EXECUTIVE SUMMARY

PROVIDING 30MBIT/S TO SPAIN'S FINAL THIRD

Under the Digital Agenda for Europe which is one of the flagship initiatives of Europe 2020, Member States are considering how they can meet their commitments to providing fast and ultrafast broadband. However, Europe is not a homogeneous entity. The economic, geographic, social and demographic features of each country make it a highly diverse region to develop best practices for Next Generation Access Networks (NGAN) deployments. There are particular concerns about NGAN deployments for 'the final third' of the population who, usually, live in rural areas.

This paper assesses, through a techno-economic analysis, the access cost of providing over 30Mbit/s broadband for the final third of Spain's population. Fixed and mobile technologies are compared in order to determine which is the most cost-effective technology for each geotype. The demographic limit for fixed networks (cable, fibre and copper) is also discussed. The assessment focuses on the supply side and the results show the access network costs only.

The 4G/LTE scenario is dimensioned to provide 30Mbit/s (best effort) broadband, assuming a network take-up of 25%. The Rocket techno-economic model is used to assess a 10-year study period deployment although noting that deployment must start in 2014 and be completed by 2020 in order to fulfil the Digital Agenda's goals.

The feasibility of the deployment is defined as the ability to recoup the investment at the end of the study period. This ability is highly related to network take-up and, therefore, to service adoption. Network deployment in each geotype is compared with the cost of the deployment in the Urban geotype and

expected penetration rates.

At the end of 2013, Spain's independent regulation agency claimed that 59% and 52% of the population was already covered by NGAN capable of providing 30Mbit/s and 100Mbit/s respectively. Hybrid Fibre Coax (HFC) and Fibre-to-the-Home (FTTH) with 47% and 17% respectively of population coverage were included in the 100Mbit/s segment. Only Very High Speed Digital Subscriber Line (VDSL), with 12% of the coverage, was included in the 30Mbit/s segment. Despite not being an NGAN, the 99% population coverage of HSPA networks, which were claimed to be capable of 21Mbit/s, were also mentioned by Spain's independent regulation agency. The large mobile operators are also required jointly to provide 30Mbit/s to 90% of the population in rural areas by the end of 2020. In Spain, spectrum in the 800MHz band is to be released for this purpose.

The authors' research sought to identify cost of the deployment per cumulative households coverage with four different NGANs: FTTH, HFC, VDSL and LTE. Investments from €2,700 million (for VDSL) to €5,400 million (for HFC) will be needed to cover the first 50% of the population with fixed technologies. In contrast €3,000 million invested in LTE could cover the entire country albeit with lower data rates. However, taking into account the throughput that fixed networks can provide and the goal of achieving the objectives of the Digital Agenda, fixed network deployments are recommended for up to 90% of the population. Fibre and cable deployments could cost-effectively cover up to 88% of Spain's population. As there are some concerns about the service adoption, the authors recommend VDSL and LTE for the final third of the population.

Despite LTE being able to provide the most economical roll-out, VDSL could cost efficiently also provide 50Mbit/s from 75% to 90% of Spain's population. For this population range, facility-based competition between VDSL providers and LTE providers should be encouraged. Regarding 90% to 98.5% of Spain's population, LTE deployment is the most appropriate. Since customers in less populated municipalities are more sensitive to cost, it is considered that a single network deployment would be appropriate. Finally, it appears that it is not possible to cost-efficiently deliver 30Mbit/s to the final 1.5% of the population and adoption predictions are not optimistic either. As there are other broadband alternatives able to deliver up to 20Mbit/s, the authors consider it is not necessary to cover the extreme rural areas, where public financing would be required.

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Catalina Ovando, Jorge Pérez

PROVIDING 30MBIT/S TO SPAIN'S FINAL THIRD - A TECHNO-ECONOMIC ASSESSMENT

Under the Digital Agenda for Europe, one of the flagship initiatives of Europe 2020, Member States are considering how they can meet their commitments to providing fast and ultrafast broadband. But Europe is not a homogeneous entity; the economic, geographic, social and demographic diversity of each country is likely to result in a diversity of Next Generation Access Networks (NGAN) solutions. There are particular concerns about NGAN deployments for 'the final third' of the population who, usually, live in rural areas, explain Catalina Ovando and Jorge Pérez from the Universidad Politécnica de Madrid

When Analysys Mason compared the cost of different NGAN technologies in the UK [1], an important finding concerning theUK's final third emerged; although it may require a large increase in base station deployment, terrestrial wireless technologies could cost-effectively support the traffic demands of the final 15% of homes. If more spectrum were available, terrestrial wireless could be the solution to the UK's final third.

By replicating the analysis, the authors set out to determine if the Analysys Mason findings could also apply to providing 30Mbit/s to Spain's final third. This article does not focus on the analysis methodology but rather on the results and the implications. It also seeks to identify the demographic limit for fixed networks (cable, fibre and copper). The analysis focuses on supply side and the results are only for the access network costs.

The feasibility of the deployment is defined as the ability to recoup the investment at the end of the study period. This feasibility is highly related to network take-up and, therefore, to service adoption. Spain's municipalities are classified based on geographic and demographic characteristics, referred to as geotypes. For clarity and simplicity, network deployment in each geotype is compared with the cost of the deployment in the Urban geotype and expected broadband penetration rates.

The detailed methodology used by the authors in their analysis is not

Geotype	Population coverage	Households per km2	Population (mean)	Percentage of national area	Expected broadband penetration rate [1]
Urban	41.0%	269.48	28,276	13.3%	80%
Suburban 1	75.0%	54.50	18,861	7.8%	75%
Suburban 2	88.0%	148.35	2,768	0.1%	65%
Rural 1	88.5%	16.04	932	0.2%	40%
Rural 2	90.0%	12.68	1,347	5.5%	20%
Rural 3	92.4%	10.26	679	13.5%	40%
Rural 4	98.5%	8.00	926	42.9%	20%
Open	100.0%	3.90	428	6.7%	20%

Table 1: *Geotype characteristics*

1. *Broadband penetration rates are from [2] and include all services considered as broadband (over 1Mbit/s downlink). Not to be confused with the service adoption.*

covered here. The basis of the approach was firstly to divide Spain's final third municipalities into a number of geotypes on a multivariable k-mean demographic basis. Then, technical, financial and service parameters were set. Finally, the techno-economic assessment was developed.

LITERATURE REVIEW

A PHD dissertation published in 2011 [2] evaluated the feasibility of fixed NGAN deployments, such as Fibre to the Home (FTTH), Fibre to the Node (FTTN), Hybrid Fibre Coax (HFC) based on a geographic and demographic classification of the 8113 Spanish municipalities covering over 14 million households. NGAN rollout strategies are highly dependent on market size and network. (As a solution for meeting 30Mbit/s for all European citizens, Spain had linked population coverage obligations to the 800MHz spectrum's holders.)

Moreover, it is unrealistic to expect homogeneous deployments, services and prices in all regions. It concluded that network competition is only feasible in regions that cover 46% of Spanish households and that, even without network competition, fixed NGAN deployment could not be expected to reach more than 72% of the population. In other words, the final third could miss out on any fixed NGAN roll-out.

A similar assessment which analysed NGAN deployment and market limits was recently published [3]. Unlike [2], it also considered Long Term Evolution (LTE) (3GPP 4G technology) as a solution for areas of low population density. This research makes a classification depending on the population of each municipality, followed by a techno-economic analysis. Although the assessment is not especially detailed, it draws overall conclusions that are still valid in in-depth case studies.

Both [2] and [3] concluded that competitive fixed NGAN infrastructure could be the solution for the first 50% of Spain's homes and [3] forecast that, with service competition on a single network, 60% to 70% of Spanish households, could be served. Whilst [2] suggested that mobile NGAN might be feasible for rural areas, [3] concluded that only LTE is feasible in areas with less than 100 inhabitants per square kilometre.

A major concern of operators is that the economics of mobile NGANs are highly dependent on take-up. Even though the costs of mobile networks are lower than fixed networks, it is unclear how to achieve the take-up levels needed to make deployment feasible. On the other hand, if LTE has to deliver 30Mbit/s, as required by the Digital Agenda for Spain, network dimensioning would need to be considered which may impact the roll-out feasibility. Since the NGAN techno-economic assessment in [2] is more detailed than [3], this article seeks to complement it with the LTE scenario in order to assess the best strategy for Spain's final third.

CURRENT NETWORK DEPLOYMENTS AND INTENTIONS

At the end of 2013, Spain's independent regulation agency claimed that 59% and 52% of the population was already covered by NGAN capable of providing 30Mbit/s and 100Mbit/s respectively. HFC and FTTH with 47% and 17% respectively of population coverage were included in the 100Mbit/s segment. Only Very High Speed Digital Subscriber Line (VDSL), with 12% of the coverage, was included in the 30Mbit/s segment.

Despite not being an NGAN, the 99% population coverage of HSPA networks, which were claimed to be capable of 21Mbit/s, were also mentioned by Spain's independent regulation agency. This increment in the 3.5G coverage might have

	Downlink speed (Mbit/s)	Uplink speed (Mbit/s)	Traffic in busy hour	Downlink traffic per user in busy hour (Mbit/s)	Monthly download limit	Weighted Average Cost of Capital
LTE	24 - 35	10	20%	6.14	10GB	13.00%
FTTN / VDSL	50	10	40%	8.00	Unlimited	10.82%
FTTH / GPON	100	10	40%	8.00	Unlimited	12.50%
HFC / DOCSIS 3	100	10	40%	8.00	Unlimited	12.50%

Table 2: *Technical and service parameters*

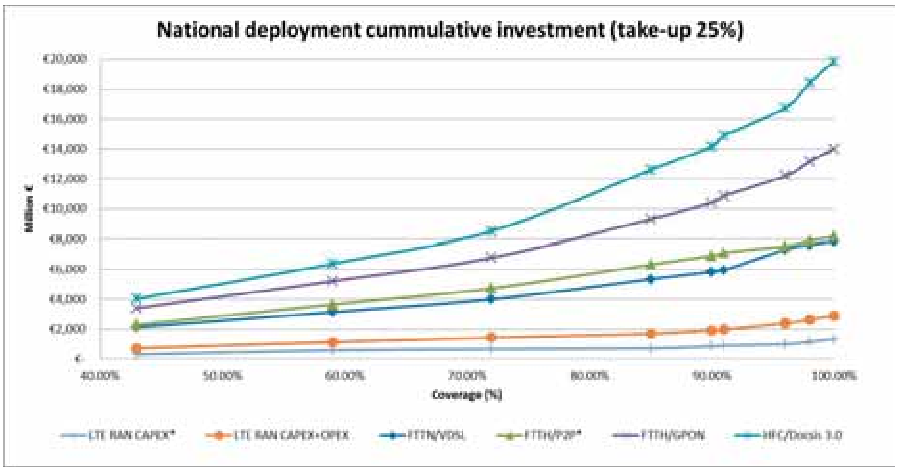

Figure 1: *Deployment costs for different fixed NGANs and LTE [2] ([2]In FTTH / Point-to-Point and LTE deployments, OPEX has a relevant weight in access costs. FTTH / Point-to-Point scenario: alternative operator costs are considered and civil works excluded. LTE scenario: spectrum fees, sites lease costs and Enhanced Node B maintenance costs play a significant role in access costs.)*

been prompted by the mobile operators' universal service obligation; since 2012, this has included 1Mbit/s broadband and the three biggest mobile operators in Spain (Telefonica, Vodafone and Orange) are required to meet the costs of this service. It is not surprising that most of the unprofitable areas are being served by mobile networks with the last 1% through satellite technologies.

Telefonica, Vodafone and Orange are also required jointly to provide 30Mbit/s to 90% of the population in rural areas by the end of 2020. (As a solution for meeting 30Mbit/s for all European citizens, Spain had linked population coverage obligations to the 800MHz spectrum's holders.) In Spain, spectrum in the 800MHz band is to be released for this purpose although, at present, LTE deployments for 4G services are in Spain's main cities in the 1800MHz and 2600MHz bands.

Regarding fixed networks deployment intentions, Telefonica, the incumbent, has recently released its FTTH coverage goals: 7 million households in 2014 and 8 million by the end of 2015. Meanwhile, Vodafone and Orange have announced a joint investment of €1,000 million to reach up to 6 million households with a single FTTH technology by 2017.

HFC providers using the Docsis 3.0 standard have also announced intentions to extend their networks. On the other hand, local cable providers, such as Euskaltel, R and Telecable, are extending their networks within the Autonomous Communities (i.e. the first-level political and administrative divisions of Spain) in which they already have a presence. Despite, not making strategic coverage announcements, Ono, the biggest provider, has declared that it is capable of providing 100Mbit/s to 7 million households.

GEOTYPING

As mentioned above, this analysis extends the assessment in [2] to cover LTE. Municipalities were compiled by population (from most to least), keeping the same classification as in [2]. However, additional considerations were taken from the municipalities containing from 41% to 100% of the population. For this section, three variables were considered in the k-nearest neighbour municipalities' classification: main household density, percentage of population covered with 1Mbit/s (before the universal service commitment became effective) and scattered population ratio. The results are shown in Table 1(page 31).

TECHNICAL AND SERVICE PARAMETERS

As the network architecture for every type of fixed NGAN is described in [2], this section only focuses on the LTE scenario. Service parameters for all NGANs considered are given in Table 2 (page31). LTE is dimensioned to provide 30Mbit/s (best effort) broadband, assuming a network take-up of 25%. The current spectrum holders' situation in Spain has been taken into account. The assessment shows the cost of a 2 x 10MHz Frequency Division Duplex LTE deployment for any of the three biggest mobile operators.

TECHNO-ECONOMIC ASSESSMENT

For the techno-economic assessment, the European Rocket's model project [4], with minimum adaptation to LTE, was used. The LTE network is structured into four aggregation levels made up of aggregation nodes, as described in [4] and [5]. The Rocket techno-economic model is used to assess a 10-year deployment period (although noting that deployment must start in 2014 and be completed by 2020.

The Rocket model develops a Discounted Cash Flow analysis. The Net present Value has been fixed at zero at the end of the study period with the aim of defining the cost of the service provision. A typical value of 45% of total expenses corresponding to network-related operational expenditure (OPEX) and the rest (55%) corresponding to business-driven expenses has been assumed as in [5].

More details on the methodology are presented in [5].

The feasibility of the deployment is defined as the ability to recoup the investment by the end of the study period. This is highly dependent on network take-up and, therefore, to service adoption. In lightly populated areas, adoption tends to be lower than in Urban areas. Network deployments in each geotype are compared with the cost of deployment in the Urban geotype and expected penetration rates as reflected in [2].

RESULTS AND DISCUSSION

COSTS PER CUMULATIVE HOUSEHOLD COVERAGE

Figure 1 shows the deployment costs of different NGANs (excluding backhaul and core network costs) per cumulative household coverage for 25% take-up. In Urban areas, 25% take-up represents an intermediate adoption value. However, as population

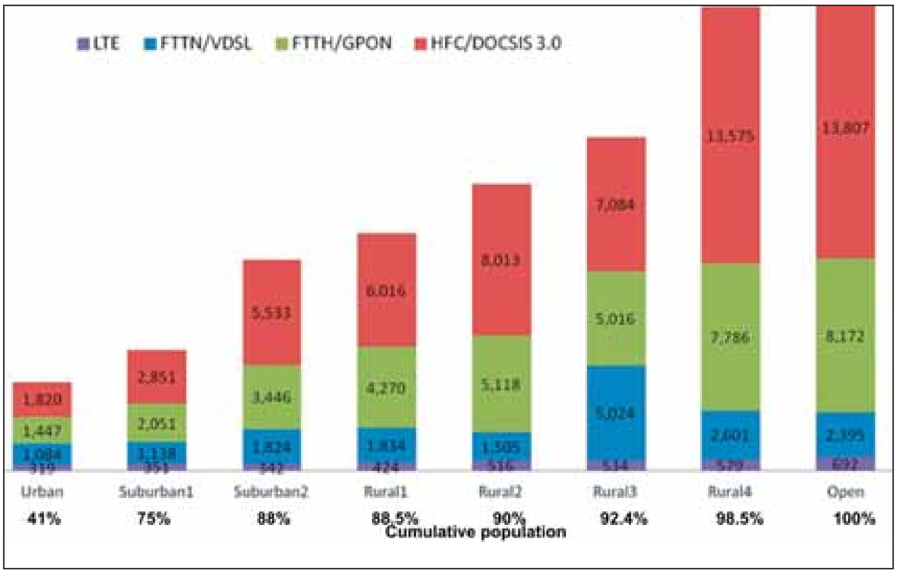

Figure 2: *Access CAPEX (€) per household connected per geotype (25% take-up)*

density decreases, this value represents the highest level of adoption (and penetration). Lower levels of investment are associated with network re-use, such as HFC brownfield or the incumbent's FTTN/VDSL networks. HFC and FTTH / Gigabit Passive Optical Network (GPON) greenfield deployments would entail the largest investments.

Regarding the LTE scenario, the Radio Access Network (RAN) shows both capital expenditure (CAPEX) only and CAPEX and OPEX combined which includes spectrum fees and site lease costs. Access OPEX is included because of its relevance in the overall cost; it can be more that double the RAN CAPEX at 100% household coverage. It is clear that, after 72% of households are covered, the only cost-effective NGAN is LTE. The final 8% shows a significant upturn in costs.

On the subject of the amount of investment, the graph shows that investments from €2,700 million (for VDSL) to €5,400 million (for HFC) will be needed to cover the first 50% of the population with fixed technologies. In contrast €3,000 million invested in LTE could cover the entire country albeit with lower data rates.

Using the same networks parameters, Figure 2 shows the cost of covering a household in each geotype with the different technologies. An Urban geotype has been chosen as the starting point in terms of feasibility.

In terms of adoption of the service it should be noted that, due to its economic and demographic characteristics, customers in the less populated municipalities are more sensitive to the cost of the service.

URBAN

As reflected in [2], broadband penetration is expected to be 80% for the Urban geotype. If the market responds well, up to three different network deployments could cost-effectively provide 100Mbit/s connections. These geotypes are more likely to have FTTH and HFC deployments given that, the more the users adopt the service, the more profitable the network for the fibre and cable operators. Despite LTE being the cheapest deployment, it should be noted that for a greater take-up, network dimensioning would need to be augmented to meet demand. Furthermore, to deliver 30Mbit/s per user, the dimensioning will be capacity-driven and may require many more base stations.

SUBURBAN 1

In the Suburban 1 scenario, none of the solutions doubles the Urban geotype cost per household connected. As the penetration rate expected is around 75%, at least two (perhaps FTTH and HFC) fixed networks could be cost effectively deployed in this scenario. Regarding the 30Mbit/s market, VDSL is a front-runner given that the Urban geotype's conclusion on LTE deployment remains valid for Suburban 1.

SUBURBAN 2 AND RURAL 1

There is not much difference between the cost per household connected in Suburban 2 and Rural 1 geotypes. The cost for FTTH and HFC networks is more than double that of Urban which makes it unlikely that operators will invest in these areas. However, as the expected penetration is around 65% and 40%, respectively there possibly could be more than one network operator for VDSL and LTE.

RURAL 2, 3 AND 4

From this analysis, the authors consider that the feasibility of any fixed network is set at the end of the Rural 1 geotype. This is because, despite the cost per household connected with VDSL in Rural 2 not being double that of the Urban geotype, the expected penetration is below 25%. For this reason, Rural 2 would receive the same treatment as Rural 3 and Rural 4 geotypes.

The cost of covering a household in Rural 3 and Rural 4 geotypes with any fixed network is more than double that of the Urban geotype. The only feasible NGAN is LTE. Considering the low penetration ratios (which encompasses all broadband services offered in these areas), as well as the low population density, a single network deployment would be appropriate.

OPEN GEOTYPE

As the cost of covering a household with any NGAN deployments exceeds the feasibility limit and as the expected broadband penetration rate is below 20%, it is concluded that an Open geotype would require public investment. These areas are outside the obligations of mobile operators to provide 30Mbit/s and therefore are considered as additional costs. Also, there are no base stations covering the final 1% of the population.

Finally, for those areas where there are no NGAN deployment plans, there is the satellite solution offering up to 20Mbit/s. This leads to the following question: as there is a broadband universal service obligation, and the cost of covering the final 1.5% of the population would require public money, is it absolutely necessary to cover it with NGAN?

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AUTHORS' CONCLUSIONS

This article assesses, through a techno-economic analysis, the access cost of providing over 30Mbit/s broadband for the final third of Spain's population. Research shows that an investment ranging from €2,700 million (for VDSL) to €5,400 million (for HFC) will be needed to cover the first 50% of the population with any fixed technology. The results indicate that at least €3,000 million will be required to cover those areas with the least expensive technology - LTE.

However, taking into account the throughput that fixed networks can provide and the goal of achieving the objectives of the Digital Agenda, fixed network deployments are recommended for up to 90% of the population. Fibre and cable deployments could cost-effectively cover up to 88% of Spain's population. As there are some concerns about the service adoption, the authors recommend VDSL and LTE for the final third of the population.

Despite LTE being able to provide the most economical roll-out, VDSL could cost efficiently also provide 50Mbit/s from 75% to 90% of Spain's population. For this population range, facility-based competition between VDSL providers and LTE providers should be encouraged. Regarding 90% to 98.5% of Spain's population, LTE deployment is the most appropriate. Since customers in less populated municipalities are more sensitive to cost, it is considered that a single network deployment would be appropriate. Finally, it appears that it is not possible to cost-efficiently deliver 30Mbit/s to the final 1.5% of the population and adoption predictions are not optimistic either. As there are other broadband alternatives able to deliver up to 20Mbit/s, the authors consider it is not necessary to cover the extreme rural areas, where public financing would be required.

ABBREVIATIONS

CAPEX	Capital Expenditure
FTTH	Fibre to the Home
FTTN	Fibre to the Node
GPON	Gigabit Passive Optical Network
HFC	Hybrid Fibre Coax
LTE	Long Term Evolution (3GPP 4G technology)
NGAN	Next Generation Access Networks
OPEX	Operational Expenditure
RAN	Radio Access Network
VDSL	Very High Speed Digital Subscriber Line

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