An Analysis of Next Generation Access Networks Deployment in Rural Areas

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Abstract—Next generation access networks (NGAN) will support a renewed electronic communication market where main opportunities lie in the provision of ubiquitous broadband connectivity, applications and content. From their deployment it is expected a wealth of innovations. Within this framework, the project reviews the variety of NGAN deployment options available for rural environments, derives a simple method for approximate cost calculations, and then discusses and compares the results obtained. Data for Spain are used for practical calculations, but the model is applicable with minor modifications to most of the rural areas of European countries. The final part of the paper is devoted to review the techno-economic implications of a network deployment in a rural environment as well as the adequacy and possible developments of the regulatory framework involved.

Keywords: *next generation networks, fibre, mobile communications, 4g, electronic communications regulation*

I. BACKGROUND

The so-called Next Generation Networks (NGN) will be the supporting infrastructure of ubiquitous ultra-broadband. For the purposes of this paper, a NGN will be a single network which delivers multiple data applications –whether originally based on voice, data, and video- to multiple devices -whether fixed or mobile. In addition, it will be considered that the provision of services is decoupled from networks. The choice of access technology is simply a matter of costs (which in turn depend basically on demographic and geographic variables), possible re-use of existing infrastructures and the user's requirements (and expectations). The access part of a NGN is usually called Next Generation Access Networks (NGAN).

Precisely, the conditions for the deployment of NGAN are currently on the forefront of the debate about the role of telecommunication market developments, the best regulation for them and the level and modes of potential public involvement. In broad terms it can be said that we are currently in a very early stage of NGAN deployment – particularly out of main urban areas. This situation is influenced by relatively unknown technology roadmaps, possibly some doubts about the implementation of the regulatory scenario, as well as,

especially, the economic uncertainties about the return on investments.

From the perspective of techno-economics, there is not a one-size-fits-all NGAN: the most suitable type of NGAN depends heavily on the re-use of existing infrastructures and on the type of geo-demographic area (the “geotype”). Indeed, operators invest in areas that are profitable. As dense areas are more profitable than rural ones, dense areas will be served first. If we consider geographic density as a continuum, there is a point where operators stop investing because it is no longer profitable. In fact, in most rural areas low population density and high deployment costs discourage private investments, creating a negative feedback of limited capacity, high prices, and low service demand.

As the profitability of any area depends basically on infrastructure costs, which tend to decrease slowly over time, there are some possibilities of less dense areas to become profitable as time passes by [1], all other parameters equal. However, this effect could be too slow and meanwhile it would impact significantly on equity in territorial terms for a potential long period of time. In fact, currently there is little or no commitment to connect areas that include smaller towns and rural villages [2]. Data collected by OECD have shown that, among the developed countries, those with a large urban population such as South Korea, Japan, France and the Netherlands are more likely to achieve a higher rate of broadband penetration than those with significant rural communities such as the United States and Canada [3].

Therefore, it is necessary to analyse the more suitable choices for NGAN deployments in these areas, depicting and accurate scenario of related deployment costs. This is the main objective of this paper. For this, a simple method for cost calculations will be derived using the data for Spain for reasons of availability. However, it would be applicable to most of the rural areas of European countries. Based on the results obtained, the techno-economic implications of NGAN deployments in rural areas will be reviewed as well as the adequacy and possible developments of the existing EU regulatory framework.

II. GEOTYPES IN THE RURAL SCENARIO

The assumptions on geotypes for network deployment consider a classification in zones based on population density as the basic parameter affecting the cost of rolling out a NGAN. This is the most used approach to network deployment cost calculations, see for instance Analysis Mason [4].

For the particular case of Spain, a division into 10 different zones (numbered I to X) has been chosen. See Annex for a detailed description of the main parameters for the geotypes used in the calculations. Apart from the direct relevance of the case of Spain as a main European instance for NGAN deployment, it is interesting to note that data for Spain are relatively similar to the Euroland scenario [5]. The population in this area adds up to 46.4 million inhabitants, which is the mean of seven European states: France, Germany, Italy, Holland, Spain, Sweden and the United Kingdom. Demographically, Euroland is made up by a few urban areas with a high population density, a greater number of suburban areas, many rural areas and very few remote areas. Last, there are 15.4 million households in Euroland and, of the total inhabitants, 17.3 million are employed in 3.2 million companies.

It is also worth to note that previous studies usually considered 3 to 7 zones. For instance, in the Euroland scenario [5] it was assumed that 50% of the population lived in urban areas (6,000 inhab/km² population density), 35% in suburban areas (500 inhab/km² density) and around 15% in rural areas (30 inhab/km² density). Gómez-Barroso and Robles-Rovalo [6] chose a division into 7 zones for WiMAX calculations in México, including rural areas. This is also the number used in Jeanjean [1] for NGAN calculations. Analysis Mason [7], apart from London, also selected 7 zones for its study on fibre deployment in the UK, however leaving aside the rural and remote areas. The motivation for using 10 different zones lies in enjoying more precise estimations in the “grey” areas that the competitive market providers could reach in the medium term as a function of technology, demand and public policies. In fact in the case of Spain about one quarter of the population lives in the 500 – 100 inhabitants/Km² area, where the population density typical of suburban zones finishes and the rural type-of-density begins. Also in Spain, about 46% of the population lives in urban areas (above 1000 inhabitants/Km²), with an additional 10% in lower-density suburban areas. Remote rural areas (below 50 inhabitants/Km²) made up 12% of the population, but 77% of the territory.

However, the main drawback of a classification based on population density is the lack of information on buildings clustering, mainly for suburban and rural areas. Therefore, to enhance the modelling of the deployment costs, each of the zones has been divided into two types, (a) and (b), resulting in a total of 18 geotypes for the calculations (in zones IX and X the population density is so low that all population is assumed to be distributed according to the b model). Looking from the perspective of network deployment, the key element for this additional categorisation is the location of the local exchange, cable headend or base station. For instance, exchanges tend to cover the central core of a settlement and, at the same time, some wider areas where the settlement is sparser [4], see Fig. 1.

Figure 1. Geotypes a) premises close to the local exchange, and b) premises sparse and far from the local exchange. Source: adapted from Analysis Mason [4]

The share of potential subscribers (inhabitants, households and businesses) among these two geotypes has been calculated using 5 prototypical municipalities (those closer to the average population and surface) for each of the zones. In each of these municipalities it has been possible to obtain the percentage of surface for dense urban¹ and scattered urban and suburban areas² using data from Spanish Housing Ministry [8]. The resulting population-weighted average has been regarded as representative of the situation in each of the zones.

III. TECHNOLOGIES FOR RURAL DEPLOYMENT OF NGAN

In general, broadband access technologies are classified by the physical medium in two major groups: wired –or fixed line– technologies and wireless technologies. The main wired technologies are based on fibre, coaxial, copper wire and power line. In the following we will consider the first three of them, leaving aside power line due to its low implantation and weak mass market prospects³. When classifying wireless technologies two main sets of characteristics are considered: being terrestrial or satellite-based and being fixed wireless or mobile wireless. Due to the requisites of NGAN – very high bandwidth for each user– only the terrestrial solutions will be considered in the following⁴.

¹ When more than 80% of the surface is covered with buildings and roads.

² When the surface is covered with buildings and roads associated with areas of vegetation or land occupying between 30-80% of the total surface.

³ However it is widely used in the home environment and as part of the smart power grids concept, for further details see, for example, [9] N. Pavlidou, et al., "Power Line Communications: state of the art and future trends," IEEE Communications Magazine, vol. 41, pp. 34-40, 2003.

⁴ For the sake of comparison, according to Eutelsat the next generation of satellites at Ka-band (scheduled to be launched in 2011) will provide 35 times more throughput than traditional Ku-band satellites, will use spot beam technology, and it will be able to provide typically dedicated coverage in 80 set areas delivering shared downstream speeds of 10 Mb/s and 2 Mb/s upstream to users in those areas.

Each of technologies considered for the study has its advantages and disadvantages in terms of maximum bandwidth/transmission speed, reliability, cost of deployment and ease of coverage. Therefore there is not an obvious choice for all situations, and in practice a telecommunications operator will likely use a “mix” of technologies, as later discussed. Table I overviews some of the main milestones and features of the technologies involved in the deployment of NGAN compiled by the authors from publicly available industry data and forecasts.

TABLE I. MAIN FEATURES OF POTENTIAL NGAN TECHNOLOGIES FOR RURAL DEPLOYMENT

Features	NGAN Technology			
	<i>FTTH GPON</i>	<i>FTTC FTTB VDSL</i>	<i>HFC DOCSIS 3.0</i>	<i>LTE (4G)</i>
Theoretical max. data rates	2,50 Gb/s ^a (downstr.) 1,25 Gb/s (upstream)	100 Mb/s (downstr.) 50 Mb/s (upstream)	400 Mb/s (downstr.) 100 Mb/s (upstream)	300 Mb/s (downstream) 75 Mb/s (upstream)
Typical data rates per user	100-250 Mb/s (d) 50-100 Mb/s (u)	30-50 Mb/s (downstr.) 5-15 Mb/s (upstream)	50 Mb/s ^b (downstr.) 10 Mb/s (upstream)	1-10 Mb/s ^c (downstr.) 1 Mb/s (upstream)
Begin of massive deployment in EU	2009 - 2012	2007 - 2010	2009 - 2011	2011 - 2013
Enhanced version max. data rate	10G GPON 10 Gb/s	Advanced DSL 100-300 Mb/s	DOCSIS 4.0 10 Gb/s	LTE Evolution 1 Gb/s
Critical technologies	WDMA	ONU	CPE	OFDMA
Main advantage	Guaranteed data rates	Re-use of legacy network	Re-use of HFC network	Evolutionary from 3.5G
Main barrier (as of July 2011)	Deploy. cost	Opto-electronic equipment	Shared media	Availability of devices Shared media

a. Single fibre with current technology

b. Depends on number of concurrent users

c. Depends on number of concurrent users and size of cell

The inclusion of 4G mobile technologies among NGAN might be controversial. In fact, as a general consideration, wireless technologies are around 3 to 5 years behind fixed ones in terms of data rates per user. However, they are about to reach the 10 Mb/s level per user with some consistency with peak speeds around 100 Mb/s. As a consequence a number of experts from the industry forecast that mobile broadband connections will overcome fixed ones sometime around 2011-2013 [10-12] and its impact will be considerable from NGAN perspective [13]. To this regard, and in the long run, the massive deployment of femtocells, mobile devices with cognitive radio capabilities and mesh network topologies could make wireless networks almost indistinguishable from most of today's ultra-broadband fixed solutions.

IV. METHODOLOGY

The methodology for the calculation of the deployment costs for NGAN technologies in rural scenarios departs from a

number of assumptions. First, the backbone network will not be included in the calculations⁵. Secondly, legacy networks will be considered where possible to re-use part of the infrastructure previously built by the same or other operators. The model has chosen the parameters for a situation reasonably as close to reality as possible. Data on lengths, types of terrain and re-use of existing infrastructures will be based on own estimations, see Annex for details.

Also the potential sharing of infrastructures between competitive providers has not been considered. On the one side, the presence of several operators leads to a potential lower utilization of assets per customer, as the customer base is shared among players, and therefore, increases the costs with regard to a monopolistic situation. On the other side, several operators depending on their commercial agreements, or the imposed regulations, can share different combinations of the infrastructures, decreasing the incurred costs per customer. Some implications of sharing infrastructures among operators are briefly considered in the results section.

Next, the model presented in this paper intends to be as agnostic as possible with regard to demand, as it had been pointed out before⁶. However it is required to include some assumptions about it since some of the costs calculations are dependent on the actual number of customers in the network. To simplify the calculations take-up is assumed to represent net additions to the network (therefore including the effect of churn) and it is also assumed that it will happen at 10% constant rate with regard to the total of potential subscribers. This means that if, for instance, the network is deployed in 4 years, the level of 80% of the total potential subscribers would be reached in 9.5 years. Once the maximum level of subscribers is attained it will remain indefinitely at that number. Obviously, this is an optimistic scenario for each technology in terms of adoption, but from the perspective of costs is a worst-case scenario. The churn rate will be 20% of existing customer base or, equivalently, on average each customer changes operator every five years, a figure similar to the existing churn in mobile networks.

To calculate the present value of investments, a weighted average cost of capital (WACC) of 12% is considered, in

⁵ For the interested reader the paper from De Antonio et al (2006) offers some estimation on the capex and opex for building such a backbone network from the scratch, using both a top-down analysis and a bottom-up approximation. For example, considering a case similar to Spain, the backbone network included 8 core routers, 77 service edge routers and 23,000 aggregation devices for the access traffic and the appropriate length of fibre. It was calculated that the investment needed (including the backbone, aggregation and edge sections) amounted to 8.300 M€. [14] J. De-Antonio, et al., "A European perspective on the deployment of next generation networks," The Journal of the Communications Network, vol. Vol 5, part 2, pp. 47-55, 2006.

⁶ Other potential choice would be to decide that the network is absolutely universal and minimum demand assumptions are made, an approach used for instance in De Antonio et al [14] *ibid.*. However, this is thought as too unrealistic, leading to increased cost estimations.

accordance to previous studies⁷ and financial conditions for European broadband operators [7]. The rate of average yearly inflation is estimated at 2%, the objective of the European Central Bank. Operating expenses are calculated just for the 10 first years of operation.

V. DEPLOYMENT MODEL DESCRIPTION

As regards the deployment model, it is considered that the network will reach 100% both of individual and business users⁸ in 10 years. From here it should be noted that potential users are not the same for fixed and mobile technologies. The total number of potential users of fixed networks is 17.9 million. However, only up to 80% of them will subscribe to a given network, i.e., they will be customers of a particular broadband service offering. The total number of potential users of mobile networks is 53.3 million, representing a 114% mobile penetration, similar to the latest data available for Spain [15]. Again, only up to 80% of them will belong to a given network at a certain time and in a certain area.

Three different network models are used in order to calculate the CAPEX and OPEX of wired (FTTH and DOCSIS technology) and wireless technologies that can be deployed, as depicted in Figs 2 to 5, and detailed in the Annex.

The detailed information about ratios and distributions of the distances, as well as the cost of every item involved in the deployment, operation maintenance and management of the networks considered are presented also in the Annex.

The limiting factor for quality in a FTTH-GPON and in a FTTC/VDSL2 deployment is the shared OLT card managing one fibre at the local exchange. For the calculations it has been supposed that each OLT card can manage 2,5 Gb/s per 64 users maximum. It has been also assumed that in FTTC/VDSL 20% of the users (those very close to it) can be served directly from the local exchange using existing copper wire and without installing any fibre. In the DOCSIS case, the limiting factor for quality is the number of channels shared among customers at the headend. Two implementations have been chosen: the first just the update of the existing network for DOCSIS 3.0 and a new implementation able to offer 50 Mb/s per user 80% guaranteed. The figures for this last implementation could be equivalent to a new plant deployment (no re-use of ducts and a ring topology). Finally, the limiting factor for quality in a LTE deployment is the amount of spectrum bandwidth allocated to a single operator. It has been set at 1800 Mb/s as the maximum total speed available for all users covered by the cell.

Figure 2. Sections for cost calculations in FTTx

Figure 3. Sections for cost calculations in cable DOCSIS 3.0

Figure 4. Sections for cost calculations in 4G mobile communications

All the data for network element costs are supplied by the industry at 2011 prices, either publically or through direct interviews.

VI. RESULTS AND DISCUSSION

In this section the results of the cost modeling of the different options for a NGAN are presented. All the costs are discounted to give their present value.

A. Capex, opex, total costs and level of investment

To begin with, the present value of the total capex by areas of maximum 16,384 users and by geotype is shown in Table II. Note that the figures presented are a good approximation to the capital investment required to deploy a neutral operator in a typical municipality of each of the geotypes, re-using existing civil infrastructures where possible.

⁷ This value has been calculated adding the interest rates (around 2 to 3%) to a 7-9% representing investment-related financial and market risks.

⁸ For comparison, in the Analysis Mason report for Ofcom the fibre network only reaches 66% of potential users [7] Analysis Mason, "Competitive models in GPON," Ofcom, London 1st December 2009.

TABLE II. PRESENT VALUE OF TOTAL CAPEX (M€) FOR ACCESS AREA (MAX. 16,384 USERS) AND BY GEOTYPE

Geotype	NGAN Technology			
	<i>FTTH GPON</i>	<i>FTTC VDSL</i>	<i>HFC DOCSIS 3.0^a</i>	<i>LTE (4G)^b</i>
VI (500-100 inh/km ²)	9.44	3.89	15.67	6.40
VII (100-50 inh/km ²)	1.60	0.75	3.92	1.51
VIII (50-10 inh/km ²)	1.53	0.37	1.96	0.73
IX (10-5 inh/km ²)	0.58	0.29	0.49	0.22
X (<5 inh/km ²)	0.40	0.07	0.24	0.12

a. Max. 50Mb/s

b. At 2.6 GHz

The present value of the total capex by zone is presented in Table III, while the annualized (i.e., divided by the number of years for the roll-out) present value per user is shown in Table IV. This table is provided to supply an easy comparison as a minimum floor with annual ARPU levels. From the figures it can be seen that, rather obviously, the costs increase with lower densities of population. They also show that wireless technologies are more cost-efficient in these lower density areas. On the contrary, it is in the higher density areas where FTTC-VDSL and DOCSIS are the less expensive as they re-use the existing infrastructures. Note that FTTH is the costlier option whatever zone is considered.

TABLE III. PRESENT VALUE OF TOTAL CAPEX (M€) BY GEOTYPE

Geotype	NGAN Technology			
	<i>FTTH GPON</i>	<i>FTTC VDSL</i>	<i>HFC DOCSIS 3.0^a</i>	<i>LTE (4G)^b</i>
VI (500-100 inh/km ²)	2,298	948	3,813	1,558
VII (100-50 inh/km ²)	518	241	1,269	489
VIII (50-10 inh/km ²)	1,356	329	1,738	646
IX (10-5 inh/km ²)	364	184	309	140
X (<5 inh/km ²)	261	49	161	84

a. Max. 50Mb/s

b. At 2.6 GHz

TABLE IV. ANNUALISED PRESENT VALUE OF CAPEX PER USER (€) BY GEOTYPE

Geotype	NGAN Technology			
	<i>FTTH GPON</i>	<i>FTTC VDSL</i>	<i>HFC DOCSIS 3.0^a</i>	<i>LTE (4G)^b</i>
VI (500-100 inh/km ²)	576	238	957	391
VII (100-50 inh/km ²)	390	182	956	369
VIII (50-10 inh/km ²)	746	181	956	357
IX (10-5 inh/km ²)	1,127	570	957	437
X (<5 inh/km ²)	1,554	289	957	482

a. Max. 50Mb/s

b. At 2.6 GHz

Another very relevant aspect of comparison among NGAN technologies refers to the cost of guaranteed data rate per user. Usually, when comparing these technologies, this very fundamental perspective is not clearly considered if at all. Table V shows the cost of 10 Mb/s of guaranteed data rate per user for different NGAN technologies and by geotype. Note that for these calculations, the size of the access area in the case of wireless technologies has had to be reduced, therefore increasing the costs of deployment with regard to above results. Also cable has assumed to be already deployed and only the upgrade to DOCSIS 3.0 is needed.

TABLE V. COST OF 10 MBPS GUARANTEED DATA RATE PER USER (€) BY GEOTYPE (50% PENETRATION)

Geotype	NGAN Technology			
	<i>FTTH GPON^a</i>	<i>FTTC VDSL^b</i>	<i>HFC DOCSIS 3.0^c</i>	<i>LTE (4G)^d</i>
VI (500-100 inh/km ²)	1,149	632	251	6,075
VII (100-50 inh/km ²)	259	161	84	1,901
VIII (50-10 inh/km ²)	678	220	114	2,508
IX (10-5 inh/km ²)	182	123	20	550
X (<5 inh/km ²)	131	32	11	328

a. 40 Mbps

b. 30 Mbps

c. 30 Mbps

d. 10 Mbps

Opex per user for the year 2015, a year representative of established operations, is shown in Table VI. Opex is dominated by typical operating costs: maintenance, support, billing, etc, in any technology.

TABLE VI. OPEX PER USER (€) FOR THE YEAR 2015

Geotype	NGAN Technology			
	<i>FTTH GPON</i>	<i>FTTC VDSL</i>	<i>HFC DOCSIS 3.0^a</i>	<i>LTE (4G)^b</i>
Opex per user	204	208	218	197
Support, management and provision per user	58	75	85	30

a. Max. 50Mb/s

b. At 2.6 GHz

Finally, the present value of the total cost per subscriber by geotype is presented in Table VII.

TABLE VII. ANNUALISED PRESENT VALUE OF CAPEX PER USER (€) BY GEOTYPE

Geotype	NGAN Technology			
	<i>FTTH GPON</i>	<i>FTTC VDSL</i>	<i>HFC DOCSIS 3.0^a</i>	<i>LTE (4G)^b</i>
VI (500-100 inh/km ²)	826	277	1,020	594
VII (100-50 inh/km ²)	717	222	1,022	571
VIII (50-10 inh/km ²)	1,167	220	1,022	558
IX (10-5 inh/km ²)	1,569	610	1,023	635

Geotype	NGAN Technology			
	FTTH GPON	FTTC VDSL	HFC DOCSIS 3.0 ^a	LTE (4G) ^b
X inh/km ²) (<5)	1,997	328	1,026	704

a. Max. 50Mb/s

b. At 2.6 GHz

B. Sensitivity analysis

Departing from the base calculations presented in the previous sub-section, Table VIII presents the effects on the costs of several other situations.

TABLE VIII. SENSITIVITY ANALYSIS (%) OF PRESENT VALUE OF TOTAL COSTS

Geotype	NGAN Technology		
	FTTH GPON	FTTC VDSL	LTE (4G) ^a
Deployment in 5 years instead of 10 years	22%	16%	34%
Coverage of 80% of premises instead of 100%	-40%	-27%	-19%
Coverage of 60% of premises instead of 100%	-59%	-46%	-40%
Increase of 10 Mb/s of guaranteed speed per user	1%	12%	69%
Increase of WACC from 12% to 15%	-7%	-5%	-8%
Decrease of 30% of civil works cost	-22%	-11%	-14%
Sharing passive infrastructures between 2 operators	-20%	-10%	-5%
Increase of 40 MHz of allocated spectrum	-	-	-10%

a. At 2.6 GHz

VII. A DECALOGUE OF CONCLUSIONS

Undoubtedly, the deployment of NGAN is the technical and business element around which the future evolution of the information and technology sector revolves. However, numerous uncertainties remain regarding their development. Some operators have started to invest but maintain their doubts over whether the applications and services offered over a NGAN shall be sufficient to provide a return to investment specially in rural areas and, at present, they are not sure which killer application, if any, will develop to provide sufficiently a new revenue stream for ultra-broadband networks.

In this scenario of uncertainty, more research works are required focusing on the economic, financial and regulatory aspects of NGAN in rural areas. The analysis that has been presented here, although quite simple and rough, allows extracting a few important consequences.

A. Investment, investment, investment

First, and the datum is not less important despite being expected, it is clear that –any– NGAN requires major

investments. Also, and as a consequence, the recovery of these investments implies that the prices charged for access and usage of the services will not differ much of current prices. Every study agrees on this point [1, 4, 7, 14]. Thus, it seems probable that the companies interested in deploying NGAN will aim first towards competition in new and attractive offers of services for the users than in prices, since any war of prices entails a reduction of the present and future ARPU.

B. A technology “mix”

Should the demand for large bandwidths appear, the case could be that no access technology by itself, at least with the technical and economic conditions expected as of today, could present the optimal characteristics for satisfying all the requirements demanded by the users in every circumstance. This has been shown in the model presented where the cheapest technologies per user are those offering the lowest speeds and the contrary being also true. However, the prices per 10 Mb/s show a different picture. Here, those technologies, such as FTTH, able to supply higher speeds appear as more competitive. They are also the technologies more easily scalable if the target is to increase significantly the speed over the existing infrastructure in some future. Wireless technologies lie in some middle ground: low speeds and intermediate costs.

Therefore, the case of different advantages and drawbacks for each technology, backed by the need to achieve a return on the investments, is leading operators to create platforms capable of integrating different access technologies over the same backbone network. The future market of the information and communications sector, characterised by “comprehensive” operators, would be, in this case, quite different from the current one, where there is a clear separation between technologies. Thus, any –policy, regulatory– measure to facilitate the “mix” of technologies without compromising competition would help to produce the case for the deployment of NGAN.

C. Distinct departure points and transition paths

However, the departure point for the different types of operators (historic, cable, wireless, alternative and even new agents) is not the same. These initial differences are conditioning, and shall do so in the future, the path followed for the transformation of their networks into NGAN. The cost calculations carried out support this first impression. As a consequence, each operator will have a different set of drivers for migrating to NGAN [16]. These drivers will dictate their base timeframes for investing in this advanced infrastructure, and subsequently migrating services from existing networks.

D. Each NGAN is different

Comparing different types of NGAN from the supply side is a difficult exercise with significant risks. In fact, a careful look into NGAN reveals that there are no easy conclusions.

Data rates are arguably the most tempting parameter for such a comparison. If we take an absolute value such as 50 Mb/s, not even a currently typical implementation of FTTH will ensure this speed for 100% of the users all of the time. Therefore, the expected market share and the expected number

of concurrent users matter to set the real data rate. In particular, cable DOCSIS, due to its “shared-channel” architecture, is a system where the number of concurrent users changes dramatically the maximum speeds available, restricting at times even the meaningfulness of comparisons among implementations of the same technology. But also matters time. Maybe today’s implementation of VDSL only reaches 30 Mb/s at several hundred metres from user premises, but new developments promise to exceed 50 Mb/s at distances above 1 Km. And not each NGAN addresses the same type –and amount- of users. Wired networks are typically for premises and wireless networks for persons. Therefore wireless systems can serve about three times the subscribers of a fixed network (and enjoy up to triple revenues). At the same time boundaries blur: picocells and femtocells create a convergence where both fibre and radio are needed and no longer is the distinction between technologies valid.

E. Sharing infrastructures

Sharing infrastructures has already been considered in the regulation, see Ruhle & Lundborg [17] and it is an area where operators are showing renewed interest. According to the model developed, sharing infrastructures can decrease costs significantly. This is not only important for wired solutions, but for wireless players, where they can achieve higher savings if they go beyond the mere civil works to share some types of active equipment –up to 30% according to Norman [18]- or even spectrum. Apart from reducing costs, infrastructure sharing can accelerate roll-out, stimulate competition, decrease the troubles of deployment for the public and have environmental benefits (sharing power supplies for instance). There are also some evident risks of collusion.

F. Long life to copper wires

Copper lines continue to be a strategic asset well into the middle term. Not only are they able to provide right now speeds that would fall into the NGAN category but, in addition, they allow for a smoother and more scalable path in the transition from ADSL to FTTH. Indeed, about 20% of potential subscribers to a NGAN live close enough to the local exchange so as to be directly provided with a VDSL2 solution from this local exchange and, therefore, requiring just a modest investment in the equipment there. Existing copper –in the part closer to subscriber premises- also allows rolling out FTTC and FTTB solutions to be completed with VDSL2 that could serve as a first step towards a definitive FTTH solution while re-using all fibre deployed so far. Last but not least new developments complemented by fibre could extend the copper capacity well into the 100 Mb/s range.

G. Cable networks, the key to a competitive landscape

The upgrade of existing cable networks with DOCSIS 3.0 is, together with VDSL from local exchange, the cheapest alternative for the deployment of NGAN in a country such as Spain. Therefore, cable networks, where they already exist, play a key role in the competitive scenario. Therefore, from the perspective of competition among different providers of NGAN, an interesting solution would be to ensure that, maybe even with some type of public support, the conditions for the

cable operators to obtain the required funding are met and they effectively deploy these solutions into the market as soon as possible.

Moreover, cable operators in Spain have a highly relevant asset when taking the perspective of NGAN: according to CMT [19] figures almost 40% of premises have, in addition to coaxial cabling, a copper wire deployed in parallel with the former. Due to the architecture of cable networks this copper line runs typically for the last 500m to user premises. Therefore, there would be possibilities to re-use this copper wire (with VDSL2, for instance) to provide an additional means of deploying NGAN for interested parties.

H. NGAN, wireless solutions and spectrum

It has not been properly understood yet the role of wireless access technologies as a fundamental part of NGAN. In fact, their use for access from mobile operators it is just a different way to address the same broadband target, but, adding along the road, the mobile advantages: a maybe much more reasonable approach in terms of financing and technology evolution, avoiding the disruptive leaps required in fixed infrastructures. In addition, wireless NGAN are the only scalable solution in terms of infrastructures for areas of low density of population. They are also a complement to NGAN competition in almost any area.

At the same time, it is true that radio-based systems are able to provide today about one tenth of sustained speed compared to wireline solutions and that this difference has been kept constant for the last years. But it is also true that the developments required to improve the capabilities of radio-based systems are at –close- sight: opening of additional spectrum, more efficient spectrum management practices, much smarter radios to access appropriate frequencies at each moment and process signals more efficiently. Therefore, although there is “a limit to the ability of wireless technology to be full players in high-speed Telecom 3.0” [20] and the investments are considerable, there is still room enough for wireless to play a role in medium-speed uses or even higher at low density of population rural areas. As the model shows, 5 Mb/s of mobile sustained speed, with much higher peaks depending on the number of concurrent users, and at a cost below that of FTTH could have a significant impact of the NGAN market. This result is coincident with some recent studies. For instance, according to Analysis Mason, terrestrial wireless technology could be used to provide broadband connections to the final 15% of UK homes not covered by fiber connections. They also acknowledge that the wireless element would be sufficient for households of average usage, after modeling low, medium and high-use scenarios, but only if the number of base stations and spectrum available was increased [21]. Therefore, the usage of spectrum for wireless solutions appears as a main element in configuring the NGAN landscape.

Two are the main relevant parameters for allocation of spectrum to wireless operators: the amount of spectrum (bandwidth) and the band of operation.

The amount of spectrum required per mobile operator depends fundamentally on the level of quality of service, including the number of users concurrently accessing mobile

data –density of users-, type of usage –more than 90% of traffic non-voice in 2013 [12], evolution of user perceptions about service quality, and the size of the cell relative to the population density. But also depends on the ability of the mobile transmission technology to manage and re-use frequencies and on the topology and type of the network. In the calculations for the model it was allocated at least 40 MHz of spectrum (already a considerable quantity) to achieve a relatively modest 5Mb/s data rate. It is obvious that, maintaining the level of investment, more bandwidth would be required to offer higher speeds to users. Therefore, a significant new quantity of spectrum should be freed up and allocated to operators so as to turn wireless solutions in an actual opportunity. This road is precisely being taken by a number of countries. For instance, the FCC has the ambitious goal to make 500 MHz of spectrum available for mobile broadband over the next 10 years, 300 MHz of them in the next five years. In the case of the EU, the need for spectrum has prompted to adopt a decision aimed at harmonising the allocation of the 790-862 MHz band spectrum, the well known digital dividend. In addition, the amount of frequency spectrum allocated to an operator has also a direct impact on costs, as it allows delivering more speed per user without decreasing the size of the cell.

The choice of the frequency band for the allocation has a significant impact on costs. For instance, the EU claims that infrastructure equipment for the 800MHz band was expected to be 70 % cheaper than that required for the radio frequencies in use on 3G networks. It has also advantages in terms of propagation, since it should provide operators with improved coverage and in-building penetration in comparison with most current 3G bands. Due to this propagation effects in theory it would look like the lower frequencies of operation saving a significant amount of base stations. But this is only partially true. The limiting factor in a wireless NGAN of the type described in this report is the quality of the service per user, and not the maximum coverage of the cell as a function of the frequency of operation. However, using lower frequencies allows an initial deployment with much less base stations that later could be completed at the same or other frequencies, and it still valid as the best solution for low density areas.

I. A baseline for the market and for policy action

The above considerations translate in a baseline for market behaviour. In 2015 it would be relatively possible for Spain to enjoy a “2+” infrastructures-based competition (incumbent, cable operator and mobile operators) for NGAN at about 50% of premises (i.e., 9 million of households and businesses). Beyond this point the required investments would be much higher. The cheapest choice would be for a “1+” infrastructures-based competition (incumbent using VDSL-type technology and mobile operators) in an additional 10% of the population, with an added cost for the VDSL of about 400 M€. For the rest of the population, the most probable option would be no access to NGAN except maybe some scattered local initiatives and some mobile 4G deployments in some particular areas, very dependent on the conditions on new spectrum licences. These figures appear lower than the objectives set out in the “Avanza” plan [22]: 70% of the population with availability of broadband at a 50 Mb/s speed or higher and 60%

of the population with availability of broadband at a 100 Mb/s speed or higher. No regulatory “carrot” seems able to easily increase the investment in the required zones, and neither a huge public effort to compensate lack of pure market action seems possible under the current economic conditions.

J. The limits of market action in the rural areas

In the case of Spain the transition between semi-urban and rural areas happens between zone V (zones I-V include 57% of the population and just 1,4% of the surface) and VI (zones VI-X include the remnant 43% of the population and 98,6% of the surface). In other words, the discontinuity in potential profitability appears at the 500 inhabitants/km² population density where the figures for capex per user jump well over the 1.000 € threshold for any technology, and where the “growth of costs overcomes the growth of the consumption of households in broadband communications” [23].

Thus, as the profitability of this areas depends basically on infrastructure costs, which tend to decrease slowly over time, there are some possibilities of less dense areas to become profitable as time passes by [1]. However, this effect could be too slow and meanwhile it would impact significantly on equity in territorial terms for a potential long period of time.

The picture on the investments required to cover the less dense zones looks rather different when just a small area is considered. Here, because, just one area is considered, it would be possible to deploy a NGAN in a small town or village at an affordable cost, especially if taken into consideration the slow development of the market towards these areas. We could, therefore, be confronted relatively soon with a “patchwork” of local initiatives which try to solve the market failures by their own means.

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ANNEX – DEMOGRAPHIC DATA

TABLE IX. SUMMARY OF DEMOGRAPHIC DATA FOR SPAIN (2001 FOR POPULATION AND HOUSEHOLDS, 2009 FOR BUSINESSES). SOURCE: INE [24, 25]

Zone	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
<i>Population density</i>	<i>>10 000 hab/km2</i>	<i>10- 5 000 hab/km2</i>	<i>5 - 3 000 hab/km2</i>	<i>3 - 1 000 hab/km2</i>	<i>1 000 - 500 hab/km2</i>	<i>500 - 100 hab/km2</i>	<i>100 - 50 hab/km2</i>	<i>50 - 10 hab/km2</i>	<i>10 - 5 hab/km2</i>	<i>< 5 hab/km2</i>	
Number of municipalities	17	28	46	175	209	946	745	2705	1444	1797	8112
Total population	2 707 360	6 300 119	3 832 203	8 596 709	5 016 333	11 326 891	3 574 008	4 406 394	668 735	317 055	46 745 807
Population per municipality	159 256	225 004	83 309	49 124	24 002	11 973	4 797	1 628	463	176	5 763
% of national population	5,79 %	13,48 %	8,20 %	18,39 %	10,73 %	24,23 %	7,65 %	9,43 %	1,43 %	0,67 %	100 %
% of national population (accumulated)	5,79 %	19,27 %	27,47%	45,86 %	56,59 %	80,82 %	88,47 %	97,90 %	99,33 %	100 %	100 %
Total surface (km2)	179,14	1 086,33	969,99	5 278,55	7 103,38	50 561,39	52 638,58	185 348,40	92 937,96	108 573,47	504 677,19
Surface per municipality	10,54	38,80	21,09	30,16	33,99	53,45	70,66	68,52	64,36	60,42	62,21
% of national surface	0,04 %	0,22 %	0,19 %	1,05 %	1,41 %	10,02 %	10,43 %	36,73 %	18,42 %	21,49%	100 %
% of national surface (accumulated)	0,04 %	0,26 %	0,45 %	1,50 %	2,91 %	12,93 %	23,36 %	60,09 %	78,51 %	100 %	100 %
Population density (inh/km2)	15 113	5 799	3 951	1 629	706	224	67,9	23,8	7,20	2,92	92,63
Number of buildings	150.991	349.457	292.268	1.001.308	768.534	2.546.655	1.195.033	2.088.085	517.713	374.469	9 284 513
Inhabitants per bulding	17,93	18,03	13,11	8,59	6,53	4,45	2,99	2,11	1,29	0,85	5,03
Buildings density (b/km2)	842,87	321,69	301,31	189,69	108,19	50,37	22,70	11,27	5,57	3,45	18,40
Number of households	956.677	2.076.924	1.170.050	2.509.817	1.406.991	3.106.774	1.056.207	1.486.870	273.065	143.794	14.187.169
Persons per household ^a	2,63	2,74	2,95	2,88	2,91	2,96	2,93	2,78	2,55	2,37	2,85
Number of businesses ^b	247.676	536.081	311.978	709.653	400.875	880.898	270.780	330.552	50.376	24.361	3.763.229
Number of households and businesses (n _{user})	1.204.353	2.613.005	1.482.028	3.219.470	1.807.866	3.987.672	1.326.987	1.817.422	323.441	168.155	17.950.398
Households and businesses per building	7,82	7,34	4,96	3,14	2,29	1,53	1,08	0,85	0,61	0,44	1,89
Multi-dwelling units	110.542	236.055	146.786	395.617	254.702	678.233	274.232	383.016	72.718	49.757	2.601.658
% of total buildings	73%	68%	50%	39%	32%	27%	23%	18%	14%	13%	28%
Single-unit buildings	40.449	113.402	145.482	614.181	542.133	1.833.646	921.000	1.706.285	442.955	323.816	6.683.349
% of total buildings	27%	32%	50%	61%	68%	73%	77%	82%	86%	87%	72%

a. INE data only gives number of households with 1, 2, 3, 4, 5, 6 and 7 or more persons. The figures in the table have been obtained supposing a maximum number of 7 persons per household

b. Businesses per municipality are obtained from businesses per province distributed proportionally to the population of the municipality. This approach includes the number of different locations for the same business.

TABLE X. NUMBER OF POTENTIAL SUBSCRIBERS TO NGAN AS A FUNCTION OF GEOTYPE. SOURCE: OWN ESTIMATIONS FROM INE [24, 25] AND MINISTERIO DE VIVIENDA [8]

Geotype	Total potential subscribers (households + businesses)	Total population	% of potential subscribers and population per zone a/b
VIa (500 – 100 inh/km ²)	1.232.210	3.500.065	31%
VIb (500 – 100 inh/km ²)	2.755.461	7.826.826	69%
VIIa (100 – 50 inh/km ²)	741.787	1.997.873	56%
VIIb (100 – 50 inh/km ²)	585.200	1.576.135	44%
VIIIa (50 – 10 inh/km ²)	790.356	1.916.242	43%
VIIIb (50 – 10 inh/km ²)	1.027.066	2.490.152	57%
IX (10 – 5 inh/km ²)	323.441	668.735	100 %
X (<5 inh/km ²)	168.155	317.055	100 %

ANNEX – COST CALCULATIONS ASSUMPTIONS

TABLE XI. NUMBER OF POTENTIAL USERS (PREMISES) PER ACCESS AREA, SPLITTER RATIO AND NUMBER OF FIBRES, DIVISION POINT, CABINETS AND DISTRIBUTION BOXES PER GEOTYPE

Zone	Number of users per access area (n_{area})	Minimum number of fibres at the exchange (n_{fibre})	Total splitter ratio (r_{split} $=r_{split1} \times r_{split2}$)	Number of fibres at each A segment (n_{fibreA})	Number of division points at A-B (n_{divAB})	Number of fibres at each B segment (n_{fibreB})	Number of cabinets (n_{cab})	Number of fibres at each C segment (n_{fibreC})	Number of division points at C-D (n_{divCD})	Number of fibres at each D segment (n_{fibreD})	Number of distribution boxes (n_{box})
VI (500-100 inh/km ²)	16384	256	8x8	96 (min 64)	4	16 (min 8)	32	96 (min 64)	32	16 (min 6)	342
VII (100-50 inh/km ²)	4096	64	8x8	24 (min 16)	4	8 (min 4)	16	48 (min 32)	16	16(min 6)	86
VIII (50-10 inh/km ²)	2048	32	8x8	16 (min 8)	4	8 (min 2)	16	24 (min 16)	16	16(min 6)	43
IX (10-5 inh/km ²)	512	8	1x8	16 (min 2)	4	3 (min 2)	4	24 (min 16)	4	16 (min 6)	11
X (<5 inh/km ²)	256	8	1x4	16 (min 2)	4	3 (min 2)	4	16 (min 6)	4	16 (min 6)	11

TABLE XII. NUMBER OF POTENTIAL SUBSCRIBERS PER ZONE AND CELL AREA AND NUMBER OF BASE STATIONS FOR WIRELESS ACCESS PER GEOTYPE

Zone	Total number of potential subscribers per zone (n_{zone})	Number of users per cell area (n_{cell})	Average radius of cell area (m) (d_c)	Number of base stations per zone	Number of users per access area (n_{area})	Number of base stations per equivalent access area (n_{bs})	Number of fibres at each B segment (n_{fibreB})	Number of division points at A-B per access area (n_{divAB})	Number of fibres at each A segment (n_{fibreA})
VI (500-100 inh/km ²)	3.987.672	360	1205	11.077	16384	46	8 (min 2)	8	16
VII (100-50 inh/km ²)	1.326.987	360	2132	3.686	4096	12	8 (min 2)	8	16
VIII (50-10 inh/km ²)	1.817.422	360	3419	5.048	2048	6	8 (min 2)	4	16
IX (10-5 inh/km ²)	323.441	223	4516	1.450	512	1	8 (min 2)	-	16
X (<5 inh/km ²)	168.155	106	4668	1.586	256	1	8 (min 2)	-	16

TABLE XIII. TYPES OF TERRAIN IN WIRED ACCESS AS A FUNCTION OF THE GEOTYPE

Geotype	Fraction $d_a d_a$ road (%)	Fraction $d_a d_a$ footpath (%)	Fraction $d_a d_a$ soft (%)	Fraction $d_e - d_f$ footpath (%)	Fraction $d_e - d_f$ soft (%)	Fraction $d_e - d_f$ aerial (%)
VIa (500 – 100 inh/km ²)	5	75	20	55	25	20
VIb (500 – 100 inh/km ²)	5	75	20	55	25	20
VIIa (100 – 50 inh/km ²)	5	45	50	40	30	30
VIIb (100 – 50 inh/km ²)	5	45	50	40	30	30
VIIIa (50 – 10 inh/km ²)	5	35	60	35	25	40
VIIIb (50 – 10 inh/km ²)	5	35	60	35	25	40
IX (10 – 5 inh/km ²)	5	25	70	30	20	50
X (<5 inh/km ²)	5	25	70	25	15	60

TABLE XIV. AVERAGE DISTANCES IN WIRED ACCESS AS A FUNCTION OF THE GEOTYPE

Geotype	$d_a(m)$	$d_b(m)$	$d_c(m)$	$d_d(m)$	$d_e(m)$	$d_f(m)$
VIa (500 – 100 inh/km ²)	100	250	300	50	10	10
VIb (500 – 100 inh/km ²)	500	1500	500	100	20	30
VIIa (100 – 50 inh/km ²)	50	200	200	40	10	10
VIIb (100 – 50 inh/km ²)	250	1000	1000	200	30	70
VIIIa (50 – 10 inh/km ²)	50	150	350	60	10	15
VIIIb (50 – 10 inh/km ²)	200	500	1000	200	30	100
IX (10 – 5 inh/km ²)	100	300	800	120	20	60
X (<5 inh/km ²)	100	300	800	120	20	60

TABLE XV. WORKS, PASSIVE AND ACTIVE EQUIPMENT COSTS FOR WIRED NGAN

Cost category	Price (€)	Yearly evolution	Comments
Civil works			
Duct deployment (road) (c_{duct-r})	70 (per m)	Inflation increase	Average of conventional trenching and microtrenching. For any technology
Duct deployment (footpath) (c_{duct-f})	50 (per m)	Inflation increase	idem
Duct deployment (soft ground) ($c_{duct-sg}$)	30 (per m)	Inflation increase	idem
Aerial deployment ($c_{duct-aer}$)	8 (per m)	Inflation increase	No ducts are required. For any technology
Sub-duct deployment (c_{sduct})	1,5 (per m)	Inflation increase	Relevant for any operator, alternative in particular, when inserting sub-duct in existing ducts. For any technology
Cable installation (c_{cinst})	10 (per m)	Inflation increase	For any type of cable and any type of duct and aerial installations. For any technology
Exchange cabinet (c_{cab-e})	3600	5% fall	Able to accommodate ODF, splitter, ONU and xDSL equipment

Cost category	Price (€)	Yearly evolution	Comments
Division point (c_{div})	600	5% fall	For separation of fibres/cables at a-b and c-d segments. Includes fibre fusion and boxes as required
Field (street) cabinet (c_{cab})	23000	2% fall	Able to accommodate ODF, MDF, power unit, AC/DC converter, batteries and xDSL equipment.
Distribution point boxes (c_{box})	2500	2% fall	Outdoor cabinet for last mile FTTH GPON splitters. Up to 48 subscribers per boxAverage price.
Distribution point boxes (c_{box})	250	2% fall	Average price. Only 10% require upgrading for FTTC/B/VDSL
In-building wiring (c_{mdw})	200	5% fall	Per premise. Only for FTTH technology and multi-dwelling units.
Passive equipment			
Fibre cable (c_{fibre}) 96 FO	6,5 (per m)	3% fall	
Fibre cable (c_{fibre}) 16 FO	2 (per m)	3% fall	
Fibre cable (c_{fibre}) 8 FO	1,3 (per m)	3% fall	
Copper cable	0	-	Existing copper does not need to be upgraded
Migration of existing copper lines (c_{mig})	20	Inflation increase	Per line. For FTTC/B/xDSL technologies
GPON splitter (c_{split})	120	5% fall	The maximum split ratio is 64 (max number of users per fibre). The split ratio of an individual splitter is 8 (therefore, two stages are required)
Optical Distribution Frame (ODF) at local exchange (c_{ODF})	2800	5% fall	Holding up to 256 fibres (and therefore up to 64x256 max number of customers)
Optical Network Unit (ONU) at cabinet (c_{ONU})	1000	5% fall	Holding 64 fibres (and therefore 64x64 max number of customers). Only used if competition takes place from the cabinet
Active equipment			
Optical Line Termination (OLT) card at local exchange (c_{OLT})	30000	10% fall	Each card holds 640 users (10 ports at 64 users per port)
Aggregation switch at local exchange (c_{switch})	3000	10% fall	10 Gb/s of switching capacity per OLT card (640 users)
Mini-VDSLAM at cabinet or distribution point box (c_{VDSL})	2000	10% fall	Each supports 64 users. For FTTC/B/xDSL technologies
Battery for VDSL at cabinet (c_{batt})	1000	5% fall	For FTTC/B/xDSL technologies

TABLE XVI. FRACTION OF PREMISES IN MULTI-DWELLING UNITS AND AVERAGE NUMBER OF PREMISES PER BUILDING AS A FUNCTION OF THE GEOTYPE.
SOURCE: OWN ESTIMATIONS

Geotypes	Fraction of premises in multi-dwelling units (frmdw)	Average premises per building
VIa (500 – 100 inh/km ²)	40	2,32
VIb (500 – 100 inh/km ²)	30	2,75
VIIa (100 – 50 inh/km ²)	30	1,28
VIIb (100 – 50 inh/km ²)	20	1,42
VIIIa (50 – 10 inh/km ²)	20	1,08
VIIIb (50 – 10 inh/km ²)	10	1,00
IX (10 – 5 inh/km ²)	10	1,00

Geotypes	Fraction of premises in multi-dwelling units (frmdw)	Average premises per building
X (<5 inh/km ²)	5	1,00

TABLE XVII. PERCENTAGE OF DUCT RE-USE (FR) AS A FUNCTION OF THE GEOTYPE

Geotype	$d_a - d_b$ (%)	$d_c - d_d$ (%)	$d_e - d_f$ (%)
VIa (500 – 100 inh/km ²)	60	40	30
VIb (500 – 100 inh/km ²)	40	20	10
VIIa (100 – 50 inh/km ²)	60	40	30
VIIb (100 – 50 inh/km ²)	40	20	10
VIIIa (50 – 10 inh/km ²)	40	20	10
VIIIb (50 – 10 inh/km ²)	40	20	10
IX (10 – 5 inh/km ²)	40	20	10
X (<5 inh/km ²)	40	20	10

TABLE XVIII. NUMBER OF POTENTIAL SUBSCRIBERS FOR NEW CABLE NETWORK AS A FUNCTION OF THE GEOTYPE

Geotype	Total potential subscribers (households + businesses)	%of potential subscribers covered with cable network	Potential subscribers for new cable network built
VIa (500 – 100 inh/km ²)	1.232.210	52%	591.461
VIb (500 – 100 inh/km ²)	2.755.461	53%	1.295.067
VIIa (100 – 50 inh/km ²)	741.787	25%	556.340
VIIb (100 – 50 inh/km ²)	585.200	25%	438.900
VIIIa (50 – 10 inh/km ²)	790.356	25%	592.767
VIIIb (50 – 10 inh/km ²)	1.027.066	18%	842.194
IX (10 – 5 inh/km ²)	323.441	17%	268.456
X (<5 inh/km ²)	168.155	0%	168.155

TABLE XIX. PASSIVE AND ACTIVE DOCSIS EQUIPMENT COSTS

Cost category	Price (€)	Yearly evolution	Comments
EdgeQUAM modulator VOD (CEQUAMVOD & BTv)	29000	7 % fall	144 Channels for Video on demand and Broadcast TV services, capacity is expected to be increased significantly in coming years
Docsis 3.0, CMTS (C_CMTS)	519000	12 % fall	Docsis 3.0, Full node CMTS in primary node
Optical Distribution Frame (ODF) at Primary Node in HFC networks (cODF)	2800	5% fall	Holding up to 256 fibres
RF combiner (C_RF combi)	250	5 % fall	RF combiner/splitter .- HFC Combination
BONT cabinet in PN (C CABN_NP)			BONT cabinet in primary node
Power node (C_NPOT)	75000	5 % fall	Power distribution node supply & installation as main power source in outdoor cabinets
Secondary node(C Cab_NS)	9250	5 % fall	cabinet with HFC O/E BONT, ODF, and primary coax distribution point in secondary node

Cost category	Price (€)	Yearly evolution	Comments
Terminal node (C_cab_NT)	9250	5 % fall	cabinet with HFC O/E BONT , ODF, and primary coax distribution point in terminal node
Coax Amplification (C_AMPLI)	70	2% fall	HFC Coax Amplification in last mile
Connection to power utility urban (C_power1)	2500	Inflation Increase	Connection to power utility company in Urban areas, for outdoor Secondary & Terminal Nodes
Connection to power utility low dense (C_power1)	12500	Inflation Increase	Connection to power utility company in non urban areas
CATV trunk 2-way tap (C_TAP2)	3,7	2% fall	Outdoor CATV sub-trunk 2-way taps , are used in last mille Drop, so highly needed in cable networks
CATV trunk 4-way tap (C_TAP4)	4,1	2% fall	Outdoor CATV sub-trunk 4-way taps
CATV trunk 4-way tap (C_TAP8)	5,8	2% fall	Outdoor CATV sub-trunk 8-way taps
Coax Cable QR540 (C_coax QR540)	5,1	3% fall	Coax Cable QR540 in mts, final drop cable
Coax Cable RG6 (C_coax QR540)	5,1	2% fall	Coax Cable RG6 in mts, distribution cable in final drop

TABLE XX. DEPLOYMENT COSTS FOR WIRELESS NGAN

Cost category	Price (€)	Yearly evolution	Comments
Civil works			
Base station deployment (c _{bs-d})	30.000	5% fall	Per site. For any technology
Spectrum			
Spectrum fees at 800 MHz (c _{spect})	20.000.000	Inflation increase	Per MHz. 20 years license.
Spectrum fees at 2,6 GHz (c _{spect})	2.000.000	Inflation increase	Per MHz. 20 years license.
Administrative licensing	3.500 €		Per site
Active equipment			
Base station at 2,6 GHz (c _{bs})	23.000	10% fall	For LTE. 3 sectors, 20 MHz each
Base station at 800 MHz (c _{bs})	18.000	10% fall	For LTE. 3 sectors, 20 MHz each
Tr-Rx equipment (c _{tr})	4.000	10% fall	For LTE. 2 Tr-Rx per sector
Power supply equipment for base station (c _{pow})	10.000	5% fall	For any technology
Pico-cell (c _{pico})	350	10% fall	Up to 8 users. For any technology
Femtocell (c _{femto})	250	10% fall	For any technology

TABLE XXI. OPERATING COSTS FOR WIRED NGAN

Cost category	Price (€)	Yearly evolution	Comments
Civil works			
Duct rental	2 (per m)	Inflation increase	Only relevant for alternative operators
Passive equipment			
Installation of final drop (c _{drop})	120	Inflation increase	Per user. Incurred only when a customer takes a service. Includes the faceplate at subscriber premises. For any technology
Migration due to churn (c _{churn})	100	Inflation increase	Average value per churned user. It could vary as a function of the access point / unbundling possibilities (at exchange, at cabinet or at distribution box). Includes internal and external migration costs. For any technology
Accommodation of equipment in the exchange	10	Inflation increase	Per user. Only relevant for alternative operators

Cost category	Price (€)	Yearly evolution	Comments
Active equipment			
Customer Premises Equipment (CPE) (c_{CPE})	100	10% fall	Per user. Including modem, routing and wireless hub. For any technology. Cost per 5 years.
Battery backup (c_{batt})	100	10% fall	Per user. For FTTH as this technology does not include power supply on the wire. Includes maintenance. Cost per 5 years.
Power consumption at exchange (c_{pow})	2	Inflation increase	Per line. Considers the average of a fixed and a variable per KWh charge (30 W consumption per OLT port).
Support and management			
Network support (FTTH) (c_{nets})	6	Inflation increase	Per line
Network support (FTTC/VDSL) (c_{nets})	12	Inflation increase	Per line
General support (FTTH) (c_{gens})	9	Inflation increase	Per line
General support (FTTC/VDSL) (c_{gens})	12	Inflation increase	Per line
General management (c_{genm})	13	Inflation increase	Per line. For any technology
Finance and billing (c_{bill})	1	Inflation increase	Per line. For any technology
Bad debts and other costs (c_{bad})	3	Inflation increase	Per line. For any technology
Provision / maintenance (FTTH) (c_{prov})	4	Inflation increase	Per line
Provision / maintenance (FTTC/VDSL) (c_{prov})	12	Inflation increase	Per line

TABLE XXII. SUMMARY OF OPERATING COSTS FOR WIRELESS NGAN

Cost category	Comments	Price (€)	Yearly evolution
Civil works			
Duct rental	Only relevant for alternative operators	2 (per m)	Inflation increase
Site rental	Per site	6.000€	Inflation increase
Passive equipment			
Installation of final drop (c_{drop})	Per user. Incurred only when a customer takes a service. Includes the faceplate at subscriber premises. For any technology	120	Inflation increase
Migration due to churn (c_{churn})	Average value per churned user. It could vary as a function of the access point / unbundling possibilities (at exchange, at cabinet or at distribution box). Includes internal and external migration costs. For any technology	100	Inflation increase
Accommodation of equipment in the exchange	Per user. Only relevant for alternative operators	10	Inflation increase
Active equipment			
Femto and Pico-cells power consumption	Considerations about the power consumption on the cells reception equipment	120	

Cost category	Comments	Price (€)	Yearly evolution
Femto and Pico-cells equipment technical maintenance	For example: Replacement of equipment due to malfunction	60	
Tx-Rx power consumption		80	Inflation increase
Tx-Rx equipment technical maintenance		30	Inflation increase
Base Station power supply	Per site	1.200	Inflation increase
Base Station equipment technical maintenance	Per site	600	Inflation increase
Sanctions	Per year for the whole network	3.000.000	20% increase
Closures and withdrawals	Per year for the whole network	15.000.000	10% increase
Adaptations	1 of 30 base stations need this type of work a year	1.000	Inflation increase
Support and management			
General management and support (c_{genm})	For any technology	25	Inflation increase
Finance and billing (c_{bill})	For any technology	1	Inflation increase
Bad debts and other costs (c_{bad})	For any technology. Include the debts, churn,	3	Inflation increase