensor will be incorporated into the e-nose to detect any solvent vapours emanating from the surface of the meat products.

To obtain another kind of measurement, the TCS 3200 RGB sensor will be used to detect the colour state of the food which will be analysed. From another point of view, bringing together these sensors can be interpreted as the different senses of a human being, and how a person could evaluate the condition of a meat product with them. The gas sensors being the nose of the person and the colour sensor representing the eyes of a person. The arrangement of the sensors is simple, they will be installed and interconnected in an ESP32. All of them will be placed on the same side to ensure measurements can be easily carried out. Moreover, the entire device will have a relatively low price, due to the inexpensive sensors incorporated. The total cost of the 4 sensors (3 gas and 1 colour sensor) and the ESP32 is 39,81 € plus the LoRaWAN Connection which costs 35 €.

(a) MQ-136 Hydrogen Sulphide gas sensor.

(b) MQ-137 Ammonia gas sensor.

(c) TGS 2620 Solvent Vapours sensor.



(d) TCS 3200 RGB colour sensor.

Figure 2.34: Gas Sensors for e-FoodSensing.

2.7.3.2.3 Dimensioning

Finally, for the dimensioning of this last service, e-FoodSensing, the total potential number of sensors for the region of Murcia has been calculated. As previously mentioned, the total number of meat companies in the region is 107.

However, the size of these companies is not in all cases equal. To calculate the number of sensor systems that each company might need, a size estimation has been made based on total sales [104]. After looking at the sales data of each company, they have been divided into large, medium, and small companies. Large companies are those with sales of more than 6 million euros. Medium-sized companies are those with sales between 1.5 and 6 million euros. And finally, small companies have sales of less than 1.5 million euros. Approximately 10% of them are large, 30% are medium-sized and the rest are small.

Taking into account that one piece of meat out of 100 will be analysed at random, 10 sensor systems will be needed for large companies, 5 for medium-sized companies and 3 for small companies. Therefore, the potential sensor systems will be 462 in total. The Table 2.52 summarises the total number of sensor systems needed for e-FoodSensing.

	Enterprise size		
	Big	**Medium**	**Small**
Systems per enterprise	10	5	3
Number of enterprises	11	32	64
Total number of systems	110	160	192

Table 2.52: Dimensioning of e-FoodSensing.

2.7.3.2.4 Traffic analysis

In this section, the total traffic that the e-FoodSensing service will send regularly into the LoRAWAN network has been calculated. As discussed in previous sections, the system consists of 1 colour sensor and 4 different gas sensors. It has been estimated that each of these 4 sensors forming the e-nose system has a payload of 12 bits. On the other hand, the colour sensor used is a high-resolution sensor, which generates a payload of 14 bits. In this case, having LoRAWAN network, the headers and the CRC are 5 bytes long. Therefore, the total size of the packets will be 126 bits.

Considering that all sensors send the information at the same time, and that approximately one piece of meat is analysed every minute, as this is the time it takes to select a product and take it to

Payload (bits)	Gas Sensor: TGS 2620	12
	Gas Sensor: TGS 2620	12
	Gas Sensor: MQ-136	12
	Gas Sensor: MQ-137	12
	Color Sensor: TCS 3200	14
Header + CRC (bits)		64
Total packet size (bits)		126

Number of systems	462
Delivery period	60 seconds
Data rate por system	2,1 bps
Total eFoodSensing traffic	970,2 bps

Table 2.53: Traffic analysis eFoodSensing.

be analysed. Table 2.53 shows the most relevant characteristics of the total traffic calculation for the service.

2.7.3.3 Requirements and non-functional requirements

FR1	The high-resolution sensors must be able to take measurements of a range of colors
FR2	The gas sensors must be able to take measurements of the different gases present
FR3	Sensors will take measurements every 60 seconds
FR4	All sensor data is sent with LoRa connection
FR5	The stored data must be accessible to remote users through a user interface
FR6	The interface should automatically report when a device needs a preventive maintenance check
FR7	The monitoring system must receive data from all sensors and evaluate whether the system is functioning properly or malfunctioning

Table 2.54: Functional requirements e-FoodSensing.

NF-R01	Performance	Accurate measurements of gas and color parameters
NF-R02	Performance	Sensors must have a high reliability in their measurements
NF-R03	Security	The system must have a low traffic data rate

Table 2.55: Non-functional requirements e-FoodSensing.

2.7.4 e-FreshGreens

2.7.4.1 State of the art

In a modern agriculture that is becoming more and more technified, the use of plant and soil sensors allows a better adjustment of irrigation doses for the cultivated plots. However, in many cases the farmer or producer is not familiar with this type of methodologies and it becomes difficult for him to invest in modernizing his farm because he does not know which sensor best suits his needs because of his lack of information.

The Finca La Orden-Valdesequera Research Center has a large number and types of plant and soil sensors, where through some researches, done in the year of 2013, the functionality of different soil and plant water status sensors have been studied to design a trial in which the farmers can see different sensors in the field and evaluate the behavior of each one, facilitating the use of them, that is to say, making them more accessible (as well as effective), by evaluating their feedback, but always with an objective view from the center's researchers [110] .

Soil moisture means the amount of liquid water contained in a soil, the amount being evaluated by a weight or volume ratio. "A wireless sensor network for drip irrigation control and automation" has been a research project implemented in 2015, that shows the implementation of a wireless sensor network capable of obtaining soil moisture measurements from a strawberry crop. For this, data has been collected, resulting in results that show an increase in water use efficiency, as well as an improvement in fruit quality compared to the traditional irrigation method [111].

2.7.4.2 Integration

2.7.4.3 Architecture

We plan to use LoRa. The architecture of LoRa is similar for all platforms. It is shown in the following figure:

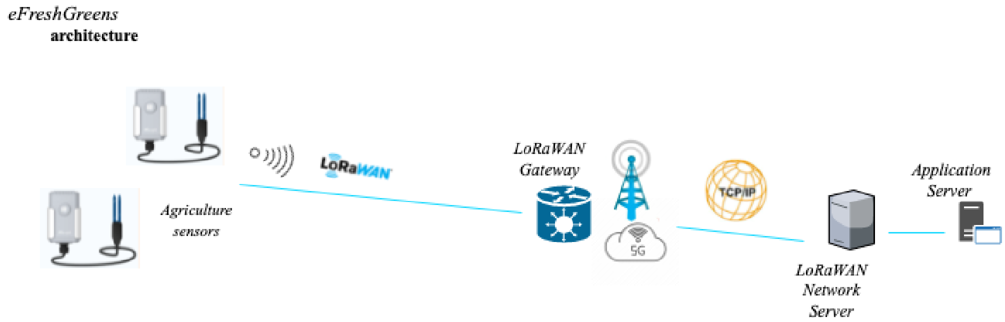


Figure 2.35: e-Freshgreens Architecture.

In this service, we want to connect the chosen sensors to gateways. For this first step, we will use both LoRa physical layer and LoRaWan in the Mac Layer. Once data reaches the gateways, it will be sent to the network server using the 5G network that we will deploy, using, IP connection, in a same way as in the e-Cleanhidroelic service.

2.7.4.3.1 Used sensors and placement

Challenges of the Spanish fresh fruit and vegetable sector in greenhouses, leads the necessity of measurement of levels for maximum plant performance (carbon dioxide (CO2), humidity, light...).

Figure 2.36: Cultivated landscapes and sensor.

LoRaWan sensor for measuring soil moisture, temperature and electrical conductivity has been chosen, to function on LoRaWAN networks. These ones will be placed and dimensioned following information on sensors needed per hectare in the area of interest.

The chosen model is known as Milesight EM500-SMTC, defined with the following characteristics [112]:

- Instantaneous information on soil moisture content, temperature, and electrical conductivity
- Easy installation into undisturbed soil
- Research-grade accuracy in multiple soil media
- Rapid monitoring of growing conditions
- Temperature : -40 to 80°C
- Battery up to 10 years service, lifeBuilt-in 19000 mAh Li-SOCl2
- IP66 (Transceiver, IP67 as required)
- Operating temperature: -30 to 70°C for Transceiver and -40 to 85°C for the Sensor

Figure 2.37: Milesight EM500-SMTC LoRaWAN.

The price is 569 US dollars per sensor [113].

2.7.4.3.2 Dimensioning

Agriculture is the most important activity of Murcia's industry. This importance is represented in the vast surface of land cultivated. Using the previous presented tables in the introduction, an accurate representation of the cultives per region can be obtained.

However, we are not covering whole regions, we pretend to offer our services in specific cities. Considering this idea, the next calculations were performed:

- First, it was calculated the surface of the total area of the three regions affected. The classification and size of the cities is available in the tables of sections 2.5 and 2.6 in Region de Murcia [114].
- Then, the proportion occupied by each of the cities covered with respect to the surface area was computed.
- Finally, the former ratio was applied to the whole amount of cultivated surface of each area and the result is the approximation that will let us make all the calculations.

	Area	**Ratio**	**Total cultivated surface (ha)**
Alcantarilla	16	0.007487321346	371.9850991
Molina de Segura	170	0.07814661134	3882.479945
Murcia	882	0.4066390041	20202.639
Lorca	1675	0.54084598	37802.42977
Cartagena	558	0.4782347901	13237.53899
Total			75497.07281

Table 2.56: Dimensioning calculations.

We have estimated a potential market of this cultivable area of about 30 percent of it. Thus, it was decided that techniques of high precision agriculture were going to be used and the result is reduced to the next table:

	Cultivated area covered (ha)
Alcantarilla	112
Molina de Segura	1165
Murcia	6061
Lorca	11341
Cartagena	3972
Total	22650

Table 2.57: Cultivated area covered (Ha) calculation.

In the former paragraph it mentioned an important set of words for this chapter: high precision agriculture. This idea implies that, for the surface covered, a sensor must be placed each hectare [115]. Therefore, the total amount of sensors used will be: 49.074 units.

2.7.4.3.3 Traffic analysis

According to the information of data sent in every message available in the EM500 sensors report [116], the next division is established:

- Basic information: 14 Bytes
- Battery level: 1 Byte
- Temperature: 2 Bytes
- Moisture: 1 Byte
- Conductivity: 2 Bytes

The sum of all these data is 20 Bytes. In the former report can be also read that this type of sensor is able to send data every 10 minutes by default. To obtain more accurate tracking, we are going to take measures each 5 minutes. With this information, we are able to calculate the next traffic rate: 12,07 Kbps.

	Total number of sensor	**Bitrate per device (bps)**	**Total bitrate (kbps)**
EMC-500-SMTC	22650	0.533	12,07245

Table 2.58: Traffic bitrate calculation.

2.7.4.4 Requirements and non-functional requirements

Being agriculture such an important industry in Murcia, it must be enhanced with this specific sensor. When designing a service for the agriculture industry, next requirements can be established:

FR1	Ability to take measures of the soil moisture
FR2	Ability to take measures of the temperature
FR3	Ability to take measures of the electric conductivity
FR4	Connectivity with LoRa
FR5	Send data tracks periodically
FR6	A sensor per hectare

(a) Functional requirements e-FreshGreens.

NFR1	Very low battery consumption
NFR2	Accurate measurement of values
NFR3	Outdoor degradation resistance
NFR4	High reliability
NFR5	Low traffic rate
NFR6	Almost full time available
NFR7	Latency of the order of minutes

(b) Non-functional requirements e-FreshGreens.

3 Conclusions

The project has required hard work from all the members across the three profiles to achieve the goals and results expected from the beginning. In addition, the processes followed have taken the feedback over the deliverable seriously, and we have implemented everything demanded on the project requirements. As a result, we have achieved excellent and feasible results, both technologically and financially.

The project started with an in-depth market and socioeconomic research on Region de Murcia. After identifying the most appealing industries and finding strategic services that could position Orange as a leading telecom operator offering IoT services, we evaluated their integrations with the current trends and technologies in the market. In addition, we evaluated all the risks and developed contingency plans.

Orange may merge with MasMovil, which would have consequences on the market presence of that new conglomerate and the integrations of their technologies. In this project, we have considered that, and we have proposed an IMS core deployed in AWS and running with Clearwater that can support up to 270000 users simultaneously. We have estimated that there will 105979 Erlangs of telephony traffic, 223978 Erlangs of VoNR traffic and 1780 Erlangs of Videoconference traffic. Regarding the fixed access network, we have upgraded to FTTH part of it, used standards like NG-GPON2 and over-dimensioned the network by a 10% as we expect to grow from 26.8% to 29.6% in market share by 2027.

For the EDGE and the CORE network, we have considered the traffic Orange has and propose an upgrade taking into the already mentioned expected growth margin. The main point to connect with Madrid is located in Murcia, where we have one of our three ROADMs in the Region. This point is essential because it has all the equipment and infrastructure required to handle and operate the network management processes, the ROADM equipment, and the 5G core equipment. In addition, we will subcontract the help desk using HelpDesk, a company that operates this kind of customer experience service.

Regarding the 5G access network, we have proposed an upgrade deploying three macrocells over the region and several microcells, continuing with Orange's trend and a local 5G core on the CPD located in Murcia.

The offer of services will bring many new customers and set Orange in a position where the current retail clients may expand the contracts to their businesses and the other way around. All the services have a 30% margin for their sale. eCleanHidroEolic will empower Orange's contribution with sustainability, and we expect to sell up to 149 air and water sensors. eSmartGas will benefit from the 5G infrastructure to tackle the 335km of gas pipeline networks, and we expect to sell up to 660 sensors. eFoodSensing will allow 107 meat enterprises to use AI for their quality standards, and we expect to deploy up to 462 sensors. eFreshGreens will ease the life of agriculturists and improve their operations using data, we hope to sell up to 22650 sensors. This services comply closely with the Sustainable Development Goals and that will set the way to innovate in many companies.

Referring to the satellite, we will offer connectivity to Aledo in Sierra Espuña, enabling remote towns connectivity and we have activated a service for hikers in emergencies over the region. As well, commercial ships with satellite antennas will benefit from the connectivity.

With an investment of 2.240.740 €the NPV of the project is 1.463.524 €, the IRR over the 5 years is 18.84%, and the payback period is 2.5 years. The project not only performs well on financial ratios but also estimates that it will increase Orange's revenues in Murcia in 26,96% and will bring many new customers and potential leads through the services offering.

With this Orange will be one of the main participants in the digitization and economical recuperation of Region de Murcia.

4 Annex

4.1 PESTLE analysis

Factors		Detail	Impact
Politic	Support from institutional bodies	Currently, both the European Union and the Spanish Government are greatly pushing forward the Internet of Things, as well as the deployment of broadband connectivity across the entire region, with an objective of 5G gigabit connectivity on the entire EU for 2030 [117]. As well, we can find similar objectives set out on [118] regarding digital connectivity and coverture of 100% of the territory with 100 Mbps, as well as different initiatives to increase digitalisation in different economic sectors.	Positive
	Chip Shortages	Due to several incidents: fire in several semiconductor plants, severe weather conditions that lead to production stopping, the US-China trade war, and the COVID pandemic; the chip supply chain has been suffering, creating a global chip shortage and causing prices to increase dramatically in many different verticals of the economy. However, governments have been acting accordingly, and experts expect the crisis to be over by the end of 2022 [119].	Negative
	Merges	On the 9th of March, Orange and MasMovil announced that they would merge into a joint venture 50-50 that will place them as the top telco in Spain (in number of clients) but still behind Telefónica inrevenues. To the moment, both companies together have 27.6 million mobile lines and 7.1 million fixed broadband lines. So far, competence authorities still have to comment on the merge, and impose the necessary restrictions, therefore, while at first sight it would have a positive impact on our project as the number of users will increase, it is still between question marks [120].	Neutral
	Wide range of suppliers	One of the advantages of using wireless technology is the increased independence we will obtain from suppliers. Therefore, by basing our network mainly on software and the openRAN protocol, we will be able to reduce costs greatly. However, the added necessary intelligence in the network adds complexity to the project.	Positive
	Cost of training	As we develop a new technology in the area, our clients will have an additional cost of training, as their employees learn how to use our services, especially those directed towards the more traditional sectors such as agriculture, that usually tend to be more reluctant to change.	Negative
	Increasing Inflation costs	We are currently seeing the highest inflation rate in Spain since 1986 [121] reaching 7.6% in February 2022, leading to increases in prices, and decline in purchase power.	Negative
	Impact of COVID crisis	COVID crisis still has retaliation on the Spanish economy, despite all the recovery and resilience funds arriving from the EU, with supply chains are still being disrupted, introducing teleworking as a rule, and forcing many SMEs out of business.	Negative

Continued on next page.

Factors		Detail	Impact
Economic	Impact of Ukraine crisis	The West continues to impose sanctions on Russia due to the recent invasion of Ukraine. Some of the sanctions have a huge impact on the economy, such as gas and oil bans that have led to a huge energy crisis in the whole Europe, raising petrol and electricity prices and increasing inflation rates.	Negative
Social	More demand by consumers	As can be seen in [122], Spain continues to increase the number of internet connections, with 95.9% of households covered by at least one mean to communicate to the Internet. Additionally, with the incorporation of teleworking to the companies' business model, and a surge of the Video on Demand, users are demanding more and more speeds.	Positive
	Improve companies' productivity	Specially regarding our smart farming solution, we expect to increase productivity of the plantations, reduce carbon footprint and overall improve the conditions of the farming sector by introducing innovative solutions.	Neutral
	Average age below Spanish average	According to INE, the average age for the region of Murcia is 42 years, that is below the Spanish average, 44 years [123].	Positive
	Digital Economy and Society Index	According to the latest Data from the DESI 2021, Spain is placed on the 16th place above the EU average regarding Integration of Digital Technologies, that includes Digital Intensity, Digital Technologies, and e-Commerce; as well as being 3th on the connectivity subindex. Both these results show the high quality of the environment we are entering [124].	Positive
	Low R&D	According to the data from the OCDE [125] we can see that Spain is far below the OCDE average, with an investment of 1.251% of its GDP.	Negative
	Impact of adding high broadband connectivity to rural areas	Regarding our more rural areas, such as Lorca or Molina de Segura, we can find many advantages brought by the incorporation of broadband services in the area. According to [126] the result of deploying 100 Mbps connectivity in rural areas is an increase of 1.4% in the GDP per capita, as well as an increase of 1.9% in population. This deployment also has a great impact on the operator, who can see an increase in 131% of pay TV users, a 28% increase in clients, and a 78€ increase in ARPU. However, these results are only seen when deploying high broadband connectivity (above 100 Mbps), when deploying only 30 Mbps we can see no impact on the economy of the area.	Positive
	Continuous developments in radio standards and electronics	As technology advances, so does communications, to improve broadband access, at less cost. In recent years we have seen the development of the 5G standard, as well as other wireless technologies such as WI-Fi6. Currently, we can find many developments in the area of 6G, that particularly Europe is pushing forward [127]. We can also find improvements in IoT devices, that not only provide more accurate data, but also their own intelligence, that allows for decentralisation of the network and a huge leap in reducing traffic in the IoT networks.	Positive
	High broadband connectivity in the area	As part of the regional analysis, we can find all the data regarding both fixed and mobile coverage in the area we are entering. We can see that we always have at least 99.9% LTE coverage, as well as an average of 84% FTTH connections in the region. This provides us with an already well deployed network that we can use to our advantage when deploying our services.	Positive
	New algorithms for machine learning	As algorithms continue to improve in performance, we can make use of the benefits that they will bring us, especially regarding data analytics. As any IoT network, we will have immense amounts of data to deal with, especially since we are offering 4 different services that involve four different networks. Big data analysis will be one of the main expenditures of the project, however, as algorithms improve, we expect the costs toreduce.	Positive
	Already available spectrum in most 5G bands	So far, Orange is the operator with more 5G spectrum in Spain, with 110 MHz in the 3.5 GHz band and 20 MHz in the 700 MHz band, this last one particularly important for the deployment of the stand-alone 5G network [128].	Positive
	Obsolescence of services	One of the main disadvantages and risks associated with new technologies is the risk of obsolescence. In our case, one of the main risks is being substituted with one of the newest developments in the area, edge computing. Edge computing provides network optimization based on decentralisation, allowing operators to greatly reduce traffic in the network and therefore reduce costs related to bandwidth and network management. So far, devices are still too expensive, however, the European Union is pushing strongly for this technology, with millions of euros spent in research [129].	Negative

Continued on next page.

Factors		**Detail**	**Impact**
Technologic	Increasing cybersecurity risks	According to Statista, over 166 thousand Spaniards suffered cyberattacks in 2019, with the time-trend growing exponentially [130] A higher cybersecurity risk will mean that our services will need to have additional protection, especially those that are aimed towards critical infrastructures (gas pipelines).	Negative
	Improvements in network optimization	With the continuous increase in data traffic, network optimization has become a priority in any IoT network. In the State of the Art, we can find a detailed analysis of the different advancements in the areas, however, it is expected that as traffic continues to increase, newer and better algorithms will be developed [131].	Positive
Environmental	Improvement gas pipelines	Since the war in Ukraine broke out, Russia closed many gas exports, Spain has become a main European gas hub, being Cartagena one of the main gas import ports of the country. Therefore, a tight and secure control of the gas pipelines will lead to an optimization in the gas network and a reduction in carbon footprint thanks to predictive maintenance and leaks control.	Positive
	Environmental Objectives: SDGs	One of the main objectives that we cover with our project is the SDG9: Build Resilient Infrastructure, as well as SDG12: Responsible Consumption and Production.	Neutral
	European Green Policies	One of Europe's most ambitious goals is to become climate neutral by 2050, for which the European Unions has published a set of milestones that countries should abide to in order to meet the imposed goals.	Neutral
Legal	European Policies: GDPR	As we are collecting data inside the European Union, we will have to abide by their current legislation regarding the privacy of the data we collect, in this case the GDPR.	Neutral
	European Policies: Open Data	In order to promote the reuse of data across the Union, the European Commission has set forth a set of regulations regarding data usage, such as the data act, that restricts who can access what information and the use they can make of it [132].	Neutral
	European Policies: NGIoT	The European Commission has published a set of recommendations and policies regarding IoT and IoST (Internet of Secure things) to address the issues relating to these technologies. We will have to abide by the existing recommendations on IoT security and the IoT strategy [133] defined by the European Union.	Neutral
	European Policies: Artificial Intelligence	As we will be making use of Machine Learning algorithms to deal with the huge amount of data coming from our network, we will need to abide by the European Regulation on Artificial Intelligence [134]. Our services would not fall under high-risk definition, lifting many of the regulatory inconveniences.	Neutral
	European Policies: 5G Toolbox	The 5G toolbox sets out the measures to ensure a coordinated European Approach to secure 5G networks. It sets out detailed mitigation plans for each of the risks identified in a previous risk assessment consultation and sets out key strategic and technical measures [135, 136].	Neutral
	European Policies: 5G antennas act	The European Commission published in 2020 the regulation defining the characteristics of low power access points designed for 5G rollout. As some of our services will be based on that technology, we will need to abide by the regulation [137].	Neutral
	European Policies: Harmonising Spectrum	The European Commission has adopted implementing decisions regarding the EU's spectrum policy to meet the demand for broadband and innovation. Therefore, they have made available the 900 MHz and the 1800 MHz for 5G applications [138].	Positive
	CEPT ECC: Use of SRD	The regulatory body CEPT has published a recommendation regarding the spectrum to be used by Short range Devices and Wi-Fi, that applies to the ones used in IoT [139].	Neutral
	Spanish Policies: Network Security Act	As specified in the European 5G Toolbox, Spain has published the necessary regulation to deal with the security of the 5G networks. The regulation aims to ensure the security of the networks as well as a wide range of suppliers and improve R&D in the region [140].	Neutral
	Spanish Policies: Telecom Act	On the Spanish telecom act we can find al the regulations that apply to our services, both fixed and wireless. It is currently under modification.	Neutral

Table 4.1: PESTLE analysis.

4.2 Tasks and Resources

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names	Work	Cost
0		achoTelecom	1263 days	Tue 01/02/22	Fri 01/01/27			50.901,6 hrs	€810.897,60
1		M0. Project start	0 days	Tue 01/02/22	Tue 01/02/22			0 hrs	€0,00
2		1. Project Management	1263 days	Tue 01/02/22	Thu 31/12/26	1		5.052 hrs	€101.040,00
3		1.1. Planification and coordination	1263 days	Tue 01/02/22	Thu 31/12/26	1	COO/CFO[10%];CEO[10%]	2.020,8 hrs	€40.416,00
4		1.2. Tracing and control	1263 days	Tue 01/02/22	Thu 31/12/26	1	COO/CFO[10%];CEO[10%];CTO[10%]	3.031,2 hrs	€60.624,00
5		2. Initial Analysis and Proposal	17 days	Tue 01/02/22	Thu 24/02/22	1		333,6 hrs	€5.904,00
6		2.1. Selection of the Project and the Role	4 days	Tue 01/02/22	Fri 04/02/22	1	COO/CFO[10%];CEO[10%];CTO[10%]	9,6 hrs	€192,00
7		2.2. Services Selection	10 days	Mon 07/02/22	Fri 18/02/22	6	COO/CFO[10%];CEO[10%];CTO[10%]	188,8 hrs	€3.368,00
8		2.2.1. Scenario Analysis	7 days	Mon 07/02/22	Tue 15/02/22	6		80,8 hrs	€1.448,00
9		2.2.1.1. Socioeconomic and demographic analysis	5 days	Mon 07/02/22	Fri 11/02/22	6	COO/CFO[10%];CEO[10%]	8 hrs	€160,00
10		2.2.1.2. Operators and strategic anal	7 days	Mon 07/02/22	Tue 15/02/22	6	CTO[10%];Subgroup 2.2;COO/CFO[10%];CEO[10%]	72,8 hrs	€1.288,00
11		2.2.2. Technical Feasibility Analysis	5 days	Mon 14/02/22	Fri 18/02/22	9	Subgroup 2.1;Subgroup 2.2;CTO[10%]	84 hrs	€1.440,00
12		2.3. State-of-the-art	5 days	Mon 14/02/22	Fri 18/02/22	9		128 hrs	€2.200,00
13		2.3.1. IMS	5 days	Mon 14/02/22	Fri 18/02/22	9	Subgroup 2.1;CTO[10%]	44 hrs	€760,00
14		2.3.2. IoT	5 days	Mon 14/02/22	Fri 18/02/22	9	CTO[10%];Subgroup 3.1;Subgroup 3.2	84 hrs	€1.440,00
15		2.4. Selection of the Operator to Offer the Project	3 days	Mon 21/02/22	Wed 23/02/22	6;7;12	COO/CFO[10%];CEO[10%];CTO[10%]	7,2 hrs	€144,00
16		M1. End of Initial Analysis and Operator Election	0 days	Thu 24/02/22	Thu 24/02/22	15		0 hrs	€0,00
17		3. Technical Solutions: IMS, IoT and 5G	1246 days	Thu 24/02/22	Thu 31/12/26	16		36.055,2 hrs	€566.040,00
18		3.1. IMS Solution	52 days	Thu 24/02/22	Fri 06/05/22	16		510,4 hrs	€7.760,00
19		3.1.1. Requirements Specifications and Alignment with Goals	1 day	Thu 24/02/22	Thu 24/02/22	16	Subgroup 2.1	8 hrs	€136,00
20		3.1.2. Architecture Design	5 days	Fri 25/02/22	Thu 03/03/22	19		100 hrs	€1.700,00
21		3.1.2.1. Interfaces, functions and protocols	5 days	Fri 25/02/22	Thu 03/03/22	19	Subgroup 2.1	40 hrs	€680,00
22		3.1.2.2. Identificaction mechanisms and required user equipment	5 days	Fri 25/02/22	Thu 03/03/22	19	Subgroup 2.1	40 hrs	€680,00
23		3.1.2.3. Applications and services exploration	5 days	Fri 25/02/22	Thu 03/03/22	19	Subgroup 2.1[50%]	20 hrs	€340,00
24		3.1.3. Architecture Dimensioning (resources + cloud)	5 days	Fri 25/02/22	Thu 03/03/22	19	Subgroup 2.1[50%]	20 hrs	€340,00
25		3.1.4. Architecture Validation	6 days	Fri 04/03/22	Fri 11/03/22	20;24	CTO[10%];Subgroup 2.1;CEO[10%];COO/CFO[10%]	62,4 hrs	€1.104,00
26		3.1.5. IMS Solution Deployment	40 days	Mon 14/03/22	Fri 06/05/22	25	Electrical technician for deployment	320 hrs	€4.480,00
27		M2. IMS Solution Deployment	0 days	Mon 09/05/22	Mon 09/05/22	26		0 hrs	€0,00
28		3.2. IoT Solution	1246 days	Thu 24/02/22	Thu 31/12/26	16		34.688,8 hrs	€545.336,00
29		3.2.1. Services Initial Definition	2 days	Thu 24/02/22	Fri 25/02/22	16	Subgroup 3.1;CEO[10%];COO/CFO[10%];CTO[10%]	20,8 hrs	€368,00
30		3.2.2. Service 1: e-SmartGas	5 days	Mon 28/02/22	Fri 04/03/22	29		16 hrs	€272,00
31		3.2.2.1. Hardware specification	2 days	Mon 28/02/22	Tue 01/03/22	29	Subgroup 3.1[25%]	4 hrs	€68,00
32		3.2.2.2. Connection specification	3 days	Wed 02/03/22	Fri 04/03/22	31	Subgroup 3.1[25%]	6 hrs	€102,00
33		3.2.2.3. Dimensioning	3 days	Wed 02/03/22	Fri 04/03/22	29	Subgroup 3.1[25%]	6 hrs	€102,00
34		3.2.3. Service 2: e-CleanHidroeolic	5 days	Mon 28/02/22	Fri 04/03/22	29		16 hrs	€272,00
35		3.2.3.1. Hardware specification	2 days	Mon 28/02/22	Tue 01/03/22	29	Subgroup 3.1[25%]	4 hrs	€68,00
36		3.2.3.2. Connection specification	3 days	Wed 02/03/22	Fri 04/03/22	35	Subgroup 3.1[25%]	6 hrs	€102,00
37		3.2.3.3. Dimensioning	3 days	Wed 02/03/22	Fri 04/03/22	29	Subgroup 3.1[25%]	6 hrs	€102,00
38		3.2.4. Service 3: e-FreshGreens	5 days	Mon 28/02/22	Fri 04/03/22			16 hrs	€272,00
39		3.2.4.1. Hardware specification	2 days	Mon 28/02/22	Tue 01/03/22	29	Subgroup 3.1[25%]	4 hrs	€68,00
40		3.2.4.2. Connection specification	3 days	Wed 02/03/22	Fri 04/03/22	39	Subgroup 3.1[25%]	6 hrs	€102,00
41		3.2.4.3. Dimensioning	3 days	Wed 02/03/22	Fri 04/03/22	29	Subgroup 3.1[25%]	6 hrs	€102,00
42		3.2.5. Service 4: e-FoodSensing	5 days	Mon 28/02/22	Fri 04/03/22			16 hrs	€272,00
43		3.2.5.1. Hardware specification	2 days	Mon 28/02/22	Tue 01/03/22	29	Subgroup 3.1[25%]	4 hrs	€68,00
44		3.2.5.2. Connection specification	3 days	Wed 02/03/22	Fri 04/03/22	43	Subgroup 3.1[25%]	6 hrs	€102,00
45		3.2.5.3. Dimensioning	3 days	Wed 02/03/22	Fri 04/03/22	29	Subgroup 3.1[25%]	6 hrs	€102,00
46		3.2.6. IoT Solution Validation	5 days	Mon 07/03/22	Fri 11/03/22	30;34;38;42	Subgroup 3.2;CEO[10%];COO/CFO[10%];CTO[10%]	52 hrs	€920,00
47		3.2.7. IoT Solution Deployment and Integration	1234 days	Mon 14/03/22	Thu 31/12/26	46	Electrical technician for deployment[150%];Subgroup 3.1;Subgroup 3.2	34.552 hrs	€542.960,00
1284		M3. IoT Solution Deployment	0 days	Mon 09/05/22	Mon 09/05/22			0 hrs	€0,00
1285		3.3. 5G Solution	52 days	Thu 24/02/22	Fri 06/05/22	16		856 hrs	€12.944,00
1286		3.3.1. 5G Core Network Solution	42 days	Thu 24/02/22	Fri 22/04/22	16		348 hrs	€5.232,00
1287		3.3.1.1. Core Network Design	7 days	Thu 24/02/22	Fri 04/03/22	16	Subgroup 2.2	56 hrs	€952,00
1288		3.3.1.2. Core Network Validation	5 days	Mon 07/03/22	Fri 11/03/22	1287	CEO[10%];COO/CFO[10%];CTO[10%];Subgroup 2.2	52 hrs	€920,00
1289		3.3.1.3. Core Network Deployment	30 days	Mon 14/03/22	Fri 22/04/22	1288	Electrical technician for deployment	240 hrs	€3.360,00
1290		3.3.2. 5G Access Network Solution	42 days	Thu 24/02/22	Fri 22/04/22	16		348 hrs	€5.232,00
1291		3.3.2.1. Access Network Design	7 days	Thu 24/02/22	Fri 04/03/22	16	Subgroup 2.2	56 hrs	€952,00
1292		3.3.2.2. Access Network Validation	5 days	Mon 07/03/22	Fri 11/03/22	1291	CEO[10%];COO/CFO[10%];CTO[10%];Subgroup 2.2	52 hrs	€920,00
1293		3.3.2.3. Access Network Deployment	30 days	Mon 14/03/22	Fri 22/04/22	1292	Electrical technician for deployment	240 hrs	€3.360,00
1294		3.3.3. 5G Core & Access Network Dimensioning & Integration	10 days	Mon 25/04/22	Fri 06/05/22	1289;1293	Subgroup 2.2;Electrical technician for deployment	160 hrs	€2.480,00
1295		M4. 5G Solution Deployment	0 days	Mon 09/05/22	Mon 09/05/22			0 hrs	€0,00
1296		4. Integration, Operation and Maintenance of the whole system	1194 days	Mon 09/05/22	Thu 31/12/26	1295		9.460,8 hrs	€137.913,60
1297		4.1. IMS, IoT and 5G Solutions Integratio	30 days	Mon 09/05/22	Fri 17/06/22	1295	Subgroup 2.1;Subgroup 2.2;Subgroup 3.1;Subgroup 3.2;CTO[50%]	1.080 hrs	€18.720,00
1298		M5. Integration of the whole solution	0 days	Mon 20/06/22	Mon 20/06/22	1297		0 hrs	€0,00
1299		4.2. Operation and Maintenance of the whole system	1164 days	Mon 20/06/22	Thu 31/12/26	1297	Subgroup 2.1[10%];Subgroup 2.2[10%];Subgroup 3.1[10%];Subgroup 3.2[10%];Electrical technician for maintenance[50%]	8.380,8 hrs	€119.193,60
1300		M6. End of project	0 days	Fri 01/01/27	Fri 01/01/27	1298		0 hrs	€0,00

Figure 4.1: Tasks and resources assignment.

4.3 KPIs annex

Improved Service for users based on 5G	KPI-Gen-01	Trafic volume density	Min 7 Mbps/sqkm-Max 674 Mbps/sqkm
	KPI-Gen-02	User density	0.1 per m2
	KPI-Gen-03	Coverage	90%
	KPI-Gen-04	Experienced Bitrate	300 Mbps
	KPI-Gen-05	Latency	RR ¡ 5ms
	KPI-Gen-06	Reliability	95%
	KPI-Gen-07	Channel Environment	Outdoor/Indoor
	KPI-Gen-08	Mobility	Static/medium speed/high speed
	KPI-Gen-09	Availability	95%
	KPI-Gen-10	Energy consumption	No special requirements

Table 4.2: 5G KPIs.

IMS	KPI-IMS-01	Availability	99.99%
	KPI-IMS-02	Bussy hour capacity	38584,6975 Erlangs
	KPI-IMS-03	Mobility	Static/medium speed/high speed
	KPI-IMS-04	Channel Environment	Outdoor/Indoor

Table 4.3: IMS KPIs.

eCleanPorts	KPI-Port-01	Trafic volume density	50 Kbps
	KPI-Port-02	Device density	1 device / 450 metres
	KPI-Port-03	Coverage	99%
	KPI-Port-04	Experienced Bitrate	1 kpbs
	KPI-Port-05	Latency	No special Requirement
	KPI-Port-06	Reliability	95% of the time
	KPI-Port-07	Channel Environment	Outdoor
	KPI-Port-08	Mobility	Static
	KPI-Port-09	Availability	99%
	KPI-Port-10	Energy consumption	Very Low

Table 4.4: eCleanPorts KPIs.

eFreshGreens	KPI-Fresh_gr-01	Trafic volume density	50 Kbps
	KPI-Fresh_gr-02	Device density	1 device / 10000 square metres
	KPI-Fresh_gr-03	Coverage	90%
	KPI-Fresh_gr_04	Experienced Bitrate	1 kbps
	KPI-Fresh_gr-05	Latency	order of minutes
	KPI-Fresh_gr-06	Reliability	95% of the time
	KPI-Fresh_gr-07	Channel Environment	Outdoor/Indoor
	KPI-Fresh_gr-08	Mobility	Static
	KPI-Fresh_gr-09	Availability	99.00%
	KPI-Fresh_gr-10	Energy consumption	Low

Table 4.5: eFreshGreens KPIs.

eSmartGas	KPI-SGas-01	Trafic volume density	3 Kbps
	KPI-SGas-02	Device density	1 device / 512 metres
	KPI-SGas-03	Coverage	-
	KPI-SGas-04	Experienced Bitrate	1 kbps
	KPI-SGas-05	Latency	RTT ¡ 5ms (User and control plane)
	KPI-SGas-06	Reliability	99.9% of the time
	KPI-SGas-07	Channel Environment	Outdoor
	KPI-SGas-08	Mobility	Static
	KPI-SGas-09	Availability	99.99%
	KPI-SGas-10	Energy consumption	Very Low

Table 4.6: eSmartGas KPIs.

eFoodSensing	KPI-FoodSens-01	Trafic volume density	0.97 Kbps
	KPI-FoodSens-02	Device density	6 devices / company
	KPI-FoodSens-03	Coverage	-
	KPI-FoodSens-04	Experienced Bitrate	1 Mbps
	KPI-FoodSens-05	Latency	RTT ¡ 5ms
	KPI-FoodSens-06	Reliability	95% of the time
	KPI-FoodSens-07	Channel Environment	Indoor
	KPI-FoodSens-08	Mobility	Static
	KPI-FoodSens-09	Availability	99%
	KPI-FoodSens-10	Energy consumption	Low

Table 4.7: eSmartSensing KPIs.

4.4 Team Roles

Full name	**Email (add @alumnos.upm.es)**	**Profile**
Yamil Mateo Rodríguez	yamil.mateo.rodriguez	CEO
Pablo Jarabo Valdivieso	p.jarabo	CFO/COO
Pilar Rodriguez Pita	pilar.rodriguez.pita	CTO
Ángel Domínguez Fernández	angel.dominguezf	Subgroup 2.1 (Technical analysis and system design)
Rubén de Miguel Gil	ruben.demiguel.gil	Subgroup 2.1 (Technical analysis and system design)
Javier Velázquez Martínez	j.velazquezm	Subgroup 2.1 (Technical analysis and system design)
Alejandro Sánchez Loscos	alejandro.sanchez.loscos	Subgroup 2.2 (Technical analysis and system design)
Álvaro Pulido Gómez	alvaro.pulido.gomez	Subgroup 2.2 (Technical analysis and system design)
Javier García Cotarelo	javier.gcotarelo	Subgroup 2.2 (Technical analysis and system design)
Kenza El Kouhen	kenza.elkouhen	Subgroup 3.1 (Technical development and feasibility)
Rodrigo Calzada Haro	rodrigo.calzadah	Subgroup 3.1 (Technical development and feasibility)
Álvaro Pascual González	alvaro.pascual.gonzalez	Subgroup 3.1 (Technical development and feasibility)
Javier López Iniesta Díaz del Campo	javier.lopeziniesta.diazdelcampo	Subgroup 3.2 (Technical development and feasibility)
Javier Sendra Ramos	javier.sendra.ramos	Subgroup 3.2 (Technical development and feasibility)
Pablo Iturbe Vera	p.iturbe	Subgroup 3.2 (Technical development and feasibility)

Table 4.8: Team Data.

4.5 Risk Register Table

ID	Risk	Cause	Risk Category	Service Associated
Gen-01	Underestimation of budget	Budget is not sufficient to carry out the tasks	3.2	General
Gen-02	Inability to meet deadlines in contract	Faulty contract obligations/too optimistic workplan schedule	5.3	
Gen-03	Staff undertraining	Error in human resources and project manager	3.4	
Gen-04	Conflicts among team members	Insufficient flow of information between teams	3.4	
Gen-05	Too optimistic assessment of staff workload	Approval of unrealistic deadlines for each individual	3.4	
Gen-06	Delays in obtaining permits of operation in the area	Incorrect formulation of petitions /faulty scope design	5.1	
Gen-07	Lack of acceptance by operator	Incomplete project design/delays in approval	5.3	
Gen-08	Lack of confidence from customers	Unclear marketing strategy	2.3	
Gen-09	Cybersecurity breaches	Lack of necessary security measures	1.3	
Gen-10	Technological obsolescence	Fault in R&D&I office	4.1	
Gen-11	Changes in current legislation	External	1.1	
Gen-12	Theft of equipment	Lack of security	1.3	
Gen-13	Additional / increase in taxes	External	2.4	
IoT-01	Overloading of Network	Un-dimensioning of resources needed/too quick expansion	4.3	IoT network
IoT-02	Storms hit the port area and damage sensors	External	1.2	
IoT-03	Fall of Cloud Provider network	External	5.3	
IoT-04	Insufficient cloud resources	Incorrect dimensioning of resources needed	3.1	
IoT-05	Ransomware attack on network	Lack of security measures	1.3	
IoT-06	Changes in spectrum for incorporation of new communication technologies	External	5.1	
Mb-01	Changes in spectrum for incorporation of new communication technologies (6G)	External	5.1	Mobile Network
Mb-02	Network under sizing	Incorrect dimensioning of resources needed	4.3	
Mb-03	Network over sizing	Incorrect dimensioning of resources needed	4.3	
Mb-04	Social rejection over new technologies	Incorrect marketing	2.3	
Fx-01	Theft of equipment	Lack of security measures	1.3	Fixed Network
Fx-02	Network under sizing	Incorrect dimensioning of resources needed	4.3	
Fx-03	Network over sizing	Incorrect dimensioning of resources needed	4.3	
Fx-04	Providers fail to deliver equipment on time	Lack of coordination	5.3	

Table 4.9: Risk Register.

4.6 Risk Breakdown Structure

0. Project	1. External-unpredictable	1.1 Legislative Changes
		1.2 Natural Disasters
		1.3 Vandalism/sabotage
	2. External-predictable	2.1 Market Changes
		2.2 Environmental Impact
		2.3 Social Impact
		2.4 Currency changes, Inflation, taxes
	3. Internal non-technical	3.1 Plan Delays
		3.2 Exceed the Budget
		3.3 Cash Flow Failure
		3.4 Human Resources
	4. Technical	4.1 Technological Obsolescence
		4.2 Insufficient Benefits
		4.3 Special Technologies
	5. Legal & IPR	5.1 Licenses
		5.2 Patents
		5.3 Breach of Contract
		5.4 Litigation

Table 4.10: Risk Breakdown structure.

4.7 Requirements Compliance Matrix

Key	Description Summary	Compliance
SCOM001	Upgrade shall contemplate very high speed access with at least 1000Mbps per user in fiber, 400Mbps with other technologies.	Section 2.2.1
SCOM002	Quintuple-play services using new technologies (e.g., G.FAST, NG-PON2, 5G...). The project shall cover the upgrade of 2 fixed and 1 mobile technology, at least.	Section 1.3.1
SCOM003	5G upgrade proposal for the mobile system shall be dimensioned.	Section 2.4
SCOM004	In the mountain areas and the sea, it will be needed to provide communications by satellite to isolated users/locations or to ships of different kinds: 2 scenarios shall be selected.	Section 2.2.1.2
SCOM005	Services can be offered via IoT networks.	Section 1.3.2
RECM001	Migrate the telephony service to VoIP in a way that does not involve changing client terminals.	Section 2.2.4
RECM002	For the fixed telephony service, a traffic of 0.9 Erlang per customer during the busy hour shall be considered.	Section 2.2.4.3.1
RECM003	The videoconference service is modeled with a traffic during the busy hour of 0.1 Erlang, session average duration of 40 minutes, and 4 users in average (during the busy hour).	Section 2.2.4.3.3
RECM004	The operator uses a Metro-Ethernet ring to connect its access technologies with its core network infrastructure.	Section 2.2.2
RECM005	The project shall consider the effects of the upgrade of the access networks on the core and edge infrastructures, re-sizing them appropriately.	Section 2.2.2-3
RECM006	IMS implementation of Clearwater deployed on AWS (Amazon Web Services) or alternative Cloud services.	Section 2.2.4
RECM007	The management infrastructure shall be also designed.	Section 2.3
RECM008	Techno-economic analysis assessing pros and cons of performing the upgrading based on traditional communication network paradigm or SDN/NFV.	Section 1.4
RECM009	5G Core Network design and interconnection with other networks.	Section 2.2.2
GEN001	Cost effectiveness shall be considered (both acquisition and operation).	Section 1.4.6
GEN002	The system shall be available 99,99% of the time, including a 24/7 maintenance.	Section 2.2
GEN003	Installation cost can be estimated as 15% of equipment purchasing price.	Section 1.4.6
GEN004	Emerging network technologies like 5G will be consider and evaluated.	Section 2.2

Table 4.11: Requirements compliance matrix.

4.8 IoT State of the Art

4.8.1 PAN Networks

Personal Area Networks is a computer network that interconnects over short distances (around 10 meters), and that on the wireless connection falls under the standards of IEEE 802.15 [141]

4.8.1.0.1 6LoWPAN The Low Power Wireless Personal Area Network makes use of the IPv6 protocol to allow the smallest devices to connect to the network. These small devices have very restrictive battery conditions, and very low processing capabilities, therefore when using this technology, header compression is mandatory [142, 143].

4.8.1.0.2 ZigBee ZigBee was designed for low data rate and battery powered applications, however, unlike 6LoWPAN, it does not interconnect easily to other protocols. It works on unlicensed spectrum bands and has the ability to create mesh networks [142, 144].

4.8.1.0.3 Thread A combination of the previous technologies, where we have the low power, low latency, and mesh network creations of ZigBee and the IP directioning of 6LoWPAN. It is mostly used for smart home applications [145].

4.8.1.0.4 BAN The Body Area Network is defined in the IEEE 802.15 as, a low power, short range network to be used near the human body [146].

4.8.1.0.5 Li-Fi Li-Fi (Light Fidelity) is a system based on visible light communications that transmit data at very high speeds (over 100 Gbps maximum theoretical). The emitter consists of a LED that transmits the information modulated over light pulses. The technology has less interference than WiFi, more security and better performance on high dense areas; however it has very low range (around 10 meters) [147].

4.8.2 NFC

The Near Field Communication is a standard developed for short range wireless communications, it uses magnetic induction between components, therefore these cannot be further away than a few centimetres [148, 149].

4.8.3 Bluetooth

One of the latest developments in the area is the Low Energy Bluetooth (LEB). This technology is focused on fast exchanges of small packets of information, with a speed of around 1 Mbps. We can find two sorts of devices, the ace and the slave, where the ace act as a controller of the other slaves that to save energy are usually in rest mode, and only wake for short periods of time to send or receive parcels.

4.8.4 Wi-Fi

Regarding data-rates, Wi-Fi offers the highest possible, with 2.4 Gbps (using 2x2 MIMO, 1024 QAM, and 160 MHz) with a range of 100 m. One of the biggest concerns over using this technology is the large energy consumption of the Wi-Fi modules. However, the Wi-Fi 6 (IEEE 802.11ax) standard aims at addressing this issue, working on 6GHz to avoid the congestion of the lower bands, it aims at increasing throughput and robustness while decreasing power consumption (Edgar 2020). One of the new features the standard introduces to increase battery life is the Target Wait Time (TWT), with which the access points and devices negotiate when they should wake up to transmit data [150, 151, 152].

4.8.5 HaLow

HaLow is a branch of Wi-Fi that works below the 1 GHz spectrum in order to offer longer range (around 1Km) and low power connectivity. It was designed by the Wi-Fi alliance to compete with BLE in the low power IoT. It is designed for industrial, agricultural and smart city environments, as it can penetrate through walls easily, supports IP, and has different power saving modes for devices [153].

4.8.6 PLC

Power Line communications are mainly used in electricity control IoT.

4.8.7 Z-Wave

Z-Wave is a wireless protocol for home automation communications. It works on the 900 MHz band and offers a maximum range of 100 meters. It uses low energy radio waves through a mesh network and like many other home automation protocols it can connect to IP [154].

4.8.8 LPWAN

4.8.8.0.1 LoRA LoRa is an RF modulation technology designed for low-power, long range IoT communications. It can provide up to 5 Km coverage in urban areas and 15 Km coverage in rural areas (LOS). One of the most attractive features of this technology is its ultra-low power requirements, that allows battery operated devices to last up to 10 years. On top of this physical layer we have the LoRaWAN networking protocol, that allows for secure bidirectional communications with roaming. Its architecture is formed of devices, gateways, and servers. In order to reduce packet error rate, each device is covered by multiple gateways that transmit the packets to the servers [155, 156, 157].

4.8.8.0.2 Nb-IoT The most recent release 15 builds on the previous to provide the best possible performance, increasing battery life up to 10 years. As an improvement over previous releases we can find the incorporation of a wake-up signal, that allows the device to be in Idle state for longer periods of time without having to be checking the paging channel constantly. However, it lacks strong security measures due to its simple architecture and limited resources, as well as having very low performance on mobility management [158, 159, 160, 161].

4.8.8.0.3 LTE-M One of the main advantages LTE-M offers over NB-IoT is higher data rate, as well as better mobility and VoIP. However, it requires more user bandwidth and end devices consume more power, making their batteries last significantly less time. Moreover, it is more security oriented, basing its battery savings on reduction of overheads, making it more costly and complex than others [162, 160, 161].

4.8.8.0.4 SigFox SigFox was designed to offer low power, long range and small data (up to 12 bytes) end-to-end connectivity. It is complementary to other network solutions such as Wi-Fi, Bluetooth or GPRS [163, 164, 165].

	Wi-Fi 6	*LoRa*	*BLE*	*ZigBee*	*Z-Wave*	*NB-IoT*	*LTE-M*	*SigFox*
Operating Frequency	2.4/5/6 GHz	860-870 MHz	2.4 GHz	868/915 MHz, 2.4 GHz	900 MHz	E-UTRA 3, 8, 20 bands	E-UTRA 1-5, 12, 13, 20, 25, 26, 28 bands	860-870 MHz
Modulation	OFDMA & 1024-QAM	LoRa CSS	GFSK	DSSS & O-QPSK	FSK	SC-FDMA & QPSK	16-QAM	DBPSK & GFSK
Max Range (outdoor)	100 m	15 Km	50 m	500 m	100 m	35 Km	11 Km	40 Km
Max Data Rate	9.6 Gbps	50 Kbps	1-2 Mbps	250 kbps	40 kbps	250 Kbps	1 Mbps	100 bps
Max Nodes	N/A	100.000 mess/GW	N/A	65536	232	52500	N/A	Billions
Topology	One-hop star	Star of stars	P2P	Mesh	Mesh	Cellular	Cellular	One-hop star
Interoperability	High	High	Medium	High	High	Medium	High	Medium
Reliability	Medium	Medium	Medium	Low	Low	Low	High	High
Security	Very High	Medium	Medium	Medium	Medium	High	High	Medium
Price	Medium	Medium	Low	Medium	High	Medium	High	Very Low
Application	High Bandwidth, short distance	Long Distance, low power	Very Short Distance	Low power, low data rate, short distance	Low power for home automation	Low power, wide area, very low complexity	Low power, wide area, wide range of devices	Low power, very low bandwidth, wide area

Table 4.12: Summary IoT technologies.

4.9 IMS

4.9.1 Protocols

All components within the IMS architecture employ IP-based protocols. Here are the most important ones:

- **SDP:** SDP is intended for describing multimedia sessions for the purposes of session announcement, session invitation, and other forms of multimedia session initiation.
- **RTCP:** The RTP control protocol (RTCP) is based on the periodic transmission of control packets to all participants in the session, using the same distribution mechanism as the data packets.
- **SIP:** Session Initiation Protocol (SIP), an application-layer control (signaling) protocol for creating, modifying, and terminating sessions with one or more participants. These sessions include Internet telephone calls, multimedia distribution, and multimedia conferences.
- **TCP:** The Transmission Control Protocol (TCP) is one of the main protocols of the Internet protocol suite. It originated in the initial network implementation in which it complemented the Internet Protocol (IP). TCP is connection-oriented, and a connection between client and server is established before data can be sent. The server must be listening (passive open) for connection requests from clients before a connection is established. Three-way handshake (active open), retransmission, and error-detection adds to reliability but lengthens latency.
- **RTP:** The real-time transport protocol provides end-to-end network transport functions suitable for applications transmitting real-time data, such as audio, video or simulation data, over multicast or unicast network services. RTP does not address resource reservation and does not guarantee quality-of-service for real-time services.
- **UDP:** The User Datagram Protocol (UDP) is a transport layer protocol based on the exchange of datagrams (Layer 4 Encapsulation or Transport of the OSI Model). It allows sending datagrams through the network without having a previously established connection, since the datagram itself incorporates sufficient addressing information in its header. It also has no confirmation or flow control, so packets can run ahead of each other; and it is also not known if it has arrived correctly, since there is no delivery or receipt confirmation.
- **Diameter:** The Diameter base protocol is intended to provide an Authentication, Authorization, and Accounting (AAA) framework for applications such as network access or IP mobility in both local and roaming situations.
- **H.248:** The Gateway Control Protocol (Megaco, H.248) is an implementation of the media gateway control protocol architecture for providing telecommunication services across a converged internetwork consisting of the traditional public switched telephone network (PSTN) and modern packet networks, such as the Internet.
- **ISUP:** signaling transport between signaling gateways, gateways and the corresponding controller. It is a group of protocols that encapsulate the control messages arriving through the signaling gateways for transport over IP to gateways to transport them over IP to the controller and vice versa.

4.9.2 Scenarios IMS

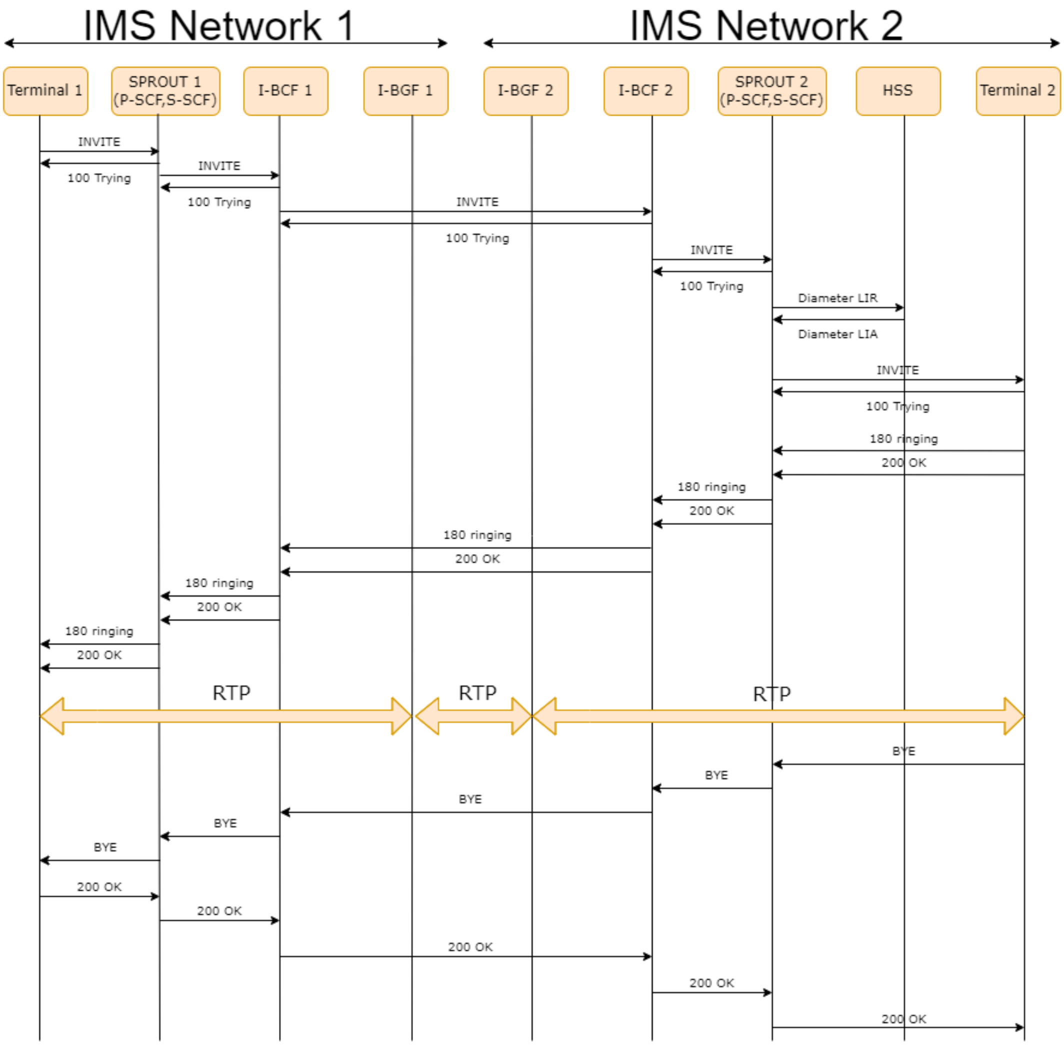


Figure 4.2: Call from AchoTelecom to another operator using IMS

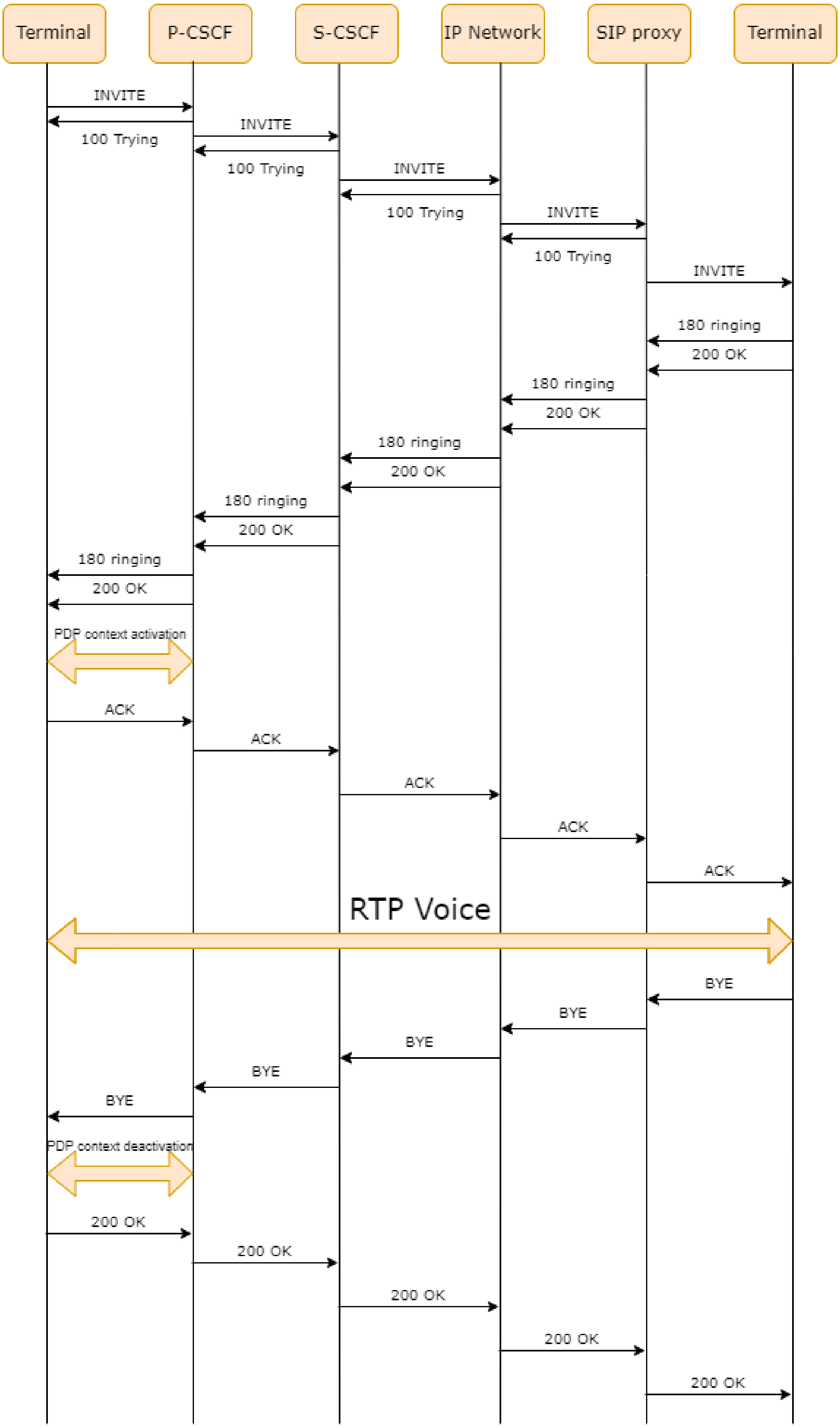


Figure 4.3: Call from AchoTelecom to IP network

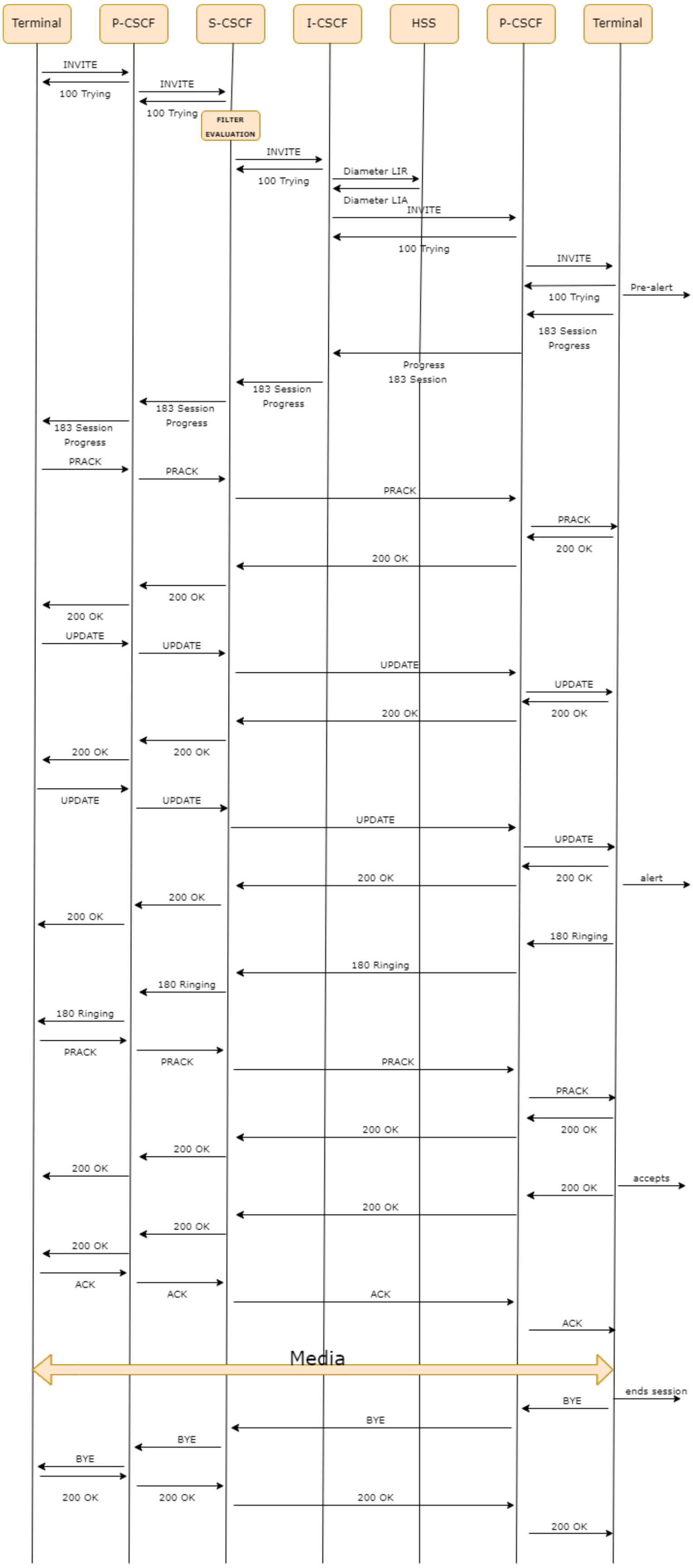


Figure 4.4: Call between two AchoTelecom terminals

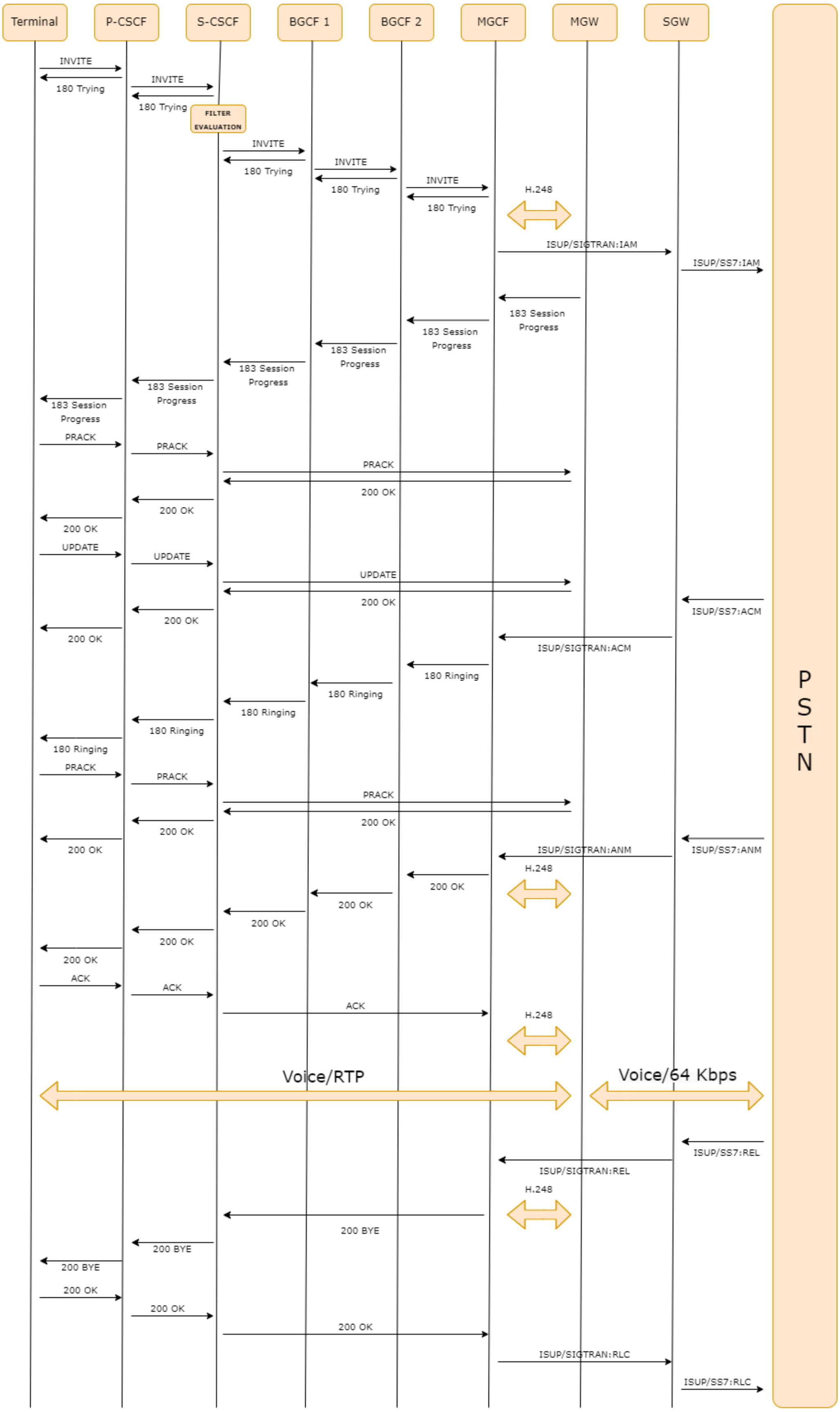


Figure 4.5: Call from AchoTelecom to PSTN network

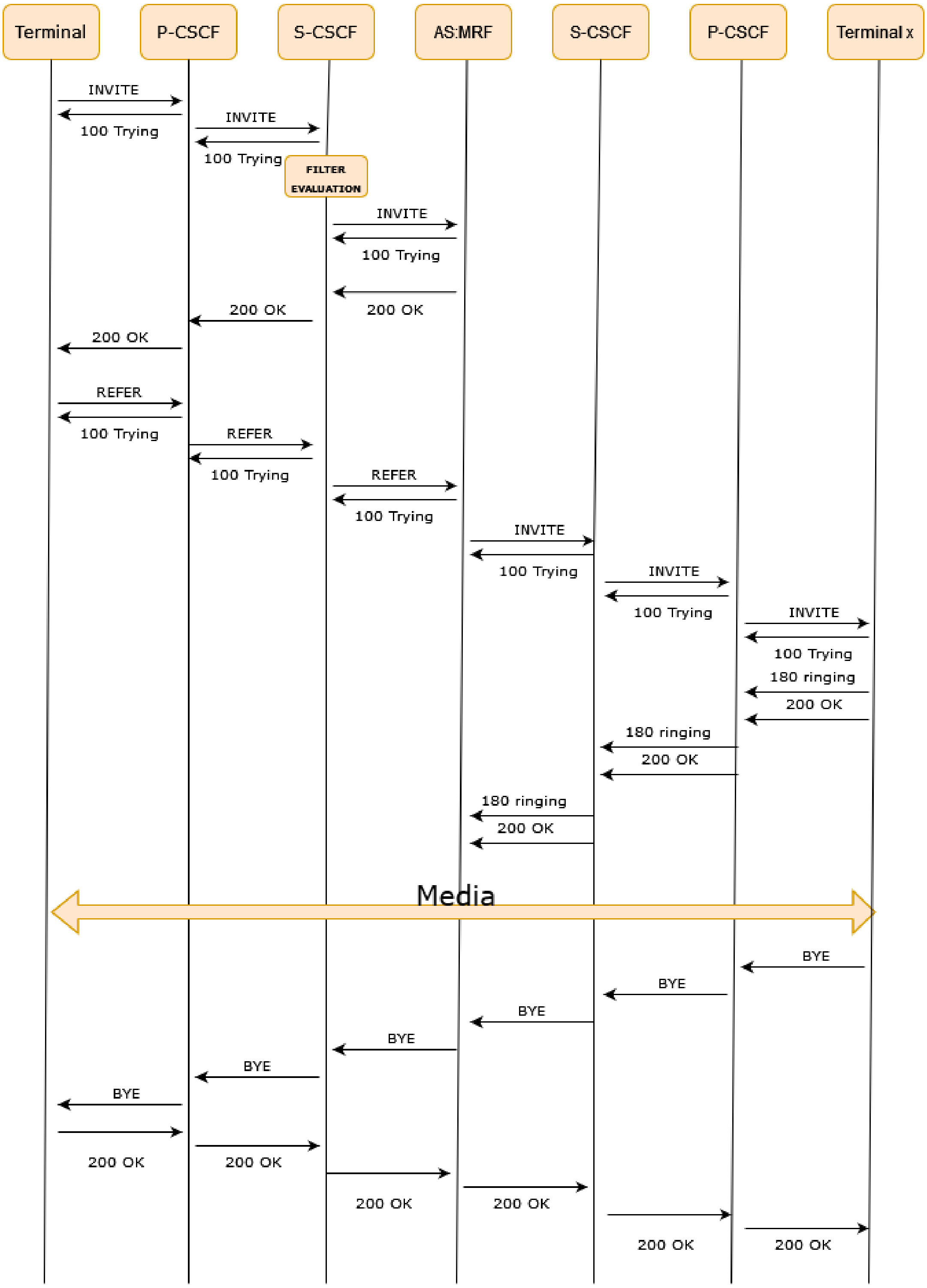


Figure 4.6: Call between two terminals making a video conference call

4.9.3 State of the Art: Providers comparison

	Free	*Open Source*	*Cloud computing*	*Services*	*Market Share*	*Associated costs*
Clearwater	Y	Y	Y	VoIP, WebRTC, includes video disabling, Instant messaging with SIP, VoLTE		
Open Source IMS	Y	Y	N			
ZTE	N	N	Y	VoNR, VoLTE, VoWiFI, VoBB, ICS and FMC, HD voice and HD video, Converged SMS		
Ericsson	N	N	Y	VoLTE and 5G voice, Wi-Fi calling, Enriched messaging, Enriched calling with pre-call info, Video calling, HD video conferencing, Web communication		
Mavenir	N	N	Y	VoLTE, VoNR, VoWiFi, VoiceMail, SMS and text messaging, RCS		
NEC	N	N	Y	3G mobile voice services, VoLTE, HD video calling, VoIP		
Nokia-Alcatel-Lucent	N	N	Y	Voice call (VoIP), VoLTE, VoWiFi, Video call (HD), Text messaging		
Cisco	N	N	Y	VoIP, VoLTE, RCS, SMS over LTE, HD video call		

Table 4.13: Providers comparison.

4.10 Network Management

NMS	*SolarWinds Network Performance Monitor*	*Auvik*	*Datadog Network Monitoring*	*Nagios XI*	*Zabbix*	*Icinga*	*LogicMonitor*	*Progress Whastapp Gold*	*ManageEngine OpManage*
Multi-user support	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Network discovery	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mapping	Yes – Automated device and connection maps	Yes	Yes, graph view	Yes, simple	Yes, manually	Yes, manually	Yes - Automated	Manual included. Automate connection maps available with WhatsConnected Add-on	Manual device mapping
Notifications	Email, SMS, scripts, twitter, etc	Yes, including MS Teams	Email, app, Slack…	Email, Telegram, SMS, audio	Email, SMS, script, MS Temas, Telegram…	Email, XMPP, IRC, Twitter…	Email, SMS	Email, SMS, scripts, twitter, etc.	Email, SMS, scripts, etc.
Alerting	Support for correlated events, sustained condition threshold, combination of device states	Emergency, critical, warning and info	Support metrics, integration availability, network endpoints…	Proactive. Support automated, integrated trending and capacity	Configurable	Warning and critical	Support datas sources, event, LM logs, websites, device groups, collectors	Support for polling dependencies, warning/critical thresholds, downtime scheduler	Support for polling dependencies, downtime scheduler, alert escalations
Monitoring abilities	SNMP polling	SNMP, WMI, VPN, ISP	SNMP, WMI, app	SNMP	Web, SNMP (trapping and polling), scriptable, Java app, IPMI, SSH	HTTP, SMTP, SNMP, SSH	SNMP, WMI, script	SNMP, WMI, ICMP, app polling (HTTP/SQL), agentless SSH	SNMP, ICMP, app polling (HTTP/SQL), agentless SSH
Reporting	Built-in and customizable	Built-in and APIs	Built-in	Built-in	Built-in and customizable	Built-in	Built-in	Built-in and customizable	Built-in and customizable
Syslog	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SNMP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Scalable	Yes (extra-cost)	Yes	Yes	Yes	Yes	Yes	Yes	Yes (extra-cost)	Yes (extra-cost)
Virtual device support	Native support for VMWare	Commercial cloud, Microsoft Hyper-V, Citrix Xen, VMware	Native (Amazon Linux, CentOS, Windows, Debian, Fedora, Red Hat, SUSE, Ubuntu..) or Docker image	Vmware, Vsphere, Hyper-V	Vmware	Vmware, VirtualBox	Cisco Hyperflex, Hyper-V, Nutanix, vCenter, Vmware	WhatsVirtual plugin adds native support for VMWare	Native support for VMWare
Live demo	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Trial software	Yes	Yes	Yes	Yes	Already free	Already free	Yes	Yes	Yes
Price	Startas at $2475 USD for 100 elements	Starting 150$/month	15$/host each month	$3,495	Open-source	Open-source	Not available	Starting at $2695 for 100 devices	Starts at $3495 USD for 100 devices (perpetual license)

Table 4.14: Comparison between the most popular Network Management.

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